STATA MULTIPLE-IMPUTATION REFERENCE MANUAL
RELEASE 19



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Cross-referencing the documentation

When reading this manual, you will find references to other Stata manuals, for example, **[U] 27 Overview of Stata estimation commands**; [R] **regress**; and [D] **reshape**. The first example is a reference to chapter 27, *Overview of Stata estimation commands*, in the *User's Guide*; the second is a reference to the `regress` entry in the *Base Reference Manual*; and the third is a reference to the `reshape` entry in the *Data Management Reference Manual*.

All the manuals in the Stata Documentation have a shorthand notation:

[GSM]	*Getting Started with Stata for Mac*
[GSU]	*Getting Started with Stata for Unix*
[GSW]	*Getting Started with Stata for Windows*
[U]	*Stata User's Guide*
[R]	*Stata Base Reference Manual*
[ADAPT]	*Stata Adaptive Designs: Group Sequential Trials Reference Manual*
[BAYES]	*Stata Bayesian Analysis Reference Manual*
[BMA]	*Stata Bayesian Model Averaging Reference Manual*
[CAUSAL]	*Stata Causal Inference and Treatment-Effects Estimation Reference Manual*
[CM]	*Stata Choice Models Reference Manual*
[D]	*Stata Data Management Reference Manual*
[DSGE]	*Stata Dynamic Stochastic General Equilibrium Models Reference Manual*
[ERM]	*Stata Extended Regression Models Reference Manual*
[FIN]	*Stata Financial Statistics Reference Manual*
[FMM]	*Stata Finite Mixture Models Reference Manual*
[FN]	*Stata Functions Reference Manual*
[G]	*Stata Graphics Reference Manual*
[H2OML]	*Machine Learning in Stata Using H2O: Ensemble Decision Trees Reference Manual*
[IRT]	*Stata Item Response Theory Reference Manual*
[LASSO]	*Stata Lasso Reference Manual*
[XT]	*Stata Longitudinal-Data/Panel-Data Reference Manual*
[META]	*Stata Meta-Analysis Reference Manual*
[ME]	*Stata Multilevel Mixed-Effects Reference Manual*
[MI]	*Stata Multiple-Imputation Reference Manual*
[MV]	*Stata Multivariate Statistics Reference Manual*
[PSS]	*Stata Power, Precision, and Sample-Size Reference Manual*
[P]	*Stata Programming Reference Manual*
[RPT]	*Stata Reporting Reference Manual*
[SP]	*Stata Spatial Autoregressive Models Reference Manual*
[SEM]	*Stata Structural Equation Modeling Reference Manual*
[SVY]	*Stata Survey Data Reference Manual*
[ST]	*Stata Survival Analysis Reference Manual*
[TABLES]	*Stata Customizable Tables and Collected Results Reference Manual*
[TS]	*Stata Time-Series Reference Manual*
[I]	*Stata Index*
[M]	*Mata Reference Manual*

Description Remarks and examples References Also see

Description

Missing data arise frequently. Various procedures have been suggested in the literature over the last several decades to deal with missing data (for example, Anderson [1957]; Hartley and Hocking [1971]; Rubin [1972, 1987]; and Dempster, Laird, and Rubin [1977]). The technique of multiple imputation, which originated in early 1970 in application to survey nonresponse (Rubin 1976), has gained popularity increasingly over the years as indicated by literature (for example, Rubin [1976, 1987, 1996]; Little [1992]; Meng [1994]; Schafer [1997]; van Buuren, Boshuizen, and Knook [1999]; Little and Rubin [2020]; Carlin et al. [2003]; Royston [2004, 2005a, 2005b, 2007, 2009]; Reiter and Raghunathan [2007]; Carlin, Galati, and Royston [2008]; Royston, Carlin, and White [2009]; White, Royston, and Wood [2011]; and Carpenter and Kenward [2013]).

This entry presents a general introduction to multiple imputation and describes relevant statistical terminology used throughout the manual. The discussion here, as well as other statistical entries in this manual, is based on the concepts developed in Rubin (1987) and Schafer (1997).

Remarks and examples

Remarks are presented under the following headings:

Motivating example
What is multiple imputation?
Theory underlying multiple imputation
How large should M be?
Assumptions about missing data
Patterns of missing data
Proper imputation methods
Analysis of multiply imputed data
A brief introduction to MI using Stata
Summary

We will use the following definitions and notation.

An imputation represents one set of plausible values for missing data, and so multiple imputations represent multiple sets of plausible values. With a slight abuse of the terminology, we will use the term *imputation* to mean the data where missing values are replaced with one set of plausible values.

We use M to refer to the number of imputations and m to refer to each individual imputation; that is, $m = 1$ means the first imputation, $m = 2$ means the second imputation, and so on.

Motivating example

Consider a fictional case–control study examining a relationship between smoking and heart attacks.

```
. use https://www.stata-press.com/data/r19/mheart0
(Fictional heart attack data; BMI missing)
. describe
Contains data from https://www.stata-press.com/data/r19/mheart0.dta
 Observations:           154                  Fictional heart attack data;
                                                BMI missing
    Variables:             9                  19 Jun 2024 10:50
-------------------------------------------------------------------------------
Variable      Storage   Display    Value
    name         type    format    label      Variable label
-------------------------------------------------------------------------------
attack          byte    %9.0g                 Outcome (heart attack)
smokes          byte    %9.0g                 Current smoker
age             float   %9.0g                 Age, in years
bmi             float   %9.0g                 Body mass index, kg/m^2
female          byte    %9.0g                 Gender
hsgrad          byte    %9.0g                 High school graduate
marstatus       byte    %9.0g      mar        Marital status: single, married,
                                                divorced
alcohol         byte    %24.0g     alc        Alcohol consumption: none, <2
                                                drinks/day, >=2 drinks/day
hightar         byte    %9.0g                 Smokes high tar cigarettes
-------------------------------------------------------------------------------
Sorted by:
```

In addition to the primary variables `attack` and `smokes`, the dataset contains information about subjects' ages, body mass indexes (BMIs), genders, educational statuses, marital statuses, alcohol consumptions, and the types of cigarettes smoked (low/high tar).

We will use logistic regression to study the relationship between `attack`, recording heart attacks, and `smokes`:

```
. logit attack smokes age bmi hsgrad female
Iteration 0:  Log likelihood = -91.359017
Iteration 1:  Log likelihood = -79.374749
Iteration 2:  Log likelihood = -79.342218
Iteration 3:  Log likelihood =  -79.34221
Logistic regression                                     Number of obs =    132
                                                        LR chi2(5)    =  24.03
                                                        Prob > chi2   = 0.0002
Log likelihood = -79.34221                              Pseudo R2     = 0.1315
------------------------------------------------------------------------------
      attack | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
      smokes |   1.544053   .3998329     3.86   0.000     .7603945    2.327711
         age |    .026112    .017042     1.53   0.125    -.0072898    .0595137
         bmi |   .1129938   .0500061     2.26   0.024     .0149837     .211004
      hsgrad |   .4048251   .4446019     0.91   0.363    -.4665786    1.276229
      female |   .2255301   .4527558     0.50   0.618    -.6618549    1.112915
       _cons |  -5.408398   1.810603    -2.99   0.003    -8.957115   -1.85968
------------------------------------------------------------------------------
```

The above analysis used 132 observations out of the available 154 because some of the covariates contain missing values. Let's examine the data for missing values, something we could have done first:

```
. misstable summarize
```

Variable	Obs=.	Obs>.	Obs<.	Obs<. Unique values	Obs<. Min	Obs<. Max
bmi	22		132	132	17.22643	38.24214

We discover that `bmi` is missing in 22 observations. Our analysis ignored the information about the other covariates in these 22 observations. Can we somehow preserve this information in the analysis? The answer is yes, and one solution is to use multiple imputation.

What is multiple imputation?

Multiple imputation (MI) is a flexible, simulation-based statistical technique for handling missing data. Multiple imputation consists of three steps:

1. *Imputation step.* M imputations (completed datasets) are generated under some chosen imputation model.
2. *Completed-data analysis (estimation) step.* The desired analysis is performed separately on each imputation $m = 1, \ldots, M$. This is called completed-data analysis and is the primary analysis to be performed once missing data have been imputed.
3. *Pooling step.* The results obtained from M completed-data analyses are combined into a single multiple-imputation result.

The completed-data analysis step and the pooling step can be combined and thought of generally as the analysis step.

MI as a missing-data technique has two appealing main features: 1) the ability to perform a wide variety of completed-data analyses using existing statistical methods; and 2) separation of the imputation step from the analysis step. We discuss these two features in more detail in what follows.

Among other commonly used missing-data techniques that allow a variety of completed-data analyses are complete-case analysis or listwise (casewise) deletion, available-case analysis, and single-imputation methods. Although these procedures share one of MI's appealing properties, they lack some of MI's statistical properties.

For example, listwise deletion discards all observations with missing values and thus all information contained in the nonmissing values of these observations. With a large number of missing observations, this may lead to results that will be less efficient (larger standard errors, wider confidence intervals, less power) than MI results. In situations when the remaining complete cases are not representative of the population of interest, listwise deletion may also lead to biased parameter estimates.

In our opening logistic analysis of heart attacks, we used listwise deletion. The effect of age was not statistically significant based on the reduced sample. The MI analysis of these data (see *A brief introduction to MI using Stata* below) will reveal the statistical significance of age by using all available observations after imputing missing values for BMI.

Unlike listwise deletion, single-imputation methods do not discard missing values. They treat the imputed values as known in the analysis. This underestimates the variance of the estimates and so overstates precision and results in confidence intervals and significance tests that are too optimistic. MI rectifies

this problem by creating multiple imputations and taking into account the sampling variability due to the missing data (between-imputation variability). See Little and Rubin (2020) and Allison (2001), among others, for a more detailed comparison of the methods.

The independence of the imputation step from the analysis step is the property MI shares with other imputation methods. The imputation step fills in missing values. The analysis step provides inference about multiply imputed results and does not require any information about the missing-data aspect of the problem.

The separation of the two steps allows different individuals, a data collector/imputer and a data analyst, to perform these steps independently of one another. The advantage is that the data collector/imputer usually has access to more information about the data than may be disclosed to the data analyst and thus can create more accurate imputations. The data analyst can use the imputed data released by the data collector in a number of different analyses. Of course, it is crucial that the imputer make the imputation model as general as possible to accommodate a wide variety of analyses that the data analyst might choose to perform; see *Proper imputation methods* below for details.

In our heart attack example, the imputer would create multiple imputations of missing values of BMI using, for example, a linear regression method, and then release the resulting data to the analyst. The analyst could then analyze these multiply imputed data using an ordinary logistic regression. That is, no adjustment is needed to the analysis model itself to account for missing BMI—the pooling portion of the analysis will account for the increased variability because of imputed missing data.

Theory underlying multiple imputation

MI was derived using the Bayesian paradigm yet was proved to be statistically valid from the frequentist (randomization-based) perspective. We use the definition from Rubin (1996) of statistical validity that implies approximately unbiased point estimates and implies confidence intervals achieving their nominal coverages when averaged over the randomization distributions induced by the known sampling and the posited missing-data mechanisms.

To explain the role the Bayesian and frequentist concepts play in MI, we need to consider the MI procedure in more detail. MI requires specification of two models—the imputation model and the analysis model. The imputation model is the model used to create imputations in the imputation step. The analysis model is the completed-data model used during the analysis step to obtain completed-data estimates, $\widehat{Q}$, of parameters of interest, Q, and the estimate, U, of sampling variability associated with $\widehat{Q}$. During the pooling step, the individual completed-data estimates $(\widehat{Q}, U)$ are combined into $(\widehat{Q}_{\text{MI}}, T)$ to form one repeated-imputation inference. The statistical validity of the repeated-imputation inference is of interest.

Consider the case when both the imputation model and the analysis model are the same Bayesian models. Then the repeated imputations (multiple imputations) are repeated draws from the posterior predictive distribution of the missing data under a posited Bayesian model. The combined parameter estimates, $\widehat{Q}_{\text{MI}}$, and their associated sampling variance estimate, $T = W + B$, are the approximations to the posterior mean and variance of Q. Here W represents the within-imputation variability (average of the completed-data variance estimates, U), and B represents the between-imputation variability (variance estimate of $\widehat{Q}_{\text{MI}}$ over repeated imputations). Provided that the posterior mean and variance are adequate summaries of the posterior distribution, the repeated-imputation inference based on these combined estimates can be justified either from a purely Bayesian standpoint or from a purely frequentist standpoint. Thus a Bayesian apparatus is used to create imputations and also underlies the rules for combining parameter estimates.

In reality, the analysis model is rarely the same as the imputation model, and neither of them is an explicit Bayesian model. Repeated-imputation inference is still statistically valid in those cases. The rigorous justification is given in chapters 3 and 4 of Rubin (1987) from the frequentist perspective. Below we briefly summarize the conditions under which the repeated-imputation inference from the pooling step is statistically valid; also see Rubin (1987, 117–119) for more detail.

The repeated-imputation inference is statistically valid if 1) the multiple imputations from the imputation step are proper (see *Proper imputation methods* below) and 2) the completed-data inference based on $(\widehat{Q}, U)$ from the analysis step is randomization valid. Completed-data inference based on $(\widehat{Q}, U)$ is randomization valid if $\widehat{Q} \sim N\{Q, \text{Var}(\widehat{Q})\}$ and U is a consistent estimate of $\text{Var}(\widehat{Q})$ over the distribution of the sampling mechanism.

The randomization validity of MI was derived under the assumption of an infinite number of imputations. In practice, however, the number of imputations tends to be small and so the finite-M properties of the MI estimators must be explored. Rubin (1987) derives the fundamental result underlying the MI inference based on a finite M. We restate it below for a scalar Q:

$$T_M^{-1/2}(Q - \widehat{Q}_M) \sim t_{\nu_M}$$

where $\widehat{Q}_M$ is the average of M completed-data estimates of Q, $T_M = W + (1 + 1/M)B$, and t_{ν_M} is a Student's t distribution with degrees of freedom ν_M that depend on the number of imputations and rates of missing information (or the fraction of information missing because of nonresponse that measures the influence of the missing data on parameter estimates). Later, Li, Raghunathan, and Rubin (1991) derived an improved procedure for multiple testing, and Barnard and Rubin (1999) and Reiter (2007) extended the MI inference to account for small samples. For computation details, see *Methods and formulas* in [MI] **mi estimate**.

How large should M be?

The theory underlying the validity of MI relies on an infinite number of imputations, M. The procedure is also known to have good statistical properties with finite M, but what values of M should we use in practice? Rubin (1987, 114) answers this question: the asymptotic relative efficiency (RE) of the MI procedure with finite M compared with infinite M is roughly 90% with only two imputations for a missing-information rate as high as 50%.

Most literature (for example, Rubin [1987] and van Buuren, Boshuizen, and Knook [1999]) suggests that $M = 5$ (corresponding to RE of 95% for 50% of information missing) should be sufficient to obtain valid inference. In general, however, the actual number of imputations necessary for MI to perform satisfactorily depends not only on the amount of information missing due to nonresponse but also on the analysis model and the data. Some analyses may require M to be 50 or more to obtain stable results (Kenward and Carpenter 2007; Horton and Lipsitz 2001).

Literature with formal recommendations on how to choose M is very sparse. Royston (2004), Royston, Carlin, and White (2009), and White, Royston, and Wood (2011) discuss the impact of the number of imputations on the precision of estimates and suggest ways of determining the required number of imputations by evaluating the sampling error of the MI estimates.

Because it is computationally feasible to obtain more imputations, we recommend using at least 20 imputations to reduce the sampling error due to imputations.

Assumptions about missing data

The theory underlying MI methodology makes no assumption about the missing-data mechanism. However, many imputation methods (including those provided by Stata) require that the missing-data mechanism be ignorable. Before we discuss the ignorability conditions, consider the following definitions.

Missing data are said to be missing completely at random (MCAR) if the probability that data are missing does not depend on observed or unobserved data. Under MCAR, the missing-data values are a simple random sample of all data values, and so any analysis that discards the missing values remains consistent, albeit perhaps inefficient.

Consider a hypothetical longitudinal study comparing different blood-pressure treatments. Suppose that the follow-up blood-pressure measurements were not collected from some subjects because they moved to a different area. These missing blood-pressure measurements can be viewed as MCAR as long as subjects' decisions to move were unrelated to any item in the study.

Missing data are said to be missing at random (MAR) if the probability that data are missing does not depend on unobserved data but may depend on observed data. Under MAR, the missing-data values do not contain any additional information given observed data about the missing-data mechanism. Note that MCAR can be viewed as a particular case of MAR. When missing data are MAR, listwise deletion may lead to biased results.

Suppose that some subjects decided to leave the study because of severe side effects from the assigned treatment of a high dosage of a medicine. Here it is unlikely that missing blood-pressure measurements are MCAR because the subjects who received a higher dosage of the medicine are more likely to suffer severe side effects than those who received a lower dosage and thus are more likely to drop out of the study. Missing blood-pressure measurements depend on the dosage of the received treatment and therefore are MAR.

On the other hand, if the subjects are withdrawn from the study for ethical reasons because of extremely high blood pressures, missing blood-pressure measurements would not be MAR. The measurements for the subjects with very high blood pressures will be missing and thus the reason for drop out will depend on the missing blood pressures. This type of missing-data mechanism is called missing not at random (MNAR). For such missing data, the reasons for its missingness must be accounted for in the model to obtain valid results.

Model parameters are said to be *distinct* from a Bayesian standpoint if their joint prior distribution can be factorized into independent marginal prior distributions.

The missing-data mechanism is said to be *ignorable* if missing data are MAR and the parameters of the data model and the parameters of the missing-data mechanism are distinct (Rubin 1976).

The ignorability assumption makes it possible to ignore the process that causes missing data in the imputation model—something not possible with MNAR—which simplifies the imputation step while still ensuring correct inference. The provided imputation methods assume that missing data are MAR.

In practice, it is difficult to test the ignorability assumption formally because the MAR mechanism can be distinguished from the MNAR mechanism only through the missing data that are not observed. Thus careful consideration is necessary before accepting this assumption. If in doubt, sensitivity analysis—analysis repeated under various missing-data models—needs to be performed to verify the stability of inference. In the context of MI, sensitivity analysis can be performed by modifying the imputation step to accommodate the nonignorable missing-data mechanism (for example, Kenward and Carpenter [2007], van Buuren, Boshuizen, and Knook [1999], and Cro, Kenward, Morris, and Carpenter [2016]).

Patterns of missing data

Another issue we need to consider related to missing data is a pattern of missingness (or missing-data pattern).

Consider an $N \times p$ data matrix $Y = (Y_1, Y_2, \ldots, Y_p)'$ with p variables and N observations. Consider a permutation of column indices $(i_1, i_2, \ldots, i_p)$ such that Y_{i_1} is at least as observed as Y_{i_2}, which is at least as observed as Y_{i_3}, and so on. In other words, Y_{i_2} has missing values in the same observations (and possibly more) as Y_{i_1}, Y_{i_3} has missing values (and possibly more) in the same observations as Y_{i_2}, and so on. If such a permutation exists, then the pattern of missingness in Y is said to be monotone. If the pattern of missingness is not monotone, it is assumed to be arbitrary. Loss to follow-up often leads to a monotone-missing pattern in the data.

For example, consider the following indicator matrix recording the missing pattern in Y:

$$R_1 = \begin{pmatrix} 1 & 1 & 1 \\ 0 & 0 & 1 \\ 0 & 1 & 1 \\ 0 & 1 & 1 \end{pmatrix}$$

where R_1^{ij} is 1 if variable Y_j is observed (complete) in observation i and 0 otherwise. We can see that Y has a monotone-missing pattern if we interchange the first and the third columns of R_1. In fact, if we also rearrange the rows such that

$$R_1 = \begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 0 \\ 1 & 1 & 0 \\ 1 & 0 & 0 \end{pmatrix}$$

then the monotonicity of missing values becomes even more evident. An example of a nonmonotone missing-value pattern is

$$R_2 = \begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 0 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \end{pmatrix}$$

There is no ordering of the first two columns of R_2 such that the missing values in one column imply missing values in the other column.

Why is it important to consider the monotone missing-value pattern? A monotone-missing pattern greatly simplifies the imputation task. Under a monotone-missing pattern, a multivariate imputation task can be formulated as a sequence of independent univariate (conditional) imputation tasks, which allows the creation of a flexible imputation model; see [MI] **mi impute monotone** for details, and see Rubin (1987, 174) for more technical conditions under which such a formulation is applicable.

Proper imputation methods

As we mentioned earlier, a key concept underlying the randomization-based evaluations of the repeated-imputation inference is proper multiple imputation.

A multiple-imputation method is said to be proper if it produces proper multiple imputations, which we are about to define. Rubin (1987, 118–119) gives a full technical definition for proper multiple imputations. Ignoring the more technical definition, Rubin (1996) states the following main conditions. The multiple imputations are said to be proper if

1. MI estimates $\widehat{Q}_{\text{MI}}$ are asymptotically normal with mean $\widehat{Q}$ and a consistent variance–covariance estimate B.
2. The within-imputation variance estimate W is a consistent estimate of the variance–covariance estimate U with variability of a lower order than $\text{Var}(\widehat{Q}_{\text{MI}})$.

The above statements assume a large number of imputations and the randomization distribution induced by the missing-data mechanism.

In general, it is difficult to determine if an imputation method is proper using the above definition. Rubin (1987, sec. 4.3) and Binder and Sun (1996) describe several examples of proper and improper imputation methods. Rubin (1987, 125–127) recommends drawing imputations from a Bayesian posterior predictive distribution (or an appropriate approximation to it) of missing values under the chosen model for the data and the missing-data mechanism. The chosen imputation model must also be appropriate for the completed-data statistics likely to be used at the analysis stage. Schafer (1997, 145) points out that from a practical standpoint, it is more important that the chosen imputation model performs well over the repeated samples than that it be technically proper. This can be checked via simulation.

With the exception of predictive mean matching and chained equations, the imputation methods available in Stata obtain imputations by simulating from a Bayesian posterior predictive distribution of the missing data (or its approximation) under the conventional (or chosen) prior distribution; see *Imputation methods* in [MI] **mi impute** for details. To ensure that the multiple imputations are proper, you must choose an appropriate imputation model, which we briefly discuss next.

The imputation model must include all predictors relevant to the missing-data mechanism, and it must preserve all data characteristics likely to be explored at the analysis stage. For example, if the analysis model explores a correlation between two variables, then omitting either of those variables from the imputation model will lead to estimates of the correlation biased toward zero. Another common mistake that may lead to biased estimates is when an outcome variable of the analysis model is not used in the imputation model. In the survey context, all structural variables such as sampling weights, strata, and cluster identifiers (or at least main strata and main clusters) need to be included in the imputation model.

In general, any predictors involved in the definition of the completed-data estimators and the sampling design should be included in the imputation model. If you intend to use the multiply imputed data in an analysis involving a wide range of completed-data estimators, you should include as many variables as possible.

Using our heart attack data, if we were to release the multiply imputed version of the dataset for general analyses, we would have included all available covariates as predictors in the regression model used to impute BMI and not only the subset of covariates (heart attacks, smoking status, age, gender, and educational status) used in our specific data analysis.

The severity of the effect of a misspecified imputation model will typically depend on the amount of imputed data relative to the observed data—a small number of observations with improperly imputed values may not affect the inference greatly if there is a large number of observations with complete data.

For more details about imputation modeling, see Rubin (1996), Schafer (1997, 139–144), Schafer and Olsen (1998), Allison (2001), Schafer and Graham (2002), Kenward and Carpenter (2007), Graham (2009), and White, Royston, and Wood (2011), among others. For imputation modeling of large surveys, see, for example, Schafer, Khare, and Ezzati-Rice (1993) and Ezzati-Rice et al. (1995).

Analysis of multiply imputed data

Once we have multiply imputed data, we perform our primary analysis on each completed dataset and then use Rubin's combination rules to form one set of results. Assuming that the underlying imputation model is properly specified (see, for example, Abayomi, Gelman, and Levy [2008] and Gelman et al. [2005] for multiple-imputation diagnostics), we can choose from a variety of statistical methods. For example, the methods can include maximum likelihood methods, survey methods, nonparametric methods, and any other method appropriate for the type of data we have.

Each of the methods have certain concepts associated with them. For example, maximum likelihood methods use a likelihood function, whereas a deviance is associated with generalized linear models. While these concepts are well defined within each individual completed-data analysis, they may not have a clear interpretation when the individual analyses are combined in the pooling step. (Only in the special case when the imputation and analysis models are compatible Bayesian models can the estimated parameters be viewed as approximations to the mode of the posterior distribution.)

As a result, various statistical (postestimation) procedures based on these concepts, such as likelihood-ratio tests, goodness-of-fit tests, etc., are not directly applicable to MI results. Instead, their "MI" versions are being studied in the literature (Li et al. 1991; Meng and Rubin 1992). Another concept that is not uniquely defined within MI is that of prediction; see Carlin, Galati, and Royston (2008) and White, Royston, and Wood (2011) for one definition.

Donald Bruce Rubin (1943–) was born in Washington, DC. He entered Princeton intending to become a physicist but ended up majoring in psychology. He entered Harvard intending to continue as a psychologist, but in the event, gained further degrees in computer science and statistics. After periods at the Educational Testing Service and the University of Chicago, Rubin returned to Harvard in 1984. He has had many visiting appointments and has carried out extensive consultancy work. Rubin has long been a leader in research on causal inference in experiments and observational studies, and problems of nonresponse and missing data. Among many major contributions is his formalization of the expectation-maximization algorithm with Arthur Dempster and Nan Laird. Rubin's work ranges over a wide variety of sciences and is often Bayesian in style. Rubin was elected a member of the National Academy of Sciences in 2010.

A brief introduction to MI using Stata

Stata offers full support for MI analysis from the imputation step to the pooling step.

The imputation step can be performed for one variable or multiple variables. A number of imputation methods, including flexible methods accommodating variables of different types and an iterative Markov chain Monte Carlo method based on multivariate normal, are available; see [MI] **mi impute** for details.

The analysis and pooling steps are combined into one step and performed by `mi estimate`; see [MI] **mi estimate**. You can fit many commonly used models and obtain combined estimates of coefficients (or transformed coefficients) (see [MI] **Estimation** for a list of supported estimation commands), or you can create your own estimation command and use it with the `mi estimate` prefix.

In addition to the conventional estimation steps, Stata facilitates many data-manipulation routines for managing your multiply imputed data and verifying its integrity over the imputations; see [MI] **Intro** for a full list of commands.

As a short demonstration of mi, let's analyze the heart attack data introduced earlier using MI; see [MI] **Workflow** for more thorough guidelines.

The goals are 1) to fill in missing values of bmi using, for example, a linear regression imputation method (mi impute regress) to obtain multiply imputed data and 2) to analyze the multiply imputed data using logistic regression, which we will do using mi estimate. Before we can accomplish these two steps, we need to prepare the data so they can be used with mi. First, we declare the data to be mi data:

```
. use https://www.stata-press.com/data/r19/mheart0
(Fictional heart attack data; BMI missing)
. mi set mlong
```

We choose to use the data in the marginal long style (mlong) because it is a memory-efficient style; see [MI] **Styles** for details.

To use mi impute, we must first register imputation variables. In general, we recommend that you register all variables relevant to the analysis as imputed, passive, or regular with mi register (see [MI] **mi set**), especially if you plan on doing any data management of your multiply imputed data.

```
. mi register imputed bmi
(22 m=0 obs now marked as incomplete)
. mi register regular attack smokes age hsgrad female
```

We are now ready to use mi impute. To lessen the simulation (Monte Carlo) error, we arbitrarily choose to create 20 imputations (add(20) option). We also specify the rseed() option for reproducibility:

```
. mi impute regress bmi attack smokes age hsgrad female, add(20) rseed(2232)
Univariate imputation                       Imputations =       20
Linear regression                                 added =       20
Imputed: m=1 through m=20                       updated =        0

------------------------------------------------------------------
                             |              Observations per m
                             |----------------------------------------
                    Variable |   Complete   Incomplete    Imputed |  Total
-----------------------------+----------------------------------------+-----
                         bmi |        132           22         22 |    154
------------------------------------------------------------------

(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

From the output, we see that all 22 incomplete values of bmi were successfully imputed. You may want to examine your imputations to verify that nothing abnormal occurred during imputation. For example, as a quick check, we can compare main descriptive statistics from some imputations (say, the first and the last one) to those from the observed data. We use mi xeq (see [MI] **mi xeq**) to execute Stata's summarize command on the original data ($m = 0$), the first imputation ($m = 1$), and the last imputation ($m = 20$):

```
. mi xeq 0 1 20: summarize bmi
m=0 data:
-> summarize bmi
    Variable |        Obs        Mean    Std. dev.       Min        Max
-------------+---------------------------------------------------------
         bmi |        132    25.24136    4.027137   17.22643   38.24214
m=1 data:
-> summarize bmi
    Variable |        Obs        Mean    Std. dev.       Min        Max
-------------+---------------------------------------------------------
         bmi |        154    25.28134    3.969649   17.22643   38.24214
m=20 data:
-> summarize bmi
    Variable |        Obs        Mean    Std. dev.       Min        Max
-------------+---------------------------------------------------------
         bmi |        154    25.30992     4.05665   16.44644   38.24214
```

The summary statistics of the imputed datasets look reasonable.

We now fit the logistic regression using the `mi estimate` prefix command:

```
. mi estimate, dots: logit attack smokes age bmi hsgrad female
Imputations (20):
  .........10.........20 done
Multiple-imputation estimates                   Imputations       =         20
Logistic regression                             Number of obs     =        154
                                                Average RVI       =     0.0611
                                                Largest FMI       =     0.2518
DF adjustment:   Large sample                   DF:     min       =     311.30
                                                        avg       = 116,139.89
                                                        max       = 252,553.06
Model F test:       Equal FMI                   F(   5,19590.7)   =       3.52
Within VCE type:          OIM                   Prob > F          =     0.0035
------------------------------------------------------------------------------
      attack | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
      smokes |   1.222431   .3608138     3.39   0.001     .5152409     1.92962
         age |   .0358403   .0154631     2.32   0.020     .0055329    .0661476
         bmi |   .1094125   .0518803     2.11   0.036     .0073322    .2114929
      hsgrad |   .1740094   .4055789     0.43   0.668    -.6209156    .9689344
      female |  -.0985455   .4191946    -0.24   0.814    -.9201594    .7230684
       _cons |  -5.625926   1.782136    -3.16   0.002    -9.124984   -2.126867
------------------------------------------------------------------------------
```

Compared with the earlier `logit` analysis (using listwise deletion), we detect the significance of `age`, whose effect was apparently disguised by the missing data. See [MI] **mi estimate** for details.

We will be using variations of these data throughout the `mi` documentation.

Summary

- MI is a simulation-based procedure. Its purpose is not to re-create the individual missing values as close as possible to the true ones but to handle missing data in a way resulting in valid statistical inference (Rubin 1987, 1996).
- MI yields valid inference if 1) the imputation method is proper with respect to the posited missing-data mechanism (see *Proper imputation methods* above) and 2) completed-data analysis is valid in the absence of missing data.

- A small number of imputations (5 to 20) may be sufficient when fractions of missing data are low. High fractions of missing data as well as particular data structures may require up to 100 (or more) imputations. Whenever feasible to do so, we recommend that you vary the number of imputations to see if this affects your results.
- With a small number of imputations, the reference distribution for the MI inference is Student's t (or F in multiple-hypothesis testing). The residual degrees of freedom depend on M and the rates of missing information and thus are different for each parameter of interest.
- With a large number of imputations, the reference distribution for MI inference is approximately normal (or χ^2 in multiple-hypothesis testing).
- When the imputer's model is more restrictive than the analyst's model, the MI inference can be invalid if the imputer's assumptions are not true. On the other hand, when the analyst's model is more restrictive than the imputer's model, the MI results will be valid but somewhat conservative if the analyst's assumptions are true. If the analyst's assumptions are false, the results can be biased; see, for example, Schafer (1997) for details.
- MI is relatively robust to departures from the correct specification of the imputation model, provided the rates of missing information are low and the correct completed-data model is used in the analysis.
- Certain concepts, for example, likelihood and deviance, do not have clear interpretation within the MI framework. As such, various statistical (postestimation) procedures based on these concepts (for example, likelihood-ratio tests, goodness-of-fit tests) are not directly applicable to MI results.

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Also see

[MI] **Intro** — Introduction to mi

[MI] **Estimation** — Estimation commands for use with mi estimate

[MI] **mi estimate** — Estimation using multiple imputations

[MI] **mi impute** — Impute missing values

[MI] **Workflow** — Suggested workflow

[MI] **Glossary**

Description Remarks and examples Acknowledgments Also see

Description

The `mi` suite of commands deals with multiple-imputation data, abbreviated as `mi` data. To become familiar with `mi` as quickly as possible, do the following:

1. See *A simple example* under *Remarks and examples* below.
2. If you have data that require imputing, see [MI] **mi set** and [MI] **mi impute**.
3. Alternatively, if you have already imputed data, see [MI] **mi import**.
4. To fit your model, see [MI] **mi estimate**.

To create `mi` data from original data

`mi set`	declare data to be `mi` data
`mi register`	register imputed, passive, or regular variables
`mi unregister`	unregister previously registered variables
`mi unset`	return data to unset status (rarely used)

See *Summary* below for a summary of `mi` data and these commands.
See [MI] **Glossary** for a definition of terms.

To import data that already have imputations for the missing values (do not `mi set` the data)

`mi import`	import `mi` data
`mi export`	export `mi` data to non-Stata application

Once data are `mi set` or `mi imported`

`mi query`	query whether and how `mi set`
`mi describe`	describe `mi` data
`mi varying`	identify variables that vary over m
`mi misstable`	tabulate missing values
`mi passive`	create passive variable and register it

To perform estimation on mi data

mi impute	impute missing values
mi estimate	perform and combine estimation on $m > 0$
mi ptrace	check stability of MCMC
mi test	perform tests on coefficients
mi testtransform	perform tests on transformed coefficients
mi predict	obtain linear predictions
mi predictnl	obtain nonlinear predictions

To stset, svyset, tsset, or xtset any mi data that were not set at the time they were mi set

mi fvset	fvset for mi data
mi svyset	svyset for mi data
mi xtset	xtset for mi data
mi tsset	tsset for mi data
mi stset	stset for mi data
mi streset	streset for mi data
mi st	st for mi data

To perform data management on mi data

mi rename	rename variable
mi append	append for mi data
mi merge	merge for mi data
mi expand	expand for mi data
mi reshape	reshape for mi data
mi stsplit	stsplit for mi data
mi stjoin	stjoin for mi data
mi add	add imputations from one mi dataset to another

To perform data management for which no mi prefix command exists

mi extract	extract $m = 0$ data
...	perform data management the usual way
mi replace0	replace $m = 0$ data in mi data

To perform the same data management or data-reporting command(s) on $m = 0$, $m = 1$, ...

`mi xeq: ...`	execute commands on $m = 0$, $m = 1$, $m = 2$, ..., $m = M$
`mi xeq #: ...`	execute commands on $m = \#$
`mi xeq # # ...: ...`	execute commands on specified values of m

Useful utility commands

`mi convert`	convert `mi` data from one style to another
`mi extract #`	extract $m = \#$ from `mi` data
`mi select #`	programmer's command similar to `mi extract`
`mi copy`	copy `mi` data
`mi erase`	erase files containing `mi` data
`mi update`	verify/make `mi` data consistent
`mi reset`	reset imputed or passive variable

For programmers interested in extending `mi`

[MI] **Technical**	Detail for programmers

Summary of styles

There are four styles or formats in which `mi` data are stored: flongsep, flong, mlong, and wide.

1. Flongsep: $m = 0$, $m = 1$, ..., $m = M$ are each separate `.dta` datasets. If $m = 0$ data are stored in `pat.dta`, then $m = 1$ data are stored in `_1_pat.dta`, $m = 2$ in `_2_pat.dta`, and so on. Flongsep stands for *full long and separate*.
2. Flong: $m = 0$, $m = 1$, ..., $m = M$ are stored in one dataset with $_N = N + M \times N$ observations, where N is the number of observations in $m = 0$. Flong stands for *full long*.
3. Mlong: $m = 0$, $m = 1$, ..., $m = M$ are stored in one dataset with $_N = N + M \times n$ observations, where n is the number of incomplete observations in $m = 0$. Mlong stands for *marginal long*.
4. Wide: $m = 0$, $m = 1$, ..., $m = M$ are stored in one dataset with $_N = N$ observations. Each imputed and passive variable has M additional variables associated with it. If variable `bp` contains the values in $m = 0$, then values for $m = 1$ are contained in variable `_1_bp`, values for $m = 2$ in `_2_bp`, and so on. Wide stands for *wide*.

See *style* in [MI] **Glossary** and see [MI] **Styles** for examples. See [MI] **Technical** for programmer's details.

Summary

1. mi data may be stored in one of four formats—flongsep, flong, mlong, and wide—known as styles. Descriptions are provided in *Summary of styles* directly above.
2. mi data contain M imputations numbered $m = 1, 2, \ldots, M$, and contain $m = 0$, the original data with missing values.
3. Each variable in mi data is registered as imputed, passive, or regular, or it is unregistered.
    a. Unregistered variables are mostly treated like regular variables.
    b. Regular variables usually do not contain missing, or if they do, the missing values are not imputed in $m > 0$.
    c. Imputed variables contain missing in $m = 0$, and those values are imputed, or are to be imputed, in $m > 0$.
    d. Passive variables are algebraic combinations of imputed, regular, or other passive variables.
4. If an imputed variable contains a value greater than . in $m = 0$—it contains .a, .b, …, .z—then that value is considered a hard missing and the missing value persists in $m > 0$.

See [MI] **Glossary** for a more thorough description of terms used throughout this manual.

Remarks and examples

Remarks are presented under the following headings:

A simple example
Suggested reading order

A simple example

We are about to type six commands:

```
. use https://www.stata-press.com/data/r19/mheart5                    (1)
. mi set mlong                                                        (2)
. mi register imputed age bmi                                         (3)
. set seed 29390                                                      (4)
. mi impute mvn age bmi = attack smokes hsgrad female, add(10)        (5)
. mi estimate: logistic attack smokes age bmi hsgrad female           (6)
```

The story is that we want to fit

```
. logistic attack smokes age bmi hsgrad female
```

but the age and bmi variables contain missing values. Fitting the model by typing logistic … would ignore some of the information in our data. Multiple imputation (MI) attempts to recover that information. The method imputes M values to fill in each of the missing values. After that, statistics are performed on the M imputed datasets separately and the results combined. The goal is to obtain better estimates of parameters and their standard errors.

In the solution shown above,

1. We load the data.
2. We set our data for use with `mi`.
3. We inform `mi` which variables contain missing values for which we want to impute values.
4. We impute values in command 5; we prefer that our results be reproducible, so we set the random-number seed in command 4. This step is optional.
5. We create $M = 10$ imputations for each missing value in the variables we registered in command 3.
6. We fit the desired model separately on each of the 10 imputed datasets and combine the results.

The results of running the six-command solution are

```
. webuse mheart5
(Fictional heart attack data)
. mi set mlong
. mi register imputed age bmi
(28 m=0 obs now marked as incomplete)
. set seed 29390
. mi impute mvn age bmi = attack smokes hsgrad female, add(10)
Performing EM optimization:
note: 12 observations omitted from EM estimation because of all imputation
      variables missing.
  observed log likelihood = -651.75868 at iteration 7
Performing MCMC data augmentation ...
Multivariate imputation                     Imputations =       10
Multivariate normal regression                    added =       10
Imputed: m=1 through m=10                       updated =        0
Prior: uniform                               Iterations =     1000
                                                burn-in =      100
                                                between =      100
```

Variable	Observations per *m*			
	Complete	Incomplete	Imputed	Total
age	142	12	12	154
bmi	126	28	28	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

```
. mi estimate: logistic attack smokes age bmi hsgrad female
Multiple-imputation estimates                   Imputations       =         10
Logistic regression                             Number of obs     =        154
                                                Average RVI       =     0.0835
                                                Largest FMI       =     0.2642
DF adjustment:   Large sample                   DF:     min       =     139.75
                                                        avg       =  19,591.87
                                                        max       =  67,578.07
Model F test:       Equal FMI                   F(   5, 4836.6)   =       3.32
Within VCE type:          OIM                   Prob > F          =     0.0054
------------------------------------------------------------------------------
      attack | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
      smokes |   1.187152   .3623514     3.28   0.001     .4768502    1.897453
         age |   .0315179   .0163884     1.92   0.055    -.0006696    .0637055
         bmi |   .1090419   .0516554     2.11   0.037     .0069434    .2111404
     hsgrad |   .1712372   .4054594     0.42   0.673     -.623472    .9659464
      female |   -.065744   .4156809    -0.16   0.874    -.8804781    .7489901
       _cons |  -5.369962   1.863821    -2.88   0.005    -9.054895   -1.685029
------------------------------------------------------------------------------
```

Note that the output from the last command,

```
. mi estimate: logistic attack smokes age bmi hsgrad female
```

reported coefficients rather than odds ratios, which `logistic` would usually report. That is because the estimation command is not `logistic`, it is `mi estimate`, and `mi estimate` happened to use `logistic` to obtain results that `mi estimate` combined into its own estimation results.

`mi estimate` by default displays coefficients. If we now wanted to see odds ratios, we could type

```
. mi estimate, or
```
(*output showing odds ratios would appear*)

Note carefully: We replay results by typing `mi estimate`, not by typing `logistic`. If we had wanted to see the odds ratios from the outset, we would have typed

```
. mi estimate, or: logistic attack smokes age bmi hsgrad female
```

Suggested reading order

The order of suggested reading of this manual is

[MI] **Intro substantive**
[MI] **Intro**
[MI] **Glossary**
[MI] **Workflow**

[MI] **mi set**
[MI] **mi import**
[MI] **mi describe**
[MI] **mi misstable**

[MI] **mi impute**
[MI] **mi estimate**
[MI] **mi estimate postestimation**

[MI] **Styles**
[MI] **mi convert**
[MI] **mi update**

[MI] **mi rename**
[MI] **mi copy**
[MI] **mi erase**
[MI] **mi XXXset**

[MI] **mi extract**
[MI] **mi replace0**

[MI] **mi append**
[MI] **mi add**
[MI] **mi merge**
[MI] **mi reshape**
[MI] **mi stsplit**
[MI] **mi varying**

Programmers will want to see [MI] **Technical**.

Acknowledgments

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Also see

[MI] **Intro substantive** — Introduction to multiple-imputation analysis

[MI] **Glossary**

[MI] **Styles** — Dataset styles

[MI] **Workflow** — Suggested workflow

[U] 1.3 What's new

Description Also see

Description

Multiple-imputation data analysis in Stata is similar to standard data analysis. The standard syntax applies, but you need to remember the following for MI data analysis:

1. The data must be declared as `mi` data.

   If you already have multiply imputed data (saved in Stata format), use `mi import` to import it into `mi`; see [MI] **mi import**.

   If you do not have multiply imputed data, use `mi set` (see [MI] **mi set**) to declare your original data to be `mi` data and use `mi impute` (see [MI] **mi impute**) to fill in missing values.

2. After you have declared `mi` data, commands such as `svyset`, `stset`, and `xtset` cannot be used. Instead use `mi svyset` to declare survey data, use `mi stset` to declare survival data, and use `mi xtset` to declare panel data. See [MI] **mi XXXset**.

3. Prefix the estimation commands with `mi estimate:` (see [MI] **mi estimate**).

The following estimation commands support the `mi estimate` prefix.

Command	Entry	Description
Linear regression models		
`regress`	[R] **regress**	Linear regression
`cnsreg`	[R] **cnsreg**	Constrained linear regression
`mvreg`	[MV] **mvreg**	Multivariate regression
Binary-response regression models		
`logistic`	[R] **logistic**	Logistic regression, reporting odds ratios
`logit`	[R] **logit**	Logistic regression, reporting coefficients
`probit`	[R] **probit**	Probit regression
`cloglog`	[R] **cloglog**	Complementary log–log regression
`binreg`	[R] **binreg**	GLM for the binomial family
Count-response regression models		
`poisson`	[R] **poisson**	Poisson regression
`nbreg`	[R] **nbreg**	Negative binomial regression
`gnbreg`	[R] **nbreg**	Generalized negative binomial regression
Ordinal-response regression models		
`ologit`	[R] **ologit**	Ordered logistic regression
`oprobit`	[R] **oprobit**	Ordered probit regression
Categorical-response regression models		
`mlogit`	[R] **mlogit**	Multinomial (polytomous) logistic regression
`mprobit`	[R] **mprobit**	Multinomial probit regression
`clogit`	[R] **clogit**	Conditional (fixed-effects) logistic regression

Fractional-response regression models		
`fracreg`	[R] **fracreg**	Fractional response regression
Quantile regression models		
`qreg`	[R] **qreg**	Quantile regression
`iqreg`	[R] **qreg**	Interquantile range regression
`sqreg`	[R] **qreg**	Simultaneous-quantile regression
`bsqreg`	[R] **qreg**	Bootstrapped quantile regression
Survival regression models		
`stcox`	[ST] **stcox**	Cox proportional-hazards model
`streg`	[ST] **streg**	Parametric survival models
`stcrreg`	[ST] **stcrreg**	Competing-risks regression
Other regression models		
`glm`	[R] **glm**	Generalized linear models
`areg`	[R] **areg**	Linear regression with many indicator variables
`rreg`	[R] **rreg**	Robust regression
`truncreg`	[R] **truncreg**	Truncated regression
Descriptive statistics		
`mean`	[R] **mean**	Estimate means
`proportion`	[R] **proportion**	Estimate proportions
`ratio`	[R] **ratio**	Estimate ratios
`total`	[R] **total**	Estimate totals
Panel-data models		
`xtreg`	[XT] **xtreg**	Linear models for panel data
`xtrc`	[XT] **xtrc**	Random-coefficients model
`xtlogit`	[XT] **xtlogit**	Fixed-effects, random-effects, and population-averaged logit models
`xtprobit`	[XT] **xtprobit**	Random-effects and population-averaged probit models
`xtcloglog`	[XT] **xtcloglog**	Random-effects and population-averaged cloglog models
`xtpoisson`	[XT] **xtpoisson**	Fixed-effects, random-effects, and population-averaged Poisson models
`xtnbreg`	[XT] **xtnbreg**	Fixed-effects, random-effects, and population-averaged negative binomial models
`xtgee`	[XT] **xtgee**	GEE population-averaged panel-data models
Multilevel mixed-effects models		
`mixed`	[ME] **mixed**	Multilevel mixed-effects linear regression
Survey regression models		
`svy:`	[SVY] **svy**	Estimation commands for survey data (excluding commands that are not listed above)

Only Taylor-linearized survey variance estimation is supported with `svy:`.

Also see

[MI] **mi estimate** — Estimation using multiple imputations

[MI] **mi estimate postestimation** — Postestimation tools for mi estimate

[MI] **mi import** — Import data into mi

[MI] **mi impute** — Impute missing values

[MI] **mi set** — Declare multiple-imputation data

[MI] **Workflow** — Suggested workflow

[MI] **Intro** — Introduction to mi

[MI] **Intro substantive** — Introduction to multiple-imputation analysis

[MI] **Glossary**

mi add — Add imputations from another mi dataset

Description Menu Syntax Options
Remarks and examples Stored results Also see

Description

`mi add` adds the imputations from the using dataset on disk to the end of the master dataset in memory.

Menu

Statistics > Multiple imputation

Syntax

`mi add` *varlist* `using` *filename* [`,` *options*]

options	Description
`assert(master)`	assert all observations found in master
`assert(match)`	assert all observations found in master and in using
`noupdate`	see [MI] **noupdate option**

`collect` is allowed; see **[U] 11.1.10 Prefix commands**.

Notes:

1. Jargon:
   match variables = *varlist*, variables on which match performed
   master = data in memory
   using = data on disk (*filename*)
2. Master must be `mi set`.
3. Using must be `mi set`.
4. *filename* must be enclosed in double quotes if *filename* contains blanks or other special characters.

Options

`assert(`*results*`)` specifies how observations are expected to match. If results are not as you expect, an error message will be issued and the master data left unchanged.

`assert(master)` specifies that you expect a match for every observation in the master, although there may be extra observations in the using that `mi add` is to ignore.

`assert(match)` specifies that you expect every observation in the master to match an observation in the using and vice versa.

The default is that the master may have observations that are missing from the using and vice versa. Only observations in common are used by `mi add`.

`noupdate` in some cases suppresses the automatic `mi update` this command might perform; see [MI] **noupdate option**.

Remarks and examples

Think of the result produced by `mi add` as being

Result	Source
$m = 0$	$m = 0$ from master
$m = 1$	$m = 1$ from master
$m = 2$	$m = 2$ from master
.	.
.	.
$m = M_{\text{master}}$	$m = M_{\text{master}}$ from master
$m = M_{\text{master}} + 1$	$m = 1$ from using
$m = M_{\text{master}} + 2$	$m = 2$ from using
.	.
.	.
$m = M_{\text{master}} + M_{\text{using}}$	$m = M_{\text{using}}$ from using

That is, the original data in the master remain unchanged. All that happens is the imputed data from the using are added to the end of the master as additional imputations.

For instance, say you discover that you and a coworker have been working on the same data. You have added $M = 20$ imputations to your data. Your coworker has separately added $M = 17$. To combine the data, type something like

```
. use mydata
. mi add patientid using karensdata
(17 imputations added; M=37)
```

The only thing changed in your data is M. If your coworker's data have additional variables, they are ignored. If your coworker has variables registered differently from how you have them registered, that is ignored. If your coworker has not yet registered as imputed a variable that you have registered as imputed, that is noted in the output. You might see

```
. use mydata
. mi add patientid using karensdata
(17 imputations added; M=37)
(imputed variable grade not found in using data;
    added imputations contain m=0 values for that variable)
```

Stored results

`mi add` stores the following in `r()`:

Scalars

`r(m)`	number of added imputations
`r(unmatched_m)`	number of unmatched master observations
`r(unmatched_u)`	number of unmatched using observations

Macros

`r(imputed_f)`	variables for which imputed found
`r(imputed_nf)`	variables for which imputed not found

Also see

[MI] **Intro** — Introduction to mi

[MI] **mi append** — Append mi data

[MI] **mi merge** — Merge mi data

mi append — Append mi data

Description Menu Syntax Options
Remarks and examples Stored results Also see

Description

`mi append` is `append` for `mi` data; see [D] **append** for a description of appending datasets.

Menu

Statistics > Multiple imputation

Syntax

`mi append using` *filename* [, *options*]

options	Description
`generate(`*newvar*`)`	create *newvar*; 0 = master, 1 = using
`nolabel`	do not copy value labels from using
`nonotes`	do not copy notes from using
`force`	string ↔ numeric not type mismatch error
`noupdate`	see [MI] **noupdate option**

`collect` is allowed; see **[U] 11.1.10 Prefix commands**.

Notes:

1. Jargon:
   master = data in memory
   using = data on disk (*filename*)
2. Master must be `mi set`; using may be `mi set`.
3. `mi append` is logically equivalent to `append`; see [D] **append**. The resulting data have $M = \max(M_{\text{master}}, M_{\text{using}})$, not their sum. See [MI] **mi add** to append imputations holding $m = 0$ constant.
4. `mi append` syntactically differs from `append` in that multiple using files may not be specified and the `keep(`*varlist*`)` option is not allowed.
5. *filename* must be enclosed in double quotes if *filename* contains blanks or other special characters.

Options

`generate(`*newvar*`)` specifies that new variable *newvar* be created containing 0 for observations from the master and 1 for observations from the using.

`nolabel` prevents copying the value-label definitions from the using data to the master. Even if you do not specify this option, label definitions from the using never replace those of the master.

nonotes prevents any notes in the using from being incorporated into the master; see [D] **notes**.

force allows string variables to be appended to numeric variables and vice versa. The results of such type mismatches are, of course, missing values. Default behavior is to issue an error message rather than append datasets with such violently differing types.

noupdate in some cases suppresses the automatic mi update this command might perform; see [MI] **noupdate option**.

Remarks and examples

Use mi append when you would use append if the data were not mi.

Remarks are presented under the following headings:

Adding new observations
Adding new observations and imputations
Adding new observations and imputations, M unequal
Treatment of registered variables

Adding new observations

Assume that file mymi.dta contains data on three-quarters of the patients in the ICU. The data are mi set and $M = 5$. File remaining.dta arrives containing the remaining patients. The data are not mi set. To combine the datasets, you type

```
. use mymi, clear
. mi append using remaining
```

The original mi data had $M = 5$ imputations, and so do the resulting data. If the new data contain no missing values of the imputed variables, you are ready to go. Otherwise, you will need to impute values for the new data.

Adding new observations and imputations

Assume that file westwing.dta contains data on patients in the west wing of the ICU. File eastwing.dta contains data on patients in the east wing of the ICU. Both datasets are mi set with $M = 5$. You originally intended to analyze the datasets separately, but you now wish to combine them. You type

```
. use westwing, clear
. mi append using eastwing
```

The original data had $M = 5$ imputations, and so do the resulting data.

The data for $m = 0$ are the result of running an ordinary append on the two $m = 0$ datasets.

The data for $m = 1$ are also the result of running an ordinary append, this time on the two $m = 1$ datasets. Thus the result is a combination of observations of westwing.dta and eastwing.dta in the same way that $m = 0$ is. Imputations for observations that previously existed are obtained from westwing.dta, and imputations for the newly appended observations are obtained from eastwing.dta.

Adding new observations and imputations, M unequal

Consider the same situation as above, but this time assume $M = 5$ in `westwing.dta` and $M = 4$ in `eastwing.dta`. The combined result will still have $M = 5$. Imputed values in $m = 5$ will be missing for imputed variables from observations in `westwing.dta`.

Treatment of registered variables

It is possible that the two datasets will have variables registered inconsistently.

Variables registered as imputed in either dataset will be registered as imputed in the final result regardless of how they were registered (or unregistered) in the other dataset.

Barring that, variables registered as passive in either dataset will be registered as passive in the final result.

Barring that, variables registered as regular in either dataset will be registered as regular in the final result.

Stored results

`mi append` stores the following in `r()`:

Scalars

`r(N_master)`	number of observations in $m = 0$ in master
`r(N_using)`	number of observations in $m = 0$ in using
`r(M_master)`	number of imputations (M) in master
`r(M_using)`	number of imputations (M) in using

Macros

`r(newvars)`	new variables added

Thus values in the resulting data are

N = # of observations in $m = 0$
= `r(N_master) + r(N_using)`

k = # of variables
= *k_master* + `` `:word count `r(newvars)' ``

M = # of imputations
= `max(r(M_master), r(M_using))`

Also see

[MI] **Intro** — Introduction to mi

[D] **append** — Append datasets

[MI] **mi add** — Add imputations from another mi dataset

[MI] **mi merge** — Merge mi data

mi convert — Change style of mi data

Description Menu Syntax Options
Remarks and examples Also see

Description

`mi convert` converts `mi` data from one style to another.

Menu

Statistics > Multiple imputation

Syntax

`mi convert wide` [, *options*]

`mi convert mlong` [, *options*]

`mi convert flong` [, *options*]

`mi convert flongsep` *name* [, *options*]

options	Description
`clear`	okay to convert if data not saved
`noupdate`	see [MI] **noupdate option**

Options

`clear` specifies that it is okay to convert the data even if the data have not been saved to disk since they were last changed.

`noupdate` in some cases suppresses the automatic `mi update` this command might perform; see [MI] **noupdate option**.

Remarks and examples

Remarks are presented under the following headings:

Using mi convert as a convenience tool
Converting from flongsep
Converting to flongsep

Using mi convert as a convenience tool

Some tasks are easier in one style than another. `mi convert` allows you to switch to the more convenient style. It would not be unreasonable for a snippet of a session to read

```
. mi convert wide
. drop if sex=="male"
. mi convert mlong, clear
. replace age2 = age^2
```

This user is obviously exploiting his or her knowledge of [MI] **Styles**. The official way to do the above would be

```
. drop if sex=="male"
. mi update
. mi passive: replace age2 = age^2
```

It does not matter which approach you choose.

Converting from flongsep

If you have flongsep data, it is worth finding out whether you can convert it to one of the other styles. The other styles are more convenient than flongsep, and `mi` commands run faster on them. With your flongsep data in memory, type

```
. mi convert mlong
```

The result will be either success or an insufficient-memory error.

If you wish, you can make a crude guess as to how much memory is required as follows:

1. Use your flongsep data. Type `mi describe`. Write down M, the number of imputations, and write down the number of complete observations, which we will call N, and the number of incomplete observations, which we will call n.
2. With your flongsep data still in memory, type `memory`. Write down the sum of the numbers reported as "data" and "overhead" under the "used" column. We will call this sum S for size.
3. Calculate $T = S + M \times S \times (n/N)$. T is an approximation of the memory your `mi` data would consume in the mlong style. To that, we need to add a bit to account for extra memory used by Stata commands and for variables or observations you might want to add. How much to add is always debatable. For large datasets, add 10% or 5 MB, whichever is smaller.

   For instance, you might have

$$\begin{aligned} M &= 30 \\ N &= 10{,}000 \\ n &= 1{,}500 \\ S &= 8{,}040{,}000 = 8 \text{ MB} \end{aligned}$$

   and thus we would calculate $T = 8 + 30 \times 8 \times (1500/10000) = 44$ MB, to which we would add another 4 or 5 MB, to obtain 48 or 49 MB.

Converting to flongsep

Note that `mi convert`'s syntax for converting to flongsep is

`mi convert flongsep` *name*

You must specify a name, and that name will become the basis for the names of the datasets that comprise the collection of flongsep data. Data for $m = 0$ will be stored in *name*`.dta`; data for $m = 1$, in `_1_`*name*`.dta`; data for $m = 2$, in `_2_`*name*`.dta`; and so on. The files will be stored in the current directory; see the `pwd` command in [D] **cd**.

If you are going to use flongsep data, see *Advice for using flongsep* in [MI] **Styles**. Also see [MI] **mi copy** and [MI] **mi erase**.

Also see

[MI] **Intro** — Introduction to mi

[MI] **Styles** — Dataset styles

mi copy — Copy mi flongsep data

Description Menu Syntax Option
Remarks and examples Also see

Description

`mi copy` *newname* copies flongsep data in memory to *newname* and sets it so that you are working with that copy. *newname* may not be specified with the `.dta` suffix.

In detail, `mi copy` *newname* 1) completes saving the flongsep data to its current name if that is necessary; 2) copies the data to *newname*`.dta`, `_1_`*newname*`.dta`, `_2_`*newname*`.dta`, ..., `_`M`_`*newname*`.dta`; and 3) tells `mi` that you are now working with *newname*`.dta` in memory.

`mi copy` can also be used with wide, mlong, or flong data, although there is no reason you would want to do so. The data are not saved to the original filename as flongsep data would be, but otherwise actions are the same: the data in memory are copied to *newname*`.dta`, and *newname*`.dta` is loaded into memory.

Menu

Statistics > Multiple imputation

Syntax

`mi copy` *newname* [`, replace`]

Option

`replace` specifies that it is okay to overwrite *newname*`.dta`, `_1_`*newname*`.dta`, `_2_`*newname*`.dta`, ..., if they already exist.

Remarks and examples

In Stata, one usually works with a copy of the data in memory. Changes you make to the data are not saved in the underlying disk file until and unless you explicitly save your data. That is not true when working with flongsep data.

Flongsep data are a matched set of datasets, one containing $m = 0$, another containing $m = 1$, and so on. You work with one of them in memory, namely, $m = 0$, but as you work, the other datasets are automatically updated; as you make changes, the datasets on disk change.

Therefore, it is best to work with a copy of your flongsep data and then periodically save the data to the real files, thus mimicking how you work with ordinary Stata datasets. `mi copy` is for just that purpose. After loading your flongsep data, type, for example,

```
. use myflongsep
```

and immediately make a copy,

```
. mi copy newname
```

You are now working with the same data but under a new name. Your original data are safe.

When you reach a point where you would ordinarily save your data, whether under the original name or a different one, type

```
. mi copy original_name_or_different_name, replace
. use newname
```

Later, when you are done with *newname*, you can erase it by typing

```
. mi erase newname
```

Concerning erasure, you will discover that `mi erase` will not let you erase the files when you have one of the files to be erased in memory. Then you will have to type

```
. mi erase newname, clear
```

See [MI] **mi erase** for more information.

For more information on flongsep data, see *Advice for using flongsep* in [MI] **Styles**.

Also see

[MI] **Intro** — Introduction to mi

[MI] **mi erase** — Erase mi datasets

[MI] **Styles** — Dataset styles

mi describe — Describe mi data

Description Menu Syntax Options
Remarks and examples Stored results Also see

Description

`mi query` reports whether the data in memory are `mi` data and, if they are, reports the style in which they are set.

`mi describe` provides a more detailed report on `mi` data.

Menu

Statistics > Multiple imputation

Syntax

`mi query`

`mi describe` [, *describe_options*]

describe_options	Description
`detail`	show missing-value counts for $m = 1$, $m = 2$, …
`noupdate`	see [MI] **noupdate option**

`collect` is allowed with `mi query` and `mi describe`; see [U] **11.1.10 Prefix commands**.

Options

`detail` reports the number of missing values in $m = 1$, $m = 2$, …, $m = M$ in the imputed and passive variables, along with the number of missing values in $m = 0$.

`noupdate` in some cases suppresses the automatic `mi update` this command might perform; see [MI] **noupdate option**.

Remarks and examples

Remarks are presented under the following headings:

mi query
mi describe

mi query

`mi query` without `mi` data in memory reports

```
. mi query
(data not mi set)
```

With `mi` data in memory, you see something like

```
. mi query
data mi set wide, M = 15
last mi update 20jan2025 15:30:20, approximately 5 minutes ago
```

`mi query` does not burden you with unnecessary information. It mentions when `mi update` was last run because you should run it periodically; see [MI] **mi update**.

mi describe

`mi describe` more fully describes `mi` data:

```
. mi describe
Style: mlong
       last mi update 22dec2024 15:30:20, approximately 2 minutes ago
Observations:
   Complete            90
   Incomplete          10  (M = 20 imputations)
   ---------------------
   Total               100
Variables:
   Imputed: 2; smokes(10) age(5)
   Passive: 1; agesq(5)
   Regular: 0
   System:  3; _mi_m _mi_id _mi_miss
   (there are 3 unregistered variables; gender race chd)
```

`mi describe` lists the style of the data, the number of complete and incomplete observations, M (the number of imputations), the registered variables, and the number of missing values in $m = 0$ of the imputed and passive variables. In the output, the lines

```
Variables:
   Imputed: 2; smokes(10) age(5)
```

means that the `smokes` variable contains 10 missing values in $m = 0$ and that `age` contains 5. Those values are soft missings and thus eligible to be imputed. If one of `smokes`' missing values in $m = 0$ were hard, the lines would read

```
Variables:
   Imputed: 2; smokes(9+1) age(5)
```

`mi describe` reports information about $m = 0$. To obtain information about all m's, use `mi describe, detail`:

```
. mi describe, detail
Style: mlong
       last mi update 22dec2024 15:30:20, approximately 3 minutes ago
Observations:
   Complete            90
   Incomplete          10  (M = 20 imputations)
   ----------------------
   Total              100
Variables:
   Imputed: 2; smokes(10; 20*0) age(5; 20*0)
   Passive: 1; agesq(5; 20*0)
   Regular: 0
   System:  3; _mi_m _mi_id _mi_miss
   (there are 3 unregistered variables; gender race chd)
```

In this example, all imputed values are nonmissing. We can see that from

```
Variables:
   Imputed: 2; smokes(10; 20*0) age(5; 20*0)
```

Note the `20*0` after the semicolons. That is the number of missing values in $m = 1$, $m = 2$, …, $m = 20$. In the `smokes` variable, there are 10 missing values in $m = 0$, then 0 in $m = 1$, then 0 in $m = 2$, and so on. If $m = 17$ had two missing imputed values, the lines would read

```
Variables:
   Imputed: 2; smokes(10; 16*0, 2, 3*0) age(5; 20*0)
```

`16*0, 2, 3*0` means that for $m = 1$, $m = 2$, …, $m = 20$, the first 16 have 0 missing values, the next has 2, and the last 3 have 0.

If `smokes` had $9 + 1$ missing values rather than 10—that is, 9 soft missing values plus 1 hard missing rather than all 10 being soft missing—and all 9 soft missings were filled in, the line would read

```
Variables:
   Imputed: 2; smokes(9+1; 20*0) age(5; 20*0)
```

The 20 imputations are shown as having no soft missing values. It goes without saying that they have 1 hard missing. Think of `20*0` as meaning `20*(0+1)`.

If `smokes` had $9 + 1$ missing values and two of the soft missings in $m = 18$ were still missing, the line would read

```
Variables:
   Imputed: 2; smokes(9+1; 16*0, 2, 3*0) age(5; 20*0)
```

Stored results

`mi query` stores the following in `r()`:

Scalars

`r(update)`	seconds since last `mi update`
`r(m)`	m if `r(style)=="flongsep"`
`r(M)`	M if `r(style)!="flongsep"`

Macros

`r(style)`	*style*
`r(name)`	*name* if `r(style)=="flongsep"`

Note that `mi query` issues a return code of 0 even if the data are not `mi`. In that case, `r(style)` is " ".

`mi describe` stores the following in `r()`:

Scalars

`r(update)`	seconds since last `mi update`
`r(N)`	number of observations in $m = 0$
`r(N_incomplete)`	number of incomplete observations in $m = 0$
`r(N_complete)`	number of complete observations in $m = 0$
`r(M)`	M

Macros

`r(style)`	*style*
`r(ivars)`	names of imputed variables
`r(_0_miss_ivars)`	$\# = .$ in each `r(ivars)` in $m = 0$
`r(_0_hard_ivars)`	$\# > .$ in each `r(ivars)` in $m = 0$
`r(pvars)`	names of passive variables
`r(_0_miss_pvars)`	$\# \geq .$ in each `r(pvars)` in $m = 0$
`r(rvars)`	names of regular variables

If the `detail` option is specified, for each m, $m = 1, 2, \ldots, M$, also stored are

Macros

`r(_`m`_miss_ivars)`	$\# = .$ in each `r(ivars)` in m
`r(_`m`_miss_pvars)`	$\# \geq .$ in each `r(pvars)` in m

Also see

[MI] **Intro** — Introduction to mi

mi erase — Erase mi datasets

Description Menu Syntax Option
Remarks and examples Also see

Description

`mi erase` erases `mi .dta` datasets.

Menu

Statistics > Multiple imputation

Syntax

`mi erase` *name* [`, clear`]

Option

`clear` specifies that it is okay to erase the files even if one of the files is currently in memory. If `clear` is specified, the data are dropped from memory and the files are erased.

Remarks and examples

Stata's ordinary `erase` (see [D] **erase**) is not sufficient for erasing `mi` datasets because an `mi` dataset might be flongsep, in which case the single name would refer to a collection of files, one containing $m = 0$, another containing $m = 1$, and so on. `mi erase` deletes all the files associated with `mi` dataset *name*`.dta`, which is to say, it erases *name*`.dta`, `_1_`*name*`.dta`, `_2_`*name*`.dta`, and so on:

```
. mi erase mysep
(files mysep.dta _1_mysep.dta _2_mysep.dta _3_mysep.dta erased)
```

Also see

[MI] **Intro** — Introduction to mi

[MI] **mi copy** — Copy mi flongsep data

[MI] **Styles** — Dataset styles

mi estimate — Estimation using multiple imputations

Description | Menu | Syntax | Options
Remarks and examples | Stored results | Methods and formulas | Acknowledgments
References | Also see

Description

`mi estimate:` *estimation_command* runs *estimation_command* on the imputed `mi` data, and adjusts coefficients and standard errors for the variability between imputations according to the combination rules by Rubin (1987).

Menu

Statistics > Multiple imputation

Syntax

Compute MI estimates of coefficients by fitting estimation command to mi data

`mi estimate` [, *options*] : *estimation_command* ...

Compute MI estimates of transformed coefficients by fitting estimation command to mi data

`mi estimate` [*spec*] [, *options*] : *estimation_command* ...

where *spec* may be one or more terms of the form `(`[*name*`:`] *exp*`)`. *exp* is any function of the parameter estimates allowed by `nlcom`; see [R] **nlcom**.

options	Description
Options	
nimputations(#)	specify number of imputations to use; default is to use all existing imputations
imputations(*numlist*)	specify which imputations to use
mcerror	compute Monte Carlo error estimates
ufmitest	perform unrestricted FMI model test
nosmall	do not apply small-sample correction to degrees of freedom
saving(*miestfile*[, replace])	save individual estimation results to *miestfile*.ster
Tables	
[no]citable	suppress/display standard estimation table containing parameter-specific confidence intervals; default is citable
dftable	display degrees-of-freedom table; dftable implies nocitable
vartable	display variance information about estimates; vartable implies citable
table_options	control table output
display_options	control columns and column formats, row spacing, display of omitted variables and base and empty cells, and factor-variable labeling
Reporting	
level(#)	set confidence level; default is level(95)
dots	display dots as estimations are performed
noisily	display any output from *estimation_command* (and from nlcom if transformations specified)
trace	trace *estimation_command* (and nlcom if transformations specified); implies noisily
nogroup	suppress summary about groups displayed for xt commands
me_options	control output from mixed-effects commands
Advanced	
esample(*newvar*)	store estimation sample in variable *newvar*; available only in the flong and flongsep styles
errorok	allow estimation even when *estimation_command* (or nlcom) errors out; such imputations are discarded from the analysis
esampvaryok	allow estimation when estimation sample varies across imputations
cmdok	allow estimation when *estimation_command* is not one of the supported estimation commands
coeflegend	display legend instead of statistics
nowarning	suppress the warning about varying estimation samples
eform_option	display coefficient table in exponentiated form
post	post estimated coefficients and VCE to e(b) and e(V)
noupdate	do not perform mi update; see [MI] **noupdate option**

You must mi set your data before using mi estimate; see [MI] **mi set**.

collect is allowed; see **[U] 11.1.10 Prefix commands**.

The mi suite of commands does not allow alias variables; see [D] **frunalias** for advice on how to get around this restriction.

coeflegend, nowarning, *eform_option*, post, and noupdate do not appear in the dialog box.

table_options	Description
noheader	suppress table header(s)
notable	suppress table(s)
nocoef	suppress table output related to coefficients
nocmdlegend	suppress command legend that appears in the presence of transformed coefficients when nocoef is used
notrcoef	suppress table output related to transformed coefficients
nolegend	suppress table legend(s)
nocnsreport	do not display constraints

See [MI] **mi estimate postestimation** for features available after estimation. mi estimate is its own estimation command. The postestimation features for mi estimate do not include by default the postestimation features for *estimation_command*. To replay results, type mi estimate without arguments.

Options

Options

nimputations(#) specifies that the first # imputations be used; # must be $M_{\min} \leq \# \leq M$, where $M_{\min} = 3$ if mcerror is specified and $M_{\min} = 2$, otherwise. The default is to use all imputations, M. Only one of nimputations() or imputations() may be specified.

imputations(*numlist*) specifies which imputations to use. The default is to use all of them. *numlist* must contain at least two numbers. If mcerror is specified, *numlist* must contain at least three numbers. Only one of nimputations() or imputations() may be specified.

mcerror specifies to compute Monte Carlo error (MCE) estimates for the results displayed in the estimation, degrees-of-freedom, and variance-information tables. MCE estimates reflect variability of MI results across repeated uses of the same imputation procedure and are useful for determining an adequate number of imputations to obtain stable MI results; see White, Royston, and Wood (2011) for details and guidelines.

MCE estimates are obtained by applying the jackknife procedure to multiple-imputation results. That is, the jackknife pseudovalues of MI results are obtained by omitting one imputation at a time; see [R] **jackknife** for details about the jackknife procedure. As such, the MCE computation requires at least three imputations.

If level() is specified during estimation, MCE estimates are obtained for confidence intervals using the specified confidence level instead of using the default 95% confidence level. If any of the options described in [R] ***eform_option*** is specified during estimation, MCE estimates for the coefficients, standard errors, and confidence intervals in the exponentiated form are also computed. mcerror can also be used upon replay to display MCE estimates. Otherwise, MCE estimates are not reported upon replay even if they were previously computed.

ufmitest specifies that the unrestricted fraction missing information (FMI) model test be used. The default test performed assumes equal fractions of information missing due to nonresponse for all coefficients. This is equivalent to the assumption that the between-imputation and within-imputation variances are proportional. The unrestricted test may be preferable when this assumption is suspect provided the number of imputations is large relative to the number of estimated coefficients.

nosmall specifies that no small-sample correction be made to the degrees of freedom. The small-sample correction is made by default to estimation commands that account for small samples. If the command stores residual degrees of freedom in e(df_r), individual tests of coefficients (and transformed coefficients) use the small-sample correction of Barnard and Rubin (1999) and the overall model test uses the small-sample correction of Reiter (2007). If the command does not store residual degrees of freedom, the large-sample test is used and the nosmall option has no effect.

saving(*miestfile*[, replace]) saves estimation results from each model fit in *miestfile*.ster. The replace suboption specifies to overwrite *miestfile*.ster if it exists. *miestfile*.ster can later be used by mi estimate using (see [MI] **mi estimate using**) to obtain MI estimates of coefficients or of transformed coefficients without refitting the completed-data models. This file is written in the format used by estimates use; see [R] **estimates save**.

Tables

All table options below may be specified at estimation time or when redisplaying previously estimated results. Table options must be specified as options to mi estimate, not to *estimation_command*.

citable and nocitable specify whether the standard estimation table containing parameter-specific confidence intervals is displayed. The default is citable. nocitable can be used with vartable to suppress the confidence interval table.

dftable displays a table containing parameter-specific degrees of freedom and percentages of increase in standard errors due to nonresponse. dftable implies nocitable.

vartable displays a table reporting variance information about MI estimates. The table contains estimates of within-imputation variances, between-imputation variances, total variances, relative increases in variance due to nonresponse, fractions of information about parameter estimates missing due to nonresponse, and relative efficiencies for using finite M rather than a hypothetically infinite number of imputations. vartable implies citable.

table_options control the appearance of all displayed table output:

noheader suppresses all header information from the output. The table output is still displayed.

notable suppresses all tables from the output. The header information is still displayed.

nocoef suppresses the display of tables containing coefficient estimates. This option affects the table output produced by citable, dftable, and vartable.

nocmdlegend suppresses the table legend showing the specified command line, *estimation_command*, from the output. This legend appears above the tables containing transformed coefficients (or above the variance-information table if vartable is used) when nocoef is specified.

notrcoef suppresses the display of tables containing estimates of transformed coefficients (if specified). This option affects the table output produced by citable, dftable, and vartable.

nolegend suppresses all table legends from the output.

nocnsreport; see [R] **Estimation options**.

display_options: noci, nopvalues, noomitted, vsquish, noemptycells, baselevels, allbaselevels, nofvlabel, fvwrap(#), fvwrapon(*style*), cformat(%*fmt*), pformat(%*fmt*), and sformat(%*fmt*); see [R] **Estimation options**.

Reporting

Reporting options must be specified as options to `mi estimate` and not as options to *estimation_command*.

`level(#)`; see [R] **Estimation options**.

`dots` specifies that dots be displayed as estimations are successfully completed. An `x` is displayed if the *estimation_command* returns an error, if the model fails to converge, or if `nlcom` fails to estimate one of the transformed coefficients specified in *spec*.

`noisily` specifies that any output from *estimation_command* and `nlcom`, used to obtain the estimates of transformed coefficients if transformations are specified, be displayed.

`trace` traces the execution of *estimation_command* and traces `nlcom` if transformations are specified. `trace` implies `noisily`.

`nogroup` suppresses the display of group summary information (number of groups, average group size, minimum, and maximum) as well as other command-specific information displayed for `xt` commands; see the list of commands under *Panel-data models* in [MI] **Estimation**.

me_options: `stddeviations`, `variance`, `noretable`, `nofetable`, and `estmetric`. These options are relevant only with the mixed-effects command `mixed` (see [ME] **mixed**). See the corresponding mixed-effects commands for more information. The `stddeviations` option is the default with `mi estimate`, because MI-based confidence intervals may not be computable for some random-effects variances and covariances; see `help mi_me_note` for details. The `estmetric` option is implied when `vartable` or `dftable` is used.

Advanced

`esample(`*newvar*`)` creates *newvar* containing `e(sample)`. This option is useful to identify which observations were used in the estimation, especially when the estimation sample varies across imputations (see *Potential problems that can arise when using mi estimate* for details). *newvar* is zero in the original data ($m = 0$) and in any imputations ($m > 0$) in which the estimation failed or that were not used in the computation. `esample()` may be specified only if the data are flong or flongsep; see [MI] **mi convert** to convert to one of those styles. The variable created will be super varying and therefore must not be registered; see [MI] **mi varying** for more explanation. The saved estimation sample *newvar* may be used later with `mi extract` (see [MI] **mi extract**) to set the estimation sample.

`errorok` specifies that estimations that fail be skipped and the combined results be based on the successful individual estimation results. The default is that `mi estimate` stops if an individual estimation fails. If `errorok` is specified with `saving()`, all estimation results, including failed, are saved to a file.

`esampvaryok` allows estimation to continue even if the estimation sample varies across imputations. `mi estimate` stops if the estimation sample varies. If `esampvaryok` is specified, results from all imputations are used to compute MI estimates and a warning message is displayed at the bottom of the table. Also see the `esample()` option. See *Potential problems that can arise when using mi estimate* for more information.

`cmdok` allows unsupported estimation commands to be used with `mi estimate`; see [MI] **Estimation** for a list of supported estimation commands. Alternatively, if you want `mi estimate` to work with your estimation command, add the property `mi` to the program properties; see [P] **program properties**.

The following options are available with mi estimate but are not shown in the dialog box:

coeflegend; see [R] **Estimation options**. coeflegend implies nocitable and cannot be combined with citable or dftable.

nowarning suppresses the warning message at the bottom of table output that occurs if the estimation sample varies and esampvaryok is specified. See *Potential problems that can arise when using mi estimate* for details.

eform_option; see [R] ***eform_option***. Regardless of the *estimation_command* specified, mi estimate reports results in the coefficient metric under which the combination rules are applied. You may use the appropriate *eform_option* to redisplay results in exponentiated form, if desired. If dftable is also specified, the reported degrees of freedom and percentage increases in standard errors are not adjusted and correspond to the original coefficient metric.

post requests that MI estimates of coefficients and their respective VCEs be posted in the usual way. This allows the use of *estimation_command*-specific postestimation tools with MI estimates. There are issues; see *Using the command-specific postestimation tools* in [MI] **mi estimate postestimation**. post may be specified at estimation time or when redisplaying previously estimated results.

noupdate in some cases suppresses the automatic mi update this command might perform; see [MI] **noupdate option**. This option is seldom used.

Remarks and examples

mi estimate requires that imputations be already formed; see [MI] **mi impute**. To import existing multiply imputed data, see [MI] **mi import**.

Remarks are presented under the following headings:

Using mi estimate
Example 1: Completed-data logistic analysis
Example 2: Completed-data linear regression analysis
Example 3: Completed-data survival analysis
Example 4: Panel data and multilevel models
Example 5: Estimating transformations
Example 6: Monte Carlo error estimates
Potential problems that can arise when using mi estimate

Using mi estimate

mi estimate estimates model parameters from multiply imputed data and adjusts coefficients and standard errors for the variability between imputations. It runs the specified *estimation_command* on each of the M imputed datasets to obtain the M completed-data estimates of coefficients and their VCEs. It then computes MI estimates of coefficients and standard errors by applying combination rules (Rubin 1987, 77) to the M completed-data estimates. See [MI] **Intro substantive** for a discussion of MI analysis and see *Methods and formulas* for computational details.

To use mi estimate, your data must contain at least two imputations. The basic syntax of mi estimate is

```
. mi estimate: estimation_command ...
```

estimation_command is any estimation command from the list of supported estimation commands; see [MI] **Estimation**.

If you wish to estimate on survey data, type

```
. mi estimate: svy: estimation_command ...
```

If you want to vary the number of imputations or select which imputations to use in the computations, use the `nimputations()` or the `imputations()` option, respectively.

```
. mi estimate, nimputations(9): estimation_command ...
```

Doing so is useful to evaluate the stability of MI results. MCE estimates of the parameters are also useful for determining the stability of MI results. You can use the `mcerror` option to obtain these estimates. Your data must contain at least three imputations to use `mcerror`.

You can obtain more-detailed information about imputation results by specifying the `dftable` and `vartable` options.

You can additionally obtain estimates of transformed coefficients by specifying expressions with `mi estimate`; see *Example 5: Estimating transformations* for details.

When using `mi estimate`, keep in mind that

1. `mi estimate` is its own estimation command.
2. `mi estimate` uses different degrees of freedom for each estimated parameter when computing its significance level and confidence interval.
3. `mi estimate` reports results in the coefficient metric under which combination rules are applied regardless of the default reporting metric of the specified *estimation_command*. Use *eform_option* with `mi estimate` to report results in the exponentiated metric, if you wish. For example, `mi estimate: logistic` reports coefficients and not odds ratios as `logistic`. To obtain odds ratios, you must specify the `or` option with `mi estimate`:

```
. mi estimate, or: logistic ...
```

4. `mi estimate` has its own reporting options and does not respect command-specific reporting options. The reporting options specified with *estimation_command* affect only the output of the command that is displayed when `mi estimate`'s `noisily` option is specified. Specify `mi estimate`'s options immediately after the `mi estimate` command:

```
. mi estimate, options: estimation_command ...
```

Example 1: Completed-data logistic analysis

Recall the logistic analysis of the heart attack data from [MI] **Intro substantive**. The goal of the analysis was to explore the relationship between heart attacks and smoking adjusted for other factors such as age, body mass index (BMI), gender, and educational status. The original data contain missing values of BMI. The listwise-deletion analysis on the original data determined that smoking and BMI have significant impact on a heart attack. After imputing missing values of BMI, age was determined to be a significant factor as well. See *A brief introduction to MI using Stata* in [MI] **Intro substantive** for details. The data we used are stored in `mheart1s20.dta`.

Below we refit the logistic model using the imputed data. We also specify the `dots` option so that dots will be displayed as estimations are completed.

```
. use https://www.stata-press.com/data/r19/mheart1s20
(Fictional heart attack data; BMI missing)
. mi estimate, dots: logit attack smokes age bmi hsgrad female
Imputations (20):
  .........10.........20 done
Multiple-imputation estimates                   Imputations       =         20
Logistic regression                             Number of obs     =        154
                                                Average RVI       =     0.0312
                                                Largest FMI       =     0.1355
DF adjustment:   Large sample                   DF:     min       =   1,060.38
                                                        avg       = 223,362.56
                                                        max       = 493,335.88
Model F test:       Equal FMI                   F(   5,71379.3)   =       3.59
Within VCE type:          OIM                   Prob > F          =     0.0030
```

attack	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
smokes	1.198595	.3578195	3.35	0.001	.4972789	1.899911
age	.0360159	.0154399	2.33	0.020	.0057541	.0662776
bmi	.1039416	.0476136	2.18	0.029	.010514	.1973692
hsgrad	.1578992	.4049257	0.39	0.697	-.6357464	.9515449
female	-.1067433	.4164735	-0.26	0.798	-.9230191	.7095326
_cons	-5.478143	1.685075	-3.25	0.001	-8.782394	-2.173892

The left header column reports information about the fitted MI model. The right header column reports the number of imputations and the number of observations used, the average relative variance increase (RVI) due to nonresponse, the largest fraction of missing information (FMI), a summary about parameter-specific degrees of freedom (DF), and the overall model test that all coefficients, excluding the constant, are equal to zero.

Notice first that `mi estimate` reports Student's t and F statistics for inference although `logit` would usually report Z and χ^2 statistics.

`mi estimate: logit` is not `logit`. `mi estimate` uses Rubin's combination rules to obtain the estimates from multiply imputed data. The variability of the MI estimates consists of two components: variability within imputations and variability between imputations. Therefore, the precision of the MI estimates is governed not only by the number of observations in the sample but also by the number of imputations. As such, even if the number of observations is large, if the number of imputations is small and the FMI are not low, the reference distribution used for inference will deviate from the normal distribution. Because in practice the number of imputations tends to be small, `mi estimate` uses a reference t distribution.

Returning to the output, average RVI reports the average relative increase (averaged over all coefficients) in variance of the estimates because of the missing `bmi` values. A relative variance increase is an increase in the variance of the estimate because of the loss of information about the parameter due to nonresponse relative to the variance of the estimate with no information lost. The closer this number is to zero, the less effect missing data have on the variance of the estimate. Note that the reported RVI will be zero if you use `mi estimate` with the complete data or with missing data that have not been imputed. In our case, average RVI is small: 0.0312.

Largest FMI reports the largest of all the FMI about coefficient estimates due to nonresponse. This number can be used to get an idea of whether the specified number of imputations is sufficient for the analysis. A rule of thumb is that $M \geq 100 \times \text{FMI}$ provides an adequate level of reproducibility of MI analysis. In our example, the largest FMI is 0.14 and the number of imputations, 20, exceeds the required number of imputations: 14 ($= 100 \times 0.14$) according to this rule.

The coefficient-specific degrees of freedom (DF) averaging 223,363 are large. They are large because the MI degrees of freedom depends not only on the number of imputations but also on the RVI due to nonresponse. Specifically, the degrees of freedom is inversely related to RVI. The closer RVI is to zero, the larger the degrees of freedom regardless of the number of imputations.

To the left of the DF, we see that the degrees of freedom is obtained under a large-sample assumption. The alternative is to use a small-sample adjustment. Whether the small-sample adjustment is applied is determined by the type of the reference distribution used for inference by the specified estimation command. For the commands that use a large-sample (normal) approximation for inference, a large-sample approximation is used when computing the MI degrees of freedom. For the commands that use a small-sample (Student's t) approximation for inference, a small-sample approximation is used when computing the MI degrees of freedom. See *Methods and formulas* for details. As we already mentioned, logit assumes large samples for inference, and thus the MI degrees of freedom is computed assuming a large sample.

The model F test rejects the hypothesis that all coefficients are equal to zero and thus rules out a constant-only model for heart attacks. By default, the model test uses the assumption that the fractions of missing information of all coefficients are equal (as noted by Equal FMI to the left). Although this assumption may not be supported by the data, it is used to circumvent the difficulties arising with the estimation of the between-imputation variance matrix based on a small number of imputations. See *Methods and formulas* and [MI] **mi test** for details.

mi estimate also reports the type of variance estimation used by the estimation command to compute variance estimates in the individual completed-data analysis. These completed-data variance estimates are then used to compute the within-imputation variance. In our example, the observed-information-matrix (OIM) method, the default variance-estimation method used by maximum likelihood estimation, is used to compute completed-data VCEs. This is labeled as Within VCE type: OIM in the output.

Finally, mi estimate reports a coefficient table containing the combined estimates. Unlike all other Stata estimation commands, the reported significance levels and confidence intervals in this table are based on degrees of freedom that is specific to each coefficient. Remember that the degrees of freedom depends on the relative variance increases and thus on how much information is lost about the estimated parameter because of missing data. How much information is lost is specific to each parameter and so is the degrees of freedom.

As we already saw, a summary of the coefficient-specific degrees of freedom (minimum, average, and maximum) was reported in the header. We can obtain a table containing coefficient-specific degrees of freedom by replaying the results with the dftable option:

```
. mi estimate, dftable
Multiple-imputation estimates                   Imputations       =         20
Logistic regression                             Number of obs     =        154
                                                Average RVI       =     0.0312
                                                Largest FMI       =     0.1355
DF adjustment:   Large sample                   DF:     min       =   1,060.38
                                                        avg       = 223,362.56
                                                        max       = 493,335.88
Model F test:       Equal FMI                   F(   5,71379.3)   =       3.59
Within VCE type:          OIM                   Prob > F          =     0.0030
```

attack	Coefficient	Std. err.	t	P>|t|	df	% increase std. err.
smokes	1.198595	.3578195	3.35	0.001	320019.4	0.39
age	.0360159	.0154399	2.33	0.020	493335.9	0.31
bmi	.1039416	.0476136	2.18	0.029	1060.4	7.45
hsgrad	.1578992	.4049257	0.39	0.697	165126.7	0.54
female	-.1067433	.4164735	-0.26	0.798	358078.3	0.37
_cons	-5.478143	1.685075	-3.25	0.001	2554.8	4.61

Notice that we type `mi estimate` to replay the results, not `logit`.

The header information remains the same. In particular, degrees of freedom ranges from 1,060 to 493,336 and averages 223,363. In the table output, the columns for the confidence intervals are replaced with the `DF` and `% Increase std. err.` columns. We now see that the smallest degrees of freedom corresponds to the coefficient for `bmi`. We should have anticipated this because `bmi` is the only variable containing missing values in this example. The largest degrees of freedom is observed for the coefficient for `age`, which suggests that the loss of information due to nonresponse is the smallest for the estimation of this coefficient.

The last column displays as a percentage the increase in standard errors of the parameters due to nonresponse. We observe a 7% increase in the standard error for the coefficient of `bmi` and a 5% increase in the standard error for the constant. Increases in standard errors of other coefficients are negligible.

In this example, we displayed a degrees-of-freedom table on replay by specifying the `dftable` option. We could also obtain this table if we specified this option at estimation time. Alternatively, if desired, we could display both tables by specifying the `citable` and `dftable` options together.

We can obtain more detail about imputation results by specifying the `vartable` option. We specify this option on replay and also use the `nocitable` option to suppress the default confidence interval table:

```
. mi estimate, vartable nocitable
Multiple-imputation estimates                   Imputations       =         20
Logistic regression
Variance information
```

	Imputation variance					Relative
	Within	Between	Total	RVI	FMI	efficiency
smokes	.127048	.00094	.128035	.007765	.007711	.999615
age	.000237	1.4e-06	.000238	.006245	.00621	.99969
bmi	.001964	.000289	.002267	.154545	.135487	.993271
hsgrad	.162206	.001675	.163965	.010843	.010739	.999463
female	.172187	.001203	.17345	.007338	.00729	.999636
_cons	2.5946	.233211	2.83948	.094377	.086953	.995671

The first three columns of the table provide the variance information specific to each parameter. As we already discussed, MI variance contains two sources of variation: within imputation and between imputation. The first two columns provide estimates for the within-imputation and between-imputation variances. The third column is a total variance that is the sum of the two variances plus an adjustment for using a finite number of imputations. The next two columns are individual RVIs and fractions of missing information (FMIs) due to nonresponse. The last column records relative efficiencies for using a finite number of imputations (20 in our example) versus the theoretically optimal infinite number of imputations.

We notice that the coefficient for age has the smallest within-imputation and between-imputation variances. The between-imputation variability is very small relative to the within-imputation variability, which is why age had such a large estimate of the degrees of freedom we observed earlier. Correspondingly, this coefficient has the smallest values for RVI and FMI. As expected, the coefficient for bmi has the highest RVI and FMI.

The reported relative efficiencies are high for all coefficient estimates, with the smallest relative efficiency, again, corresponding to bmi. These estimates, however, are only approximations and thus should not be used exclusively to determine the required number of imputations. See Royston, Carlin, and White (2009) and White, Royston, and Wood (2011) for other ways of determining a suitable number of imputations.

Example 2: Completed-data linear regression analysis

Recall the data on house resale prices from example 3 of [MI] **mi impute mvn**. We use the imputed data stored in mhouses1993s30.dta to examine the relationship of various predictors on price via linear regression:

```
. use https://www.stata-press.com/data/r19/mhouses1993s30
(Albuquerque home prices Feb15-Apr30, 1993)
. mi estimate, ni(5): regress price tax sqft age nfeatures ne custom corner
Multiple-imputation estimates                   Imputations       =          5
Linear regression                               Number of obs     =        117
                                                Average RVI       =     0.0685
                                                Largest FMI       =     0.2075
                                                Complete DF       =        109
DF adjustment:   Small sample                   DF:     min       =      48.59
                                                        avg       =      85.22
                                                        max       =     104.79
Model F test:       Equal FMI                   F(   7,  103.9)   =      67.50
Within VCE type:          OLS                   Prob > F          =     0.0000
```

price	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
tax	.6631356	.122443	5.42	0.000	.4195447	.9067265
sqft	.2185884	.0670182	3.26	0.002	.0856051	.3515718
age	-.0395402	1.613185	-0.02	0.981	-3.28205	3.202969
nfeatures	8.735622	13.42251	0.65	0.517	-18.01198	35.48323
ne	4.069381	36.94491	0.11	0.913	-69.4355	77.57426
custom	130.4925	42.93286	3.04	0.003	45.36257	215.6225
corner	-71.25406	40.06697	-1.78	0.078	-150.7152	8.207084
_cons	130.2002	70.38012	1.85	0.068	-9.624642	270.025

By default, mi estimate uses all available imputations in the analysis. For the purpose of illustration, we use only the first 5 imputations out of the available 30 by specifying the nimputations(5) option, which we abbreviated as ni(5).

Compared with the output from the previous example, an additional result, Complete DF, is reported. Also notice that the adjustment for the degrees of freedom is now labeled as Small sample. Remember that mi estimate determines what adjustment to use based on the reference distribution used for inference by the specified estimation command.

regress uses a reference t distribution with $117 - 8 = 109$ residual degrees of freedom. Thus a small-sample adjustment is used by mi estimate for the MI degrees of freedom.

Complete DF contains the degrees of freedom used for inference with complete data. It corresponds to the completed-data residual degrees of freedom stored by the command in e(df_r). In most applications, the completed-data residual degrees of freedom will be the same, and so Complete DF will correspond to the complete degrees of freedom, the degrees of freedom that would have been used for inference if the data were complete. In the case when the completed-data residual degrees of freedom varies across imputations (as may happen when the estimation sample varies; see *Potential problems that can arise when using mi estimate*), Complete DF reports the smallest of them.

In our example, all completed-data residual degrees of freedom are equal, and Complete DF is equal to 109, the completed-data residual degrees of freedom obtained from regress. mi estimate uses the complete degrees of freedom to adjust the MI degrees of freedom for a small sample (Barnard and Rubin 1999).

Example 3: Completed-data survival analysis

Consider survival data on 48 participants in a cancer drug trial. The dataset contains information about participants' ages, treatments received (drug or placebo), times to death measured in months, and a censoring indicator. The data are described in more detail in *Cox regression with censored data* of [ST] **stcox**. We consider a version of these data containing missing values for age. The imputed data are saved in mdrugtrs25.dta:

```
. use https://www.stata-press.com/data/r19/mdrugtrs25
(Patient survival in drug trial)
. mi describe
Style: mlong
       last mi update 04feb2025 12:58:57, 10 days ago
Observations:
   Complete            40
   Incomplete           8  (M = 25 imputations)
   ----------------------
   Total               48
Variables:
   Imputed: 1; age(8)
   Passive: 0
   Regular: 3; studytime died drug
   System:  3; _mi_m _mi_id _mi_miss
   (there are no unregistered variables)
```

The dataset contains 25 imputations for 8 missing values of age. Missing values were imputed following guidelines in White and Royston (2009).

We analyze these data using stcox with mi estimate. These data have not yet been stset, so we use mi stset (see [MI] **mi XXXset**) to set them and then perform the analysis using mi estimate: stcox:

```
. mi stset studytime, failure(died)
Survival-time data settings
         Failure event: died!=0 & died<.
Observed time interval: (0, studytime]
     Exit on or before: failure
------------------------------------------------------------------------------
         48  total observations
          0  exclusions
------------------------------------------------------------------------------
         48  observations remaining, representing
         31  failures in single-record/single-failure data
        744  total analysis time at risk and under observation
                                                At risk from t =         0
                                     Earliest observed entry t =         0
                                          Last observed exit t =        39
. mi estimate, dots: stcox drug age
Imputations (25):
  .........10.........20..... done
Multiple-imputation estimates                   Imputations       =         25
Cox regression: Breslow method for ties         Number of obs     =         48
                                                Average RVI       =     0.1059
                                                Largest FMI       =     0.1567
DF adjustment:   Large sample                   DF:     min       =     998.63
                                                        avg       =  11,621.53
                                                        max       =  22,244.42
Model F test:       Equal FMI                   F(   2, 4448.6)   =      13.43
Within VCE type:          OIM                   Prob > F          =     0.0000
------------------------------------------------------------------------------
          _t | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
        drug |  -2.204572   .4589047    -4.80   0.000    -3.104057   -1.305086
         age |   .1242711    .040261     3.09   0.002     .0452652    .2032771
------------------------------------------------------------------------------
```

Notice that `mi estimate` displays the results in the coefficient metric and not in the hazard-ratio metric. By default, `mi estimate` reports results in the metric under which the combination rules were applied. To obtain the results as hazard ratios, we can use the `hr` option with `mi estimate`:

```
. mi estimate, hr
Multiple-imputation estimates                   Imputations       =         25
Cox regression: Breslow method for ties         Number of obs     =         48
                                                Average RVI       =     0.1059
                                                Largest FMI       =     0.1567
DF adjustment:   Large sample                   DF:     min       =     998.63
                                                        avg       =  11,621.53
                                                        max       =  22,244.42
Model F test:       Equal FMI                   F(   2, 4448.6)   =      13.43
Within VCE type:          OIM                   Prob > F          =     0.0000
------------------------------------------------------------------------------
          _t | Haz. ratio   Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
        drug |   .1102977   .0506161    -4.80   0.000     .0448668    .2711491
         age |   1.132323   .0455885     3.09   0.002     1.046305    1.225412
------------------------------------------------------------------------------
```

We obtain results similar to those from the corresponding example in [ST] **stcox**.

We specified the hr option above on replay. We can also specify it at estimation time:

```
. mi estimate, hr: stcox drug age
  (output omitted)
```

Notice that the hr option must be specified with mi estimate to obtain hazard ratios. Specifying it with the command itself,

```
. mi estimate: stcox drug age, hr
  (output omitted)
```

will not affect the output from mi estimate but only that of the command, stcox. You see stcox's output only if you specify mi estimate's noisily option.

See Cleves, Gould, and Marchenko (2016, sec. 9.6) for more information on Cox regression with multiply imputed data.

Example 4: Panel data and multilevel models

We have data on the math scores of students in their third and fifth years of education. There are 887 students from 48 schools in inner London; see Mortimore et al. (1988) for more information on the study. We would like to fit a random-effects model to the fifth-year score, math5, on the third-year score, math3, using a random effect at the school level.

We created a version of the data that contains missing values for math3 and then performed imputation following guidelines from the Stata FAQ "How can I account for clustering when creating imputations with mi impute?"; see https://www.stata.com/support/faqs/stat/impute_cluster.html. The resulting imputed data are saved in mjsps5.dta:

```
. use https://www.stata-press.com/data/r19/mjsps5, clear
(LEA Junior School Project data (Mortimore et al., 1988) with missing values)
. mi describe
Style: mlong
       last mi update 04feb2025 12:58:57, 10 days ago
Observations:
   Complete          705
   Incomplete        182  (M = 5 imputations)
   ----------------------
   Total             887
Variables:
   Imputed: 1; math3(182)
   Passive: 0
   Regular: 2; school math5
   System:  3; _mi_m _mi_id _mi_miss
   (there are no unregistered variables)
```

There are five imputations for 182 missing values of the third-year score, math3. Variable math3 is an imputed variable, whereas variable math5 and variable school, recording school identifiers, are complete and are registered as regular.

Our random-effects model includes only a random intercept, the school effect, so we can use the xtreg command, or more specifically mi estimate: xtreg, for our primary analysis.

Without imputed data, to use xtreg or any other panel-data command, we must first declare data to be panel (xt) data by using xtset. With imputed data, we should use the mi xtset command instead. We declare school as our panel variable:

```
. mi xtset school
Panel variable: school (unbalanced)
```

Next we use mi estimate: xtreg to regress the fifth-year math score on the third-year score.

```
. mi estimate: xtreg math5 math3
Multiple-imputation estimates                   Imputations       =          5
Random-effects GLS regression                   Number of obs     =        887
Group variable: school                          Number of groups  =         48
                                                Obs per group:
                                                              min =          5
                                                              avg =       18.5
                                                              max =         62
                                                Average RVI       =     0.0595
                                                Largest FMI       =     0.1071
DF adjustment:   Large sample                   DF:     min       =     381.40
                                                        avg       =  85,771.71
                                                        max       = 171,162.01
Model F test:       Equal FMI                   F(   1,  381.4)   =     305.71
Within VCE type: Conventional                   Prob > F          =     0.0000
```

math5	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
math3	.6101277	.0348951	17.48	0.000	.5415168	.6787385
_cons	30.48295	.3576417	85.23	0.000	29.78198	31.18392
sigma_u	2.0684286					
sigma_e	5.3206673					
rho	.13128791	(fraction of variance due to u_i)				

Note: **sigma_u** and **sigma_e** are combined in the original metric.

Third-year math scores are positively associated with fifth-year math scores. Because we use a random-effects model, the coefficient on math3 is for comparison of students from the same school or from different schools.

In the above results, multiple-imputation estimates of variance components sigma_u and sigma_e are obtained by applying Rubin's combination rules to the completed-data estimates in the original, standard deviation metric.

Alternatively, we can use the mixed command to fit our two-level random-effects model and to obtain variance-component estimates of the school effect. mixed can be used to fit more complicated multilevel models; see [ME] **mixed** for details.

We fit a two-level linear model with mi estimate: mixed and specify school as our second-level variable. mixed does not require prior declaration of the data, so we do not need to use mi xtset with mi estimate: mixed:

```
. mi estimate: mixed math5 math3 || school: , reml
Multiple-imputation estimates                   Imputations       =          5
Mixed-effects REML regression                   Number of obs     =        887
Group variable: school                          Number of groups  =         48
                                                Obs per group:
                                                              min =          5
                                                              avg =       18.5
                                                              max =         62
                                                Average RVI       =     0.0574
                                                Largest FMI       =     0.1079
DF adjustment:   Large sample                   DF:     min       =     376.05
                                                        avg       =  44,112.02
                                                        max       = 167,428.86
Model F test:       Equal FMI                   F(   1,  376.0)   =     305.41
                                                Prob > F          =     0.0000
```

math5	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
math3	.6100335	.0349069	17.48	0.000	.5413963	.6786708
_cons	30.48217	.3536049	86.20	0.000	29.78911	31.17522

Random-effects parameters	Estimate	Std. err.	[95% conf.	interval]
school: Identity				
sd(_cons)	2.033826	.3069989	1.512894	2.734129
sd(Residual)	5.321503	.1355669	5.061821	5.594508

The estimated coefficients, random-effects standard deviations, and other statistics are similar to those from `mi estimate: xtreg`. Unlike `mi estimate: xtreg`, the `mi estimate: mixed` command combines variance components in the estimation metric described in [ME] **mixed** and then back-transforms the estimates to display results in the original metric. In our example, the reported standard deviations are exponentiated multiple-imputation estimates of the log standard-deviations.

The random-effects parameters are displayed as standard deviations. We can display variances instead by replaying the `mi estimate` command with the `variance` option:

```
. mi estimate, variance
Multiple-imputation estimates                   Imputations       =          5
Mixed-effects REML regression                   Number of obs     =        887
Group variable: school                          Number of groups  =         48
                                                Obs per group:
                                                              min =          5
                                                              avg =       18.5
                                                              max =         62
                                                Average RVI       =     0.0574
                                                Largest FMI       =     0.1079
DF adjustment:   Large sample                   DF:     min       =     376.05
                                                        avg       =  44,112.02
                                                        max       = 167,428.86
Model F test:       Equal FMI                   F(   1,  376.0)   =     305.41
                                                Prob > F          =     0.0000
```

math5	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
math3	.6100335	.0349069	17.48	0.000	.5413963	.6786708
_cons	30.48217	.3536049	86.20	0.000	29.78911	31.17522

Random-effects parameters	Estimate	Std. err.	[95% conf.	interval]
school: Identity				
var(_cons)	4.136447	1.248765	2.288848	7.475462
var(Residual)	28.3184	1.442839	25.62204	31.29852

Although the random-effects parameters are now displayed as variances, they are still combined and stored in the log-standard-deviation metric.

Example 5: Estimating transformations

Stata estimation commands usually support `lincom` and `nlcom` (see [R] **lincom** and [R] **nlcom**) to obtain estimates of the transformed coefficients after estimation by using the delta method. Because MI estimates based on a small number of imputations may not yield a valid VCE, this approach is not generally viable. Also, transformations applied to the combined coefficients are only asymptotically equivalent to the combined transformed coefficients. With a small number of imputations, these two ways of obtaining transformed coefficients can differ significantly.

Thus `mi estimate` provides its own way of combining transformed coefficients. You need to use `mi estimate`'s method for both linear and nonlinear combinations of coefficients. We are about to demonstrate how to use the method using the ratio of coefficients as an example, but what we are about to do would be equally necessary if we wanted to obtain the difference in two coefficients.

For the purpose of illustration, suppose that we want to estimate the ratio of the coefficients, say, age and sqft from example 2. We can do this by typing

```
. use https://www.stata-press.com/data/r19/mhouses1993s30, clear
(Albuquerque home prices Feb15-Apr30, 1993)
. mi estimate (ratio: _b[age]/_b[sqft]):
> regress price tax sqft age nfeatures ne custom corner
Multiple-imputation estimates                   Imputations       =         30
Linear regression                               Number of obs     =        117
                                                Average RVI       =     0.0648
                                                Largest FMI       =     0.2533
                                                Complete DF       =        109
DF adjustment:   Small sample                   DF:     min       =      69.12
                                                        avg       =      94.02
                                                        max       =     105.51
Model F test:       Equal FMI                   F(   7,  106.5)   =      67.18
Within VCE type:          OLS                   Prob > F          =     0.0000
```

price	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
tax	.6768015	.1241568	5.45	0.000	.4301777	.9234253
sqft	.2118129	.069177	3.06	0.003	.0745091	.3491168
age	.2471445	1.653669	0.15	0.882	-3.051732	3.546021
nfeatures	9.288033	13.30469	0.70	0.487	-17.12017	35.69623
ne	2.518996	36.99365	0.07	0.946	-70.90416	75.94215
custom	134.2193	43.29755	3.10	0.002	48.35674	220.0818
corner	-68.58686	39.9488	-1.72	0.089	-147.7934	10.61972
_cons	123.9118	71.05816	1.74	0.085	-17.19932	265.0229

```
Transformations                                 Average RVI       =     0.2899
                                                Largest FMI       =     0.2316
                                                Complete DF       =        109
DF adjustment:   Small sample                   DF:     min       =      72.51
                                                        avg       =      72.51
Within VCE type:          OLS                           max       =      72.51
       ratio: _b[age]/_b[sqft]
```

price	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
ratio	1.44401	8.217266	0.18	0.861	-14.93485	17.82287

We use the nlcom syntax to specify the transformation: (ratio: _b[age]/_b[sqft]) defines the transformation and its name is ratio. All transformations must be specified following mi estimate and before the colon, and must be bound in parentheses.

A separate table containing the estimate of the ratio is displayed following the estimates of coefficients. If desired, we can suppress the table containing the estimates of coefficients by specifying the nocoef option. The header reports the average RVI due to nonresponse, the largest FMI, and the summaries of the degrees of freedom specific to the estimated transformations. Because we specified only one transformation, the minimum, average, and maximum degrees of freedom are the same. They correspond to the individual degrees of freedom for ratio.

See [MI] **mi test** for an example of linear transformation.

Example 6: Monte Carlo error estimates

Multiple imputation is a stochastic procedure. Each time we reimpute our data, we get different sets of imputations because of the randomness of the imputation step, and therefore we get different multiple-imputation estimates. However, we want to be able to reproduce MI results. Of course, we can always set the random-number seed to ensure reproducibility by obtaining the same imputed values. However, what if we use a different seed? Would we not want our results to be similar regardless of what seed we use? This leads us to a notion we call statistical reproducibility—we want results to be similar across repeated uses of the same imputation procedure; that is, we want to minimize the simulation error associated with our results.

To assess the level of simulation error, White, Royston, and Wood (2011) propose to use a Monte Carlo error of the MI results, defined as the standard deviation of the results across repeated runs of the same imputation procedure using the same data. The authors suggest evaluating Monte Carlo error estimates not only for parameter estimates but also for other statistics, including p-values and confidence intervals, as well as MI statistics including RVI and FMI.

Clearly, as the number of imputations increases, the simulation error decreases. Consider the total MI variance $T = \overline{U} + B + B/M$ of a single parameter, where $\overline{U}$ is the within-imputation variance and B is the between-imputation variance; see *Methods and formulas* for details. The term B/M reflects the increase in variance due to using a finite number of imputations, and its square root defines the Monte Carlo error associated with a single parameter. In general, Monte Carlo error estimates are obtained by applying a jackknife procedure to MI results. That is, an MCE estimate of an MI statistic is the standard error of the mean of the pseudovalues for that statistic, computed by omitting one imputation at a time; see [R] **jackknife** for technical details.

Consider our heart attack data analysis from example 1. Let's compute Monte Carlo error estimates of MI results. To obtain MCE estimates, we specify the `mcerror` option during estimation:

```
. use https://www.stata-press.com/data/r19/mheart1s20
(Fictional heart attack data; BMI missing)
. mi estimate, dots mcerror: logit attack smokes age bmi hsgrad female
Imputations (20):
  .........10.........20 done
Multiple-imputation estimates                   Imputations       =         20
Logistic regression                             Number of obs     =        154
                                                Average RVI       =     0.0312
                                                Largest FMI       =     0.1355
DF adjustment:   Large sample                   DF:     min       =   1,060.38
                                                        avg       = 223,362.56
                                                        max       = 493,335.88
Model F test:       Equal FMI                   F(   5,71379.3)   =       3.59
Within VCE type:          OIM                   Prob > F          =     0.0030
```

attack	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
smokes	1.198595	.3578195	3.35	0.001	.4972789	1.899911
	.0068541	.0008562	0.01	0.000	.0056572	.0082212
age	.0360159	.0154399	2.33	0.020	.0057541	.0662776
	.0002654	.0000351	0.01	0.001	.0002319	.0003108
bmi	.1039416	.0476136	2.18	0.029	.010514	.1973692
	.0038014	.0008904	0.09	0.006	.0039928	.0044049
hsgrad	.1578992	.4049257	0.39	0.697	-.6357464	.9515449
	.0091517	.0010209	0.02	0.016	.0086215	.0100602
female	-.1067433	.4164735	-0.26	0.798	-.9230191	.7095326
	.0077566	.0009279	0.02	0.015	.006985	.0088408
_cons	-5.478143	1.685075	-3.25	0.001	-8.782394	-2.173892
	.1079841	.0248274	0.07	0.000	.1310618	.1050817

```
Note: Values displayed beneath estimates are Monte Carlo error estimates.
```

As the note describes, MCE estimates are displayed beneath parameter estimates. Following practical guidelines from White, Royston, and Wood (2011), MCE estimates of coefficients should be less than 10% of the standard errors of the coefficients; MCE estimates of test statistics should be approximately 0.1; and MCE estimates of p-values should be approximately 0.01 when the true p-value is 0.05 and 0.02 when the true p-value is 0.1. Our results based on 20 imputations satisfy these conditions, so we can be reasonably sure about the statistical reproducibility of our results.

We can also see Monte Carlo error estimates for other MI statistics reported by the `vartable` option. To redisplay Monte Carlo error estimates, we use the `mcerror` option upon replay. We also suppress the coefficient table by using the `nocitable` option.

```
. mi estimate, vartable mcerror nocitable
Multiple-imputation estimates                   Imputations       =         20
Logistic regression
Variance information
```

	Imputation variance					Relative
	Within	Between	Total	RVI	FMI	efficiency
smokes	.127048	.00094	.128035	.007765	.007711	.999615
	.000559	.000211	.000613	.001744	.00172	.00009
age	.000237	1.4e-06	.000238	.006245	.00621	.99969
	8.6e-07	4.6e-07	1.1e-06	.002054	.002033	.000107
bmi	.001964	.000289	.002267	.154545	.135487	.993271
	.000026	.000077	.000085	.04134	.031986	.00166
hsgrad	.162206	.001675	.163965	.010843	.010739	.999463
	.000521	.000552	.000827	.003579	.003516	.000185
female	.172187	.001203	.17345	.007338	.00729	.999636
	.000614	.000297	.000773	.001811	.001788	.000094
_cons	2.5946	.233211	2.83948	.094377	.086953	.995671
	.029651	.070081	.083436	.028332	.024216	.001263

```
Note: Values displayed beneath estimates are Monte Carlo error estimates.
```

MCE estimates of all statistics are small.

What if we want to see MCE estimates of odds ratios? We know that we can use the `or` option on replay to redisplay results as odds ratios. However, using this option in combination with `mcerror` upon replay will not display MCE estimates of odds ratios:

```
. mi estimate, or mcerror
Multiple-imputation estimates                   Imputations       =         20
Logistic regression                             Number of obs     =        154
                                                Average RVI       =     0.0312
                                                Largest FMI       =     0.1355
DF adjustment:   Large sample                   DF:     min       =   1,060.38
                                                        avg       = 223,362.56
                                                        max       = 493,335.88
Model F test:       Equal FMI                   F(   5,71379.3)   =       3.59
Within VCE type:          OIM                   Prob > F          =     0.0030
```

attack	Odds ratio	Std. err.	t	P>|t|	[95% conf.	interval]
smokes	3.315455	1.186334	3.35	0.001	1.644241	6.685298
age	1.036672	.0160061	2.33	0.020	1.005771	1.068523
bmi	1.109536	.052829	2.18	0.029	1.010569	1.218194
hsgrad	1.171048	.4741875	0.39	0.697	.5295401	2.589707
female	.8987564	.3743082	-0.26	0.798	.3973177	2.033041
_cons	.0041771	.0070387	-3.25	0.001	.0001534	.1137342

```
Note: _cons estimates baseline odds.
Note: Monte Carlo error estimates are not available for exponentiated
      coefficients.
```

The same applies to a combination of the `level()` and `mcerror` options specified on replay to try to display MCE estimates of confidence intervals for a confidence level other than the one used during estimation.

To compute MCE estimates for odds ratios in addition to coefficients, you need to specify the `or` option in combination with `mcerror` during estimation. Similarly, to compute MCE estimates for confidence intervals with a specific confidence level, you need to specify the `level()` option in combination with `mcerror` during estimation. Otherwise, MCE estimates of 95% confidence intervals are computed.

```
. mi estimate, mcerror or level(90): logit attack smokes age bmi hsgrad female
Multiple-imputation estimates                   Imputations       =         20
Logistic regression                             Number of obs     =        154
                                                Average RVI       =     0.0312
                                                Largest FMI       =     0.1355
DF adjustment:   Large sample                   DF:     min       =   1,060.38
                                                        avg       = 223,362.56
                                                        max       = 493,335.88
Model F test:       Equal FMI                   F(   5,71379.3)   =       3.59
Within VCE type:          OIM                   Prob > F          =     0.0030
```

attack	Odds ratio	Std. err.	t	P>|t|	[90% conf.	interval]
smokes	3.315455	1.186334	3.35	0.001	1.840491	5.97245
	.0227267	.0104806	0.01	0.000	.0107398	.0477351
age	1.036672	.0160061	2.33	0.020	1.010676	1.063337
	.0002752	.000039	0.01	0.001	.0002388	.0003221
bmi	1.109536	.052829	2.18	0.029	1.025885	1.200007
	.0042178	.001033	0.09	0.006	.0040064	.0051089
hsgrad	1.171048	.4741875	0.39	0.697	.6016087	2.279478
	.0107188	.0049031	0.02	0.016	.0052248	.02254
female	.8987564	.3743082	-0.26	0.798	.4530363	1.782998
	.0069686	.00341	0.02	0.015	.0032087	.0154128
_cons	.0041771	.0070387	-3.25	0.001	.000261	.0668412
	.0004519	.0007338	0.07	0.000	.0000336	.0068716

```
Note: _cons estimates baseline odds.
Note: Values displayed beneath estimates are Monte Carlo error estimates.
```

Similarly to the MCE estimates for coefficients, the MCE estimates for odds ratios are within acceptable limits.

If you wish to obtain Monte Carlo error estimates of confidence intervals for a number of different confidence levels, a more computationally efficient way of doing so is to use `mi estimate using` (see [MI] **mi estimate using**).

First, use `mi estimate` to save individual estimation results from a model to an estimation file:

```
. mi estimate, saving(miest): ...
```

Then use `mi estimate using` to obtain MCE estimates for different confidence intervals,

```
. mi estimate using miest, mcerror level(90) ...
. mi estimate using miest, mcerror level(80) ...
```

or for odds ratios,

```
. mi estimate using miest, mcerror or ...
```

without refitting the model.

Potential problems that can arise when using mi estimate

There are two problems that can arise when using `mi estimate`:

1. The estimation sample varies across imputations.
2. Different covariates are omitted across the imputations.

`mi estimate` watches for and issues an error message if either of these problems occur. Below we explain how each can arise and what to do about it. If you see one of these messages, be glad that `mi estimate` mentioned the problem, because otherwise, it might have gone undetected. A varying-estimation sample may result in biased or inefficient estimates. Different covariates being omitted always results in the combined results being biased.

If the first problem arises, `mi estimate` issues the error message "estimation sample varies between $m = \#$ and $m = \#$". `mi estimate` expects that when it runs the estimation command on the first imputation, on the second, and so on, the estimation command will use the same observations in each imputation. `mi estimate` does not just count, it watches which observations are used.

Perhaps the difference is due to a past mistake, such as not having imputed all the missing values. Perhaps you even corrupted your `mi` data so that the imputed variable is missing in some imputations and not in others.

Another reason the error can arise is because you specified an `if` condition based on imputed or passive variables. `mi estimate` considers this a mistake but, if this is your intent, you can reissue the `mi estimate` command and include the `esampvaryok` option.

Finally, it is possible that the varying observations are merely a characteristic of the estimator when combined with the two different imputed datasets. In this case, just as in the previous one, you can reissue `mi estimate` with the `esampvaryok` option.

The easy way to diagnose why you got this error is to use `mi xeq` (see [MI] **mi xeq**) to run the estimation command separately on the two imputations mentioned in the error message. Alternatively, you can rerun the `mi estimate` command immediately with the `esampvaryok` option and with the `esample(`*varname*`)` option, which will create in new variable *varname* the `e(sample)` from each of the individual estimations. If you use the second approach, you must first `mi convert` your data to flong or flongsep if they are not recorded in that style already; see [MI] **mi convert** for details.

The second problem we mentioned concerns omitted variables as opposed to omitted observations. `mi estimate` reports that "omitted variables vary" and goes on to mention the two imputations between which the variation was detected.

This can be caused when you include factor variables but did not specify base categories. It was the base categories that differed in the two imputations. That could happen if you specified `i.group`. By default, Stata chooses to omit the most frequent category. If `group` were imputed or passive, then the most frequent category could vary between two imputations. The solution is to specify the base category for yourself by typing, for instance, `b2.group`; see **[U] 11.4.3 Factor variables**.

There are other possible causes. Varying omitted variables 1) includes different variables being omitted in the two imputations and 2) includes no variables being omitted in one imputation and, in the other, one or more variables being omitted.

When different variables are being omitted, it is usually caused by collinearity, and one of the variables needs to be omitted from the model. Variables x1 and x2 are collinear; sometimes the estimation command is choosing to omit x1 and other times, x2. The solution is that you choose which to omit by removing it from your model.

If no variables were omitted in one of the imputations, the problem is more difficult to explain. Say that you included i.group in your model, the base category remained the same for the two imputations, but in one of the imputations, no one is observed in group 3, and thus no coefficient for group 3 could be estimated. You choices are to accept that you cannot estimate a group 3 coefficient and combine group 3 with, say, group 4, or to drop all imputations in which there is no one in group 3. If you want to drop imputations 3, 9, and 12, you type mi set m -= (3,9,12); see [MI] **mi set**.

❑ Technical note

As we already mentioned, mi estimate obtains MI estimates by using the combination rules to pool results from the specified command executed separately on each imputation. As such, certain concepts (for example, likelihood function) and most postestimation tools specific to the command may not be applicable to the MI estimates; see *Analysis of multiply imputed data* in [MI] **Intro substantive**. MI estimates may not even have a valid variance–covariance matrix associated with them when the number of imputations is smaller than the number of estimated parameters. For these reasons, the system matrices e(b) and e(V) are not set by mi estimate. If desired, you can save the MI estimates and their variance–covariance estimates in e(b) and e(V) by specifying the post option. See [MI] **mi estimate postestimation** for postestimation tools available after mi estimate.

❑

Stored results

mi estimate stores the following in e():

Scalars

e(df_avg[_Q]_mi)	average degrees of freedom
e(df_c_mi)	complete degrees of freedom (if originally stored by *estimation_command* in e(df_r))
e(df_max[_Q]_mi)	maximum degrees of freedom
e(df_min[_Q]_mi)	minimum degrees of freedom
e(df_m_mi)	MI model test denominator (residual) degrees of freedom
e(df_r_mi)	MI model test numerator (model) degrees of freedom
e(esampvary_mi)	varying-estimation sample flag (0 or 1)
e(F_mi)	model test F statistic
e(k_exp_mi)	number of expressions (transformed coefficients)
e(M_mi)	number of imputations
e(N_mi)	number of observations (minimum, if varies)
e(N_min_mi)	minimum number of observations
e(N_max_mi)	maximum number of observations
e(N_g_mi)	number of groups
e(g_min_mi)	smallest group size
e(g_avg_mi)	average group size
e(g_max_mi)	largest group size
e(p_mi)	MI model test p-value
e(cilevel_mi)	confidence level used to compute Monte Carlo error estimates of confidence intervals
e(fmi_max[_Q]_mi)	largest FMI
e(rvi_avg[_Q]_mi)	average RVI
e(rvi_avg_F_mi)	average RVI associated with the residual degrees of freedom for model test
e(ufmi_mi)	1 if unrestricted FMI model test is performed, 0 if equal FMI model test is performed

Macros

e(mi)	mi
e(cmdline_mi)	command as typed
e(prefix_mi)	mi estimate
e(cmd_mi)	name of *estimation_command*
e(cmd)	mi estimate (equals e(cmd_mi) when post is used)
e(title_mi)	"Multiple-imputation estimates"
e(wvce_mi)	title used to label within-imputation variance in the table header
e(modeltest_mi)	title used to label the model test in the table header
e(dfadjust_mi)	title used to label the degrees-of-freedom adjustment in the table header
e(expnames_mi)	names of expressions specified in *spec*
e(exp#_mi)	expressions of the transformed coefficients specified in *spec*
e(rc_mi)	return codes for each imputation
e(m_mi)	specified imputation numbers
e(m_est_mi)	imputation numbers used in the computation
e(names_vvl_mi)	command-specific e() macro names that contents varied across imputations
e(names_vvm_mi)	command-specific e() matrix names that values varied across imputations (excluding b, V, and Cns)
e(names_vvs_mi)	command-specific e() scalar names that values varied across imputations

Matrices

e(b)	MI estimates of coefficients (equals e(b_mi); stored only if post is used)
e(V)	variance–covariance matrix (equals e(V_mi); stored only if post is used)
e(Cns)	constraint matrix, for constrained estimation only (equals e(Cns_mi); stored only if post is used)
e(N_g_mi)	group counts
e(g_min_mi)	group-size minimums
e(g_avg_mi)	group-size averages
e(g_max_mi)	group-size maximums
e(b[_Q]_mi)	MI estimates of coefficients (or transformed coefficients)
e(V[_Q]_mi)	variance–covariance matrix (total variance)
e(Cns_mi)	constraint matrix (for constrained estimation only)
e(W[_Q]_mi)	within-imputation variance matrix
e(B[_Q]_mi)	between-imputation variance matrix
e(re[_Q]_mi)	parameter-specific relative efficiencies
e(rvi[_Q]_mi)	parameter-specific RVIs
e(fmi[_Q]_mi)	parameter-specific FMIs
e(df[_Q]_mi)	parameter-specific degrees of freedom
e(pise[_Q]_mi)	parameter-specific percentages increase in standard errors
e(*vs_names*_vs_mi)	values of command-specific e() scalar *vs_names* that varied across imputations

vs_names include (but are not restricted to) df_r, N, N_strata, N_psu, N_pop, N_sub, N_postrata, N_stdize, N_subpop, N_over, and converged.

Results N_g_mi, g_min_mi, g_avg_mi, and g_max_mi are stored for panel-data models only. The results are stored as matrices for mixed-effects models and as scalars for other panel-data models.

If transformations are specified, the corresponding estimation results are stored with the _Q_mi suffix, as described above.

Command-specific e() results that remain constant across imputations are also stored. Command-specific results that vary from imputation to imputation are posted as missing, and their names are stored in the corresponding macros e(names_vvl_mi), e(names_vvm_mi), and e(names_vvs_mi). For some command-specific e() scalars (see *vs_names* above), their values from each imputation are stored in a corresponding matrix with the _vs_mi suffix.

In addition to the above, the following is stored in `r()`:

Matrices

`r(table)` matrix containing the coefficients with their standard errors, test statistics, p-values, and confidence intervals

Note that results stored in `r()` are updated when the command is replayed and will be replaced when any r-class command is run after the estimation command.

Methods and formulas

Let $\mathbf{q}$ define a column vector of parameters of interest. For example, $\mathbf{q}$ may be a vector of coefficients (or functions of coefficients) from a regression model. Let $\{(\hat{\mathbf{q}}_i, \widehat{\mathbf{U}}_i) : i = 1, 2, \ldots, M\}$ be the completed-data estimates of $\mathbf{q}$ and the respective variance–covariance estimates from M imputed datasets.

The MI estimate of $\mathbf{q}$ is

$$\overline{\mathbf{q}}_M = \frac{1}{M}\sum_{i=1}^{M} \hat{\mathbf{q}}_i$$

The variance–covariance estimate (VCE) of $\overline{\mathbf{q}}_M$ (total variance) is

$$\mathbf{T} = \overline{\mathbf{U}} + (1 + \frac{1}{M})\mathbf{B}$$

where $\overline{\mathbf{U}} = \sum_{i=1}^{M} \widehat{\mathbf{U}}_i/M$ is the within-imputation variance–covariance matrix and $\mathbf{B} = \sum_{i=1}^{M}(\mathbf{q}_i - \overline{\mathbf{q}}_M)(\mathbf{q}_i - \overline{\mathbf{q}}_M)'/(M-1)$ is the between-imputation variance–covariance matrix.

Methods and formulas are presented under the following headings:

Univariate case
Multivariate case

Univariate case

Let Q, $\overline{Q}_M$, B, $\overline{U}$, and T correspond to the scalar analogues of the above formulas. Univariate inferences are based on the approximation

$$T^{-1/2}(Q - \overline{Q}_M) \sim t_\nu \tag{1}$$

where t_ν denotes a Student's t distribution with ν degrees of freedom, which depends on the number of imputations, M, and the increase in variance of estimates due to missing data. Under the large-sample assumption with respect to complete data, the degrees of freedom is

$$\nu_{\text{large}} = (M-1)\left(1 + \frac{1}{r}\right)^2 \tag{2}$$

where

$$r = \frac{(1 + M^{-1})B}{\overline{U}} \tag{3}$$

is an RVI due to missing data. Under the small-sample assumption, the degrees of freedom is

$$\nu_{\text{small}} = \left(\frac{1}{\nu_{\text{large}}} + \frac{1}{\widehat{\nu}_{\text{obs}}}\right)^{-1} \tag{4}$$

where $\hat{\nu}_{\text{obs}} = \nu_c(\nu_c+1)(1-\gamma)/(\nu_c+3)$, $\gamma = (1+1/M)B/T$, and ν_c are the complete degrees of freedom, the degrees of freedom used for inference when data are complete (Barnard and Rubin 1999).

The small-sample adjustment (4) is applied to the degrees of freedom ν when the specified command stores the residual degrees of freedom in `e(df_r)`. This number of degrees of freedom is used as the complete degrees of freedom, ν_c, in the computation. (If `e(df_r)` varies across imputations, the smallest is used in the computation, resulting in conservative inference.) If `e(df_r)` is not set by the specified command or if the `nosmall` option is specified, then (2) is used to compute the degrees of freedom, ν.

Parameter-specific significance levels, confidence intervals, and degrees of freedom as reported by `mi estimate` are computed using the formulas above.

The percentage of standard error increase due to missing data, as reported by `mi estimate, dftable`, is computed as $\{(T/\overline{U})^{1/2}-1\}\times 100\%$.

The FMIs due to missing data and relative efficiencies reported by `mi estimate, vartable` are computed as follows.

In the large-sample case, the fraction of information about Q missing due to nonresponse (Rubin 1987, 77) is

$$\lambda = \frac{r + 2/(\nu_{\text{large}}+3)}{r+1}$$

where the RVI, r, is defined in (3). In the small-sample case, the fraction of information about Q missing due to nonresponse (Barnard and Rubin 1999, 953) is

$$\lambda = 1 - \frac{\lambda(\nu_{\text{small}})}{\lambda(\nu_c)}\frac{\overline{U}}{T}$$

where $\lambda(u) = (u+1)/(u+3)$.

The relative (variance) efficiency of using M imputations versus the infinite number of imputations is RE $= (1+\lambda/M)^{-1}$ (Rubin 1987, 114).

Also see Rubin (1987, 76–77) and Schafer (1997, 109–111) for details.

Multivariate case

The approximation (1) can be generalized to the multivariate case:

$$(\mathbf{q}-\overline{\mathbf{q}}_M)\mathbf{T}^{-1}(\mathbf{q}-\overline{\mathbf{q}}_M)'/k \sim F_{k,\nu} \tag{5}$$

where $F_{k,\nu}$ denotes an F distribution with $k = \text{rank}(T)$ numerator degrees of freedom and ν denominator degrees of freedom defined as in (2), where the RVI, r, is replaced with the average RVI, r_{ave}:

$$r_{\text{ave}} = (1+1/M)\text{tr}(\mathbf{B}\overline{\mathbf{U}}^{-1})/k$$

The approximation (5) is inadequate with a small number of imputations because the between-imputation variance, **B**, cannot be estimated reliably based on small M. Moreover, when M is smaller than the number of estimated parameters, **B** does not have a full rank. As such, the total variance, **T**, may not be a valid variance–covariance matrix for $\overline{\mathbf{q}}_M$.

One solution is to assume that the between-imputation and within-imputation matrices are proportional, that is $B = \overline{\lambda}\times\overline{\mathbf{U}}$ (Rubin 1987, 78). This assumption implies that FMIs of all estimated parameters are equal. Under this assumption, approximation (5) becomes

$$(1+r_{\text{ave}})^{-1}(\mathbf{q}-\overline{\mathbf{q}}_M)\overline{\mathbf{U}}^{-1}(\mathbf{q}-\overline{\mathbf{q}}_M)'/k \sim F_{k,\nu_\star} \tag{6}$$

where $k = \text{rank}(U)$ and $\nu_\star$ is computed as described in Li et al. (1991, 1067).

Also see Rubin (1987, 77–78) and Schafer (1997, 112–114) for details.

We refer to (6) as an equal FMI test and to (5) as the unrestricted FMI test. By default, `mi estimate` uses the approximation (6) for the model test. If the `ufmitest` option is specified, it uses the approximation (5) for the model test.

Similar to the univariate case, the degrees of freedom $\nu_\star$ and ν are adjusted for small samples when the command stores the completed-data residual degrees of freedom in `e(df_r)`.

In the small-sample case, the degrees of freedom $\nu_\star$ is computed as described in Reiter (2007) (in the rare case, when $k(M-1) \leq 4$, $\nu_\star = (k+1)\nu_1/2$, where ν_1 is the degrees of freedom from Barnard and Rubin [1999]). In the small-sample case, the degrees of freedom ν is computed as described in Barnard and Rubin (1999) and Marchenko and Reiter (2009).

Acknowledgments

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Also see

[MI] **mi estimate postestimation** — Postestimation tools for mi estimate

[MI] **mi estimate using** — Estimation using previously saved estimation results

[MI] **Intro** — Introduction to mi

[MI] **Intro substantive** — Introduction to multiple-imputation analysis

[MI] **Glossary**

[D] **frunalias** — Change storage type of alias variables

mi estimate using — Estimation using previously saved estimation results

Description Menu Syntax Options
Remarks and examples Stored results Methods and formulas References
Also see

Description

`mi estimate using` *miestfile* is for use after `mi estimate, saving(`*miestfile*`):` .... It allows obtaining multiple-imputation (MI) estimates, including standard errors and confidence intervals, for transformed coefficients or the original coefficients, this time calculated on a subset of the imputations. The transformation can be linear or nonlinear.

Menu

Statistics > Multiple imputation

Syntax

Compute MI estimates of coefficients using previously saved estimation results

`mi estimate using` *miestfile* [`,` *options*]

Compute MI estimates of transformed coefficients using previously saved estimation results

`mi estimate` [*spec*] `using` *miestfile* [`,` *options*]

where *spec* may be one or more terms of the form `(`[*name*`:`] *exp*`)`. *exp* is any function of the parameter estimates allowed by `nlcom`; see [R] **nlcom**.

miestfile`.ster` contains estimation results previously saved by `mi estimate, saving(`*miestfile*`)`; see [MI] **mi estimate**.

options	Description
Options	
nimputations(#)	specify number of imputations to use; default is to use all existing imputations
imputations(*numlist*)	specify which imputations to use
estimations(*numlist*)	specify which estimation results to use
mcerror	compute Monte Carlo error estimates
ufmitest	perform unrestricted FMI model test
nosmall	do not apply small-sample correction to degrees of freedom
Tables	
[no]citable	suppress/display standard estimation table containing parameter-specific confidence intervals; default is citable
dftable	display degrees-of-freedom table; dftable implies nocitable
vartable	display variance information about estimates; vartable implies citable
table_options	control table output
display_options	control columns and column formats, row spacing, display of omitted variables and base and empty cells, and factor-variable labeling
Reporting	
level(#)	set confidence level; default is level(95)
dots	display dots as estimations are performed
noisily	display any output from nlcom if transformations are specified
trace	trace nlcom if transformations are specified; implies noisily
replay	replay command-specific results from each individual estimation in *miestfile*.ster; implies noisily
cmdlegend	display the command legend
nogroup	suppress summary about groups displayed for xt commands
me_options	control output from mixed-effects commands
Advanced	
errorok	allow estimation even when nlcom errors out in some imputations; such imputations are discarded from the analysis
coeflegend	display legend instead of statistics
nowarning	suppress the warning about varying estimation samples
noerrnotes	suppress error notes associated with failed estimation results in *miestfile*.ster
showimputations	show imputations saved in *miestfile*.ster
eform_option	display coefficient table in exponentiated form
post	post estimated coefficients and VCE to e(b) and e(V)

coeflegend, nowarning, noerrnotes, showimputations, *eform_option*, and post do not appear in the dialog box.

table_options	Description
noheader	suppress table header(s)
notable	suppress table(s)
nocoef	suppress table output related to coefficients
nocmdlegend	suppress command legend that appears in the presence of transformed coefficients when nocoef is used
notrcoef	suppress table output related to transformed coefficients
nolegend	suppress table legend(s)
nocnsreport	do not display constraints

See [MI] **mi estimate postestimation** for features available after estimation. To replay results, type mi estimate without arguments.

Options

Options

nimputations(#) specifies that the first # imputations be used; # must be $M_{\min} \leq \# \leq M$, where $M_{\min} = 3$ if mcerror is specified and $M_{\min} = 2$, otherwise. The default is to use all imputations, M. Only one of nimputations(), imputations(), or estimations() may be specified.

imputations(*numlist*) specifies which imputations to use. The default is to use all of them. *numlist* must contain at least two numbers corresponding to the imputations saved in *miestfile*.ster. If mcerror is specified, *numlist* must contain at least three numbers. You can use the showimputations option to display imputations currently saved in *miestfile*.ster. Only one of nimputations(), imputations(), or estimations() may be specified.

estimations(*numlist*) does the same thing as imputations(*numlist*), but this time the imputations are numbered differently. Say that *miestfile*.ster was created by mi estimate and mi estimate was told to limit itself to imputations 1, 3, 5, and 9. With imputations(), the imputations are still numbered 1, 3, 5, and 9. With estimations(), they are numbered 1, 2, 3, and 4. Usually, one does not specify a subset of imputations when using mi estimate, and so usually, the imputations() and estimations() options are identical. The specified *numlist* must contain at least two numbers. If mcerror is specified, *numlist* must contain at least three numbers. Only one of nimputations(), imputations(), or estimations() may be specified.

mcerror specifies to compute Monte Carlo error (MCE) estimates for the results displayed in the estimation, degrees-of-freedom, and variance-information tables. MCE estimates reflect variability of MI results across repeated uses of the same imputation procedure and are useful for determining an adequate number of imputations to obtain stable MI results; see White, Royston, and Wood (2011) for details and guidelines.

MCE estimates are obtained by applying the jackknife procedure to multiple-imputation results. That is, the jackknife pseudovalues of MI results are obtained by omitting one imputation at a time; see [R] **jackknife** for details about the jackknife procedure. As such, the Monte Carlo error computation requires at least three imputations.

If level() is specified during estimation, MCE estimates are obtained for confidence intervals with the specified confidence level instead of using the default 95% confidence level. If any of the options described in [R] ***eform_option*** is specified during estimation, MCE estimates for the coefficients, stan-

dard errors, and confidence intervals in the exponentiated form are also computed. `mcerror` can also be used upon replay to display MCE estimates. Otherwise, MCE estimates are not reported upon replay even if they were previously computed.

`ufmitest` specifies that the unrestricted fraction missing information (FMI) model test be used. The default test performed assumes equal fractions of information missing due to nonresponse for all coefficients. This is equivalent to the assumption that the between-imputation and within-imputation variances are proportional. The unrestricted test may be preferable when this assumption is suspect provided the number of imputations is large relative to the number of estimated coefficients.

`nosmall` specifies that no small-sample correction be made to the degrees of freedom. By default, individual tests of coefficients (and transformed coefficients) use the small-sample correction of Barnard and Rubin (1999), and the overall model test uses the small-sample correction of Reiter (2007).

Tables

All table options below may be specified at estimation time or when redisplaying previously estimated results.

`citable` and `nocitable` specify whether the standard estimation table containing parameter-specific confidence intervals is displayed. The default is `citable`. `nocitable` can be used with `vartable` to suppress the confidence interval table.

`dftable` displays a table containing parameter-specific degrees of freedom and percentages of increase in standard errors due to nonresponse. `dftable` implies `nocitable`.

`vartable` displays a table reporting variance information about MI estimates. The table contains estimates of within-imputation variances, between-imputation variances, total variances, relative increases in variance due to nonresponse, fractions of information about parameter estimates missing due to nonresponse, and relative efficiencies for using finite M rather than a hypothetically infinite number of imputations. `vartable` implies `citable`.

table_options control the appearance of all displayed table output:

`noheader` suppresses all header information from the output. The table output is still displayed.

`notable` suppresses all tables from the output. The header information is still displayed.

`nocoef` suppresses the display of tables containing coefficient estimates. This option affects the table output produced by `citable`, `dftable`, and `vartable`.

`nocmdlegend` suppresses the table legend showing the command line, used to produce results in *miestfile*`.ster`, from the output. This legend appears above the tables containing transformed coefficients (or above the variance-information table if `vartable` is used) when `nocoef` is specified.

`notrcoef` suppresses the display of tables containing estimates of transformed coefficients (if specified). This option affects the table output produced by `citable`, `dftable`, and `vartable`.

`nolegend` suppresses all table legends from the output.

`nocnsreport`; see [R] **Estimation options**.

display_options: `noci`, `nopvalues`, `noomitted`, `vsquish`, `noemptycells`, `baselevels`, `allbaselevels`, `nofvlabel`, `fvwrap(#)`, `fvwrapon(`*style*`)`, `cformat(%`*fmt*`)`, `pformat(%`*fmt*`)`, and `sformat(%`*fmt*`)`; see [R] **Estimation options**.

Reporting

`level(#)`; see [R] **Estimation options**.

dots specifies that dots be displayed as estimations of transformed coefficients are successfully completed. An x is displayed if nlcom fails to estimate one of the transformed coefficients specified in *spec*. This option is relevant only if transformations are specified.

noisily specifies that any output from nlcom, used to obtain the estimates of transformed coefficients, be displayed. This option is relevant only if transformations are specified.

trace traces the execution of nlcom. trace implies noisily and is relevant only if transformations are specified.

replay replays estimation results from *miestfile*.ster, previously saved by mi estimate, saving(*miestfile*). This option implies noisily.

cmdlegend requests that the command line corresponding to the estimation command used to produce the estimation results saved in *miestfile*.ster be displayed. cmdlegend may be specified at run time or when redisplaying results.

nogroup suppresses the display of group summary information (number of groups, average group size, minimum, and maximum) as well as other command-specific information displayed for xt commands.

me_options: stddeviations, variance, noretable, nofetable, and estmetric. These options are relevant only with the mixed-effects command mixed (see [ME] **mixed**). See the corresponding mixed-effects commands for more information. The stddeviations option is the default with mi estimate using, because MI-based confidence intervals may not be computable for some random-effects variances and covariances; see help mi_me_note for details. The estmetric option is implied when vartable or dftable is used.

Advanced

errorok specifies that estimations of transformed coefficients that fail be skipped and the combined results be based on the successful estimation results. The default is that mi estimate stops if an individual estimation fails. If the *miestfile*.ster file contains failed estimation results, mi estimate using does not error out; it issues notes about which estimation results failed and discards these estimation results in the computation. You can use the noerrnotes option to suppress the display of the notes.

The following options are available with mi estimate using but are not shown in the dialog box:

coeflegend; see [R] **Estimation options**. coeflegend implies nocitable and cannot be combined with citable or dftable.

nowarning suppresses the warning message at the bottom of table output that occurs if the estimation sample varies and esampvaryok is specified. See *Potential problems that can arise when using mi estimate* in [MI] **mi estimate** for details.

noerrnotes suppresses notes about failed estimation results. These notes appear when *miestfile*.ster contains estimation results, previously saved by mi estimate, saving(*miestfile*), from imputations for which the estimation command used with mi estimate failed to estimate parameters.

showimputations displays imputation numbers corresponding to the estimation results saved in *miestfile*.ster. showimputations may be specified at run time or when redisplaying results.

eform_option; see [R] ***eform_option***. `mi estimate using` reports results in the coefficient metric under which the combination rules are applied. You may use the appropriate *eform_option* to redisplay results in exponentiated form, if desired. If `dftable` is also specified, the reported degrees of freedom and percentage increases in standard errors are not adjusted and correspond to the original coefficient metric.

`post` requests that MI estimates of coefficients and their respective VCEs be posted in the usual way. This allows the use of *estimation_command*-specific postestimation tools with MI estimates. There are issues; see *Using the command-specific postestimation tools* in [MI] **mi estimate postestimation**. `post` may be specified at estimation time or when redisplaying previously estimated results.

Remarks and examples

`mi estimate using` is convenient when refitting models using `mi estimate` would be tedious or time consuming. In such cases, you can perform estimation once and save the uncombined, individual results by specifying `mi estimate`'s `saving(`*miestfile*`)` option. After that, you can repeatedly use `mi estimate using` *miestfile* to estimate linear and nonlinear transformations of coefficients or to obtain MI estimates using a subset of saved imputations.

`mi estimate using` performs the pooling step of the MI procedure; see [MI] **Intro substantive**. That is, it combines completed-data estimates from the *miestfile*`.ster` file by applying Rubin's combination rules (Rubin 1987, 77).

▷ Example 1

Recall the analysis of house resale prices from *Example 2: Completed-data linear regression analysis* in [MI] **mi estimate**:

```
. use https://www.stata-press.com/data/r19/mhouses1993s30
(Albuquerque home prices Feb15-Apr30, 1993)
. mi estimate, saving(miest): regress price tax sqft age nfeatures ne custom
> corner
Multiple-imputation estimates                   Imputations       =         30
Linear regression                               Number of obs     =        117
                                                Average RVI       =     0.0648
                                                Largest FMI       =     0.2533
                                                Complete DF       =        109
DF adjustment:   Small sample                   DF:     min       =      69.12
                                                        avg       =      94.02
                                                        max       =     105.51
Model F test:       Equal FMI                   F(   7,  106.5)   =      67.18
Within VCE type:          OLS                   Prob > F          =     0.0000
------------------------------------------------------------------------------
       price | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
         tax |   .6768015   .1241568     5.45   0.000     .4301777    .9234253
        sqft |   .2118129    .069177     3.06   0.003     .0745091    .3491168
         age |   .2471445   1.653669     0.15   0.882    -3.051732    3.546021
    nfeatures |   9.288033   13.30469     0.70   0.487    -17.12017    35.69623
          ne |   2.518996   36.99365     0.07   0.946    -70.90416    75.94215
      custom |   134.2193   43.29755     3.10   0.002     48.35674    220.0818
      corner |  -68.58686    39.9488    -1.72   0.089    -147.7934    10.61972
       _cons |   123.9118   71.05816     1.74   0.085    -17.19932    265.0229
------------------------------------------------------------------------------
```

In the above, we use the `saving()` option to save the individual completed-data estimates from a regression analysis in Stata estimation file `miest.ster`. We can now use `mi estimate using` to recombine the first 5 imputations, and ignore the remaining 25, without reestimation:

```
. mi estimate using miest, ni(5)
Multiple-imputation estimates                   Imputations       =          5
Linear regression                               Number of obs     =        117
                                                Average RVI       =     0.0685
                                                Largest FMI       =     0.2075
                                                Complete DF       =        109
DF adjustment:   Small sample                   DF:     min       =      48.59
                                                        avg       =      85.22
                                                        max       =     104.79
Model F test:       Equal FMI                   F(   7,  103.9)   =      67.50
Within VCE type:          OLS                   Prob > F          =     0.0000
```

price	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
tax	.6631356	.122443	5.42	0.000	.4195447	.9067265
sqft	.2185884	.0670182	3.26	0.002	.0856051	.3515718
age	-.0395402	1.613185	-0.02	0.981	-3.28205	3.202969
nfeatures	8.735622	13.42251	0.65	0.517	-18.01198	35.48323
ne	4.069381	36.94491	0.11	0.913	-69.4355	77.57426
custom	130.4925	42.93286	3.04	0.003	45.36257	215.6225
corner	-71.25406	40.06697	-1.78	0.078	-150.7152	8.207084
_cons	130.2002	70.38012	1.85	0.068	-9.624642	270.025

We obtain results identical to those shown in the example in [MI] **mi estimate**.

We can also obtain estimates of transformed coefficients without refitting the models to the imputed dataset. Recall the example from *Example 5: Estimating transformations* in [MI] **mi estimate**, where we estimated the ratio of the coefficients for `age` and `sqft`. We can obtain the same results by using the following:

```
. mi estimate (ratio: _b[age]/_b[sqft]) using miest
Multiple-imputation estimates                   Imputations       =         30
Linear regression                               Number of obs     =        117
                                                Average RVI       =     0.0648
                                                Largest FMI       =     0.2533
                                                Complete DF       =        109
DF adjustment:   Small sample                   DF:     min       =      69.12
                                                        avg       =      94.02
                                                        max       =     105.51
Model F test:       Equal FMI                   F(   7,  106.5)   =      67.18
Within VCE type:          OLS                   Prob > F          =     0.0000
------------------------------------------------------------------------------
       price | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
         tax |   .6768015   .1241568     5.45   0.000     .4301777    .9234253
        sqft |   .2118129    .069177     3.06   0.003     .0745091    .3491168
         age |   .2471445   1.653669     0.15   0.882    -3.051732    3.546021
   nfeatures |   9.288033   13.30469     0.70   0.487    -17.12017    35.69623
          ne |   2.518996   36.99365     0.07   0.946    -70.90416    75.94215
      custom |   134.2193   43.29755     3.10   0.002     48.35674    220.0818
      corner |  -68.58686    39.9488    -1.72   0.089    -147.7934    10.61972
       _cons |   123.9118   71.05816     1.74   0.085    -17.19932    265.0229
------------------------------------------------------------------------------

Transformations                                 Average RVI       =     0.2899
                                                Largest FMI       =     0.2316
                                                Complete DF       =        109
DF adjustment:   Small sample                   DF:     min       =      72.51
                                                        avg       =      72.51
Within VCE type:          OLS                   max       =      72.51
        ratio: _b[age]/_b[sqft]
------------------------------------------------------------------------------
       price | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
       ratio |    1.44401   8.217266     0.18   0.861    -14.93485    17.82287
------------------------------------------------------------------------------
```

The results are the same as in the example in [MI] **mi estimate**.

◁

For more examples, see [MI] **mi test**.

Stored results

See *Stored results* in [MI] **mi estimate**.

Methods and formulas

See *Methods and formulas* in [MI] **mi estimate**.

References

Barnard, J., and D. B. Rubin. 1999. Small-sample degrees of freedom with multiple imputation. *Biometrika* 86: 948–955. https://doi.org/10.1093/biomet/86.4.948.

Reiter, J. P. 2007. Small-sample degrees of freedom for multi-component significance tests with multiple imputation for missing data. *Biometrika* 94: 502–508. https://doi.org/10.1093/biomet/asm028.

Rubin, D. B. 1987. *Multiple Imputation for Nonresponse in Surveys*. New York: Wiley.

White, I. R., P. Royston, and A. M. Wood. 2011. Multiple imputation using chained equations: Issues and guidance for practice. *Statistics in Medicine* 30: 377–399. https://doi.org/10.1002/sim.4067.

Also see

[MI] **mi estimate** — Estimation using multiple imputations

[MI] **mi estimate postestimation** — Postestimation tools for mi estimate

[MI] **Intro** — Introduction to mi

[MI] **Intro substantive** — Introduction to multiple-imputation analysis

[MI] **Glossary**

mi estimate postestimation — Postestimation tools for mi estimate

Postestimation commands Remarks and examples Also see

Postestimation commands

The following postestimation commands are of special interest after `mi estimate` and `mi estimate using`:

Command	Description
`mi test`	perform tests on coefficients
`mi testtransform`	perform tests on transformed coefficients
`mi predict`	obtain linear predictions
`mi predictnl`	obtain nonlinear predictions

See [MI] **mi test** and [MI] **mi predict**.

The following standard postestimation command is also available:

Command	Description
`etable`	table of estimation results

Remarks and examples

After estimation by `mi estimate:` *estimation_command*, in general, you may not use the standard postestimation commands such as `test`, `testnl`, or `predict`; nor may you use *estimation_command*-specific postestimation commands such as `estat`. As we have mentioned often, `mi estimate` is its own estimation command, and the postestimation commands available after `mi estimate` (and `mi estimate using`) are listed in the table above.

Using the command-specific postestimation tools

After `mi estimate:` *estimation_command*, you may not use *estimation_command*'s postestimation features. More correctly, you may not use them unless you specify `mi estimate`'s `post` option:

```
. mi estimate, post: estimation_command ...
```

Specifying `post` causes many statistical issues, so do not be casual about specifying it.

First, the MI estimate of the VCE is poor unless the number of imputations, M, is sufficiently large. How large is uncertain, but you should not be thinking $M = 20$ rather than $M = 5$; you should be thinking of M in the hundreds. What is statistically true is that, asymptotically in M (and in the number of observations, N), the MI estimated coefficients approach normality and the VCE becomes well estimated.

Second, there are substantive issues about what is meant by *estimation_command*'s prediction after MI estimation that you are going to have to resolve for yourself. There is no one estimation sample. There are M of them, and as we have just argued, M is large. Do not expect postestimation commands that depend on predicted values such as `margins`, `lroc`, and the like, to produce correct results, if they produce results at all.

Which brings us to the third point. Even when you specify `mi estimate`'s `post` option, `mi estimate` still does not post everything the estimation command expects to see. It does not post likelihood values, for instance, because there is no counterpart after MI estimation. Thus, you should be prepared to see unexpected and inelegant error messages if you use a postestimation command that depends on an unestimated and unposted result.

All of which is to say that if you specify the `post` option, you have a responsibility beyond the usual to ensure the validity of any statistical results.

Also see

[MI] **mi predict** — Obtain multiple-imputation predictions

[MI] **mi test** — Test hypotheses after mi estimate

[MI] **mi estimate** — Estimation using multiple imputations

[MI] **mi estimate using** — Estimation using previously saved estimation results

[MI] **Intro** — Introduction to mi

[MI] **Intro substantive** — Introduction to multiple-imputation analysis

[MI] **Glossary**

mi expand — Expand mi data

Description Menu Syntax Options
Remarks and examples Also see

Description

`mi expand` is `expand` (see [D] **expand**) for `mi` data. The syntax is identical to `expand` except that `in` *range* is not allowed and the `noupdate` option is allowed.

`mi expand` *exp* replaces each observation in the dataset with n copies of the observation, where n is equal to the required expression rounded to the nearest integer. If the expression is less than 1 or equal to missing, it is interpreted as if it were 1, meaning that the observation is retained but not duplicated.

Menu

Statistics > Multiple imputation

Syntax

`mi expand` [`=`]*exp* [*if*] [, *options*]

options	Description
`generate(`*newvar*`)`	create *newvar*; 0 = original, 1 = expanded
`noupdate`	see [MI] **noupdate option**

Options

`generate(`*newvar*`)` creates new variable *newvar* containing 0 if the observation originally appeared in the dataset and 1 if the observation is a duplication.

`noupdate` in some cases suppresses the automatic `mi update` this command might perform; see [MI] **noupdate option**.

Remarks and examples

`mi expand` amounts to performing `expand` on $m = 0$, then duplicating the result on $m = 1$, $m = 2$, …, $m = M$, and then combining the result back into `mi` format. Thus if the requested expansion specified by *exp* is a function of an imputed, passive, varying, or super-varying variable, then it is the values of the variable in $m = 0$ that will be used to produce the result for $m = 1$, $m = 2$, …, $m = M$, too.

Also see

[MI] **Intro** — Introduction to mi

[D] **expand** — Duplicate observations

mi export — Export mi data

Description Syntax Remarks and examples References Also see

Description

Use `mi export nhanes1` to export data in the format used by the National Health and Nutrition Examination Survey.

Use `mi export ice` to export data in the format used by `ice` (Royston 2004, 2005a, 2005b, 2007, 2009).

If and when other standards develop for recording multiple-imputation data, other `mi export` subcommands will be added.

Syntax

```
mi export nhanes1 ...

mi export ice ...
```

See [MI] **mi export nhanes1** and [MI] **mi export ice**.

Remarks and examples

If you wish to send data to other Stata users, ignore `mi export` and just send them your `mi` dataset(s).

To send data to users of other packages, however, you will have to negotiate the format you will use. The easiest way to send data to non–Stata users is probably to `mi convert` (see [MI] **mi convert**) your data to flongsep and then use `outfile` (see [D] **outfile**) or `export delimited` (see [D] **import delimited**). Also see [U] **22 Entering and importing data**.

References

Royston, P. 2004. Multiple imputation of missing values. *Stata Journal* 4: 227–241.

———. 2005a. Multiple imputation of missing values: Update. *Stata Journal* 5: 188–201.

———. 2005b. Multiple imputation of missing values: Update of ice. *Stata Journal* 5: 527–536.

———. 2007. Multiple imputation of missing values: Further update of ice, with an emphasis on interval censoring. *Stata Journal* 7: 445–464.

———. 2009. Multiple imputation of missing values: Further update of ice, with an emphasis on categorical variables. *Stata Journal* 9: 466–477.

Also see

[MI] **Intro** — Introduction to mi

[MI] **mi export nhanes1** — Export mi data to NHANES format

[MI] **mi export ice** — Export mi data to ice format

mi export ice — Export mi data to ice format

Description Menu Syntax Option
Remarks and examples References Also see

Description

`mi export ice` converts the `mi` data in memory to `ice` format. See Royston (2004, 2005a, 2005b, 2007, 2009) for a description of `ice`.

Menu

Statistics > Multiple imputation

Syntax

`mi export ice` [`, clear`]

Option

`clear` specifies that it is okay to replace the data in memory even if they have changed since they were last saved to disk.

Remarks and examples

`mi export ice` is the inverse of `mi import ice` (see [MI] **mi import ice**). Below we use `mi export ice` to convert `miproto.dta` to `ice` format. `miproto.dta` happens to be in wide form, but that is irrelevant.

```
. use https://www.stata-press.com/data/r19/miproto
(mi prototype)
. mi describe
Style: wide
       last mi update 04feb2025 12:58:57, 10 days ago
Observations:
   Complete            1
   Incomplete          1  (M = 2 imputations)
   ----------------------
   Total               2
Variables:
   Imputed: 1; b(1)
   Passive: 1; c(1)
   Regular: 1; a
   System:  1; _mi_miss
   (there are no unregistered variables)
. list
```

	a	b	c	_1_b	_2_b	_1_c	_2_c	_mi_miss
1.	1	2	3	2	2	3	3	0
2.	4	.	.	4.5	5.5	8.5	9.5	1

```
. mi export ice
. list, separator(2)
```

	a	b	c	_mj	_mi
1.	1	2	3	0	1
2.	4	.	.	0	2
3.	1	2	3	1	1
4.	4	4.5	8.5	1	2
5.	1	2	3	2	1
6.	4	5.5	9.5	2	2

References

Royston, P. 2004. Multiple imputation of missing values. *Stata Journal* 4: 227–241.

———. 2005a. Multiple imputation of missing values: Update. *Stata Journal* 5: 188–201.

———. 2005b. Multiple imputation of missing values: Update of ice. *Stata Journal* 5: 527–536.

———. 2007. Multiple imputation of missing values: Further update of ice, with an emphasis on interval censoring. *Stata Journal* 7: 445–464.

———. 2009. Multiple imputation of missing values: Further update of ice, with an emphasis on categorical variables. *Stata Journal* 9: 466–477.

Also see

[MI] **Intro** — Introduction to mi

[MI] **mi export** — Export mi data

[MI] **mi import ice** — Import ice-format data into mi

mi export nhanes1 — Export mi data to NHANES format

Description Menu Syntax Options
Remarks and examples Also see

Description

`mi export nhanes1` writes the `mi` data in memory to disk files in nhanes1 format. The files will be named *filenamestub*`.dta`, *filenamestub*`1.dta`, *filenamestub*`2.dta`, and so on. In addition to the variables in the original `mi` data, new variable `seqn` will be added to record the sequence number. After using `mi export nhanes1`, you can use `outfile` (see [D] **outfile**) or `export delimited` (see [D] **import delimited**) to convert the resulting `.dta` files into a format suitable for sending to a non-Stata user. Also see **[U] 22 Entering and importing data**.

`mi export nhanes1` leaves the data in memory unchanged.

Menu

Statistics > Multiple imputation

Syntax

`mi export nhanes1` *filenamestub* [, *options odd_options*]

options	Description
`replace`	okay to replace existing files
`uppercase`	uppercase prefix and suffix
`passiveok`	include passive variables

odd_options	Description
`nacode(#)`	not applicable code; default is `0`
`obscode(#)`	observed code; default is `1`
`impcode(#)`	imputed code; default is `2`
`impprefix("`*string*`" "`*string*`")`	variable prefix; default is `"" ""`
`impsuffix("`*string*`" "`*string*`")`	variable suffix; default is `"if" "mi"`

Note: *odd_options* are not specified unless you want to create results that are nhanes1-like but not really nhanes1 format.

Options

`replace` indicates that it is okay to overwrite existing files.

`uppercase` specifies that the new sequence variable `SEQN` and the variable suffixes `IF` and `MI` be in uppercase. The default is lowercase. (More correctly, when generalizing beyond nhanes1 format, the `uppercase` option specifies that `SEQN` be created in uppercase along with all prefixes and suffixes.)

`passiveok` specifies that passive variables are to be written as if they were imputed variables. The default is to issue an error if passive variables exist in the original data.

`nacode(#)`, `obscode(#)`, and `impcode(#)` are optional and are never specified when reading true nhanes1 data. The default `nacode(0) obscode(1) impcode(2)` corresponds to the nhanes1 definition. These options allow changing the codes for not applicable, observed, and imputed.

`impprefix("`*string*`" "`*string*`")` and `impsuffix("`*string*`" "`*string*`")` are optional and are never specified when reading true nhanes1 data. The default `impprefix("" "") impsuffix("if" "mi")` corresponds to the nhanes1 definition. These options allow setting different prefixes and suffixes.

Remarks and examples

`mi export nhanes1` is the inverse of `mi import nhanes1`; see [MI] **mi import nhanes1** for a description of the nhanes1 format.

Below we use `mi export nhanes1` to convert `miproto.dta` to nhanes1 format. `miproto.dta` happens to be in wide form, but that is irrelevant.

```
. use https://www.stata-press.com/data/r19/miproto
(mi prototype)
. mi describe
Style: wide
       last mi update 04feb2025 12:58:57, 10 days ago
Observations:
   Complete            1
   Incomplete          1  (M = 2 imputations)
   ---------------------
   Total               2
Variables:
   Imputed: 1; b(1)
   Passive: 1; c(1)
   Regular: 1; a
   System:  1; _mi_miss
   (there are no unregistered variables)
. list
```

	a	b	c	_1_b	_2_b	_1_c	_2_c	_mi_miss
1.	1	2	3	2	2	3	3	0
2.	4	.	.	4.5	5.5	8.5	9.5	1

```
. mi export nhanes1 mynh, passiveok replace
files mynh.dta mynh1.dta mynh2.dta created
```

```
. use mynh
(mi prototype)
. list
```

	seqn	a	bif	cif
1.	1	1	1	1
2.	2	4	2	2

```
. use mynh1
(mi prototype)
. list
```

	seqn	a	bmi	cmi
1.	1	1	2	3
2.	2	4	4.5	8.5

```
. use mynh2
(mi prototype)
. list
```

	seqn	a	bmi	cmi
1.	1	1	2	3
2.	2	4	5.5	9.5

Also see

[MI] **Intro** — Introduction to mi

[MI] **mi export** — Export mi data

[MI] **mi import nhanes1** — Import NHANES-format data into mi

mi extract — Extract original or imputed data from mi data

Description Menu Syntax Options
Remarks and examples Also see

Description

`mi extract` # replaces the data in memory with the data for $m = \#$. The data are not `mi set`.

Menu

Statistics > Multiple imputation

Syntax

`mi extract` # [, *options*]

where $0 \leq \# \leq M$

options	Description
`clear`	okay to replace unsaved data in memory
`esample(...)`	rarely specified option
`esample(`*varname*`)`	... syntax when $\# > 0$
`esample(`*varname* $\#_e$`)`	... syntax when $\# = 0$; $1 \leq \#_e \leq M$

Options

`clear` specifies that it is okay to replace the data in memory even if the current data have not been saved to disk.

`esample(`*varname* [$\#_e$]`)` is rarely specified. It is for use after `mi estimate` (see [MI] **mi estimate**) when the `esample(`*newvar*`)` option was specified to store in *newvar* the `e(sample)` for $m = 1$, $m = 2$, ..., $m = M$. It is now desired to extract the data for one m and for `e(sample)` set correspondingly.

`mi extract` #, `esample(`*varname*`)`, $\# > 0$, is the usual case in this unlikely event. One extracts one of the imputation datasets and redefines `e(sample)` based on the `e(sample)` previously stored for $m = \#$.

The odd case is `mi extract 0, esample(`*varname* $\#_e$`)`, where $\#_e > 0$. One extracts the original data but defines `e(sample)` based on the `e(sample)` previously stored for $m = \#_e$.

Specifying the `esample()` option changes the sort order of the data.

Remarks and examples

If you wanted to give up on mi and just get your original data back, you could type

```
. mi extract 0
```

You might do this if you wanted to send your original data to a coworker or you wanted to try a different approach to dealing with the missing values in these data. Whatever the reason, the result is that the original data replace the data in memory. The data are not mi set. Your original mi data remain unchanged.

If you suspected there was something odd about the imputations in $m = 3$, you could type

```
. mi extract 3
```

You would then have a dataset in memory that looked just like your original, except the missing values of the imputed and passive variables would be replaced with the imputed and passive values from $m = 3$. The data are not mi set. Your original data remain unchanged.

Also see

[MI] **Intro** — Introduction to mi

[MI] **mi replace0** — Replace original data

mi import — Import data into mi

Description Syntax Remarks and examples References Also see

Description

`mi import` imports into `mi` data that contain original data and imputed values.

Syntax

```
mi import nhanes1 ...

mi import ice ...

mi import flong ...

mi import flongsep ...

mi import wide ...
```

See [MI] **mi import nhanes1**, [MI] **mi import ice**, [MI] **mi import flong**, [MI] **mi import flongsep**, and [MI] **mi import wide**.

Remarks and examples

Remarks are presented under the following headings:

When to use which mi import command
Import data into Stata before importing into mi
Using mi import nhanes1, ice, flong, and flongsep

When to use which mi import command

`mi import nhanes1` imports data recorded in the format used by the National Health and Nutrition Examination Survey (NHANES) produced by the National Center for Health Statistics of the US Centers for Disease Control and Prevention (CDC); see https://www.cdc.gov/nchs/.

`mi import ice` imports data recorded in the format used by `ice` (Royston 2004, 2005a, 2005b, 2007, 2009).

`mi import flong` and `mi import flongsep` import data that are in flong- and flongsep-like format, which is to say, the data are repeated for $m = 0$, $m = 1$, …, and $m = M$. `mi import flong` imports data in which the information is contained in one file. `mi import flongsep` imports data in which the information is recorded in a collection of files.

`mi import wide` imports data that are in wide-like format, where additional variables are used to record the imputed values.

Import data into Stata before importing into mi

With the exception of `mi import ice`, you must import the data into Stata before you can use `mi import` to import the data into `mi`. `mi import ice` is the exception only because the data are already in Stata format. That is, `mi import` requires that the data be stored in Stata-format `.dta` datasets. You perform the initial import into Stata by using any method described in [D] **import**.

Using mi import nhanes1, ice, flong, and flongsep

Import commands `mi import nhanes1` and `mi import flongsep` produce an flongsep result; `mi import ice` and `mi import flong` produce an flong result. You can use `mi convert` (see [MI] **mi convert**) afterward to convert the result to another style, and we usually recommend that. Before doing that, however, you need to examine the freshly imported data and verify that all imputed and passive variables are registered correctly. If they are not registered correctly, you risk losing imputed values.

To perform this verification, use the `mi describe` (see [MI] **mi describe**) and `mi varying` (see [MI] **mi varying**) commands immediately after `mi import`:

```
. mi import ...
. mi describe
. mi varying
```

`mi describe` will list the registration status of the variables. `mi varying` will report the varying and super-varying variables. Verify that all varying variables are registered as imputed or passive. If one or more is not, register them now:

```
. mi register imputed forgottenvar
. mi register passive another_forgottenvar
```

There is no statistical distinction between imputed and passive variables, so you may register variables about which you are unsure either way. If an unregistered variable is found to be varying and you are convinced that is an error, register the variable as regular:

```
. mi register regular variable_in_error
```

Next, if `mi varying` reports that your data contain any super-varying variables, determine whether the variables are due to errors in the source data or really are intended to be super varying. If they are errors, register the variables as imputed, passive, or regular, as appropriate. Leave any intended super-varying variables unregistered, however, and make a note to yourself: never convert these data to the wide or mlong styles. Data with super-varying variables can be stored only in the flong and flongsep styles.

Now run `mi describe` and `mi varying` again:

```
. mi describe
. mi varying
```

Ensure that you have registered variables correctly, and, if necessary, repeat the steps above to fix any remaining problems.

After that, you may use `mi convert` to switch the data to a more convenient style. We generally start with style wide:

```
. mi convert wide
```

Do not switch to wide, however, if you have any super-varying variables. Try flong instead:

```
. mi convert flong
```

Whichever style you choose, if you get an insufficient-memory error, you will have to either increase the amount of memory dedicated to Stata or use these data in the more inconvenient, but perfectly workable, flongsep style. Concerning increasing memory, see *Converting from flongsep* in [MI] **mi convert**. Concerning the workability of flongsep, see *Advice for using flongsep* in [MI] **Styles**.

We said to perform the checks above before using `mi convert`. It is, however, safe to convert the just-imported flongsep data to flong, perform the checks, and then convert to the desired form. The checks will run more quickly if you convert to flong first.

You can vary how you perform the checks. The logic underlying our recommendations is as follows:

- It is possible that you did not specify all the imputed and passive variables when you imported the data, perhaps due to errors in the data's documentation. It is also possible that there are errors in the data that you imported. It is worth checking.
- As long as the imported data are recorded in the flongsep or flong style, unregistered variables will appear exactly as they appeared in the original source. It is only when the data are converted to the wide or mlong style that assumptions about the structure of the data are exploited to save memory. Thus you need to perform checks before converting the data to the more convenient wide or mlong style.
- If you find errors, you could go back and reimport the data correctly, but it is easier to use `mi register` after the fact. When you type `mi register` you are not only informing `mi` about how to deal with the variable but also asking `mi register` to examine the variable and fix any problems given its new registration status.

References

Royston, P. 2004. Multiple imputation of missing values. *Stata Journal* 4: 227–241.

———. 2005a. Multiple imputation of missing values: Update. *Stata Journal* 5: 188–201.

———. 2005b. Multiple imputation of missing values: Update of ice. *Stata Journal* 5: 527–536.

———. 2007. Multiple imputation of missing values: Further update of ice, with an emphasis on interval censoring. *Stata Journal* 7: 445–464.

———. 2009. Multiple imputation of missing values: Further update of ice, with an emphasis on categorical variables. *Stata Journal* 9: 466–477.

Also see

[MI] **Intro** — Introduction to mi

[MI] **mi import flong** — Import flong-like data into mi

[MI] **mi import flongsep** — Import flongsep-like data into mi

[MI] **mi import ice** — Import ice-format data into mi

[MI] **mi import nhanes1** — Import NHANES-format data into mi

[MI] **mi import wide** — Import wide-like data into mi

[MI] **Styles** — Dataset styles

mi import flong — Import flong-like data into mi

Description Menu Syntax Options
Remarks and examples Also see

Description

`mi import flong` imports flong-like data, that is, data in which $m = 0$, $m = 1$, …, $m = M$ are all recorded in one `.dta` dataset.

`mi import flong` converts the data to `mi` flong style. The data are `mi set`.

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Statistics > Multiple imputation

Syntax

`mi import flong,` *required_options* [*true_options*]

required_options	Description
`m(`*varname*`)`	name of variable containing m
`id(`*varlist*`)`	identifying variable(s)

true_options	Description
`imputed(`*varlist*`)`	imputed variables to be registered
`passive(`*varlist*`)`	passive variables to be registered
`clear`	okay to replace unsaved data in memory

Options

`m(`*varname*`)` and `id(`*varlist*`)` are required. `m(`*varname*`)` specifies the variable that takes on values 0, 1, …, M, the variable that identifies observations corresponding to $m = 0$, $m = 1$, …, $m = M$. *varname* $= 0$ identifies the original data, *varname* $= 1$ identifies $m = 1$, and so on.

`id(`*varlist*`)` specifies the variable or variables that uniquely identify observations within `m()`.

`imputed(`*varlist*`)` and `passive(`*varlist*`)` are truly optional options, although it would be unusual if `imputed()` were not specified.

`imputed(`*varlist*`)` specifies the names of the imputed variables.

`passive(`*varlist*`)` specifies the names of the passive variables, if any.

`clear` specifies that it is okay to replace the data in memory even if they have changed since they were saved to disk. Remember, `mi import flong` starts with flong-like data in memory and ends with `mi` flong data in memory.

Remarks and examples

The procedure to convert flong-like data to mi flong is this:

1. use the unset data.
2. Issue the mi import flong command.
3. Perform the checks outlined in *Using mi import nhanes1, ice, flong, and flongsep* of [MI] **mi import**.
4. Use mi convert (see [MI] **mi convert**) to convert the data to a more convenient style, such as wide or mlong.

For instance, you have the following unset data:

```
. use https://www.stata-press.com/data/r19/ourunsetdata
(mi prototype)
. list, separator(2)
```

	m	subject	a	b	c
1.	0	101	1	2	3
2.	0	102	4	.	.
3.	1	101	1	2	3
4.	1	102	4	4.5	8.5
5.	2	101	1	2	3
6.	2	102	4	5.5	9.5

You are told that these data contain the original data (m = 0) and two imputations (m = 1 and m = 2), that variable b is imputed, and that variable c is passive and in fact equal to a + b. These are the same data discussed in [MI] **Styles** but in unset form.

The fact that these data are nicely sorted is irrelevant. To import these data, type

```
. mi import flong, m(m) id(subject) imputed(b) passive(c)
(1 m=0 obs now marked as incomplete)
```

These data are short enough that we can list the result:

```
. list, separator(2)
```

	m	subject	a	b	c	_mi_m	_mi_id	_mi_miss
1.	0	101	1	2	3	0	1	0
2.	0	102	4	.	.	0	2	1
3.	1	101	1	2	3	1	1	.
4.	1	102	4	4.5	8.5	1	2	.
5.	2	101	1	2	3	2	1	.
6.	2	102	4	5.5	9.5	2	2	.

We will now perform the checks outlined in *Using mi import nhanes1, ice, flong, and flongsep* of [MI] **mi import**, which are to run mi describe and mi varying to verify that variables are registered correctly:

```
. mi describe
Style: flong
       last mi update 03mar2025 18:20:15, 0 seconds ago
Observations:
   Complete            1
   Incomplete          1  (M = 2 imputations)
   ---------------------
   Total               2
Variables:
   Imputed: 1; b(1)
   Passive: 1; c(1)
   Regular: 0
   System:  3; _mi_m _mi_id _mi_miss
   (there are 3 unregistered variables; m subject a)
. mi varying
            Possible problem   Variable names
------------------------------------------------------------------------------
         imputed nonvarying:  (none)
         passive nonvarying:  (none)
       unregistered varying:  (none)
 *unregistered super/varying:  (none)
  unregistered super varying:  m
------------------------------------------------------------------------------
  * super/varying means super varying but would be varying if registered as
    imputed; variables vary only where equal to soft missing in m=0.
```

We discover that unregistered variable `m` is super varying (see [MI] **Glossary**). Here we no longer need `m`, so we will drop the variable and rerun `mi varying`. We will find that there are no remaining problems, so we will convert our data to our preferred wide style:

```
. drop m
. mi varying
            Possible problem   Variable names
------------------------------------------------------------------------------
         imputed nonvarying:  (none)
         passive nonvarying:  (none)
       unregistered varying:  (none)
 *unregistered super/varying:  (none)
  unregistered super varying:  (none)
------------------------------------------------------------------------------
  * super/varying means super varying but would be varying if registered as
    imputed; variables vary only where equal to soft missing in m=0.
. mi convert wide, clear
. list
```

	subject	a	b	c	_mi_miss	_1_b	_1_c	_2_b	_2_c
1.	101	1	2	3	0	2	3	2	3
2.	102	4	.	.	1	4.5	8.5	5.5	9.5

Also see

[MI] **Intro** — Introduction to mi

[MI] **mi import** — Import data into mi

mi import flongsep — Import flongsep-like data into mi

Description Menu Syntax Options
Remarks and examples Also see

Description

`mi import flongsep` imports flongsep-like data, that is, data in which $m = 0$, $m = 1$, …, $m = M$ are each recorded in separate `.dta` datasets.

`mi import flongsep` converts the data to `mi` flongsep and `mi sets` the data.

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Statistics > Multiple imputation

Syntax

`mi import flongsep` *name*`,` *required_options* [*true_options*]

where *name* is the name of the flongsep data to be created.

required_options	Description
`using(`*filenamelist*`)`	input filenames for $m = 1$, $m = 2$, …
`id(`*varlist*`)`	identifying variable(s)

Note: `use` the input file for $m = 0$ before issuing `mi import flongsep`.

true_options	Description
`imputed(`*varlist*`)`	imputed variables to be registered
`passive(`*varlist*`)`	passive variables to be registered
`clear`	okay to replace unsaved data in memory

Options

`using(`*filenamelist*`)` is required; it specifies the names of the `.dta` datasets containing $m = 1$, $m = 2$, …, $m = M$. The dataset corresponding to $m = 0$ is not specified; it is to be in memory at the time the `mi import flongsep` command is given.

The filenames might be specified as

```
using(ds1 ds2 ds3 ds4 ds5)
```

which states that $m = 1$ is in file `ds1.dta`, $m = 2$ is in file `ds2.dta`, …, and $m = 5$ is in file `ds5.dta`. Also, {#-#} is understood, so the above could just as well be specified as

```
using(ds{1-5})
```

The braced numeric range may appear anywhere in the name, and thus

```
using(ds{1-5}imp)
```

would mean that `ds1imp.dta`, `ds2imp.dta`, …, `ds5imp.dta` contain $m = 1$, $m = 2$, …, $m = 5$.

Alternatively, a comma-separated list can appear inside the braces. Filenames `dsfirstm.dta`, `dssecondm.dta`, …, `dsfifthm.dta` can be specified as

```
using(ds{first,second,third,fourth,fifth}m)
```

Filenames can be specified with or without the `.dta` suffix and may be enclosed in quotes if they contain special characters.

`id(`*varlist*`)` is required; it specifies the variable or variables that uniquely identify the observations in each dataset. The coding must be the same across datasets.

`imputed(`*varlist*`)` and `passive(`*varlist*`)` are truly optional options, although it would be unusual if `imputed()` were not specified.

`imputed(`*varlist*`)` specifies the names of the imputed variables.

`passive(`*varlist*`)` specifies the names of the passive variables.

`clear` specifies that it is okay to replace the data in memory even if they have changed since they were saved to disk.

Remarks and examples

The procedure to convert flongsep-like data to `mi` flongsep is this:

1. `use` the dataset corresponding to $m = 0$.
2. Issue the `mi import flongsep` *name* command, where *name* is the name of the `mi` flongsep data to be created.
3. Perform the checks outlined in *Using mi import nhanes1, ice, flong, and flongsep* of [MI] **mi import**.
4. Use `mi convert` (see [MI] **mi convert**) to convert the data to a more convenient style such as wide, mlong, or flong.

For instance, you have been given the unset datasets `imorig.dta`, `im1.dta`, and `im2.dta`. You are told that these datasets contain the original data and two imputations, that variable `b` is imputed, and that variable `c` is passive and in fact equal to `a` + `b`. Here are the datasets:

```
. use https://www.stata-press.com/data/r19/imorig
. list
```

	subject	a	b	c
1.	101	1	2	3
2.	102	4	.	.

```
. use https://www.stata-press.com/data/r19/im1
```

```
. list
```

	subject	a	b	c
1.	101	1	2	3
2.	102	4	4.5	8.5

```
. save im1
file im1.dta saved
. use https://www.stata-press.com/data/r19/im2
. list
```

	subject	a	b	c
1.	101	1	2	3
2.	102	4	5.5	9.5

```
. save im2
file im2.dta saved
```

These are the same data discussed in [MI] **Styles** but in unset form.

The fact that these datasets are nicely sorted is irrelevant. To import these datasets, you type

```
. use https://www.stata-press.com/data/r19/imorig
. mi import flongsep mymi, using(im1 im2) id(subject) imputed(b) passive(c)
```

We will now perform the checks outlined in *Using mi import nhanes1, ice, flong, and flongsep* of [MI] **mi import**, which are to run `mi describe` and `mi varying` to verify that variables are registered correctly:

```
. mi describe
Style: flongsep mymi
       last mi update 03mar2025 18:20:15, 0 seconds ago
Observations:
   Complete            1
   Incomplete          1  (M = 2 imputations)
   ---------------------
   Total               2
Variables:
   Imputed: 1; b(1)
   Passive: 1; c(1)
   Regular: 0
   System:  2; _mi_id _mi_miss
   (there are 2 unregistered variables; subject a)
. mi varying
            Possible problem   Variable names
-------------------------------------------------------------------------------
         imputed nonvarying:  (none)
         passive nonvarying:  (none)
       unregistered varying:  (none)
 *unregistered super/varying:  (none)
  unregistered super varying:  (none)
-------------------------------------------------------------------------------
 * super/varying means super varying but would be varying if registered as
   imputed; variables vary only where equal to soft missing in m=0.
```

`mi varying` reported no problems. We finally convert to our preferred wide style:

```
. mi convert wide, clear
. list
```

	subject	a	b	c	_mi_miss	_1_b	_1_c	_2_b	_2_c
1.	101	1	2	3	0	2	3	2	3
2.	102	4	.	.	1	4.5	8.5	5.5	9.5

We are done with the converted data in flongsep format, so we will erase the files:

```
. mi erase mymi
(files mymi.dta _1_mymi.dta _2_mymi.dta erased)
```

Also see

[MI] **Intro** — Introduction to mi

[MI] **mi import** — Import data into mi

mi import ice — Import ice-format data into mi

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Remarks and examples References Also see

Description

`mi import ice` converts the data in memory to `mi` data, assuming the data in memory are in `ice` format. See Royston (2004, 2005a, 2005b, 2007, 2009) for a description of `ice`.

`mi import ice` converts the data to `mi` style flong. The data are `mi set`.

Menu

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Syntax

`mi import ice` [, *options*]

options	Description
`automatic`	register variables automatically
`imputed(`*varlist*`)`	imputed variables to be registered
`passive(`*varlist*`)`	passive variables to be registered
`clear`	okay to replace unsaved data

Options

`automatic` determines the identity of the imputed variables automatically. Use of this option is recommended.

`imputed(`*varlist*`)` specifies the names of the imputed variables. This option may be used with `automatic`, in which case `automatic` is taken to mean automatically determine the identity of imputed variables in addition to the `imputed()` variables specified. It is difficult to imagine why one would want to do this.

`passive(`*varlist*`)` specifies the names of the passive variables. This option may be used with `automatic` and usefully so. `automatic` cannot distinguish imputed variables from passive variables, so it assumes all variables that vary are imputed. `passive()` allows you to specify the subset of varying variables that are passive.

Concerning the above options: If none are specified, all variables are left unregistered in the result. You can then use `mi varying` to determine the varying variables and use `mi register` to register them appropriately; see [MI] **mi varying** and [MI] **mi set**. If you follow this approach, remember to register imputed variables before registering passive variables.

`clear` specifies that it is okay to replace the data in memory even if they have changed since they were last saved to disk. Remember, `mi import ice` starts with `ice` data in memory and ends with `mi` data in memory.

Remarks and examples

The procedure to convert ice data to mi flong is

1. use the ice data.
2. Issue the mi import ice command, preferably with the automatic option and perhaps with the passive() option, too, although it really does not matter if passive variables are registered as imputed, so long as they are registered.
3. Perform the checks outlined in *Using mi import nhanes1, ice, flong, and flongsep* of [MI] **mi import**.
4. Use mi convert (see [MI] **mi convert**) to convert the data to a more convenient style such as wide or mlong.

For instance, you have the following ice data:

```
. use https://www.stata-press.com/data/r19/icedata
. list, separator(2)
```

	_mj	_mi	a	b	c
1.	0	1	1	2	3
2.	0	2	4	.	.
3.	1	1	1	2	3
4.	1	2	4	4.5	8.5
5.	2	1	1	2	3
6.	2	2	4	5.5	9.5

_mj and _mi are ice system variables. These data contain the original data and two imputations. Variable b is imputed, and variable c is passive and in fact equal to a + b. These are the same data discussed in [MI] **Styles** but in ice format.

The fact that these data are nicely sorted is irrelevant. To import these data, you type

```
. mi import ice, automatic
(1 m=0 obs now marked as incomplete)
```

although it would be even better if you typed

```
. use https://www.stata-press.com/data/r19/icedata
. mi import ice, automatic passive(c)
(1 m=0 obs now marked as incomplete)
```

With the first command, both b and c will be registered as imputed. With the second, c will instead be registered as passive. Whether c is registered as imputed or passive makes no difference statistically.

These data are short enough that we can list the result:

```
. list, separator(2)
```

	a	b	c	_mi_m	_mi_id	_mi_miss
1.	1	2	3	0	1	0
2.	4	.	.	0	2	1
3.	1	2	3	1	1	.
4.	4	4.5	8.5	1	2	.
5.	1	2	3	2	1	.
6.	4	5.5	9.5	2	2	.

We will now perform the checks outlined in *Using mi import nhanes1, ice, flong, and flongsep* of [MI] **mi import**, which are to run `mi describe` and `mi varying` to verify that variables are registered correctly:

```
. mi describe
Style: flong
       last mi update 03mar2025 18:20:15, 0 seconds ago
Observations:
   Complete            1
   Incomplete          1  (M = 2 imputations)
   ---------------------
   Total               2
Variables:
   Imputed: 1; b(1)
   Passive: 1; c(1)
   Regular: 0
   System:  3; _mi_m _mi_id _mi_miss
   (there is one unregistered variable; a)
. mi varying
            Possible problem   Variable names
-------------------------------------------------------------------------------
         imputed nonvarying:  (none)
         passive nonvarying:  (none)
       unregistered varying:  (none)
  *unregistered super/varying:  (none)
   unregistered super varying:  (none)
-------------------------------------------------------------------------------
  * super/varying means super varying but would be varying if registered as
    imputed; variables vary only where equal to soft missing in m=0.
```

We find that there are no remaining problems, so we convert our data to our preferred wide style:

```
. mi convert wide, clear
. list
```

	a	b	c	_mi_miss	_1_b	_1_c	_2_b	_2_c
1.	1	2	3	0	2	3	2	3
2.	4	.	.	1	4.5	8.5	5.5	9.5

References

Royston, P. 2004. Multiple imputation of missing values. *Stata Journal* 4: 227–241.

———. 2005a. Multiple imputation of missing values: Update. *Stata Journal* 5: 188–201.

———. 2005b. Multiple imputation of missing values: Update of ice. *Stata Journal* 5: 527–536.

———. 2007. Multiple imputation of missing values: Further update of ice, with an emphasis on interval censoring. *Stata Journal* 7: 445–464.

———. 2009. Multiple imputation of missing values: Further update of ice, with an emphasis on categorical variables. *Stata Journal* 9: 466–477.

Also see

[MI] **Intro** — Introduction to mi

[MI] **mi import** — Import data into mi

mi import nhanes1 — Import NHANES-format data into mi

Description Menu Syntax Options
Remarks and examples Also see

Description

`mi import nhanes1` imports data recorded in the format used by the National Health and Nutrition Examination Survey (NHANES) produced by the National Center for Health Statistics (NCHS) of the US Centers for Disease Control and Prevention (CDC); see https://www.cdc.gov/nchs/.

Menu

Statistics > Multiple imputation

Syntax

`mi import nhanes1` *name*`,` *required_options* [*true_options odd_options*]

where *name* is the name of the flongsep data to be created.

required_options	Description
`using(`*filenamelist*`)`	input filenames for $m = 1, m = 2, \ldots$
`id(`*varlist*`)`	identifying variable(s)

Note: `use` the input file for $m = 0$ before issuing `mi import nhanes1`.

true_options	Description
`uppercase`	prefix and suffix in uppercase
`clear`	okay to replace unsaved data in memory

odd_options	Description
`nacode(#)`	not applicable code; default is `0`
`obscode(#)`	observed code; default is `1`
`impcode(#)`	imputed code; default is `2`
`impprefix("`*string*`" "`*string*`")`	variable prefix; default is `"" ""`
`impsuffix("`*string*`" "`*string*`")`	variable suffix; default is `"if" "mi"`

Note: The *odd_options* are not specified unless you need to import data that are nhanes1-like but not really nhanes1 format.

Options

`using(`*filenamelist*`)` is required; it specifies the names of the `.dta` datasets containing $m = 1$, $m = 2$, …, $m = M$. The dataset corresponding to $m = 0$ is not specified; it is to be in memory at the time the `mi import nhanes1` command is given.

The filenames might be specified as

```
using(nh1 nh2 nh3 nh4 nh5)
```

which states that $m = 1$ is in file `nh1.dta`, $m = 2$ is in file `nh2.dta`, …, and $m = 5$ is in file `nh5.dta`. Also, {*#*-*#*} is understood, so the files could just as well be specified as

```
using(nh{1-5})
```

The braced numeric range may appear anywhere in the name, and thus

```
using(nh{1-5}imp)
```

would mean that `nh1imp.dta`, `nh2imp.dta`, …, `nh5imp.dta` contain $m = 1$, $m = 2$, …, $m = 5$.

Alternatively, a comma-separated list can appear inside the braces. Filenames `nhfirstm.dta`, `nhsecondm.dta`, …, `nhfifthm.dta` can be specified as

```
using(nh{first,second,third,fourth,fifth}m)
```

Filenames can be specified with or without the `.dta` suffix and must be enclosed in quotes if they contain special characters.

`id(`*varlist*`)` is required and is usually specified as `id(seqn)` or `id(SEQN)` depending on whether your variable names are in lowercase or uppercase. `id()` specifies the variable or variables that uniquely identify the observations in each dataset. Per the nhanes1 standard, the variable should be named `seqn` or `SEQN`.

`uppercase` is optional; it specifies that the variable suffixes `IF` and `MI` of the nhanes1 standard are in uppercase. The default is lowercase. (More correctly, when generalizing beyond nhanes1 format, the `uppercase` option specifies that all prefixes and suffixes are in uppercase.)

`nacode(#)`, `obscode(#)`, and `impcode(#)` are optional and are never specified when reading true nhanes1 data. The defaults `nacode(0)`, `obscode(1)`, and `impcode(2)` correspond to the nhanes1 definition. These options allow changing the codes for not applicable, observed, and imputed.

`impprefix("`*string*`" "`*string*`")` and `impsuffix("`*string*`" "`*string*`")` are optional and are never specified when reading true nhanes1 data. The defaults `impprefix("" "")` and `impsuffix("if" "mi")` correspond to the nhanes1 definition. These options allow setting different prefixes and suffixes.

`clear` specifies that it is okay to replace the data in memory even if they have changed since they were saved to disk. Remember, `mi import nhanes1` starts with the first of the NHANES data in memory and ends with `mi` data in memory.

Remarks and examples

Remarks are presented under the following headings:

Description of the nhanes1 format
Importing nhanes1 data

Description of the nhanes1 format

Nhanes1 is not really an official format; it is the format used for a particular dataset distributed by NCHS. Because there currently are no official or even informal standards for multiple-imputation data, perhaps the method used by the NCHS for NHANES will catch on, so we named it nhanes1. We included the 1 on the end of the name in case the format is modified.

Data in nhanes1 format consist of a collection of $M + 1$ separate files. The first file contains the original data. The remaining M files contain the imputed values for $m = 1$, $m = 2$, …, $m = M$.

The first file contains a variable named `seqn` containing a sequence number. The file also contains other variables that comprise the nonimputed variables. Imputed variables, however, have their names suffixed with `IF`, standing for imputation flag, and those variables contain 1s, 2s, and 0s. 1 means that the value of the variable in that observation was observed, 2 means that the value was missing, and 0 means not applicable. Think of 0 as being equivalent to hard missing. The value is not observed for good reason and therefore was not imputed.

The remaining M files contain `seqn` and the imputed variables themselves. In these files, unobserved values are imputed. This time, imputed variable names are suffixed with `MI`.

Here is an example:

```
. use https://www.stata-press.com/data/r19/nhorig
. list
```

	seqn	a	bIF	cIF
1.	1	11	1	1
2.	2	14	2	2

The above is the first of the $M + 1$ datasets. The `seqn` variable is the sequence number. The `a` variable is a regular variable; we know that because the name does not end in `IF`. The `b` and `c` variables are imputed, and this dataset contains their imputation flags. Both variables are observed in the first observation and unobserved in the second.

Here is the corresponding dataset for $m = 1$:

```
. use https://www.stata-press.com/data/r19/nh1
. list
```

	seqn	bMI	cMI
1.	1	2	3
2.	2	4.5	8.5

```
. save nh1
file nh1.dta saved
```

This dataset states that in $m = 1$, `b` is equal to 2 and 4.5 and `c` is equal to 3 and 8.5.

We are about to show you the dataset for $m = 2$. Even before looking at it, however, we know that 1) it will have two observations; 2) it will have the `seqn` variable containing 1 and 2; 3) it will have two more variables named `bMI` and `cMI`; and 4) `bMI` will be equal to 2 and `cMI` will be equal to 3 in observations corresponding to `seqn` $= 1$. We know the last because in the first dataset, we learned that `b` and `c` were observed in `seqn` $= 1$.

```
. use https://www.stata-press.com/data/r19/nh2
. list
```

	seqn	a	bMI	cMI
1.	1	11	2	3
2.	2	14	5.5	9.5

```
. save nh2
file nh2.dta saved
```

Importing nhanes1 data

The procedure to import nhanes1 data is this:

1. `use` the dataset corresponding to $m = 0$; see [D] **use**.
2. Issue `mi import nhanes1` *name* ..., where *name* is the name of the `mi` flongsep dataset to be created.
3. Perform the checks outlined in *Using mi import nhanes1, ice, flong, and flongsep* of [MI] **mi import**.
4. Use `mi convert` (see [MI] **mi convert**) to convert the data to a more convenient style such as wide, mlong, or flong.

To import the `nhorig.dta`, `nh1.dta`, and `nh2.dta` datasets described in the section above, we will specify `mi import nhanes1`'s `uppercase` option because the suffixes were in uppercase. We type

```
. use https://www.stata-press.com/data/r19/nhorig
. mi import nhanes1 mymi, using(nh1 nh2) id(seqn) uppercase
```

The lack of any error message means that we have successfully converted nhanes1-format files `nhorig.dta`, `nh1.dta`, and `nh2.dta` to `mi` flongsep files `mymi.dta`, `_1_mymi.dta`, and `_2_mymi.dta`.

We will now perform the checks outlined in *Using mi import nhanes1, ice, flong, and flongsep* of [MI] **mi import**, which are to run `mi describe` and `mi varying` (see [MI] **mi describe** and [MI] **mi varying**) to verify that variables are registered correctly:

```
. mi describe
Style: flongsep mymi
       last mi update 03mar2025 18:20:15, 0 seconds ago
Observations:
   Complete            1
   Incomplete          1  (M = 2 imputations)
   ---------------------
   Total               2
Variables:
   Imputed: 2; b(1) c(1)
   Passive: 0
   Regular: 0
   System:  2; _mi_id _mi_miss
   (there are 2 unregistered variables; seqn a)
```

```
. mi varying
            Possible problem   Variable names
-------------------------------------------------------------------------------
         imputed nonvarying:  (none)
         passive nonvarying:  (none)
       unregistered varying:  (none)
*unregistered super/varying:  (none)
 unregistered super varying:  (none)
-------------------------------------------------------------------------------
  * super/varying means super varying but would be varying if registered as
    imputed; variables vary only where equal to soft missing in m=0.
```

`mi varying` reported no problems.

We finally convert to style flong, although in real life we would choose styles mlong or wide. We are choosing flong because it is more readable:

```
. mi convert flong, clear
. list, separator(2)
```

	seqn	a	b	c	_mi_id	_mi_miss	_mi_m
1.	1	11	2	3	1	0	0
2.	2	14	.	.	2	1	0
3.	1	11	2	3	1	.	1
4.	2	14	4.5	8.5	2	.	1
5.	1	11	2	3	1	.	2
6.	2	14	5.5	9.5	2	.	2

The flong data are in memory. We are done with the converted data in flongsep format, so we erase the files:

```
. mi erase mymi
(files mymi.dta _1_mymi.dta _2_mymi.dta erased)
```

Also see

[MI] **Intro** — Introduction to mi

[MI] **mi import** — Import data into mi

mi import wide — Import wide-like data into mi

Description Menu Syntax Options
Remarks and examples Also see

Description

`mi import wide` imports wide-like data, that is, data in which $m = 0$, $m = 1$, …, $m = M$ values of imputed and passive variables are recorded in separate variables.

`mi import wide` converts the data to `mi` wide style and `mi sets` the data.

Menu

Statistics > Multiple imputation

Syntax

`mi import wide` [, *options*]

options	Description
`imputed(`*mvlist*`)`	imputed variables
`passive(`*mvlist*`)`	passive variables
`dupsok`	allow variable to be posted repeatedly
`drop`	drop imputed and passive after posting
`clear`	okay to replace unsaved data in memory

See description of options below for definition of *mvlist*.

Options

`imputed(`*mvlist*`)` and `passive(`*mvlist*`)` specify the imputed and passive variables.

For instance, if the data had two imputed variables, `x` and `y`; `x` and `y` contained the $m = 0$ values; the corresponding $m = 1$, $m = 2$, and $m = 3$ values of `x` were in `x1`, `x2`, and `x3`; and the corresponding values of `y` were in `y1`, `y2`, and `y3`, then the `imputed()` option would be specified as

```
imputed(x=x1 x2 x3 y=y1 y2 y3)
```

If variable `y2` were missing from the data, you would specify

```
imputed(x=x1 x2 x3 y=y1 . y3)
```

The same number of imputations must be specified for each variable.

`dupsok` specifies that it is okay if you specify the same variable name for two different imputations. This would be an odd thing to do, but if you specify `dupsok`, then you can specify

```
imputed(x=x1 x1 x3 y=y1 y2 y3)
```

Without the `dupsok` option, the above would be treated as an error.

drop specifies that the original variables containing values for $m = 1$, $m = 2$, …, $m = M$ are to be dropped from the data once mi import wide has recorded the values. This option is recommended.

clear specifies that it is okay to replace the data in memory even if they have changed since they were last saved to disk.

Remarks and examples

The procedure to convert wide-like data to mi wide style is this:

1. use the unset data; see [D] **use**.
2. Issue the mi import wide command.
3. Use mi describe (see [MI] **mi describe**) and mi varying (see [MI] **mi varying**) to verify that the result is as you anticipated.
4. Optionally, use mi convert (see [MI] **mi convert**) to convert the data to what you consider a more convenient style.

For instance, you have been given unset dataset wi.dta and have been told that it contains variables a, b, and c; that variable b is imputed and contains $m = 0$ values; that variables b1 and b2 contain the $m = 1$ and $m = 2$ values; that variable c is passive (equal to a + b) and contains $m = 0$ values; and that variables c1 and c2 contain the corresponding $m = 1$ and $m = 2$ values. Here are the data:

```
. use https://www.stata-press.com/data/r19/wi
(mi prototype)
. list
```

	a	b	c	b1	b2	c1	c2
1.	1	2	3	2	2	3	3
2.	4	.	.	4.5	5.5	8.5	9.5

These are the same data discussed in [MI] **Styles**. To import these data, type

```
. mi import wide, imputed(b=b1 b2  c=c1 c2) drop
```

These data are short enough that we can list the result:

```
. list
```

	a	b	c	_mi_miss	_1_b	_2_b	_1_c	_2_c
1.	1	2	3	0	2	2	3	3
2.	4	.	.	1	4.5	5.5	8.5	9.5

Returning to the procedure, we run `mi describe` and `mi varying` on the result:

```
. mi describe
Style: wide
       last mi update 03mar2025 18:20:16, 0 seconds ago
Observations:
   Complete            1
   Incomplete          1  (M = 2 imputations)
   ---------------------
   Total               2
Variables:
   Imputed: 2; b(1) c(1)
   Passive: 0
   Regular: 0
   System:  1; _mi_miss
   (there is one unregistered variable; a)
. mi varying
            Possible problem   Variable names
-------------------------------------------------------------------------------
         imputed nonvarying:  (none)
         passive nonvarying:  (none)
-------------------------------------------------------------------------------
```

Perhaps you would prefer seeing these data in flong style:

```
. mi convert flong, clear
. list, separator(2)
```

	a	b	c	_mi_miss	_mi_m	_mi_id
1.	1	2	3	0	0	1
2.	4	.	.	1	0	2
3.	1	2	3	.	1	1
4.	4	4.5	8.5	.	1	2
5.	1	2	3	.	2	1
6.	4	5.5	9.5	.	2	2

Also see

[MI] **Intro** — Introduction to mi

[MI] **mi import** — Import data into mi

mi impute — Impute missing values

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Remarks and examples | Stored results | Methods and formulas | References
Also see

Description

`mi impute` fills in missing values (`.`) of a single variable or of multiple variables using the specified method. The available methods (by variable type and missing-data pattern) are summarized in the tables below.

Single imputation variable (univariate imputation)

Pattern	Type	Imputation method
	continuous	`regress`, `pmm`, `truncreg`, `intreg`
always monotone	binary	`logit`
	categorical	`ologit`, `mlogit`
	count	`poisson`, `nbreg`

Multiple imputation variables (multivariate imputation)

Pattern	Type	Imputation method
monotone missing	mixture	`monotone`
arbitrary missing	mixture	`chained`
arbitrary missing	continuous	`mvn`

The suggested reading order of `mi impute`'s subentries is

[MI] **mi impute regress**
[MI] **mi impute pmm**
[MI] **mi impute truncreg**
[MI] **mi impute intreg**
[MI] **mi impute logit**
[MI] **mi impute ologit**
[MI] **mi impute mlogit**
[MI] **mi impute poisson**
[MI] **mi impute nbreg**
[MI] **mi impute monotone**
[MI] **mi impute chained**
[MI] **mi impute mvn**
[MI] ***mi impute usermethod***

Menu

Statistics > Multiple imputation

Syntax

```
mi impute method ... [ , impute_options ... ]
```

method	Description
Univariate	
regress	linear regression for a continuous variable
pmm	predictive mean matching for a continuous variable
truncreg	truncated regression for a continuous variable with a restricted range
intreg	interval regression for a continuous partially observed (censored) variable
logit	logistic regression for a binary variable
ologit	ordered logistic regression for an ordinal variable
mlogit	multinomial logistic regression for a nominal variable
poisson	Poisson regression for a count variable
nbreg	negative binomial regression for an overdispersed count variable
Multivariate	
monotone	sequential imputation using a monotone-missing pattern
chained	sequential imputation using chained equations
mvn	multivariate normal regression
User-defined	
usermethod	user-defined imputation methods

impute_options	Description
Main	
* add(#)	specify number of imputations to add; required when no imputations exist
* replace	replace imputed values in existing imputations
rseed(#)	specify random-number seed
double	store imputed values in double precision; the default is to store them as float
by(*varlist*[, *byopts*])	impute separately on each group formed by *varlist* (not allowed with *usermethod*)
Reporting	
dots	display dots as imputations are performed
noisily	display intermediate output
nolegend	suppress all table legends
Advanced	
force	proceed with imputation, even when missing imputed values are encountered
noupdate	do not perform mi update (not allowed with *usermethod*); see [MI] **noupdate option**

*add(#) is required when no imputations exist; add(#) or replace is required if imputations exist.

You must mi set your data before using mi impute; see [MI] mi set.

collect is allowed; see [U] 11.1.10 Prefix commands.

The mi suite of commands does not allow alias variables; see [D] frunalias for advice on how to get around this restriction.

noupdate does not appear in the dialog box.

Options

Main

add(#) specifies the number of imputations to add to the mi data. This option is required if there are no imputations in the data. If imputations exist, then add() is optional. The total number of imputations cannot exceed 1,000.

replace specifies to replace existing imputed values with new ones. One of replace or add() must be specified when mi data already have imputations.

rseed(#) sets the random-number seed. This option can be used to reproduce results. rseed(#) is equivalent to typing set seed # prior to calling mi impute; see [R] set seed. You may also need to use the same stable ordering of the data prior to executing mi impute to reproduce results; see [D] sort.

double specifies that the imputed values be stored as doubles. By default, they are stored as floats. mi impute makes this distinction only when necessary. For example, if the logit method is used, the imputed values are stored as bytes.

by(*varlist*[, *byopts*]) specifies that imputation be performed separately for each by-group. By-groups are identified by equal values of the variables in *varlist* in the original data ($m = 0$). Missing categories in *varlist* are omitted, unless the missing suboption is specified within by(). Imputed and passive variables may not be specified within by(). This option is not allowed with user-defined imputation methods, *usermethod*. *byopts* are missing, noreport, nolegend, and nostop.

missing specifies that missing categories in *varlist* are not omitted.

noreport suppresses reporting of intermediate information about each group.

nolegend suppresses the display of group legends that appear before the imputation table when long group descriptions are encountered.

nostop specifies to proceed with imputation when imputation fails in some groups. By default, mi impute terminates with error when this happens.

Reporting

dots specifies to display dots as imputations are successfully completed. An x is displayed if any of the specified imputation variables still have missing values.

noisily specifies that intermediate output from mi impute be displayed.

nolegend suppresses the display of all legends that appear before the imputation table.

Advanced

force specifies to proceed with imputation even when missing imputed values are encountered. By default, mi impute terminates with error if missing imputed values are encountered.

The following option is available with `mi impute` but is not shown in the dialog box:

`noupdate` in some cases suppresses the automatic `mi update` this command might perform; see [MI] **noupdate option**. This option is rarely used and is not allowed with user-defined imputation methods, *usermethod*.

Remarks and examples

Remarks are presented under the following headings:

Imputation methods
Imputation modeling
  Model building
  Outcome variables
  Transformations
  Categorical variables
  The issue of perfect prediction during imputation of categorical data
  Convergence of iterative methods
  Imputation diagnostics
Using mi impute
Univariate imputation
Multivariate imputation
Imputing on subsamples
Conditional imputation
Imputation and estimation samples
Imputing transformations of incomplete variables

Imputation methods

`mi impute` supports both univariate and multivariate imputation under the missing at random assumption (see *Assumptions about missing data* under *Remarks and examples* in [MI] **Intro substantive**).

Univariate imputation is used to impute a single variable. It can be used repeatedly to impute multiple variables only when the variables are independent and will be used in separate analyses. To impute a single variable, you can choose from the following methods: `regress`, `pmm`, `truncreg`, `intreg`, `logit`, `ologit`, `mlogit`, `poisson`, and `nbreg`; see [MI] **mi impute regress**, [MI] **mi impute pmm**, [MI] **mi impute truncreg**, [MI] **mi impute intreg**, [MI] **mi impute logit**, [MI] **mi impute ologit**, [MI] **mi impute mlogit**, [MI] **mi impute poisson**, and [MI] **mi impute nbreg**.

For a continuous variable, either `regress` or `pmm` can be used (for example, Rubin [1987] and Schenker and Taylor [1996]). For a continuous variable with a restricted range, a truncated variable, either `pmm` or `truncreg` (Raghunathan et al. 2001) can be used. For a continuous partially observed or censored variable, `intreg` can be used (Royston 2007). For a binary variable, `logit` can be used (Rubin 1987). For a categorical variable, `ologit` can be used to impute missing categories if they are ordered, and `mlogit` can be used to impute missing categories if they are unordered (Raghunathan et al. 2001). For a count variable, either `poisson` (Raghunathan et al. 2001) or `nbreg` (Royston 2009), in the presence of overdispersion, is often suggested. Also see van Buuren (2007) for a detailed list of univariate imputation methods.

Theory dictates that multiple variables usually must be imputed simultaneously, and that requires using a multivariate imputation method. The choice of an imputation method in this case also depends on the pattern of missing values.

If variables follow a monotone-missing pattern (see *Patterns of missing data* under *Remarks and examples* in [MI] **Intro substantive**), they can be imputed sequentially using univariate conditional distributions, which is implemented in the `monotone` method (see [MI] **mi impute monotone**). A separate univariate imputation model can be specified for each imputation variable, which allows simultaneous imputation of variables of different types (Rubin 1987).

When a pattern of missing values is arbitrary, iterative methods are used to fill in missing values. The `mvn` method (see [MI] **mi impute mvn**) uses multivariate normal data augmentation to impute missing values of continuous imputation variables (Schafer 1997). Allison (2001), for example, also discusses how to use this method to impute binary and categorical variables.

Another multivariate imputation method that accommodates arbitrary missing-value patterns is multivariate imputation using chained equations (MICE), also known as imputation using fully conditional specifications (van Buuren, Boshuizen, and Knook 1999) and as sequential regression multivariate imputation (Raghunathan et al. 2001) in the literature. The MICE method is implemented in the `chained` method (see [MI] **mi impute chained**) and uses a Gibbs-like algorithm to impute multiple variables sequentially using univariate fully conditional specifications. Despite a lack of rigorous theoretical justification, the flexibility of MICE has made it one of the most popular choices used in practice.

For a comparison of MICE and multivariate normal imputation, see Lee and Carlin (2010).

Imputation modeling

As discussed in [MI] **Intro substantive**, imputation modeling is important to obtain proper imputations. Imputation modeling is not confined to the specification of an imputation method and an imputation model. It also requires careful consideration of how to handle complex data structures, such as survey or longitudinal data, and how to preserve existing relationships in the data during the imputation step. Rubin (1987), Meng (1994), Schafer (1997), Allison (2001), Royston (2007), Graham (2009), White, Royston, and Wood (2011), and others provide guidelines about imputation modeling. We summarize some of them below.

As with any statistical procedure, choosing an appropriate imputation approach is an art, and the choice should ultimately be determined by your data and research objectives. Regardless of which imputation approach you decide to pursue, it is good practice to check that your imputations are sensible before performing primary data analysis (see *Imputation diagnostics*) and to perform sensitivity analysis (for example, Kenward and Carpenter [2007]).

Model building

Perhaps the most important component of imputation modeling is the construction of an imputation model that preserves all the main characteristics of the observed data. This includes the following:

1. Use as many predictors as possible in the model to avoid making incorrect assumptions about the relationships between the variables. Omitting key predictors from the imputation model may lead to biased estimates for these predictors in the analysis. On the other hand, including insignificant predictors will result in less efficient yet still statistically valid results.
2. Include design variables representing the structure of the data in your imputation model. For example, sampling weights, strata and cluster identifiers of survey data, repeated-measures identifiers of longitudinal data must be included in the imputation model.

3. Specify the correct functional form of an imputation model. For example, include interactions of variables (or impute missing values separately using different subsamples; see *Imputing on subsamples*) to preserve higher-order dependencies.

The imputation model must be compatible with any model that can be used for the analysis. If variable X is to be included in the analysis model, it should also be used in the imputation model. If the analysis model estimates a correlation of X_1 and X_2, then both variables should be present in the imputation model. Accordingly, the outcome variable should always be present in the imputation model. Also, in addition to all the variables that may be used in the analysis model, you should include any auxiliary variables that may contain information about missing data. This will make the MAR assumption more plausible and will improve the quality of the imputed values. For more information about congeniality between the imputation and complete-data models, see Meng (1994).

As we mentioned above, it is important to specify the correct functional form of an imputation model to obtain proper imputations. The failure to accommodate such model features as interactions and nonlinearities during imputation may lead to severely biased results. There is no definitive recommendation for the best way to incorporate various functional forms into the imputation model. Currently, two main approaches are the joint modeling of all functional terms and modeling using passive variables (variables derived from imputation variables) also known as *passive imputation*. The joint modeling approach simply treats all functional terms as separate variables and imputes them together with the underlying imputation variables using a multivariate model, often a multivariate normal model. On the other hand, passive imputation—available within the MICE framework—fills in only the underlying imputation variables and computes the respective functional terms from the imputed variables, maintaining functional dependencies between the imputed and derived variables. The joint modeling approach imposes a rather stringent assumption of multivariate normality for possibly highly nonlinear terms and does not recognize functional dependencies between the imputed and derived variables. The naíve application of passive imputation, however, may omit certain functional relationships and thus lead to biased results. So, careful consideration for the specification of each conditional model is important. See White, Royston, and Wood (2011) for more details and some guidelines.

Outcome variables

Imputing outcome variables receive special attention in the literature because of the controversy about whether they should be imputed. As we already mentioned, it is important to include the outcome variable in the imputation model to obtain valid results. But what if the outcome variable itself has missing values? Should it be imputed? Should missing values be discarded from the analysis? There is no definitive answer to this question. The answer ultimately comes down to whether the specified imputation model describes the missing data adequately. When the percentage of missing values is low, using an incorrect imputation model may have little effect on the resulting repeated-imputation inference. With a large fraction of missing observations, a misspecified imputation model may distort the observed relationship between the outcome and predictor variables. In general, with large fractions of missing observations on any variable, the imputed values have more influence on the results, and thus more careful consideration of the imputation probability model is needed.

Transformations

Although the choice of an imputation method may not have significant impact on the results with low fractions of missing data, it may with larger fractions. A number of different imputation methods are available to model various types of imputation variables: continuous, categorical, count, and so on. However, in practice, these methods in no way cover all possible distributions that imputation variables

may have. Often, the imputation variables can be transformed to the scale appropriate for an imputation method. For example, a log transformation (or, more generally, a Box–Cox transformation) can be used for highly skewed continuous variables to make them suitable for imputation using the linear regression method. If desired, the imputed values can be transformed back after the imputation. Transformations are useful when a variable has a restricted range. For instance, a preimputation logit transformation and a postimputation inverse-logit transformation can be used to ensure that the imputed values are between 0 and 1.

It is important to remember that although the choice of a transformation is often determined based on the variable of interest alone, it is the conditional distribution of that variable given other predictors that is being modeled, and so the transformation must be suitable for it.

Categorical variables

To impute one categorical variable, you can use one of the categorical imputation methods: logistic, ordered logistic, or multinomial logistic regressions (see [MI] **mi impute logit**, [MI] **mi impute ologit**, or [MI] **mi impute mlogit**). These methods can also be used to impute multiple categorical variables with a monotone missing-data pattern using monotone imputation (see [MI] **mi impute monotone**) and with an arbitrary missing-data pattern using MICE (see [MI] **mi impute chained**). Also, for multiple categorical variables with only two categories (binary or dummy variables), a multivariate normal approach (see [MI] **mi impute mvn**) can be used to impute missing values and then, if needed, the imputed values can be rounded to 0 if the value is smaller than 0.5, or 1 otherwise. For categorical variables with more than two categories, Allison (2001) describes how to use the normal model to impute missing values.

The issue of perfect prediction during imputation of categorical data

Perfect prediction (or separation—for example, see Albert and Anderson [1984]) occurs often in the analysis of categorical data. The issue of perfect prediction is inherent to the discrete nature of categorical data and arises in the presence of covariate patterns for which outcomes of a categorical variable can be predicted almost perfectly. Perfect prediction usually leads to infinite coefficients with infinite standard errors and often causes numerical instability during estimation. This issue is often resolved by discarding the observations corresponding to offending covariate patterns as well as the independent variables perfectly predicting outcomes during estimation; see, for example, *Model identification* in [R] **logit**.

Perfect prediction is even more likely to arise during imputation because imputation models, per imputation modeling guidelines, tend to include many variables and thus may include many categorical variables. Perfect prediction may arise when variables are imputed using one of these imputation methods: `logit`, `ologit`, or `mlogit`.

Let's discuss how perfect prediction affects imputation. Recall that to obtain proper imputations (*Proper imputation methods* in [MI] **Intro substantive**), imputed values must be simulated from the posterior predictive distribution of missing data given observed data. The categorical imputation methods achieve this by first drawing a new set of regression coefficients from a normal distribution (a large-sample approximation to their posterior distribution) with mean and variance determined by the maximum likelihood estimates of the coefficients from the observed data and their variance–covariance matrix. The imputed values are then obtained using the new set of coefficients; see *Methods and formulas* in the method-specific manual entries for details.

In the presence of perfect prediction, very large estimates of coefficients and their standard errors arise during estimation. As a result, new coefficients, drawn from the corresponding asymptotic normal distribution, will either be large and positive or large and negative. As such, missing values—say, of a

binary imputation variable—may all be imputed as ones in some imputations and may all be imputed as zeros in other imputations. This will clearly bias the multiple-imputation estimate of the proportion of ones (or zeros) in the sample of perfectly predicted cases.

To eliminate the issue of perfect prediction during imputation, we cannot, unfortunately, drop observations and variables when estimating model parameters as is normally done during estimation using, for example, the `logit` command. Doing so would violate one of the main requirements of imputation modeling: all variables and cases that may be used during primary, completed-data analysis must be included in the imputation model. So, what can you do?

When perfect prediction is detected, `mi impute` issues an error message:

```
. mi impute logit x1 z1 z2 ..., ...
mi impute logit: perfect predictor(s) detected
    Variables that perfectly predict an outcome were detected when logit
    executed on the observed data.  First, specify mi impute's option noisily
    to identify the problem covariates.  Then either remove perfect predictors
    from the model or specify mi impute logit's option augment to perform
    augmented regression; see The issue of perfect prediction during imputation
    of categorical data in [MI] mi impute for details.
r(498);
```

You have two alternatives at this point.

You can fit the specified imputation model to the observed data using the corresponding command (in our example, `logit`) to identify the observations and variables causing perfect prediction in your data. Depending on the research objective and specifics of the data collection process, it may be reasonable to omit the offending covariate patterns and perfect predictors from your analysis. If you do so, you must carefully document which observations and variables were removed and adjust your inferential conclusions accordingly. Once offending instances are removed, you can proceed with imputation followed by your primary data analysis. Make sure that the instances you removed from the imputation model are not used in your further analysis.

The above approach may be difficult to pursue when imputing a large number of variables, among which are many categorical variables. Another option is to handle perfect prediction directly during imputation via the `augment` option, which is available for all categorical imputation methods: `logit`, `ologit`, and `mlogit`.

`mi impute ..., augment ...` implements an augmented-regression approach, an ad hoc but computationally convenient approach suggested by White, Daniel, and Royston (2010). According to this approach, a few extra observations with small weights are added to the data during estimation of model parameters in a way that prevents perfect prediction. See White, Daniel, and Royston (2010) for simulation results and computational details.

Convergence of iterative methods

When the missing-value pattern is arbitrary, iterative Markov chain Monte Carlo (MCMC-like) imputation methods are used to simulate imputed values from the posterior predictive distribution of the missing data given the observed data; also see *Multivariate imputation*. In this case, the resulting sequences (chains) of simulated parameters or imputed values should be examined to verify the convergence of the algorithm. The modeling task may be influenced by the convergence process of the algorithm given the data. For example, a different prior distribution for the model parameters may be needed with `mi impute mvn` when some aspects of the model cannot be estimated because of the sparseness of the missing data.

Markov chain simulation is often done in one of two ways: subsampling a single chain or running multiple independent chains. Subsampling a chain involves running a single chain for a prespecified number of iterations T, discarding the first b iterations until the chain reaches stationarity (the burn-in period), and sampling the chain each kth iteration to produce a final sequence of independent draws $\{\mathbf{X}^{(b)}, \mathbf{X}^{(b+k)}, \mathbf{X}^{(b+2k)}, \dots\}$ from the target distribution. The number of between iterations k is chosen such that draws $\mathbf{X}^{(t)}$ and $\mathbf{X}^{(t+k)}$ are approximately independent. Alternatively, one can obtain independent draws by running multiple independent chains using different starting values $\{\mathbf{X}^{(i,t)} : t = 0, 1, \dots\}$, $i = 1, 2, \dots$, and discarding the first b iterations of each to obtain a final sample $\{\mathbf{X}^{(1,b)}, \mathbf{X}^{(2,b)}, \mathbf{X}^{(3,b)}, \dots\}$ from the target distribution.

`mi impute mvn` subsamples the chain, whereas `mi impute chained` runs multiple independent chains; see [MI] **mi impute mvn** and [MI] **mi impute chained** for details on how to monitor convergence of each method.

Imputation diagnostics

After imputation, it is important to examine the sensibility of the obtained imputed values. If any abnormalities are detected, the imputation model must be revised. Diagnostics for imputations is still an ongoing research topic, but two general recommendations are to check model fit of the specified imputation model to the observed data and to compare distributions of the imputed and observed data. To check model fit of an imputation model to the observed data, you can use any standard postestimation tools usually used with that type of model. Also see, for example, [R] **mfp** to help determine an appropriate functional form of the imputation model. The differences (if any) between the distributions of the observed and of the imputed data should be plausible within the context of your study. For more information, see for example, Gelman et al. (2005), Abayomi, Gelman, and Levy (2008), Eddings and Marchenko (2012), and Marchenko and Eddings (2011) for how to perform multiple-imputation diagnostics in Stata.

Using mi impute

To use `mi impute`, you first `mi set` your data; see [MI] **mi set**. Next you register all variables whose missing values are to be imputed; see `mi register` in [MI] **mi set**.

`mi impute` has two main options: `add()` and `replace`. If you do not have imputations, use `add()` to create them. If you already have imputations, you have three choices:

1. Add new imputations to the existing ones by specifying the `add()` option.
2. Add new imputations and also replace the existing ones by specifying both the `add()` and the `replace` options.
3. Replace existing imputed values by specifying the `replace` option.

`add()` is required if no imputations exist in the `mi` data, and either `add()` or `replace` must be specified if imputations exist. See *Univariate imputation* for examples. Note that with `replace`, only imputed values of the specified imputation variables within the specified subsample will be updated.

For reproducibility, use the `rseed()` option to set the random-number seed, or equivalently, set the seed by using `set seed` immediately before calling `mi impute`. If you forget and still have `mi impute`'s stored results in memory, you can retrieve the seed from the stored result `r(rngstate)`; see *Stored results* below. If you sort your data prior to imputation, you may also need to ensure that your sorting is stable for reproducibility of your results; see [D] **sort**.

By default, mi impute stores the imputed values using float precision. If you need more accuracy, you can specify the double option. Depending on the mi data style, the type of the imputed variable may change in the original data, $m = 0$. For example, if your data are in the mlong (or flong) style and you are imputing a binary variable using the regression method, the type of the variable will become float. If you are using the logistic method, the type of the variable may become byte even if originally your variable was declared as float or int. mi impute will never demote a variable if that would result in loss of precision.

Use the by(*varlist*) option to perform imputation separately on each group formed by *varlist*. Specifying by() is equivalent to the repeated use of an if condition with mi impute to restrict the imputation sample to each of the categories formed by *varlist*. Use the missing option within by() to prevent mi impute from omitting missing categories in *varlist*. By default, mi impute terminates with error if imputation fails in any of the groups; use by()'s nostop option to proceed with imputation. You may not specify imputation and passive variables within by().

mi impute terminates with error if the imputation procedure results in missing imputed values. This may happen if you include variables containing missing values as predictors in your imputation model. If desired, you can override this behavior with the force option.

mi impute may change the sort order of the data.

Univariate imputation

Univariate imputation by itself has limited application in practice. The situations in which only one variable needs to be imputed or in which multiple incomplete variables can be imputed independently are rare in real-data applications. Univariate imputation is most useful when it is used as a building block of sequential multivariate imputation methods; see *Multivariate imputation*. It is thus beneficial to first become familiar with univariate imputation.

Consider the heart attack data in which bmi contains missing values, as described in *A brief introduction to MI using Stata* of [MI] **Intro substantive**. Here we use the already mi set version of the data with a subset of covariates of interest:

```
. use https://www.stata-press.com/data/r19/mheart1s0
(Fictional heart attack data; BMI missing)
. mi describe
Style: mlong
       last mi update 04feb2025 12:58:57, 11 days ago
Observations:
   Complete           132
   Incomplete          22  (M = 0 imputations)
   ----------------------
   Total              154
Variables:
   Imputed: 1; bmi(22)
   Passive: 0
   Regular: 5; attack smokes age female hsgrad
   System:  3; _mi_m _mi_id _mi_miss
   (there are no unregistered variables)
```

According to mi describe, the mi data style is mlong, and the dataset contains no imputations and 22 incomplete observations. The only registered imputed variable is bmi containing the 22 missing values. The other variables are registered as regular. See [MI] **mi describe** for details.

In the example in [MI] **Intro substantive**, we used `mi impute regress` to impute missing values of `bmi`. Let's concentrate on the imputation step in more detail here:

```
. mi impute regress bmi attack smokes age female hsgrad, add(20)
Univariate imputation                       Imputations =       20
Linear regression                                 added =       20
Imputed: m=1 through m=20                       updated =        0
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
bmi	132	22	22	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

The above output is common to all imputation methods of `mi impute`. In the left column, `mi impute` reports information about which imputation method was used and which imputations were created or updated. The right column contains the total number of imputations, and how many of them are new and how many are updated. The table contains the number of complete, incomplete, and imputed observations, and the total number of observations in the imputation sample, per imputation for each variable (see *Imputation and estimation samples* below). As indicated by the note, complete and incomplete observations sum to the total number of observations. The `imputed` column reports how many incomplete observations were actually imputed. This number represents the minimum across all imputations used ($m = 1$ through $m = 20$ in our example).

In the above example, we used `add(20)` to create 20 new imputations. Suppose that we decided that 20 is not enough and we want to add 30 more:

```
. mi impute regress bmi attack smokes age female hsgrad, add(30)
Univariate imputation                       Imputations =       50
Linear regression                                 added =       30
Imputed: m=21 through m=50                      updated =        0
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
bmi	132	22	22	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

The table output is unchanged, but the header reports that total number of imputations is now 50. Thirty new imputations (from $m = 21$ to $m = 50$) were added, and the existing 20 imputations were left unchanged.

Suppose that we decide we want to impute bmi using the predictive mean matching (PMM) imputation method instead of the regression method. We use mi impute pmm with five nearest neighbors and specify the replace option to update all existing imputations with new ones:

```
. mi impute pmm bmi attack smokes age female hsgrad, replace knn(5)
Univariate imputation                       Imputations =       50
Predictive mean matching                          added =        0
Imputed: m=1 through m=50                       updated =       50
                                      Nearest neighbors =        5
```

	Observations per m			
Variable	Complete	Incomplete	Imputed	Total
bmi	132	22	22	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

The header reports that all 50 existing imputations, from $m = 1$ to $m = 50$, are replaced with new ones.

Later we decide to use more nearest neighbors with mi impute pmm and also add 15 more imputations. We can do the latter by combining replace and add(). We specify replace to update the existing imputations with imputations from PMM with ten nearest neighbors (knn(10)) and use add(15) to add 15 more imputations.

```
. mi impute pmm bmi attack smokes age female hsgrad, add(15) replace knn(10) dots
Imputing m=1 through m=65:
  .....10.....20.....30.....40.....50.....60..... done
Univariate imputation                       Imputations =       65
Predictive mean matching                          added =       15
Imputed: m=1 through m=65                       updated =       50
                                      Nearest neighbors =       10
```

	Observations per m			
Variable	Complete	Incomplete	Imputed	Total
bmi	132	22	22	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

The header reports a total of 65 imputations, among which 15 are new and 50 are updated. In this example, we also used the dots option to see the imputation progress. This option is useful with larger datasets to monitor the imputation process.

See *Imputing on subsamples* for other usage of add() and replace.

Multivariate imputation

When imputing multiple variables, their missing-data pattern must first be considered. As we briefly mentioned in *Patterns of missing data* in [MI] **Intro substantive**, when a missing-data pattern is monotone distinct, multiple variables can be imputed sequentially without iteration using univariate conditional models (or monotone imputation). That is, a complicated multivariate imputation task can be replaced with a sequence of simpler univariate imputation tasks; see [MI] **mi impute monotone**.

Monotone missing-data patterns rarely arise naturally in practice. As such, it is important to be able to handle arbitrary missing-data patterns during imputation. Before we describe imputation methods accommodating arbitrary missing-data patterns, we will first discuss the difficulties arising with such patterns during imputation.

Monotone imputation is possible because variables can be ordered such that the complete observations of a variable being imputed are also complete in all prior imputed variables used to predict it. This means that the estimates of the parameters, which are obtained from complete data, do not depend on any previously imputed values (see Rubin [1987] for details). With an arbitrary pattern of missing data, such an ordering may not be possible because some variables may contain incomplete values in observations for which other variables are complete (and vice versa), resulting in estimated parameters being dependent on imputed values. The simultaneous imputation of multiple variables becomes more challenging when missingness is nonmonotone.

Consider the following example. Variable X_1 is complete in observation 1 and missing in observation 2, and variable X_2 is missing in observation 1 and complete in observation 2. We need to impute the two variables simultaneously. Suppose that we impute variable X_2 using previously imputed variable X_1. Observation 1, which contains an imputed value of X_1, is used to estimate the model parameters for X_2. As a result, the model parameters are obtained by treating the imputed value of X_1 as if it were true, thus ignoring the imputation variability in X_1. To account for the uncertainty in the imputed values during estimation, we need to iterate between the estimation step and the imputation step until the estimates of the model parameters depend only on the observed data.

Two main approaches for multivariate imputation with arbitrary missing-data patterns are joint modeling (JM) and fully conditional specification (FCS).

The JM approach assumes a genuine multivariate distribution for all imputation variables and imputes missing values as draws from the resulting posterior predictive distribution of the missing data given the observed data. The predictive distribution is often difficult to draw from directly, so the imputed values are often obtained by approximating this distribution using one of the MCMC methods. One such JM approach for continuous data is based on the multivariate normal distribution, the MVN method (Schafer 1997). The MVN method is implemented in [MI] **mi impute mvn** and uses the data augmentation MCMC method.

The FCS approach does not assume an explicit multivariate distribution for all imputation variables. Instead, it provides a set of chained equations, that is, univariate conditional distributions of each variable with fully conditional specifications of prediction equations. This approach is also known as MICE (van Buuren, Boshuizen, and Knook 1999) or sequential regression multivariate imputation (SRMI; Raghunathan et al. 2001). We will be using the terms MICE, FCS, and SRMI interchangeably throughout the documentation. MICE is similar in spirit to the Gibbs sampler, a popular MCMC method for simulating data from complicated multivariate distributions. Unlike the Gibbs sampler, however, conditional specifications within the MICE method are not guaranteed to correspond to a genuine multivariate distribution because MICE does not start from an explicit multivariate density. Regardless, MICE remains one of the popular imputation methods in practice. The MICE method is implemented in [MI] **mi impute chained**.

Currently, there is no definitive recommendation in the literature as to which approach, JM or FCS, is preferable. The JM approach ensures that imputed values are drawn from a genuine multivariate distribution, and it thus may be more attractive from a theoretical standpoint. However, except for simpler cases such as a multivariate normal model for continuous data, it may not be feasible to formulate a joint model for general data structures. In this regard, the FCS approach is more appealing because it not only can accommodate mixtures of different types of variables, but also can preserve some important charac-

teristics often observed in real data, such as restrictions to subpopulations for certain variables and range restrictions. The tradeoff for such flexibility is a current lack of theoretical justification. See Lee and Carlin (2010) and references therein for more discussion about the two approaches.

Consider the heart attack data in which both bmi and age contain missing values. Again we will use data that have already been mi set.

```
. use https://www.stata-press.com/data/r19/mheart5s0, clear
(Fictional heart attack data)
. mi describe
Style: mlong
       last mi update 04feb2025 12:58:57, 11 days ago
Observations:
   Complete           126
   Incomplete          28  (M = 0 imputations)
   ----------------------
   Total              154
Variables:
   Imputed: 2; bmi(28) age(12)
   Passive: 0
   Regular: 4; attack smokes female hsgrad
   System:  3; _mi_m _mi_id _mi_miss
   (there are no unregistered variables)
```

There are 28 incomplete observations in the dataset. The bmi variable contains 28 missing values and the age variable contains 12 missing values. Both bmi and age are registered as imputed. If we assume that age and BMI are independent, we can impute each of them separately by using the previously described univariate imputation methods. It is likely, however, that these variables are related, and so we use multivariate imputation.

First, we examine missing-value patterns of the data.

```
. mi misstable patterns
   Missing-value patterns
     (1 means complete)
                 |  Pattern
     Percent     |  1  2
-----------------+-------
         82%     |  1  1
                 |
          10     |  1  0
           8     |  0  0
-----------------+-------
         100%    |
  Variables are  (1) age  (2) bmi
```

From the output, 82% of observations are complete, 10% of observations contain missing values for bmi, and 8% of observations have both bmi and age missing. We can see that the dataset has a monotone-missing pattern (see [MI] **Intro substantive**), that is, missing values of age are nested within missing values of bmi. Another way to see if the pattern of missingness is monotone is to use mi misstable nested ([MI] **mi misstable**):

```
. mi misstable nested
     1.  age(12) -> bmi(28)
```

Because the missing-data pattern is monotone, we can use `mi impute monotone` to impute missing values of `bmi` and `age` simultaneously:

```
. mi impute monotone (regress) age bmi = attack smokes hsgrad female, add(10)
Conditional models:
               age: regress age attack smokes hsgrad female
               bmi: regress bmi age attack smokes hsgrad female

Multivariate imputation                     Imputations =       10
Monotone method                                    added =       10
Imputed: m=1 through m=10                        updated =        0
               age: linear regression
               bmi: linear regression
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
age	142	12	12	154
bmi	126	28	28	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

Without going into detail, `mi impute monotone` imputes missing values of multiple variables by performing a sequence of independent univariate conditional imputations. In the above example, the regression method is used to impute missing values of both variables. `age` is imputed first from the observed variables `attack`, `smokes`, `hsgrad`, and `female`. Then `bmi` is imputed using the imputed `age` variable in addition to other observed variables. The output is consistent with that of the univariate imputation methods described earlier, with some additional information. See [MI] **mi impute monotone** for details.

We can also impute missing values of `bmi` and `age` simultaneously using either `mi impute mvn`

```
. mi impute mvn age bmi = attack smokes hsgrad female, replace nolog
Multivariate imputation                     Imputations =       10
Multivariate normal regression                     added =        0
Imputed: m=1 through m=10                        updated =       10
Prior: uniform                               Iterations =     1000
                                                burn-in =      100
                                                between =      100
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
age	142	12	12	154
bmi	126	28	28	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

or mi impute chained

```
. mi impute chained (regress) age bmi = attack smokes hsgrad female, replace
note: missing-value pattern is monotone; no iteration performed.

Conditional models (monotone):
                age: regress age attack smokes hsgrad female
                bmi: regress bmi age attack smokes hsgrad female

Performing chained iterations ...

Multivariate imputation                     Imputations =       10
Chained equations                                 added =        0
Imputed: m=1 through m=10                       updated =       10

Initialization: monotone                     Iterations =        0
                                                burn-in =        0

                age: linear regression
                bmi: linear regression
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
age	142	12	12	154
bmi	126	28	28	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

Neither mi impute mvn nor mi impute chained requires the missing-data pattern to be monotone. mi impute mvn iterates to produce imputations. When the data are monotone missing, however, no iteration is required, and because mi impute monotone executes more quickly, it is preferred. mi impute chained also iterates to produce imputations, unless the missing-data pattern is monotone. However, mi impute monotone is still faster because it performs estimation only once on the original data, whereas mi impute chained performs estimation on each imputation. Use mi impute mvn and mi impute chained when there is an arbitrary missing-data pattern. See [MI] **mi impute mvn** and [MI] **mi impute chained** for details.

Imputing on subsamples

Consider the earlier example of the univariate imputation of bmi. Suppose that we want to perform imputation separately for females and males. Imputation on subsamples is useful when the imputation model must accommodate the interaction effects (see, for example, Allison [2001]). For example, if we want the effect of bmi on attack to vary by gender, we can perform imputation of bmi separately for females and males.

We first show how to do it manually using `if` and the `add()` and `replace` options:

```
. use https://www.stata-press.com/data/r19/mheart1s0, clear
(Fictional heart attack data; BMI missing)
. mi impute regress bmi attack smokes age hsgrad if female==1, add(20)
Univariate imputation                       Imputations =       20
Linear regression                                 added =       20
Imputed: m=1 through m=20                       updated =        0

------------------------------------------------------------------
                                Observations per m
                  ----------------------------------------------
        Variable |   Complete   Incomplete    Imputed      Total
-----------------+------------------------------------------------
             bmi |         33            5          5         38
------------------------------------------------------------------
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)

. mi impute regress bmi attack smokes age hsgrad if female==0, replace
Univariate imputation                       Imputations =       20
Linear regression                                 added =        0
Imputed: m=1 through m=20                       updated =       20

------------------------------------------------------------------
                                Observations per m
                  ----------------------------------------------
        Variable |   Complete   Incomplete    Imputed      Total
-----------------+------------------------------------------------
             bmi |         99           17         17        116
------------------------------------------------------------------
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

First, we created 20 imputations and filled in the missing values of `bmi` for females by using the corresponding subset of observations. Then we filled in the remaining missing values of `bmi` for males in the existing imputations by using the subset of male observations. We will now be able to include the interaction between `bmi` and `female` in our logistic model.

A much easier way to do the above is to use by():

```
. use https://www.stata-press.com/data/r19/mheart1s0, clear
(Fictional heart attack data; BMI missing)
. mi impute regress bmi attack smokes age hsgrad, add(20) by(female)
Performing setup for each by() group:
-> female = 0
-> female = 1

Univariate imputation                       Imputations =       20
Linear regression                                added =       20
Imputed: m=1 through m=20                        updated =       0
```

by() Variable	Observations per *m*			
	Complete	Incomplete	Imputed	Total
female = 0				
bmi	99	17	17	116
female = 1				
bmi	33	5	5	38
Overall				
bmi	132	22	22	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

Conditional imputation

Often in practice, some variables are defined only within what we call a conditional sample, a subset of observations satisfying certain restrictions (Raghunathan et al. 2001, Royston 2009). For example, the number of cigarettes smoked is relevant to smokers only, the number of pregnancies is relevant to females only, etc. Outside the conditional sample, such variables are assumed to contain soft missing values and a nonmissing constant value, further referred to as a conditional constant, which represents a known value or an inadmissible value. We will refer to conditional imputation as imputation of such variables. So, the task of conditional imputation is to impute missing values of a variable within a conditional sample using only observations from that sample and to replace missing values outside the conditional sample with a conditional constant.

In the previous section, we learned that we can specify an `if` condition with `mi impute` to restrict imputation of variables to a subset of observations. Is this sufficient to accommodate conditional imputation? To answer this question, let's consider several examples.

We use our heart attack data as an example. Suppose that our only variable containing missing values is `hightar`, the indicator for smoking high-tar cigarettes. We want to impute missing values in `hightar` and use it among other predictors in the logistic analysis of heart attacks. Because `hightar` is relevant to smokers only, we want to impute `hightar` using the subset of observations with `smokes==1`.

Thus to impute `hightar`, we restrict our imputation sample to smokers:

```
. mi impute logit hightar attack age bmi ... if smokes==1, ...
```

Are we now ready to proceed with our primary logistic analysis of heart attacks? Not quite. Recall that we wish to use all observations of hightar in our analysis. If hightar contains missing values only in the conditional sample, smokes==1, we are finished. Otherwise, we need to replace all remaining missing values outside the conditional sample, for smokes==0, with the conditional constant, the nonmissing value of hightar in observations with smokes==0. In our example, this value is zero, so our final step is

```
. mi xeq: replace hightar = 0 if smokes==0
```

What if we have several imputation variables? Suppose now that age and bmi also contain missing values. Without making any assumptions about a missing-data pattern, we use mi impute chained to impute variables of different types: age, bmi, and hightar. We need to impute hightar for smokes==1 but use the unrestricted sample to impute age and bmi. Can we still accomplish this by specifying an if condition? The answer is yes, but we need to replace missing values of hightar for smokes==0 before imputation to ensure that age and bmi are imputed properly, using all observations, when hightar is used in their prediction equations:

```
. mi xeq: replace hightar = 0 if smokes==0
. mi impute chained (regress) bmi age (logit if smokes==1) hightar = ..., ...
```

It seems that we can get away with using if to perform conditional imputation. What is the catch? So far, we assumed that smokes does not contain any missing values. Let's see what happens if it does.

Because hightar depends on smokes, we must first impute missing values of smokes before we can impute missing values of hightar. As such, the set of observations for which smokes==1 will vary from imputation to imputation and, in the case of mi impute chained, from iteration to iteration. The replacement of missing values of hightar outside the conditional sample should be performed each time a new set of imputed values is obtained for smokes, and thus must be directly incorporated into the imputation procedure.

The answer to our earlier question about using an if condition to perform conditional imputation is no, in general. To perform conditional imputation, use the conditional() option:

```
. mi imp chained (reg) bmi age (logit) smokes (logit, conditional(if smokes==1))
> hightar ...
```

Every univariate imputation method supports option conditional(). This option is most useful within specifications of univariate methods when multiple variables are being imputed using mi impute monotone or mi impute chained, as we showed above. Although in some cases, as we saw earlier, specifying an if condition in combination with manual replacement of missing values outside the conditional sample may produce equivalent results, such use should generally be avoided and conditional() should be used instead.

When you specify option conditional(), mi impute performs checks necessary for proper conditional imputation. For example, the imputed variable is verified to be constant outside the conditional sample and an error message is issued if it is not:

```
. mi impute logit hightar age bmi ..., conditional(if smokes==1)
conditional(): imputation variable not constant outside conditional sample;
    hightar is not constant outside the subset identified by (smokes==1)
    within the imputation sample.  This may happen when missing values of
    conditioning variables are not nested within missing values of hightar.
r(459);
```

mi impute also requires that missing values of all variables involved in conditional specifications (restrictions)—that is, conditioning variables—be nested within missing values of the conditional variable being imputed. If this does not hold true, mi impute issues an error message:

```
. mi impute logit hightar age bmi ..., conditional(if smokes==1)
conditional(): conditioning variables not nested;
    conditioning variable smokes is not nested within hightar
r(459);
```

Because missing values of all conditioning variables are assumed to be nested within missing values of a conditional variable, that conditional variable is not included in the prediction equations of the corresponding conditioning variables.

As an example, let's continue with our heart attack data, in which variables hightar and smokes contain missing values, as do age and bmi:

```
. use https://www.stata-press.com/data/r19/mheart7s0, clear
(Fictional heart attack data; BMI, age, hightar, and smokes missing)
. mi describe
Style: mlong
       last mi update 04feb2025 12:58:57, 11 days ago
Observations:
   Complete          124
   Incomplete         30  (M = 0 imputations)
   ----------------------
   Total             154
Variables:
   Imputed: 4; bmi(24) age(30) hightar(8) smokes(5)
   Passive: 0
   Regular: 3; attack female hsgrad
   System:  3; _mi_m _mi_id _mi_miss
   (there are no unregistered variables)
. mi misstable nested
     1.  smokes(5) -> hightar(8) -> bmi(24) -> age(30)
```

Our data are already `mi set`, so we proceed with imputation. According to `mi misstable nested`, all imputation variables are monotone missing, so we use `mi impute monotone` for imputation. For the purpose of illustration, we create only two imputations:

```
. mi impute monotone (regress) bmi age
>                    (logit, conditional(if smokes==1)) hightar
>                    (logit) smokes
>                                    = attack hsgrad female, add(2)

Conditional models:
            smokes: logit smokes attack hsgrad female
          hightar: logit hightar i.smokes attack hsgrad female ,
                    conditional(if smokes==1)
             bmi: regress bmi i.hightar i.smokes attack hsgrad female
             age: regress age bmi i.hightar i.smokes attack hsgrad female

note: 1.smokes omitted because of collinearity.

Multivariate imputation                     Imputations =        2
Monotone method                                   added =        2
Imputed: m=1 through m=2                        updated =        0

Conditional imputation:
  hightar: incomplete out-of-sample obs replaced with value 0

             bmi: linear regression
             age: linear regression
          hightar: logistic regression
           smokes: logistic regression
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
bmi	130	24	24	154
age	124	30	30	154
hightar	146	8	8	154
smokes	149	5	5	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

For each variable that was imputed conditionally, `mi impute` reports the conditional value used to replace all missing observations outside the conditional sample in a legend about conditional imputation. In our example, all missing values of `hightar` outside `smokes==1` are replaced with zero. The reported numbers of complete, incomplete, and imputed observations for `hightar` correspond to the entire imputation sample (see *Imputation and estimation samples*) and not only to the conditional sample. For example, there are 146 complete and 8 incomplete observations of `hightar` in the combined sample of smokers and nonsmokers. The minimum number of imputed values across imputations is 8, so all incomplete observations of `hightar` were filled in—either imputed directly or replaced with a conditional value—in both imputations. Because `smokes` is being imputed, the numbers of incomplete and imputed observations of `hightar` for smokers and nonsmokers will vary across imputations.

You can accommodate more complicated restrictions or skip patterns, which often arise with questionnaire data, by specifying more elaborate restrictions within `conditional()` or by specifying the `conditional()` option with other variables. For example, suppose that the information about cigarette tar level (`hightar`) was collected only for heavy smokers, identified by an indicator variable `heavysmoker`. The `heavysmoker` variable contains missing values and needs to be imputed before `hightar` can be imputed. To impute `heavysmoker`, we need to restrict our sample to smokers only. Then to impute `hightar`, we need to use only heavy smokers among all smokers. We can do so as follows:

```
. mi impute chained (logit) smokes                                          ///
                    (logit, conditional(if smokes==1)) heavysmoker          ///
                    (logit, conditional(if smokes==1 & heavysmoker==1))     ///
                         hightar ...
```

Imputation and estimation samples

Rubin (1987, 160–166) describes the imputation process as three tasks: modeling, estimation, and imputation. We concentrate on the latter two tasks here. The posterior distribution of the model parameters is estimated during the estimation task. This posterior distribution is used in the imputation task to simulate the parameters of the posterior predictive distribution of the missing data from which an imputed value is drawn. Accordingly, `mi impute` distinguishes between two main samples: imputation and estimation.

The imputation sample is determined by the imputation variables used in the imputation task. It is comprised of all observations for which the imputation variables contain no hard missing values (or no extended missing values). In other words, the imputation sample consists of the complete and incomplete observations as identified by the specified imputation variables. The estimation sample is comprised of all observations used by the model fit to the observed data during the estimation task.

For example,

```
. use https://www.stata-press.com/data/r19/mheart1s0, clear
(Fictional heart attack data; BMI missing)
. mi impute regress bmi attack smokes age hsgrad female, add(1) noisily
Running regress on observed data:
```

Source	SS	df	MS	Number of obs	=	132
				F(5, 126)	=	1.24
Model	99.5998228	5	19.9199646	Prob > F	=	0.2946
Residual	2024.93667	126	16.070926	R-squared	=	0.0469
				Adj R-squared	=	0.0091
Total	2124.5365	131	16.2178358	Root MSE	=	4.0089

bmi	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
attack	1.71356	.7515229	2.28	0.024	.2263179	3.200801
smokes	-.5153181	.761685	-0.68	0.500	-2.02267	.9920341
age	-.033553	.0305745	-1.10	0.275	-.0940591	.026953
hsgrad	-.4674308	.8112327	-0.58	0.566	-2.072836	1.137975
female	-.3072767	.8074763	-0.38	0.704	-1.905249	1.290695
_cons	26.96559	1.884309	14.31	0.000	23.2366	30.69458

```
Univariate imputation                       Imputations =        1
Linear regression                                 added =        1
Imputed: m=1                                    updated =        0
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
bmi	132	22	22	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

The imputation sample contains 154 observations and the estimation sample contains 132 observations (from the regression output). The estimation task of `mi impute regress` consists of fitting a linear regression of `bmi` on other variables to the observed data. We specified the `noisily` option to see results from the estimation task. Usually, the number of complete observations in the imputation sample (132 in this example) will be equal to the number of observations used in the estimation. Sometimes, however, observations may be dropped from the estimation—for example, if independent variables contain missing values. In this case, the number of complete observations in the imputation sample and the number of observations used in the estimation will be different, and the following note will appear following the table output:

```
Note: Right-hand-side variables (or weights) have missing values;
      model parameters estimated using listwise deletion.
```

You should evaluate such cases to verify that results are as expected.

In general, missing values in independent variables (or in a weighting variable) do not affect the imputation sample but they may lead to missing imputed values. In the above example, if `age` contained missing values in incomplete observations of `bmi`, the linear prediction for those observations would have been missing and thus the resulting imputed values would have been missing, too.

Imputing on subsamples, or in other words, using an `if` condition with `mi impute`, restricts both imputation and estimation samples to include only observations satisfying the `if` condition. Conditional imputation (the `conditional()` option), on the other hand, affects only the estimation sample. All values, within and outside of a conditional sample, except extended missing values, are included in the imputation sample. With conditional imputation, the reported number of complete observations will almost always be different from the number of observations in the estimation sample, unless the conditional sample coincides with the imputation sample. In the case of observations being dropped from a conditional sample during estimation, a note as shown above will appear following the table output.

Imputing transformations of incomplete variables

Continuing with the univariate example above, say that we discover that the distribution of `bmi` is skewed to the right, and thus we decide to impute `bmi` on the logarithmic scale instead of the original one. We can do this by creating a new variable, `lnbmi`, and imputing it instead of `bmi`.

What we will do is create `lnbmi`, register it as imputed, impute it, and then create `bmi` as a passive variable based on the formula `bmi` $=$ exp(`lnbmi`).

We need to be careful when we create `lnbmi` to get its missing values right. `mi` respects two kinds of missing values, called soft and hard missing. Soft missing values are missing values eligible for imputation. Hard missing values are missing values that are to remain missing even in the imputed data. Soft missing are recorded as ordinary missing (`.`), and hard missing are recorded as any of extended missing (`.a`–`.z`).

The issue here is that missing values could arise because of our application of the transform `lnbmi` $=$ ln(`bmi`). In the case of the ln() transform, missing values will be created whenever `bmi` ≤ 0. (In general, transformations leading to undefined values should be avoided so that all available observed data are used during imputation.) Body mass index does not contain such values, but let's pretend it did. Here is what we would do:

1. Create `lnbmi` $=$ ln(`bmi`).
2. Replace `lnbmi` to contain `.z` in observations for which `lnbmi` contains missing but `bmi` does not.
3. Register `lnbmi` as an imputed variable and impute it.
4. Create passive variable `newbmi` $=$ exp(`lnbmi`).
5. Replace `newbmi` equal to `bmi` in observations for which `newbmi` is missing and `bmi` is not.

Alternatively, to avoid creating hard missing values in step 2, we could consider a different transformation; see, for example, [R] **lnskew0**.

As we said, for `lnbmi` $=$ ln(`bmi`) we need not perform all the steps above because `bmi` > 0. In the `bmi` case, all we need to do is

1. Create `lnbmi` $=$ ln(`bmi`).
2. Register `lnbmi` as an imputed variable and impute it.
3. Create passive variable `newbmi` $=$ exp(`lnbmi`).

If all we wanted to do was impute `lnbmi` $=$ ln(`bmi`) and, from that point on, just work with `lnbmi`, we would perform only the first two steps of the three-step procedure.

All that said, we are going to perform the five-step procedure because it will always work. We will continue from where we left off in the last example, so we will discard our previous imputation efforts by typing `mi set M = 0`. (Instead of typing `mi set M = 0`, we could just as easily begin by typing `use https://www.stata-press.com/data/r19/mheart1s0`.)

```
. mi set M = 0                              // start again
. mi unregister bmi                         // we do not impute bmi
. generate lnbmi = ln(bmi)                  // create lnbmi
. replace lnbmi = .z if lnbmi==. & bmi!=.
. mi register imputed lnbmi
. mi impute regress lnbmi attack smokes age hsgrad female, add(5)
. mi passive: generate newbmi = exp(lnbmi)
. mi passive: replace newbmi = bmi if bmi!=.
```

The important thing about the above is the mechanical definition of an imputed variable. An imputed variable is a variable we actually impute, not a variable we desire to impute. In this case, we imputed `lnbmi` and derived `bmi` from it. Thus the variable we desired to impute became, mechanically, a passive variable.

Stored results

`mi impute` stores the following in `r()`:

Scalars

`r(M)`	total number of imputations
`r(M_add)`	number of added imputations
`r(M_update)`	number of updated imputations
`r(k_ivars)`	number of imputed variables
`r(N_g)`	number of imputed groups (`1` if `by()` is not specified)

Macros

`r(method)`	name of imputation method
`r(ivars)`	names of imputation variables
`r(rngstate)`	random-number state used
`r(by)`	names of variables specified within `by()`

Matrices

`r(N)`	number of observations in imputation sample in each group (per variable)
`r(N_complete)`	number of complete observations in imputation sample in each group (per variable)
`r(N_incomplete)`	number of incomplete observations in imputation sample in each group (per variable)
`r(N_imputed)`	number of imputed observations in imputation sample in each group (per variable)

Also see *Stored results* in the method-specific manual entries for additional stored results.

Methods and formulas

All imputation methods (except predictive mean matching) are based on simulating from a Bayesian (approximate) posterior predictive distribution of missing data. Univariate imputation methods and the sequential monotone method use noniterative techniques for simulating from the posterior predictive distribution of missing data. The imputation method based on multivariate normal regression uses an iterative MCMC technique to simulate from the posterior predictive distribution of missing data. The MICE method uses a Gibbs-like algorithm to obtain imputed values.

See *Methods and formulas* in the method-specific manual entries for details.

Herman Otto Hartley (1912–1980) was born in Germany as Herman Otto Hirschfeld and immigrated to England in 1934 after completing his PhD in mathematics at Berlin University. He completed a second PhD in mathematical statistics under John Wishart at Cambridge in 1940 and went on to hold positions at Harper Adams Agricultural College, Scientific Computing Services (London), University College (London), Iowa State College, Texas A&M University, and Duke University. Among other awards he received and distinguished titles he held, Professor Hartley served as the president of the American Statistical Association in 1979. Known affectionately as HOH by almost all who knew him, he founded the Institute of Statistics, later to become the Department of Statistics, at Texas A&M University. His contributions to statistical computing are particularly notable considering the available equipment at the time. Professor Hartley is best known for his two-volume *Biometrika Tables for Statisticians* (jointly written with Egon Pearson) and for his fundamental contributions to sampling theory, missing-data methodology, variance-component estimation, and computational statistics.

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Also see

[MI] **mi estimate** — Estimation using multiple imputations

[MI] **Intro** — Introduction to mi

[MI] **Intro substantive** — Introduction to multiple-imputation analysis

[MI] **Glossary**

[D] **frunalias** — Change storage type of alias variables

mi impute chained — Impute missing values using chained equations

Description | Menu | Syntax | Options
Remarks and examples | Stored results | Methods and formulas | Acknowledgments
References | Also see

Description

`mi impute chained` fills in missing values in multiple variables iteratively by using chained equations, a sequence of univariate imputation methods with fully conditional specification (FCS) of prediction equations. It accommodates arbitrary missing-value patterns. You can perform separate imputations on different subsets of the data by specifying the `by()` option. You can also account for frequency, analytic (with continuous variables only), importance, and sampling weights.

Menu

Statistics > Multiple imputation

Syntax

Default specification of prediction equations, basic syntax

`mi impute chained (`*uvmethod*`)` *ivars* [`=` *indepvars*] [*if*] [*weight*] [`,` *impute_options options*]

Default specification of prediction equations, full syntax

`mi impute chained` *lhs* [`=` *indepvars*] [*if*] [*weight*] [`,` *impute_options options*]

Custom specification of prediction equations

`mi impute chained` *lhsc* [`=` *indepvars*] [*if*] [*weight*] [`,` *impute_options options*]

where *lhs* is *lhs_spec* [*lhs_spec* [...]] and *lhs_spec* is

(*uvmethod* [*if*] [`,` *uvspec_options*]) *ivars*

lhsc is *lhsc_spec* [*lhsc_spec* [...]] and *lhsc_spec* is

(*uvmethod* [*if*] [`, include(`*xspec*`) omit(`*varlist*`) noimputed` *uvspec_options*]) *ivars*

ivars (or *newivar* if *uvmethod* is `intreg`) are the names of the imputation variables.

uvspec_options are `asc`ontinuous, `noi`sily, and the method-specific *options* as described in the manual entry for each univariate imputation method.

The `include()`, `omit()`, and `noimputed` options allow you to customize the default prediction equations.

uvmethod	Description
regress	linear regression for a continuous variable; [MI] **mi impute regress**
pmm	predictive mean matching for a continuous variable; [MI] **mi impute pmm**
truncreg	truncated regression for a continuous variable with a restricted range; [MI] **mi impute truncreg**
intreg	interval regression for a continuous partially observed (censored) variable; [MI] **mi impute intreg**
logit	logistic regression for a binary variable; [MI] **mi impute logit**
ologit	ordered logistic regression for an ordinal variable; [MI] **mi impute ologit**
mlogit	multinomial logistic regression for a nominal variable; [MI] **mi impute mlogit**
poisson	Poisson regression for a count variable; [MI] **mi impute poisson**
nbreg	negative binomial regression for an overdispersed count variable; [MI] **mi impute nbreg**

impute_options	Description
Main	
* add(#)	specify number of imputations to add; required when no imputations exist
* replace	replace imputed values in existing imputations
rseed(#)	specify random-number seed
double	store imputed values in double precision; the default is to store them as float
by(*varlist*[, *byopts*])	impute separately on each group formed by *varlist*
Reporting	
dots	display dots as imputations are performed
noisily	display intermediate output
nolegend	suppress all table legends
Advanced	
force	proceed with imputation, even when missing imputed values are encountered
noupdate	do not perform mi update; see [MI] **noupdate option**

*add(#) is required when no imputations exist; add(#) or replace is required if imputations exist.

noupdate does not appear in the dialog box.

options	Description
MICE options	
burnin(#)	specify number of iterations for the burn-in period; default is burnin(10)
chainonly	perform chained iterations for the length of the burn-in period without creating imputations in the data
augment	perform augmented regression in the presence of perfect prediction for all categorical imputation variables
noimputed	do not include imputation variables in any prediction equation
bootstrap	estimate model parameters using sampling with replacement
savetrace(...)	save summaries of imputed values from each iteration in *filename*.dta
Reporting	
dryrun	show conditional specifications without imputing data
report	show report about each conditional specification
chaindots	display dots as chained iterations are performed
showevery(#)	display intermediate results from every #th iteration
showiter(*numlist*)	display intermediate results from every iteration in *numlist*
Advanced	
orderasis	impute variables in the specified order
nomonotone	impute using chained equations even when variables follow a monotone-missing pattern; default is to use monotone method
nomonotonechk	do not check whether variables follow a monotone-missing pattern

You must mi set your data before using mi impute chained; see [MI] **mi set**.

You must mi register *ivars* as imputed before using mi impute chained; see [MI] **mi set**.

indepvars may contain factor variables; see **[U] 11.4.3 Factor variables**.

collect is allowed; see **[U] 11.1.10 Prefix commands**.

fweights, aweights (regress, pmm, truncreg, and intreg only), iweights, and pweights are allowed; see **[U] 11.1.6 weight**.

Options

Main

add(), replace, rseed(), double, by(); see [MI] **mi impute**.

The following options appear on a Specification dialog that appears when you click on the **Create ...** button on the **Main** tab. The include(), omit(), and noimputed options allow you to customize the default prediction equations.

include(*xspec*) specifies that *xspec* be included in prediction equations of all imputation variables corresponding to the current left-hand-side specification *lhsc_spec*. *xspec* includes complete variables and expressions of imputation variables bound in parentheses. If the noimputed option is specified within *lhsc_spec* or with mi impute chained, then *xspec* may also include imputation variables. *xspec* may contain factor variables; see **[U] 11.4.3 Factor variables**.

omit(*varlist*) specifies that *varlist* be omitted from the prediction equations of all imputation variables corresponding to the current left-hand-side specification *lhsc_spec*. *varlist* may include complete variables or imputation variables. *varlist* may contain factor variables; see **[U] 11.4.3 Factor vari-**

ables. In `omit()`, you should list variables to be omitted exactly as they appear in the prediction equation (abbreviations are allowed). For example, if variable `x1` is listed as a factor variable, use `omit(i.x1)` to omit it from the prediction equation.

`noimputed` specifies that no imputation variables automatically be included in prediction equations of imputation variables corresponding to the current *uvmethod*.

uvspec_options are options specified within each univariate imputation method, *uvmethod*. *uvspec_options* include `ascontinuous`, `noisily`, and the method-specific *options* as described in the manual entry for each univariate imputation method.

`ascontinuous` specifies that categorical imputation variables corresponding to the current *uvmethod* be included as continuous in all prediction equations. This option is only allowed when *uvmethod* is `logit`, `ologit`, or `mlogit`.

`noisily` specifies that the output from the current univariate model fit to the observed data be displayed. This option is useful in combination with the `showevery(#)` or `showiter(`*numlist*`)` option to display results from a particular univariate imputation model for specific iterations.

MICE options

`burnin(#)` specifies the number of iterations for the burn-in period for each chain (one chain per imputation). The default is `burnin(10)`. This option specifies the number of iterations necessary for a chain to reach approximate stationarity or, equivalently, to converge to a stationary distribution. The required length of the burn-in period will depend on the starting values used and the missing-data patterns observed in the data. It is important to examine the chain for convergence to determine an adequate length of the burn-in period prior to obtaining imputations; see *Convergence of MICE*. The provided default is what current literature recommends. However, you are responsible for determining that sufficient iterations are performed.

`chainonly` specifies that `mi impute chained` perform chained iterations for the length of the burn-in period and then stop. This option is useful in combination with `savetrace()` to examine the convergence of the method prior to imputation. No imputations are created when `chainonly` is specified, so `add()` or `replace` is not required with `mi impute chained, chainonly` and they are ignored if specified.

`augment` specifies that augmented regression be performed if perfect prediction is detected. By default, an error is issued when perfect prediction is detected. The idea behind the augmented-regression approach is to add a few observations with small weights to the data during estimation to avoid perfect prediction. See *The issue of perfect prediction during imputation of categorical data* under *Remarks and examples* in [MI] **mi impute** for more information. `augment` is not allowed with importance weights. This option is equivalent to specifying `augment` within univariate specifications of all categorical imputation methods: `logit`, `ologit`, and `mlogit`.

`noimputed` specifies that no imputation variables automatically be included in any of the prediction equations. This option is seldom used. This option is convenient if you wish to use different sets of imputation variables in all prediction equations. It is equivalent to specifying `noimputed` within all univariate specifications.

`bootstrap` specifies that posterior estimates of model parameters be obtained using sampling with replacement; that is, posterior estimates are estimated from a bootstrap sample. The default is to sample the estimates from the posterior distribution of model parameters or from the large-sample normal

approximation of the posterior distribution. This option is useful when asymptotic normality of parameter estimates is suspect. This option is equivalent to specifying `bootstrap` within all univariate specifications.

`savetrace(`*filename*`[ , `*traceopts*`])` specifies to save the means and standard deviations of imputed values from each iteration to a Stata dataset called *filename*`.dta`. If the file already exists, the `replace` suboption specifies to overwrite the existing file. `savetrace()` is useful for monitoring convergence of the chained algorithm. This option cannot be combined with `by()`.

traceopts are `replace`, `double`, and `detail`.

`replace` indicates that *filename*`.dta` be overwritten if it exists.

`double` specifies that the variables be stored as `doubles`, meaning 8-byte reals. By default, they are stored as `floats`, meaning 4-byte reals. See [D] **Data types**.

`detail` specifies that additional summaries of imputed values including the smallest and the largest values and the 25th, 50th, and 75th percentiles are saved in *filename*`.dta`.

Reporting

`dots`, `noisily`, `nolegend`; see [MI] **mi impute**. `noisily` specifies that the output from all univariate conditional models fit to the observed data be displayed. `nolegend` suppresses all imputation table legends that include a legend with the titles of the univariate imputation methods used, a legend about conditional imputation when `conditional()` is used within univariate specifications, and group legends when `by()` is specified.

`dryrun` specifies to show the conditional specifications that would be used to impute each variable without actually imputing data. This option is recommended for checking specifications of conditional models prior to imputation.

`report` specifies to show a report about each univariate conditional specification. This option, in combination with `dryrun`, is recommended for checking specifications of conditional models prior to imputation.

`chaindots` specifies that all chained iterations be displayed as dots. An `x` is displayed for every failed iteration.

`showevery(#)` specifies that intermediate regression output be displayed for every #th iteration. This option requires `noisily`. If `noisily` is specified with `mi impute chained`, then the output from the specified iterations is displayed for all univariate conditional models. If `noisily` is used within a univariate specification, then the output from the corresponding univariate model from the specified iterations is displayed.

`showiter(`*numlist*`)` specifies that intermediate regression output be displayed for each iteration in *numlist*. This option requires `noisily`. If `noisily` is specified with `mi impute chained`, then the output from the specified iterations is displayed for all univariate conditional models. If `noisily` is used within a univariate specification, then the output from the corresponding univariate model from the specified iterations is displayed.

Advanced

`force`; see [MI] **mi impute**.

`orderasis` requests that the variables be imputed in the specified order. By default, variables are imputed in order from the most observed to the least observed.

nomonotone, a rarely used option, specifies not to use monotone imputation and to proceed with chained iterations even when imputation variables follow a monotone-missing pattern. mi impute chained checks whether imputation variables have a monotone missing-data pattern and, if they do, imputes them using the monotone method (without iteration). If nomonotone is used, mi impute chained imputes variables iteratively even if variables are monotone-missing.

nomonotonechk specifies not to check whether imputation variables follow a monotone-missing pattern. By default, mi impute chained checks whether imputation variables have a monotone missing-data pattern and, if they do, imputes them using the monotone method (without iteration). If nomonotonechk is used, mi impute chained does not check the missing-data pattern and imputes variables iteratively even if variables are monotone-missing. Once imputation variables are established to have an arbitrary missing-data pattern, this option may be used to avoid potentially time-consuming checks; the monotonicity check may be time consuming when a large number of variables is being imputed.

The following option is available with mi impute but is not shown in the dialog box:

noupdate; see [MI] **noupdate option**.

Remarks and examples

Remarks are presented under the following headings:

Multivariate imputation using chained equations
Compatibility of conditionals
Convergence of MICE
First use
Using mi impute chained
Default prediction equations
Custom prediction equations
Link between mi impute chained and mi impute monotone
Examples

See [MI] **mi impute** for a general description and details about options common to all imputation methods, *impute_options*. Also see [MI] **Workflow** for general advice on working with mi.

Multivariate imputation using chained equations

When a missing-data structure is monotone distinct, multiple variables can be imputed sequentially without iteration by using univariate conditional models (see [MI] **mi impute monotone**). Such monotone imputation is impossible with arbitrary missing-data patterns, and simultaneous imputation of multiple variables in such cases requires iteration. We described the impact of an arbitrary missing-data pattern on multivariate imputation and two common imputation approaches used in such cases, the multivariate normal method and multivariate imputation using chained equations (MICE), in *Multivariate imputation* in [MI] **mi impute**. In this entry, we describe MICE, also known as imputation using FCS (van Buuren, Boshuizen, and Knook 1999) or sequential regression multivariate imputation (SRMI; Raghunathan et al. 2001), in more detail. We use the terms MICE, FCS, and SRMI interchangeably throughout the documentation.

MICE is similar to monotone imputation in the sense that it is also based on a series of univariate imputation models. Unlike monotone imputation, MICE uses FCSs of prediction equations (chained equations) and requires iteration. Iteration is needed to account for possible dependence of the estimated model parameters on the imputed data when a missing-data structure is not monotone distinct.

The general idea behind MICE is to impute multiple variables iteratively via a sequence of univariate imputation models, one for each imputation variable, with fully conditional specifications of prediction equations: all variables except the one being imputed are included in a prediction equation. Formally, for imputation variables $X_1, X_2, \ldots, X_p$ and complete predictors (independent variables) $\mathbf{Z}$, this procedure can be described as follows. Imputed values are drawn from

$$\begin{aligned} X_1^{(t+1)} &\sim g_1(X_1|X_2^{(t)}, \ldots, X_p^{(t)}, \mathbf{Z}, \boldsymbol{\phi}_1) \\ X_2^{(t+1)} &\sim g_2(X_2|X_1^{(t+1)}, X_3^{(t)}, \ldots, X_p^{(t)}, \mathbf{Z}, \boldsymbol{\phi}_2) \\ &\ldots \\ X_p^{(t+1)} &\sim g_p(X_p|X_1^{(t+1)}, X_2^{(t+1)}, \ldots, X_{p-1}^{(t+1)}, \mathbf{Z}, \boldsymbol{\phi}_p) \end{aligned} \tag{1}$$

for iterations $t = 0, 1, \ldots, T$ until convergence at $t = T$, where $\boldsymbol{\phi}_j$ are the corresponding model parameters with a uniform prior. The univariate imputation models, $g_j(\cdot)$, can each be of a different type (normal, logistic, etc.), as is appropriate for imputing X_j.

Fully conditional specifications (1) are similar to the Gibbs sampling algorithm (Geman and Geman 1984; Gelfand and Smith 1990), one of the MCMC methods for simulating from complicated multivariate distributions. In fact, in certain cases these specifications do correspond to a genuine Gibbs sampler. For example, when all X_j's are continuous and all $g_j(\cdot)$'s are normal linear regressions with constant variances, then (1) corresponds to a Gibbs sampler based on a multivariate normal distribution with a uniform prior for model parameters. Such correspondence does not hold in general because unlike the Gibbs sampler, the conditional densities $\{g_j(\cdot),\ j = 1, 2, \ldots, p\}$ may not correspond to any multivariate joint conditional distribution of $X_1, X_2, \ldots, X_p$ given $\mathbf{Z}$ (Arnold, Castillo, and Sarabia 2001). This issue is known as incompatibility of conditionals (for example, Arnold, Castillo, and Sarabia [1999]). When conditionals are not compatible, the MICE procedure may not converge to any stationary distribution, which can raise concerns about its validity as a principled statistical method; see *Compatibility of conditionals* and *Convergence of MICE* for more details.

Despite the lack of a general theoretical justification, MICE is very popular in practice. Its popularity is mainly due to the tremendous flexibility it offers for imputing various types of data arising in observational studies. Similarly to monotone imputation, the variable-by-variable specification of MICE allows practitioners to simultaneously impute variables of different types by choosing from several univariate imputation methods appropriate for each variable. Being able to specify a separate model for each variable provides an imputer with great flexibility in incorporating certain characteristics specific to each variable. For example, we can use predictive mean matching ([MI] **mi impute pmm**) or truncated regression ([MI] **mi impute truncreg**) to impute a variable with a restricted range. We can impute variables defined on a subsample using only observations in that subsample while using the entire sample to impute other variables; see *Conditional imputation* in [MI] **mi impute** for details. For more information about multivariate imputation using chained equations, see van Buuren, Boshuizen, and Knook (1999); Raghunathan et al. (2001); van Buuren et al. (2006); van Buuren (2007); White, Royston, and Wood (2011); and Royston (2004, 2005a, 2005b, 2007, 2009), among others.

The specification of a conditional imputation model $g_j(\cdot)$ includes an imputation method and a prediction equation relating an imputation variable to other explanatory variables. In what follows, we distinguish between the default specification (of prediction equations) in which the identities of the complete explanatory variables are the same across all prediction equations, and the custom specification in which the identities are allowed to differ.

Under the default specification, prediction equations of each imputation variable include all complete independent variables and all imputation variables except the one being imputed. Under the custom specification, each prediction equation may include a subset of the predictors that would be used under the default specification. The custom specification also allows expressions of imputation variables in prediction equations.

Model (1) corresponds to the default specification. For example, consider imputation variables X_1, X_2, and X_3 and complete predictors Z_1 and Z_2. Under the default specification, the individual prediction equations are determined as follows. The most observed variable—say, X_1—is predicted from X_2, X_3, Z_1, and Z_2. The next most observed variable—say, X_2—is predicted from X_3, Z_1, Z_2, and previously imputed X_1. The least observed variable, X_3, is predicted from Z_1, Z_2, and previously imputed X_1 and X_2. (A constant is included in all prediction equations, by default.) We use the following notation to refer to the above sequence of prediction equations (imputation sequence): $X_1|\mathbf{X}_{-1}, Z_1, Z_2 \rightarrow X_2|\mathbf{X}_{-2}, Z_1, Z_2 \rightarrow X_3|\mathbf{X}_{-3}, Z_1, Z_2$, where $\mathbf{X}_{-j}$ denotes all imputed or to-be-imputed variables except X_j.

A sequence such as $X_1|\mathbf{X}_{-1}, Z_1 \rightarrow X_2|\mathbf{X}_{-2}, Z_1, Z_2 \rightarrow X_3|\mathbf{X}_{-3}, Z_2$ would correspond to a custom specification. Here X_1 is assumed to be conditionally independent of Z_2 given $\mathbf{X}_{-1}$ and Z_1, and X_3 is assumed to be conditionally independent of Z_1 given $\mathbf{X}_{-3}$ and Z_2.

Compatibility of conditionals

A concern with MICE is its lack of a formal theoretical justification. Its theoretical weakness is possible incompatibility of fully conditional specifications (1). As we briefly mentioned earlier, it is possible to specify a set of full conditionals with MICE for which no multivariate distribution exists (for example, van Buuren et al. [2006] and van Buuren [2007]). In such a case, the validity of MICE as a statistical procedure is questionable.

The impact of incompatibility of conditional specifications in practice is still under investigation. For example, van Buuren et al. (2006) performed several simulations to investigate the consequences of strongly incompatible specifications on multiple-imputation (MI) results in a simple setting and found very little impact of it on estimated parameters. The effect of incompatible conditionals on the quality of imputations and final MI inference in general is not yet known. Of course, if a joint model is of main scientific interest, then incompatibility of conditionals poses a problem. In the discussion of Arnold, Castillo, and Sarabia (2001), Andrew Gelman and Trivellore Raghunathan mention that the existence of an underlying joint distribution may be less important within the imputation context than the ability to incorporate the unique features of the data.

For more information about the compatibility of conditional specifications, see Arnold, Castillo, and Sarabia (2001); van Buuren (2007); and Arnold, Castillo, and Sarabia (1999) and references therein.

Convergence of MICE

MICE is an iterative method and is similar in spirit to the Gibbs sampler, an MCMC method. Similarly to MCMC methods, MICE builds a sequence of draws $\{\mathbf{X}_m^{(t)} : t = 1, 2, \dots\}$, a chain, and iterates until this chain reaches a stationary distribution. So as with any MCMC method, monitoring convergence is important with MICE.

MICE performs simulation by running multiple independent chains (see *Convergence of iterative methods* in [MI] **mi impute**). To assess convergence of multiple chains, we need to examine the stationarity of each chain by the end of the specified burn-in period b. In practice, convergence of MICE is often examined visually. Trace plots—plots of summaries of the distribution (means, standard deviations, quantiles,

etc.) of imputed values against iteration numbers—are used to examine stationarity of the chain. Long-term trends in trace plots are indicative of slow convergence to stationarity. A suitable value for the burn-in period b can be inferred from a trace plot as the earliest iteration after which each chain does not exhibit a visible trend and the fluctuations in values become more regular. When the initial values are close to the mode of the target posterior distribution (when one exists), b will generally be small. When the initial values are far off in the tails of the posterior distribution, the initial number of iterations b will generally be larger.

The number of iterations necessary for MICE to converge depends on, among other things, the fractions of missing information and initial values. The higher the fractions of missing information and the farther the initial values are from the mode of the posterior predictive distribution of missing data, the slower the convergence, and thus the larger the number of iterations required. Current literature suggests that in many practical applications a low number of burn-in iterations, somewhere between 5 and 20 iterations, is usually sufficient for convergence (for example, van Buuren [2007]). In any case, examination of the data and missing-data patterns is highly recommended when investigating convergence of MICE.

The convergence of MICE may not be achieved when specified conditional models are incompatible, as described in *Compatibility of conditionals*. The simulation draws will depend on the order in which variables are imputed and on the chosen length of the burn-in period. It is important to evaluate the quality of imputations (see *Imputation diagnostics* in [MI] **mi impute**) to determine the impact of incompatibility on MI analysis.

First use

Before we describe various uses of `mi impute chained`, let's look at a simple example first.

Consider the heart attack data example examining the relationship between heart attacks and smoking from *Multivariate imputation* of [MI] **mi impute**, where the `age` and `bmi` variables contain missing values. In another version of the dataset, `bmi` and `age` have a nonmonotone missing-data pattern, and thus monotone imputation is not possible:

```
. use https://www.stata-press.com/data/r19/mheart8s0
(Fictional heart attack data; arbitrary pattern)
. mi misstable patterns, frequency
   Missing-value patterns
     (1 means complete)

                 |  Pattern
   Frequency     |  1  2
-----------------+------
         118     |  1  1
          24     |  1  0
           8     |  0  1
           4     |  0  0
-----------------+------
         154     |
Variables are  (1) age  (2) bmi
```

`mi impute chained` does not require missing data to be monotone, so we can use it to impute missing values of `age` and `bmi` in this dataset. We use the same model specification as before:

```
. mi impute chained (regress) bmi age = attack smokes hsgrad female, add(10)
Conditional models:
               age: regress age bmi attack smokes hsgrad female
               bmi: regress bmi age attack smokes hsgrad female
Performing chained iterations ...
Multivariate imputation                     Imputations =       10
Chained equations                                 added =       10
Imputed: m=1 through m=10                       updated =        0
Initialization: monotone                     Iterations =      100
                                                burn-in =       10
               bmi: linear regression
               age: linear regression
```

Variable	Observations per *m*			
	Complete	Incomplete	Imputed	Total
bmi	126	28	28	154
age	142	12	12	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

As before, 10 imputations are created (the `add(10)` option). The linear regression imputation method (`regress`) is used to impute both continuous variables. The `attack`, `smokes`, `hsgrad`, and `female` variables are used as complete predictors (independent variables).

`mi impute chained` reports the conditional specifications used to impute each variable and the order in which they were imputed. By default, `mi impute chained` imputes variables in order from the most observed to the least observed. In our example, `age` has the least number of missing values and so is imputed first, even though we listed `bmi` before `age` in the command specification.

With the default specification, `mi impute chained` builds appropriate FCSs automatically using the supplied imputation variables and complete predictors, specified as right-hand-side variables. The default prediction equation for `age` includes `bmi` and all the complete predictors, and the default prediction equation for `bmi` includes `age` and all the complete predictors.

The main header and table output were described in detail in [MI] **mi impute**. The information specific to `mi impute chained` includes the type of initialization, the burn-in period, and the number of iterations. By default, `mi impute chained` uses 10 burn-in iterations (also referred to as cycles in the literature) before drawing imputed values. The total number of iterations performed by `mi impute chained` to obtain 10 imputations is 100. Also, similarly to `mi impute monotone`, the additional information above the table includes the legend describing what univariate imputation method was used to impute each variable. (If desired, this legend may be suppressed by specifying the `nolegend` option.)

Using mi impute chained

Below we summarize general capabilities of `mi impute chained`.

1. `mi impute chained` offers two main syntaxes—one using the default prediction equations and the other allowing customization of prediction equations. We will refer to the two syntaxes as default and custom, respectively. We describe the two syntaxes in detail in the next two sections.

2. `mi impute chained` allows specification of a global (outer) `if` condition,

   ```
   . mi impute chained ... if exp ...
   ```

   and equation-specific (inner) `if` conditions,

   ```
   . mi impute chained ... (... if exp ...) ...
   ```

   A global `if` is applied to all equations. You may combine global and equation-specific `if` conditions:

   ```
   . mi impute chained ... (... if exp ...) ... if exp ...
   ```

3. `mi impute chained` allows specification of global weights, which are applied to all equations:

   ```
   . mi impute chained ... [weight] ...
   ```

4. `mi impute chained` uses fully specified prediction equations by default. Customize prediction equations by including or omitting desired terms:

   ```
   . mi imp chain (... , include(z3) ...) (..., omit(z1) ...) ...
   ```

5. `mi impute chained` automatically includes appropriate imputation variables in prediction equations. Use a global `noimputed` option to prevent inclusion of imputation variables in all prediction equations:

   ```
   . mi impute chained ..., noimputed ...
   ```

   Or use an equation-specific `noimputed` option to prevent inclusion of imputation variables in only some prediction equations:

   ```
   . mi impute chained ... (..., noimputed ...) ...
   ```

As we mentioned earlier, `mi impute chained` is an iterative imputation method. By default, it performs 10 burn-in iterations for each imputation before drawing the final set of imputed values. The number of iterations is determined by the length of the burn-in period after which a random sequence (chain) is assumed to converge to its stationary distribution. The provided default may not be applicable to all situations, so you can use the `burnin()` option to modify it.

Use the `chainonly` and `savetrace()` options to determine the appropriate burn-in period. For example,

```
. mi impute chained ..., burnin(100) chainonly savetrace(impstats) ...
```

saves summaries of imputed values from 100 iterations for each of the imputation variables to `impstats.dta` without proceeding to impute data. You can apply techniques from *Convergence of MICE* to the data in `impstats.dta` to determine an adequate burn-in period.

Use a combination of the `dryrun` and `report` options to check the specification of each univariate imputation model prior to imputing data.

In the next two sections, we describe the use of `mi impute chained` first using hypothetical situations and then using real examples.

Default prediction equations

We showed in *First use* an example of `mi impute chained` with default prediction equations using the heart attack data. Here we provide more details about this default specification.

By default, `mi impute chained` imputes missing values by using the default prediction equations. It builds the corresponding univariate imputation models based on the supplied information: *uvmethod*, the imputation method; *ivars*, the imputation variables; and *indepvars*, the complete predictors or independent variables.

Suppose that continuous variables `x1`, `x2`, and `x3` contain missing values and are ordered from the most observed to the least observed. We want to impute these variables, and we decide to use the same univariate imputation method, say, linear regression, for all. We can do this by typing

```
. mi impute chained (regress) x1 x2 x3 ...
```

The above command corresponds to the first syntax diagram of `mi impute chained`: *uvmethod* is `regress` and *ivars* is `x1 x2 x3`. Relating the above to the model notation used in (1), g_1, g_2, g_3 represent linear regression imputation models and the prediction sequence is $X_1|X_2, X_3 \rightarrow X_2|X_1, X_3 \rightarrow X_3|X_1, X_2$.

By default, `mi impute chained` imputes variables in order from the most observed to the least observed, regardless of the order in which variables were specified. For example, we can list imputation variables in the reverse order,

```
. mi impute chained (regress) x3 x2 x1 ...
```

and `mi impute chained` will still impute `x1` first, `x2` second, and `x3` last. You can use the `orderasis` option to instruct `mi impute chained` to perform imputation of variables in the specified order.

If we have additional covariates containing no missing values (say, `z1` and `z2`) that we want to include in the imputation model, we can do so by typing

```
. mi impute chained (regress) x1 x2 x3 = z1 z2 ...
```

Now *indepvars* is `z1 z2` and the prediction sequence is $X_1|X_2, X_3, Z_1, Z_2 \rightarrow X_2|X_1, X_3, Z_1, Z_2 \rightarrow X_3|X_1, X_2, Z_1, Z_2$. Independent variables are included in the prediction equations of all univariate models.

Suppose that we want to use a different imputation method for one of the variables—we want to impute `x3` using predictive mean matching. We can do this by typing

```
. mi impute chained (regress) x1 x2 (pmm, knn(5)) x3  = z1 z2 ...
```

The above corresponds to the second syntax diagram of `mi impute chained`, a generalization of the first that accommodates differing imputation methods. The right-hand side of the equation is unchanged. `z1` and `z2` are included in all three prediction equations. The left-hand side now has two specifications: `(regress) x1 x2` and `(pmm, knn(5)) x3`. In previous examples, we had only one left-hand-side specification, *lhs_spec*—`(regress) x1 x2 x3`. (The number of left-hand-side specifications does not necessarily correspond to the number of univariate models; the latter is determined by the number of imputation variables.) In this example, `x1` and `x2` are imputed using linear regression, and `x3` is imputed using predictive mean matching with five nearest neighbors specified in `pmm`'s option `knn()`. All method-specific options must be specified within the parentheses surrounding the method.

Suppose now we want to restrict the imputation sample for `x2` to observations where `z1` is one; also see *Imputing on subsamples* of [MI] **mi impute**. The corresponding syntax is

```
. mi impute chained (regress) x1 (regress if z1==1) x2 (pmm, knn(5))
> x3  = z1 z2 ...
```

If, in addition to the above, we want to impute all variables using an overall subsample where z3 is one, we can specify the global if z3==1 condition:

```
. mi impute chained (regress) x1 (regress if z1==1) x2 (pmm, knn(5))
> x3  = z1 z2 if z3==1 ...
```

In the above, restrictions included only complete variables. When restrictions include imputation variables, you should use the conditional() option instead of an if condition; see *Conditional imputation* in [MI] **mi impute**. Suppose that we need to impute x2 using only observations for which x1 is positive, provided that missing values of x1 are nested within missing values of x2. We can do this by typing

```
. mi impute chained (regress) x1 (regress, cond(if x1>0)) x2 (pmm, knn(5)) x3
> = z1 z2 ...
```

When any imputation variable is imputed using a categorical method (logit, ologit, or mlogit), mi impute chained automatically includes it as a factor variable in the prediction equations of other imputation variables. Suppose that x1 is a categorical variable and is imputed using the multinomial logistic method:

```
. mi impute chained (mlogit) x1 (regress) x2 x3 ...
```

The above will result in the prediction sequence $X_1|X_2, X_3 \rightarrow X_2|\mathtt{i}.X_1, X_3 \rightarrow X_3|\mathtt{i}.X_1, X_2$ where $\mathtt{i}.X_1$ denotes the factors of X_1.

If you wish to include a factor variable as continuous in prediction equations, you can use the ascontinuous option within the specification of the univariate imputation method for that variable:

```
. mi impute chained (mlogit, ascontinuous) x1 (regress) x2 x3 ...
```

As we discussed in *The issue of perfect prediction during imputation of categorical data* of [MI] **mi impute**, perfect prediction often occurs during imputation of categorical variables. One way of dealing with it is to use the augmented-regression approach (White, Daniel, and Royston 2010), available through the augment option. For example, if perfect prediction occurs during imputation of x1 in the above, you can specify augment within the method specification of x1 to perform augmented regression:

```
. mi impute chained (mlogit, augment) x1 (regress) x2 x3 ...
```

Alternatively, you can use the augment option with mi impute chained to perform augmented regression for all categorical variables for which the issue of perfect prediction arises:

```
. mi impute chained (mlogit) x1 (logit) x2 (regress) x3 ..., augment ...
```

The above is equivalent to specifying augment within each specification of a univariate categorical imputation method:

```
. mi impute chained (mlogit, augment) x1 (logit, augment) x2 (regress) x3 ...
```

Custom prediction equations

In the previous section, we considered various uses of mi impute chained with default prediction equations. Often, however, you may want to use different prediction equations for some or even all imputation variables. We can easily modify the above specifications to accommodate this.

Let's consider situations in which we want to use different sets of complete variables for some imputation variables first. Recall our following hypothetical example:

```
. mi impute chained (regress) x1 x2 x3 = z1 z2 ...                    (M1)
```

Suppose that we want to omit z2 from the prediction equation for x3. To accommodate this, we need to include two separate specifications: one for x1 and x2 and one for x3:

```
. mi impute chained (regress) x1 x2 (regress, omit(z2)) x3  = z1 z2 ...
```

The above corresponds to the custom specification, the third syntax diagram, of mi impute chained. As before, we list all the complete variables *indepvars* to be included in all prediction equations to the right of the = sign. So, *indepvars* is still z1 z2. The prediction equation for x3, however, omits variable z2, specified within the omit() option. The prediction sequence for the above specification is $X_1|X_2, X_3, Z_1, Z_2 \rightarrow X_2|X_1, X_3, Z_1, Z_2 \rightarrow X_3|X_1, X_2, Z_1$.

Alternatively, we could have achieved the above by including variable z1 in all prediction equations, as a right-hand-side specification *indepvars*, and using the include() option to add variable z2 to the prediction equations of x1 and x2:

```
. mi impute chained (regress, include(z2)) x1 x2 (regress) x3  = z1 ...
```

You may also want to modify the sets of imputation variables to be included in prediction equations. By default, mi impute chained automatically includes the appropriate fully conditional specifications of imputation variables in all prediction equations.

Suppose that in addition to different sets of complete predictors, we assume that X_1 and X_2 are conditionally independent given X_3, which implies that prediction equations for x1 and x2 include only x3 and not each other. We can accommodate this with the command

```
. mi impute chained (regress, include(x3 z2) noimputed) x1 x2 (regress)    ///
            x3  = z1 ...
```

which corresponds to the prediction sequence $X_1|X_3, Z_1, Z_2 \rightarrow X_2|X_3, Z_1, Z_2 \rightarrow X_3|X_1, X_2, Z_1$.

The above is also equivalent to the command

```
. mi impute chained (regress, omit(x1 x2)) x1 x2 (regress, omit(z2))      ///
            x3  = z1 z2 ...
```

There are other equivalent ways of achieving the above custom specifications by using various combinations of include(), omit(), and noimputed. The most convenient specification will depend on your particular structure of the prediction equations. You can also combine these options within the same univariate specification.

It is important to realize that equivalent syntaxes may produce different (yet equivalent with stable imputation models) sequences of imputed values when they have different ordering of variables in prediction equations. mi impute chained builds prediction equations as follows. Appropriate imputation variables are included first, unless the noimputed option is specified. By default, imputation variables are included in order from the most observed to the least observed. If the orderasis option is used, the variables are included in the specified order. Next, terms specified in the include() option are included in the listed order. Then right-hand-side variables (*indepvars*) are included in the listed order. Finally, variables listed in the omit() option are removed from the prediction equation. When you specify omit(), it is important to specify variables as they are included in the prediction equation; if x1 is included as a factor variable, omit(i.x1) should be used.

You can also include functions of imputation variables in prediction equations with the custom specification of mi impute chained. As we discussed in *Model building* in [MI] **mi impute**, there are two ways to do that. You can include functions of imputation variables as separate imputation variables directly in your imputation model or you can impute them passively using mi impute chained.

For example, using model (M1), suppose that we would like to include the interaction between x1 and x2 in the conditional model for x3:

```
. mi impute chained (regress) x1 x2                          ///
                    (regress, include((x1*x2))) x3           ///
                                                = z1 z2 ...
```

The expression x1*x2, specified in the include() option, is enclosed in parentheses.

We also could have typed

```
. mi impute chained (regress, include((x1*x2))) x1 x2 x3 = z1 z2 ...
```

and mi impute chained would appropriately include the interaction term X_1X_2 only in the prediction equation of X_3.

You can include any other expressions of imputation variables in include() within any of the left-hand-side specifications. Just remember to enclose such expressions in parentheses.

All the examples we considered in *Default prediction equations* are also applicable to mi impute chained with custom prediction equations. For example, to restrict imputation of x2 to observations where z1==1 in one of our earlier examples, we can type

```
. mi impute chained (reg) x1 (reg if z1==1) x2 (reg, omit(z2)) x3  = z1 z2 ...
```

Link between mi impute chained and mi impute monotone

Similarly to mi impute monotone (see [MI] **mi impute monotone**), mi impute chained uses a sequence of univariate imputation models to impute variables. So the use of mi impute chained is very similar to that of mi impute monotone except:

1. mi impute chained does not require that the specified imputation variables follow a monotone-missing pattern.
2. mi impute chained requires iteration to accommodate arbitrary missing-data patterns.
3. mi impute chained, by default, uses FCSs of the prediction equations where all specified complete variables and all imputation variables except the one being imputed are included in prediction equations.
4. mi impute chained provides an alternative way of specifying custom prediction equations to accommodate FCS of imputation variables.

When a missing-value pattern is monotone, mi impute chained defaults to the monotone method (unless nomonotone is specified) and produces the same results as mi impute monotone. However, using mi impute monotone in this case is faster because it performs the estimation step only once, on the original data, whereas mi impute chained performs estimation on every chained iteration.

The best approach to follow is

1. Check the missing-data pattern using misstable nested (or mi misstable nested if the data are already mi set; see [R] **misstable** or [MI] **mi misstable**) first.
2. If the missing-data pattern is monotone, use mi impute monotone to impute variables. If the missing-data pattern is not monotone, use mi impute chained to impute variables.

It is worth mentioning the difference between the documented custom syntaxes of mi impute chained and mi impute monotone.

With monotone imputation, variables are imputed in a particular, monotone-missing order and prediction equations are built in a particular way: previously imputed variables are added sequentially to the prediction equations of other imputation variables. So when building custom prediction equations, it is easier to construct one equation at a time in the order of the monotone missing pattern. As such, the custom syntax of `mi impute monotone`, as documented in [MI] **mi impute monotone**, requires full specification of a separate conditional model for each imputation variable in the monotone-missing order.

Imputation using chained equations does not require specific ordering in which variables must be imputed, although imputing variables in order from the most observed to the least observed usually leads to faster convergence. Also, because all imputation variables except the one being imputed are included in prediction equations, it does not matter in what order prediction equations are specified. The custom syntax of `mi impute chained` reflects this.

Examples

For the purpose of illustration, we use five imputations in our examples.

▷ Example 1: Different imputation methods

Recall the heart attack example from *First use*. If we wanted to impute `bmi` using predictive mean matching with, say, three nearest neighbors instead of linear regression, we could type

```
. use https://www.stata-press.com/data/r19/mheart8s0, clear
(Fictional heart attack data; arbitrary pattern)
. mi impute chained (pmm, knn(3)) bmi (reg) age = attack smokes hsgrad female,
> add(5)
Conditional models:
               age: regress age bmi attack smokes hsgrad female
               bmi: pmm bmi age attack smokes hsgrad female, knn(3)
Performing chained iterations ...
Multivariate imputation                     Imputations =        5
Chained equations                                 added =        5
Imputed: m=1 through m=5                        updated =        0
Initialization: monotone                     Iterations =       50
                                                burn-in =       10
               bmi: predictive mean matching
               age: linear regression
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
bmi	126	28	28	154
age	142	12	12	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

As shown previously, `mi impute chained` imputed `age` first and `bmi` second, because `age` is the variable with the fewest missing values.

◁

Example 2: Convergence of MICE

In *Convergence of MICE*, we described ways to assess convergence of the MICE algorithm. Continuing our previous example, let's investigate the trends in the summaries of imputed values of age and bmi over iterations.

Following the recommendation from *Using mi impute chained*, we use a combination of chainonly and savetrace() to perform chained iterations without creating imputations in the data and save summaries of imputed values to the new dataset impstats.dta. We perform 100 iterations and specify a random-number seed for reproducibility:

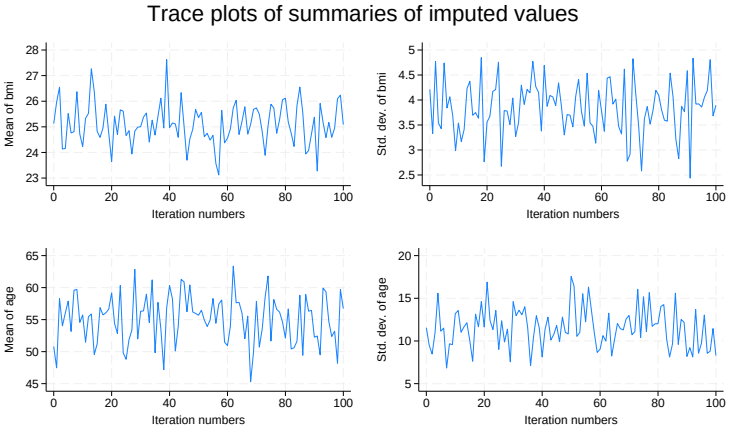
```
. use https://www.stata-press.com/data/r19/mheart8s0, clear
(Fictional heart attack data; arbitrary pattern)
. mi impute chained (pmm, knn(3)) bmi (reg) age = attack smokes hsgrad female,
> chainonly burnin(100) savetrace(impstats) rseed(1359)
Conditional models:
               age: regress age bmi attack smokes hsgrad female
               bmi: pmm bmi age attack smokes hsgrad female, knn(3)
Performing chained iterations ...
Note: No imputation performed.
```

By default, means and standard deviations of imputed values for each imputation variable are saved along with iteration and imputation numbers (imputation number is always 0 when chainonly is used):

```
. use impstats
(Summaries of imputed values from -mi impute chained-)
. describe
Contains data from impstats.dta
 Observations:           101                  Summaries of imputed values
                                                from -mi impute chained-
    Variables:             6                  4 Mar 2025 08:51
-------------------------------------------------------------------------------
Variable      Storage   Display    Value
    name         type    format    label      Variable label
-------------------------------------------------------------------------------
iter            byte    %12.0g                Iteration numbers
m               byte    %12.0g                Imputation numbers
age_mean        float   %9.0g                 Mean of age
age_sd          float   %9.0g                 Std. dev. of age
bmi_mean        float   %9.0g                 Mean of bmi
bmi_sd          float   %9.0g                 Std. dev. of bmi
-------------------------------------------------------------------------------
Sorted by:
```

We use the time-series command tsline (see [TS] **tsline**) to plot summaries of imputed values with respect to the iteration number. We first use tsset to set iter as the "time" variable and then use tsline to obtain trace plots. We create trace plots for all variables and combine them in one graph using graph combine:

```
. tsset iter
Time variable: iter, 0 to 100
        Delta: 1 unit
. tsline bmi_mean, name(gr1) nodraw
. tsline bmi_sd, name(gr2) nodraw
. tsline age_mean, name(gr3) nodraw
. tsline age_sd, name(gr4) nodraw
. graph combine gr1 gr2 gr3 gr4, title(Trace plots of summaries of imputed values)
> rows(2)
```



The trace plots show no apparent trends in the summaries of the imputed values, so the default number of burn-in iterations, 10, seems adequate. Although a low number of burn-in iterations may be sufficient in some applications, there are situations when larger numbers are required (for example, van Buuren [2007]).

It is also useful to look at several chains, each obtained using a different set of initial values, to check convergence and stability of the algorithm.

Let's look at three separate chains. The easiest way to do this is to use the `add()` option instead of `chainonly` to create three imputations. Remember that `mi impute chained` starts a new chain for each imputation, so a different set of initial values is used for each imputation. When `savetrace()` is specified, `mi impute chained` saves summaries of imputed values for each imputation.

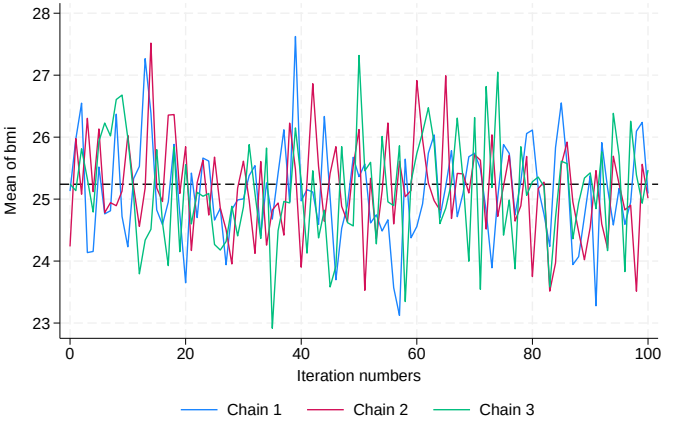
```
. use https://www.stata-press.com/data/r19/mheart8s0
(Fictional heart attack data; arbitrary pattern)
. quietly mi impute chained (pmm, knn(3)) bmi (reg) age = attack smokes hsgrad
> female, add(3) burnin(100) savetrace(impstats, replace) rseed(1359)
```

The results are saved in a long form. If we want to overlay separate chains in one graph, we need to convert our data to a wide form first—one variable per chain. We use the `reshape` command for this (see [D] **reshape**):

```
. use impstats, clear
(Summaries of imputed values from -mi impute chained-)
. reshape wide *mean *sd, i(iter) j(m)
(j = 1 2 3)
Data                                Long   ->   Wide
-----------------------------------------------------------------------------
Number of observations               303   ->   101
Number of variables                    6   ->   13
j variable (3 values)                  m   ->   (dropped)
xij variables:
                                 age_mean   ->   age_mean1 age_mean2 age_mean3
                                 bmi_mean   ->   bmi_mean1 bmi_mean2 bmi_mean3
                                   age_sd   ->   age_sd1 age_sd2 age_sd3
                                   bmi_sd   ->   bmi_sd1 bmi_sd2 bmi_sd3
-----------------------------------------------------------------------------
```

We can now plot the three chains for, say, the mean of `bmi` using `tsline`:

```
. tsset iter
Time variable: iter, 0 to 100
        Delta: 1 unit
. tsline bmi_mean1 bmi_mean2 bmi_mean3, ytitle(Mean of bmi) yline(25.24)
> legend(rows(1) label(1 "Chain 1") label(2 "Chain 2") label(3 "Chain 3"))
```



There are no apparent trends in any of the chains. All three chains seem to oscillate around the observed mean estimate of `bmi` of 25.24, providing some evidence of convergence of the algorithm.

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▷ Example 3: Custom prediction equations

Continuing example 1, we believe that there is no association between bmi and hsgrad conditional on other predictors, so we want to use hsgrad to model only age and omit it from the model for bmi:

```
. use https://www.stata-press.com/data/r19/mheart8s0, clear
(Fictional heart attack data; arbitrary pattern)
. mi impute chained
>   (pmm, knn(3) omit(hsgrad)) bmi
>   (regress)                  age
>                                  = attack smokes hsgrad female, add(5)
Conditional models:
               age: regress age bmi attack smokes hsgrad female
               bmi: pmm bmi age attack smokes female, knn(3)
Performing chained iterations ...
Multivariate imputation                     Imputations =        5
Chained equations                                 added =        5
Imputed: m=1 through m=5                        updated =        0
Initialization: monotone                     Iterations =       50
                                                burn-in =       10
               bmi: predictive mean matching
               age: linear regression
```

Variable	Observations per *m*			
	Complete	Incomplete	Imputed	Total
bmi	126	28	28	154
age	142	12	12	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

All right-hand-side complete predictors (attack, smokes, and female) are used in both prediction equations. The prediction equation for age additionally includes the hsgrad variable.

◁

▷ Example 4: Imputing variables of different types

We now consider an `mi set` version of the heart attack data containing an indicator for smoking high-tar cigarettes (variable `hightar`):

```
. use https://www.stata-press.com/data/r19/mheart9s0, clear
(Fictional heart attack data; bmi, age, and hightar missing; arbitrary pattern)
. mi describe
Style: mlong
       last mi update 04feb2025 12:58:57, 11 days ago
Observations:
   Complete            98
   Incomplete          56  (M = 0 imputations)
   ──────────────────────
   Total              154
Variables:
   Imputed: 3; bmi(24) age(30) hightar(12)
   Passive: 0
   Regular: 4; attack smokes female hsgrad
   System:  3; _mi_m _mi_id _mi_miss
   (there are no unregistered variables)
. mi misstable nested
     1.  hightar(12)
     2.  bmi(24)
     3.  age(30)
```

According to `mi describe`, there are no imputations, three registered imputed variables (`age`, `bmi`, and `hightar`), and four registered regular variables. `mi misstable nested` reports that missing values of the three imputation variables are not nested.

The `hightar` variable is a binary variable, so we choose the logistic method to impute its values (see [MI] **mi impute logit**). Because `hightar` records whether a subject smokes high-tar cigarettes, we use only those who smoke to impute its missing values. As such, including `smokes` as a predictor of `hightar` is redundant, so we omit this variable from the prediction equation for `hightar`:

```
. mi impute chained
>   (pmm, knn(3) omit(hsgrad))           bmi
>   (regress)                            age
>   (logit if smokes==1, omit(smokes)) hightar
>                                        = attack smokes hsgrad female, add(5)
Conditional models:
           hightar: logit hightar bmi age attack hsgrad female if smokes==1
               bmi: pmm bmi i.hightar age attack smokes female, knn(3)
               age: regress age i.hightar bmi attack smokes hsgrad female
Performing chained iterations ...
Multivariate imputation                     Imputations =        5
Chained equations                                 added =        5
Imputed: m=1 through m=5                        updated =        0
Initialization: monotone                     Iterations =       50
                                                burn-in =       10
               bmi: predictive mean matching
               age: linear regression
           hightar: logistic regression
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
bmi	130	24	24	154
age	124	30	30	154
hightar	52	12	12	64

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

From the output, we see that all incomplete values of each of the variables are imputed in all imputations. Because we restricted the imputation sample of `hightar` to smokers, the total number of observations reported for `hightar` is 64 and not 154. `mi impute chained` also automatically included the binary variable `hightar` as a factor variable in prediction equations for `age` and `bmi` because we used `logit` to impute it.

As we described in *Conditional imputation*, you should be careful when using an `if` statement for imputing variables conditionally on other variables. It was safe to use `if` here, because `smokes` did not contain missing values and there were no missing values of `hightar` for the subjects who do not smoke.

◁

▷ Example 5: Conditional imputation

Continuing example 4, suppose now that the smokes variable also contains missing values:

```
. use https://www.stata-press.com/data/r19/mheart10s0, clear
(Fict. heart attack data; bmi, age, hightar, & smokes missing; arbitrary pattern)
. mi describe
Style: mlong
       last mi update 04feb2025 12:58:57, 11 days ago
Observations:
   Complete            92
   Incomplete          62  (M = 0 imputations)
   ----------------------
   Total              154
Variables:
   Imputed: 4; bmi(24) age(30) hightar(19) smokes(14)
   Passive: 0
   Regular: 3; attack female hsgrad
   System:  3; _mi_m _mi_id _mi_miss
   (there are no unregistered variables)
. mi misstable nested
     1.  smokes(14) -> hightar(19)
     2.  bmi(24)
     3.  age(30)
```

The smokes variable is now registered as imputed and the three regular variables are now attack, female, and hsgrad. mi misstable nested reports that although the missing-data pattern with respect to all four imputation variables is not monotone, the missing-data pattern with respect to smokes and hightar is monotone. Recall from *Conditional imputation* that one of the requirements of conditional imputation is that missing values of all conditioning variables (smokes) are nested within missing values of the conditional variable (hightar). So this requirement is satisfied in our data.

Because smokes contains missing values, we cannot use an if condition to restrict the imputation sample of hightar to those who smoke. We must use the conditional() option. We use the logistic method (see [MI] **mi impute logit**) to fill in missing values of smokes.

```
. mi impute chained
>   (pmm, knn(3) omit(hsgrad))                bmi
>   (regress)                                 age
>   (logit, cond(if smokes==1) omit(i.smokes)) hightar
>   (logit)                                   smokes
>                                            = attack hsgrad female, add(5)

Conditional models:
            smokes: logit smokes bmi age attack hsgrad female
          hightar: logit hightar bmi age attack hsgrad female,
                     cond(if smokes==1)
              bmi: pmm bmi i.smokes i.hightar age attack female, knn(3)
              age: regress age i.smokes i.hightar bmi attack hsgrad female

Performing chained iterations ...

Multivariate imputation                     Imputations =        5
Chained equations                                 added =        5
Imputed: m=1 through m=5                        updated =        0

Initialization: monotone                     Iterations =       50
                                                burn-in =       10

Conditional imputation:
  hightar: incomplete out-of-sample obs replaced with value 0
              bmi: predictive mean matching
              age: linear regression
          hightar: logistic regression
           smokes: logistic regression
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
bmi	130	24	24	154
age	124	30	30	154
hightar	135	19	19	154
smokes	140	14	14	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

With conditional imputation, a legend appears before the imputation table, reporting the conditional constant, the value that was used to replace all incomplete values of an imputation variable outside the conditional sample. The missing values of `hightar` in that sample were replaced with 0.

The `smokes` variable is imputed using `logit` and thus is included in prediction equations as a factor variable, `i.smokes`. As such, we specified `omit(i.smokes)` to omit `smokes` from the prediction equation for `hightar`.

Also notice that compared with imputation on a restricted subsample using an `if` condition, the reported total number of observations in the imputation sample for `hightar` is still 154. All incomplete observations, within and outside the conditional sample, are included in the imputation sample during conditional imputation. So the reported numbers of complete, incomplete, and imputed observations correspond with observations within and outside the conditional sample.

◁

▷ Example 6: Including expressions of imputation variables

In *Model building* of [MI] **mi impute**, we described two ways of accommodating functional relationships during imputation. Here we demonstrate a passive imputation approach that includes expressions of imputation variables directly into the imputation model.

Continuing example 5, suppose we assume that the conditional distribution of bmi exhibits some curvature with respect to age. We want to include age^2 in the prediction equation for bmi. If the relationship between bmi and age is indeed curvilinear, it would be unreasonable to assume that the conditional distribution of age given bmi is linear. One possibility is to determine what the relationship is between age and bmi given other predictors in the observed data (see, for example, [R] **mfp**) and include the appropriate functional terms of bmi in the prediction equation for age. Following White, Royston, and Wood (2011) to relax the linearity assumption, we use predictive mean matching with, say, five nearest neighbors instead of linear regression to impute age:

```
. mi impute chained
>   (pmm, knn(3) omit(hsgrad) incl((age^2)))   bmi
>   (pmm, knn(5))                              age
>   (logit, cond(if smokes==1) omit(i.smokes)) hightar
>   (logit)                                    smokes
>                                        = attack hsgrad female, replace

Conditional models:
            smokes: logit smokes bmi age attack hsgrad female
           hightar: logit hightar bmi age attack hsgrad female,
                      cond(if smokes==1)
               bmi: pmm bmi i.smokes i.hightar age (age^2)
                      attack female, knn(3)
               age: pmm age i.smokes i.hightar bmi attack hsgrad
                      female, knn(5)

Performing chained iterations ...

Multivariate imputation                     Imputations =        5
Chained equations                                 added =        0
Imputed: m=1 through m=5                        updated =        5

Initialization: monotone                     Iterations =       50
                                                burn-in =       10

Conditional imputation:
  hightar: incomplete out-of-sample obs replaced with value 0

               bmi: predictive mean matching
               age: predictive mean matching
           hightar: logistic regression
            smokes: logistic regression
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
bmi	130	24	24	154
age	124	30	30	154
hightar	135	19	19	154
smokes	140	14	14	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

We included the expression term in parentheses in the include() option in the prediction equation for bmi.

◁

Example 7: Imputing on subsamples

Suppose that in our primary logistic analysis of heart attacks, we are planning to investigate various interaction effects with respect to gender. The `female` variable is complete, so the best way to accommodate such interactions is to use the `by()` option to perform imputation separately for females and males.

We continue example 3. Before imputing missing values, let's review our conditional specifications for each group. We can use the `dryrun` option to see univariate conditional models that will be used during imputation without actually imputing data:

```
. use https://www.stata-press.com/data/r19/mheart8s0, clear
(Fictional heart attack data; arbitrary pattern)

. mi impute chained
>   (pmm, knn(3) omit(hsgrad)) bmi
>   (regress)                  age
>                                  = attack smokes hsgrad, by(female) dryrun

Performing setup for each by() group:

-> female = 0
Conditional models:
               age: regress age bmi attack smokes hsgrad
               bmi: pmm bmi age attack smokes, knn(3)

-> female = 1
Conditional models:
               age: regress age bmi attack smokes hsgrad
               bmi: pmm bmi age attack smokes, knn(3)
```

Conditional specifications are as we expected, so we can proceed to imputation.

```
. mi impute chained
>   (pmm, knn(3) omit(hsgrad)) bmi
>   (regress)                  age
>                                = attack smokes hsgrad
>                                             , add(5) by(female, noreport) dots

-> female = 0
Performing chained iterations:
  imputing m=1 through m=5 ..... done

-> female = 1
Performing chained iterations:
  imputing m=1 through m=5 ..... done

Multivariate imputation                     Imputations =        5
Chained equations                                 added =        5
Imputed: m=1 through m=5                        updated =        0

Initialization: monotone                     Iterations =       50
                                                burn-in =       10

               bmi: predictive mean matching
               age: linear regression
```

by() Variable	Observations per *m*			
	Complete	Incomplete	Imputed	Total
female = 0				
bmi	95	21	21	116
age	106	10	10	116
female = 1				
bmi	31	7	7	38
age	36	2	2	38
Overall				
bmi	126	28	28	154
age	142	12	12	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

To avoid longer output, we specified the `noreport` option within `by()` to suppress information about the setup and imputation steps that otherwise would have been reported for each group.

◁

Stored results

`mi impute chained` stores the following in `r()`:

Scalars

`r(M)`	total number of imputations
`r(M_add)`	number of added imputations
`r(M_update)`	number of updated imputations
`r(k_ivars)`	number of imputed variables
`r(burnin)`	number of burn-in iterations
`r(N_g)`	number of imputed groups (`1` if `by()` is not specified)

Macros

`r(method)`	name of imputation method (`chained`)
`r(ivars)`	names of imputation variables
`r(uvmethods)`	names of univariate imputation methods
`r(init)`	type of initialization
`r(rngstate)`	random-number state used
`r(by)`	names of variables specified within `by()`

Matrices

`r(N)`	number of observations in imputation sample in each group (per variable)
`r(N_complete)`	number of complete observations in imputation sample in each group (per variable)
`r(N_incomplete)`	number of incomplete observations in imputation sample in each group (per variable)
`r(N_imputed)`	number of imputed observations in imputation sample in each group (per variable)

Methods and formulas

Let $X_1, X_2, \ldots, X_p$ denote imputation variables ordered from the most observed to the least observed and let $\mathbf{Z}$ denote the set of complete independent variables. (If $X_1, X_2, \ldots, X_p$ are monotone-missing and neither `nomonotone` nor `nomonotonechk` is used, then `mi impute chained` uses monotone imputation; see *Methods and formulas* of [MI] **mi impute monotone** for details.)

With the default specification of prediction equations, the chained-equation algorithm proceeds as follows. First, at iteration $t = 0$, missing values are initialized using monotone imputation. That is, missing values of $X_i^{(0)},\ i = 1, \ldots, p$, are simulated from conditional densities of the form

$$f_i(X_i|X_1^{(0)}, X_2^{(0)}, \ldots, X_{i-1}^{(0)}, \mathbf{Z}, \boldsymbol{\theta}_i) \tag{2}$$

where the conditional density $f_i(\cdot)$ is determined according to the chosen univariate imputation method and $\boldsymbol{\theta}_i$ is its corresponding set of parameters with uniform prior; see *Methods and formulas* of chosen univariate imputation methods for details.

At iteration t, missing values of X_i for all $i = 1, \ldots, p$ are simulated from full conditionals, conditional densities of the form:

$$g_i(X_i|X_1^{(t)}, X_2^{(t)}, \ldots, X_{i-1}^{(t)}, X_{i+1}^{(t-1)}, \ldots, X_p^{(t-1)}, \mathbf{Z}, \boldsymbol{\phi}_i) \tag{3}$$

where again the conditional density $g_i(\cdot)$ is determined according to the chosen univariate imputation method and $\boldsymbol{\phi}_i$ is its corresponding set of parameters with uniform prior.

The algorithm iterates for a prespecified number of iterations b, $t = 1, \ldots, b$, and a final set of imputed values is obtained from the last iteration. At each iteration, the imputation process consists of steps 1–3 described in *Methods and formulas* of each respective univariate imputation method's manual entry.

Each imputation is obtained independently by repeating (2) and (3).

Conditional specifications in (2) and (3) correspond to the default specification of prediction equations. With the custom specification, the sets of complete predictors $\mathbf{Z} = \mathbf{Z}_i$ and imputation variables may differ across univariate specifications, and prediction equations may additionally include functions of imputation variables.

In summary, `mi impute chained` follows the steps below to fill in missing values in $X_1, \ldots, X_p$:

1. `mi impute chained` first builds appropriate univariate imputation models using the supplied information about imputation methods, imputation variables $\mathbf{X}$, and complete predictors $\mathbf{Z}$. By default, fully conditional specification of prediction equations is used. The order in which imputation variables are listed is ignored unless the `orderasis` option is used. By default, `mi impute chained` imputes variables in order from the most observed to the least observed.
2. Initialize missing values at $t = 0$ using monotone imputation (2).
3. Perform the iterative procedure (3) for $t = 1, \ldots, b$, for the length of the burn-in period, to obtain imputed values. At each iteration t,
    3.1. Fit a univariate model for X_i to the observed data to obtain the estimates of $\boldsymbol{\phi}_i$. See step 1 in *Methods and formulas* of each respective univariate imputation method's manual entry for details.
    3.2. Fill in missing values of X_i according to the specified imputation model. See step 2 and step 3 in *Methods and formulas* of each respective univariate imputation method's manual entry for details.
    3.3. Repeat steps 3.1 and 3.2 for each imputation variable X_i, $i = 1, \ldots, p$.
4. Repeat steps 2 and 3 to obtain M multiple imputations.

The iterative procedure (3) may not always correspond to a genuine simulation of imputed values from their predictive distribution $f(\mathbf{X}_m|\mathbf{X}_o, \mathbf{Z})$ because the set of full conditionals $\{g_i : i = 1, 2, \ldots, p\}$ may not correspond to this distribution or, in fact, to any proper multivariate distribution. The extent to which this is a problem in practical applications is still an open research problem. Some limited simulation studies reported only minimal effect of such incompatibility on final MI estimates (for example, van Buuren et al. [2006]).

Acknowledgments

The `mi impute chained` command was inspired by the community-contributed command `ice` by Patrick Royston of the MRC Clinical Trials Unit, London, and coauthor of the Stata Press book *Flexible Parametric Survival Analysis Using Stata: Beyond the Cox Model*; and Ian White of the MRC Biostatistics Unit, London. We are indebted to them for their extensive work in the multiple-imputation area in Stata. We are also grateful to them for their comments and advice on `mi impute chained`.

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Also see

[MI] **mi impute** — Impute missing values

[MI] **mi impute monotone** — Impute missing values in monotone data

[MI] **mi impute mvn** — Impute using multivariate normal regression

[MI] **mi estimate** — Estimation using multiple imputations

[MI] **Intro** — Introduction to mi

[MI] **Intro substantive** — Introduction to multiple-imputation analysis

[MI] **Glossary**

mi impute intreg — Impute using interval regression

Description | Menu | Syntax | Options
Remarks and examples | Stored results | Methods and formulas | Reference
Also see

Description

`mi impute intreg` fills in missing values of a continuous partially observed (censored) variable using an interval regression imputation method. You can perform separate imputations on different subsets of the data by using the `by()` option. You can also account for analytic, frequency, importance, and sampling weights.

Menu

Statistics > Multiple imputation

Syntax

`mi impute intreg` *newivar* [*indepvars*] [*if*] [*weight*] [, *impute_options options*]

impute_options	Description
Main	
* `add(#)`	specify number of imputations to add; required when no imputations exist
* `replace`	replace imputed values in existing imputations
`rseed(#)`	specify random-number seed
`double`	store imputed values in double precision; the default is to store them as `float`
`by(`*varlist*[, *byopts*]`)`	impute separately on each group formed by *varlist*
Reporting	
`dots`	display dots as imputations are performed
`noisily`	display intermediate output
`nolegend`	suppress all table legends
Advanced	
`force`	proceed with imputation, even when missing imputed values are encountered
`noupdate`	do not perform `mi update`; see [MI] **noupdate option**

*`add(#)` is required when no imputations exist; `add(#)` or `replace` is required if imputations exist.

`noupdate` does not appear in the dialog box.

options	Description
Main	
noconstant	suppress constant term
* ll(*varname*)	lower limit for interval-censoring
* ul(*varname*)	upper limit for interval-censoring
offset(*varname*)	include *varname* in model with coefficient constrained to 1
conditional(*if*)	perform conditional imputation
bootstrap	estimate model parameters using sampling with replacement
Maximization	
maximize_options	control the maximization process; seldom used

*ll() and ul() are required.

You must mi set your data before using mi impute intreg; see [MI] **mi set**.

indepvars may contain factor variables; see [U] **11.4.3 Factor variables**.

collect is allowed; see [U] **11.1.10 Prefix commands**.

aweights, fweights, iweights, and pweights are allowed; see [U] **11.1.6 weight**.

Options

Main

noconstant; see [R] **Estimation options**.

ll(*varname*) and ul(*varname*) specify variables containing the lower and upper limits for interval-censoring. You must specify both. Nonmissing observations with equal values in ll() and ul() are fully observed observations with missing values in both ll() and ul() are unobserved (missing), and the remaining observations are partially observed (censored). Partially observed cases are left-censored when ll() contains missing, right-censored when ul() contains missing, and interval-censored when ll() < ul(). Fully observed cases are also known as point data; also see *Description* in [R] **intreg**. In addition to *newivar*, mi impute intreg fills in unobserved (missing) values of variables supplied in ll() and ul(); censored values remain unchanged.

add(), replace, rseed(), double, by(); see [MI] **mi impute**.

offset(*varname*); see [R] **Estimation options**.

conditional(*if*) specifies that the imputation variable be imputed conditionally on observations satisfying *exp*; see [U] **11.1.3 if exp**. That is, missing values in a conditional sample, the sample identified by the *exp* expression, are imputed based only on data in that conditional sample. Missing values outside the conditional sample are replaced with a conditional constant, the value of the imputation variable in observations outside the conditional sample. As such, the imputation variable is required to be constant outside the conditional sample. Also, if any conditioning variables (variables involved in the conditional specification if *exp*) contain soft missing values (.), their missing values must be nested within missing values of the imputation variables. See *Conditional imputation* under *Remarks and examples* in [MI] **mi impute**.

bootstrap specifies that posterior estimates of model parameters be obtained using sampling with replacement; that is, posterior estimates are estimated from a bootstrap sample. The default is to sample the estimates from the posterior distribution of model parameters or from the large-sample normal approximation of the posterior distribution. This option is useful when asymptotic normality of parameter estimates is suspect.

Reporting

dots, noisily, nolegend; see [MI] **mi impute**. noisily specifies that the output from the interval regression fit to the observed data be displayed. nolegend suppresses all legends that appear before the imputation table. Such legends include a legend about conditional imputation that appears when the conditional() option is specified and group legends that may appear when the by() option is specified.

Maximization

maximize_options; see [R] **intreg**. These options are seldom used.

Advanced

force; see [MI] **mi impute**.

The following option is available with mi impute but is not shown in the dialog box:

noupdate; see [MI] **noupdate option**.

Remarks and examples

Remarks are presented under the following headings:

Univariate imputation using interval regression
Using mi impute intreg
Example

See [MI] **mi impute** for a general description and details about options common to all imputation methods, *impute_options*. Also see [MI] **Workflow** for general advice on working with mi.

Univariate imputation using interval regression

The interval regression imputation method can be used to fill in missing values of a continuous partially observed (censored) variable (Royston 2007). It is a parametric method that assumes an underlying normal model for the partially observed imputed variable (given other predictors). This method is based on the asymptotic approximation of the posterior predictive distribution of the missing data.

Partially observed data arise when instead of observing an actual value, we observe the range where that value can lie. Such data include interval-censored, left-censored, and right-censored data; see [R] **intreg** for a more detailed discussion of censored data.

Do not confuse censoring with truncation. Truncated data are observed and are known to be in a certain range. Censored data come from a mixture of a continuous distribution and point masses at censoring limits. Truncated data come from a continuous truncated distribution. See the technical note in *Remarks and examples* of [R] **truncreg** for details. Use mi impute truncreg (see [MI] **mi impute truncreg**) to impute truncated data.

The imputation of censored data has certain unique characteristics. First, censored data are recorded in two variables containing the lower and the upper interval-censoring limits. So technically, there are two imputation variables. Second, in addition to complete observations (point data) and incomplete observations ("truly" missing data), there are partially complete (censored) observations for which only the lower and upper limits are known, not the values themselves. We can treat partially observed cases as "missing" and impute them along with other completely unobserved data, provided we respect their

observed limits during imputation. As a result, we will end up with a single imputed variable where missing and partially observed cases are replaced with plausible values consistent with the observed censoring limits. See *Methods and formulas* for technical details.

In what follows, when referring to missing data (or missing observations) we will mean completely unobserved, truly missing data and when referring to incomplete data (or incomplete observations) we will mean both censored and truly missing data.

Using mi impute intreg

To accommodate the above characteristics, `mi impute intreg` requires modifications to the standard syntax of univariate imputation methods. First, `mi impute intreg` requires that variables containing interval-censoring limits be specified in the `ll()` and `ul()` options; see the description of `ll()` and `ul()` in *Options*. Second, `mi impute intreg` requires you to specify a new variable name *newivar* to store the resulting imputed values. `mi impute intreg` creates a new variable, *newivar*, and registers it as imputed.

The values of *newivar* are determined by `ll()` and `ul()`. Observations of *newivar* for which `ll()` and `ul()` are different or for which both contain soft missing are set to soft missing (`.`) and considered incomplete. Observations for which either `ll()` or `ul()` contains hard missing are set to the extended missing value `.a` and, as usual, are omitted from imputation. The remaining observations, corresponding to the observed point data, are complete.

After imputation, `mi impute intreg` stores imputed values in *newivar*. It also registers variables in `ll()` and `ul()` as passive (see `mi register` in [MI] **mi set**), if they are not already registered as passive, and replaces observations for which `ll()` and `ul()` both contain soft missing with the corresponding imputed values. That is, only missing data are replaced in these variables; censored data are not changed.

Later, you may decide to add more imputations or to revise your imputation model and replace existing imputations with new ones. In such cases, you do not need to provide a new variable name. You can reuse the name of the variable created previously by `mi impute intreg`. `mi impute intreg` will check that the variable is registered as imputed and that it is consistent in the observed data with the variables supplied in `ll()` and `ul()`. That is, the variable must have the same values as `ll()` and `ul()` in the observations where `ll()` and `ul()` are equal, and soft missing values in the remaining observations. If `ll()` or `ul()` contain hard missing values, the variable must contain hard missing values in the corresponding observations as well.

Example

We continue the example of imputing missing values of variable `bmi` from [MI] **mi impute pmm**. The primary analysis of interest is the logistic model investigating the effect of smoking adjusted for other predictors (including `bmi`) on heart attacks; see [MI] **Intro substantive** for details.

The bmi variable is not censored in the original data. For the purpose of illustration, we use a version of the dataset in which the first three observations are censored:

```
. use https://www.stata-press.com/data/r19/mheartintreg
(Fictional heart attack data; BMI censored and missing)
. list lbmi ubmi in 1/10
```

	lbmi	ubmi
1.	.	22
2.	20	.
3.	30	31
4.	24.62917	24.62917
5.	22.52744	22.52744
6.	21.87975	21.87975
7.	17.77057	17.77057
8.	.	.
9.	23.47249	23.47249
10.	24.48916	24.48916

Rather than a single bmi variable, we have lbmi and ubmi variables containing lower and upper interval-censoring limits of BMI. The first observation is left-censored with an upper limit of 22, the second observation is right-censored with a lower limit of 20, and the third observation is interval-censored with the range [30, 31]. Observation 8, for which both lbmi and ubmi are missing, is missing.

Let's impute censored BMI values:

```
. mi set mlong
. mi impute intreg newbmi attack smokes age hsgrad female, add(20)
> ll(lbmi) ul(ubmi)
Univariate imputation                       Imputations =       20
Interval regression                               added =       20
Imputed: m=1 through m=20                         updated =      0
Limit: lower =         lbmi                 Number missing =      22
       upper =         ubmi                 Number censored =      3
                                                   interval =      1
                                                       left =      1
                                                      right =      1
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
newbmi	129	25	25	154

(Complete + Incomplete = Total; Imputed is the minimum across *m* of the number of filled-in observations.)

Following mi impute intreg, we provided a new variable name, newbmi, to contain imputed values. Because newbmi did not exist we did not need to register it before using mi impute intreg. We also specified the lower and upper interval-censoring limits in the ll() and ul() options. These options are required with mi impute intreg.

mi impute intreg reported that 25 incomplete BMI values were imputed. Among these incomplete observations, there are 22 missing observations and 3 censored observations (one interval-censored, one left-censored, and one right-censored).

Let's describe our mi data:

```
. mi describe, detail
Style: mlong
       last mi update 04mar2025 08:52:13, 0 seconds ago
Observations:
   Complete           129
   Incomplete          25  (M = 20 imputations)
   ----------------------
   Total              154
Variables:
   Imputed: 1; newbmi(25; 20*0)
   Passive: 2; lbmi(23; 20*1) ubmi(23; 20*1)
   Regular: 0
   System:  3; _mi_m _mi_id _mi_miss
   (there are 5 unregistered variables)
```

We used the `detail` option to also see missing-value counts in the imputed data.

According to `mi describe`, the new variable `newbmi` is registered as imputed and contains 25 incomplete observations in the original data. It does not contain incomplete values in any of the 20 imputations. `lbmi` and `ubmi` are registered as passive. Each of `lbmi` and `ubmi` contains 23 incomplete values in the original data and one incomplete value in each imputation. The 22 missing values for `lbmi` and `ubmi` are imputed. The incomplete value for each of these variables that is not imputed corresponds to a censored observation (left-censored observation 1 for `lbmi` and right-censored observation 2 for `ubmi`). `mi impute intreg` replaces only missing observations of `lbmi` and `ubmi` with imputed data and leaves censored observations unchanged.

As described in *Methods and formulas*, missing observations are simulated from an unrestricted normal distribution. So, the 22 imputed values may contain any value on the whole real line. This may not be desirable because the BMI measure is positive and, in fact, has a limited range.

To restrict imputed values to a certain range, we may replace `lbmi` and `ubmi` with lower and upper limits in observations for which these variables are missing. For example, let's restrict imputed values to be between 17 and 39, consistent with the observed range of BMI.

```
. use https://www.stata-press.com/data/r19/mheartintreg, clear
(Fictional heart attack data; BMI censored and missing)
. replace lbmi = 17 if lbmi==.
(23 real changes made)
. replace ubmi = 39 if ubmi==.
(23 real changes made)
. list lbmi ubmi in 1/10
```

	lbmi	ubmi
1.	17	22
2.	20	39
3.	30	31
4.	24.62917	24.62917
5.	22.52744	22.52744
6.	21.87975	21.87975
7.	17.77057	17.77057
8.	17	39
9.	23.47249	23.47249
10.	24.48916	24.48916

We replace missing lower limits with 17 and missing upper limits with 39 and proceed with imputation:

```
. mi set mlong
. mi impute intreg newbmi attack smokes age hsgrad female, add(20)
> ll(lbmi) ul(ubmi)
Univariate imputation                       Imputations =       20
Interval regression                               added =       20
Imputed: m=1 through m=20                       updated =        0
Limit: lower =         lbmi               Number missing =        0
       upper =         ubmi             Number censored =       25
                                                interval =       25
                                                    left =        0
                                                   right =        0
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
newbmi	129	25	25	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

All the incomplete observations are now interval-censored on [17, 39].

We can analyze these multiply imputed data using logistic regression with `mi estimate`:

```
. mi estimate: logit attack smokes age newbmi female hsgrad
  (output omitted)
```

In [MI] **mi impute truncreg**, we used `mi impute truncreg` to accommodate a restricted range of BMI during imputation. In the code above, we showed how to use `mi impute intreg` to ensure that imputed values are within a specified range. Which one should be used?

The answer to this question depends on our belief about the distribution of the imputation variable. If we believe that the underlying distribution of BMI is a normal distribution and we happened to only observe values within a certain range, then `mi impute intreg` should be used to impute BMI. We know, however, that BMI is positive and has an upper limit. As such, the assumption of a truncated distribution for BMI is more plausible, in which case `mi impute truncreg` should be used to impute its missing values.

Stored results

`mi impute intreg` stores the following in `r()`:

Scalars

`r(M)`	total number of imputations
`r(M_add)`	number of added imputations
`r(M_update)`	number of updated imputations
`r(N_miss)`	number of missing observations
`r(N_cens)`	number of censored observations
`r(N_lcens)`	number of left-censored observations
`r(N_rcens)`	number of right-censored observations
`r(N_intcens)`	number of interval-censored observations
`r(k_ivars)`	number of imputed variables (always `1`)
`r(N_g)`	number of imputed groups (`1` if `by()` is not specified)

Macros

`r(method)`	name of imputation method (`intreg`)
`r(ivars)`	names of imputation variables
`r(llname)`	name of variable containing lower interval-censoring limits
`r(ulname)`	name of variable containing upper interval-censoring limits
`r(rngstate)`	random-number state used
`r(by)`	names of variables specified within `by()`

Matrices

`r(N)`	number of observations in imputation sample in each group
`r(N_complete)`	number of complete observations in imputation sample in each group
`r(N_incomplete)`	number of incomplete observations in imputation sample in each group
`r(N_imputed)`	number of imputed observations in imputation sample in each group

Methods and formulas

Consider a latent univariate variable $\mathbf{x}^u = (x_1^u, x_2^u, \ldots, x_n^u)'$ that follows a normal linear regression

$$x_i^u|\mathbf{z}_i \sim N(\mathbf{z}_i'\boldsymbol{\beta}, \sigma^2) \tag{1}$$

where $\mathbf{z}_i = (z_{i1}, z_{i2}, \ldots, z_{iq})'$ records values of predictors of $\mathbf{x}^u$ for observation i, $\boldsymbol{\beta}$ is the $q \times 1$ vector of unknown regression coefficients, and σ^2 is the unknown scalar variance. (When a constant is included in the model—the default—$z_{i1} = 1,\ i = 1, \ldots, n$.)

Instead of $\mathbf{x}^u$, we observe $(\mathbf{x}^{\text{ll}}, \mathbf{x}^{\text{ul}})$, where $x_j^{\text{ll}} = x_j^{\text{ul}} = x_j^u$ for point (observed) data $j \in \mathcal{C}$; $x_j^{\text{ll}} = -\infty$ and $x_j^{\text{ul}} < +\infty$ for left-censored data $j \in \mathcal{L}$; $x_j^{\text{ll}} > -\infty$ and $x_j^{\text{ul}} = +\infty$ for right-censored data $j \in \mathcal{R}$; $x_j^{\text{ll}} = -\infty$ and $x_j^{\text{ul}} = +\infty$ for missing data $j \in \mathcal{M}$. Observations from subset $\mathcal{C}$ are considered complete and the remaining observations are considered incomplete.

Let $\mathbf{x} = \mathbf{x}^u$ for observations in subset $\mathcal{C}$, and let $\mathbf{x}$ contain missing values in the remaining observations. We want to fill in missing values in $\mathbf{x}$. Consider the partition of $\mathbf{x} = (\mathbf{x}_o{}', \mathbf{x}_m{}')$ into $n_0 \times 1$ and $n_1 \times 1$ vectors containing the complete and the incomplete observations. Consider a similar partition of $\mathbf{Z} = (\mathbf{Z}_o, \mathbf{Z}_m)$ into $n_0 \times q$ and $n_1 \times q$ submatrices.

`mi impute intreg` follows the steps below to fill in $\mathbf{x}_m$:

1. Fit an interval regression to the interval-censored data $(\mathbf{x}^{\text{ll}}, \mathbf{x}^{\text{ul}})$ to obtain the maximum likelihood estimates of parameters in (1), $\widehat{\boldsymbol{\theta}} = (\widehat{\boldsymbol{\beta}}', \ln\widehat{\sigma})'$, and their asymptotic sampling variance, $\widehat{\mathbf{U}}$. See [R] **intreg** for details.
2. Simulate new parameters, $\boldsymbol{\theta}_\star$, from the large-sample normal approximation, $N(\widehat{\boldsymbol{\theta}}, \widehat{\mathbf{U}})$, to its posterior distribution, assuming the noninformative prior $\Pr(\boldsymbol{\theta}) \propto \text{const}$.
3. Let $\mu_{\star i} = \mathbf{z}_i'\boldsymbol{\beta}_\star$. Obtain one set of imputed values, $\mathbf{x}_m^1$, by simulating from a truncated normal model with the density

$$f_{(x_i^{\text{ll}}, x_i^{\text{ul}})}(x|\mathbf{z}_i) = \frac{1}{\sigma_\star}\phi\left(\frac{x-\mu_{\star i}}{\sigma_\star}\right) \times \left\{\Phi\left(\frac{x_i^{\text{ul}}-\mu_{\star i}}{\sigma_\star}\right) - \Phi\left(\frac{x_i^{\text{ll}}-\mu_{\star i}}{\sigma_\star}\right)\right\}^{1}, \quad x_i^{\text{ll}} < x < x_i^{\text{ul}}$$

   for every incomplete observation $i \notin \mathcal{C}$. For missing observations $i \in \mathcal{M}$, when $x_i^{\text{ll}} = -\infty$ and $x_i^{\text{ul}} = +\infty$, the above density reduces to a normal density. Thus missing observations are simulated from the corresponding unrestricted normal distribution.
4. Repeat steps 2 and 3 to obtain M sets of imputed values, $\mathbf{x}_m^1, \mathbf{x}_m^2, \ldots, \mathbf{x}_m^M$.

Steps 2 and 3 above correspond to only approximate draws from the posterior predictive distribution of the missing data, $\Pr(\mathbf{x}_m|\mathbf{x}_o, \mathbf{Z}_o)$, because $\boldsymbol{\theta}_\star$ is drawn from the asymptotic approximation to its posterior distribution.

If weights are specified, a weighted regression model is fit to the observed data in step 1 (see [R] **intreg** for details). Also, in the case of `aweights`, $\sigma_\star$ is replaced with $\sigma_\star w_i^{-1/2}$ in step 3, where w_i is the analytic weight for observation i.

Reference

Royston, P. 2007. Multiple imputation of missing values: Further update of ice, with an emphasis on interval censoring. *Stata Journal* 7: 445–464.

Also see

[MI] **mi impute** — Impute missing values

[MI] **mi impute pmm** — Impute using predictive mean matching

[MI] **mi impute regress** — Impute using linear regression

[MI] **mi impute truncreg** — Impute using truncated regression

[MI] **mi estimate** — Estimation using multiple imputations

[MI] **Intro** — Introduction to mi

[MI] **Intro substantive** — Introduction to multiple-imputation analysis

mi impute logit — Impute using logistic regression

Description | Menu | Syntax | Options
Remarks and examples | Stored results | Methods and formulas | References
Also see

Description

`mi impute logit` fills in missing values of a binary variable by using a logistic regression imputation method. You can perform separate imputations on different subsets of the data by specifying the `by()` option. You can also account for frequency, importance, and sampling weights.

Menu

Statistics > Multiple imputation

Syntax

`mi impute logit` *ivar* [*indepvars*] [*if*] [*weight*] [, *impute_options options*]

impute_options	Description
Main	
* `add(#)`	specify number of imputations to add; required when no imputations exist
* `replace`	replace imputed values in existing imputations
`rseed(#)`	specify random-number seed
`double`	store imputed values in double precision; the default is to store them as `float`
`by(`*varlist*[, *byopts*]`)`	impute separately on each group formed by *varlist*
Reporting	
`dots`	display dots as imputations are performed
`noisily`	display intermediate output
`nolegend`	suppress all table legends
Advanced	
`force`	proceed with imputation, even when missing imputed values are encountered
`noupdate`	do not perform `mi update`; see [MI] **noupdate option**

*`add(#)` is required when no imputations exist; `add(#)` or `replace` is required if imputations exist.
`noupdate` does not appear in the dialog box.

options	Description
Main	
noconstant	suppress constant term
offset(*varname*)	include *varname* in model with coefficient constrained to 1
augment	perform augmented regression in the presence of perfect prediction
conditional(*if*)	perform conditional imputation
bootstrap	estimate model parameters using sampling with replacement
Maximization	
maximize_options	control the maximization process; seldom used

You must `mi set` your data before using `mi impute logit`; see [MI] **mi set**.

You must `mi register` *ivar* as imputed before using `mi impute logit`; see [MI] **mi set**.

indepvars may contain factor variables; see **[U] 11.4.3 Factor variables**.

`collect` is allowed; see **[U] 11.1.10 Prefix commands**.

`fweights`, `iweights`, and `pweights` are allowed; see **[U] 11.1.6 weight**.

Options

Main

`noconstant`; see [R] **Estimation options**.

`add()`, `replace`, `rseed()`, `double`, `by()`; see [MI] **mi impute**.

`offset(`*varname*`)`; see [R] **Estimation options**.

`augment` specifies that augmented regression be performed if perfect prediction is detected. By default, an error is issued when perfect prediction is detected. The idea behind the augmented-regression approach is to add a few observations with small weights to the data during estimation to avoid perfect prediction. See *The issue of perfect prediction during imputation of categorical data* under *Remarks and examples* in [MI] **mi impute** for more information. `augment` is not allowed with importance weights.

`conditional(`*if*`)` specifies that the imputation variable be imputed conditionally on observations satisfying *exp*; see **[U] 11.1.3 if exp**. That is, missing values in a conditional sample, the sample identified by the *exp* expression, are imputed based only on data in that conditional sample. Missing values outside the conditional sample are replaced with a conditional constant, the value of the imputation variable in observations outside the conditional sample. As such, the imputation variable is required to be constant outside the conditional sample. Also, if any conditioning variables (variables involved in the conditional specification `if` *exp*) contain soft missing values (`.`), their missing values must be nested within missing values of the imputation variables. See *Conditional imputation* under *Remarks and examples* in [MI] **mi impute**.

`bootstrap` specifies that posterior estimates of model parameters be obtained using sampling with replacement; that is, posterior estimates are estimated from a bootstrap sample. The default is to sample the estimates from the posterior distribution of model parameters or from the large-sample normal approximation of the posterior distribution. This option is useful when asymptotic normality of parameter estimates is suspect.

Reporting

dots, noisily, nolegend; see [MI] **mi impute**. noisily specifies that the output from the logistic regression fit to the observed data be displayed. nolegend suppresses all legends that appear before the imputation table. Such legends include a legend about conditional imputation that appears when the conditional() option is specified and group legends that may appear when the by() option is specified.

Maximization

maximize_options; see [R] **logit**. These options are seldom used. difficult, technique(), gradient, showstep, hessian, and showtolerance are not allowed when the augment option is used.

Advanced

force; see [MI] **mi impute**.

The following option is available with mi impute but is not shown in the dialog box:

noupdate; see [MI] **noupdate option**.

Remarks and examples

Remarks are presented under the following headings:

Univariate imputation using logistic regression
Using mi impute logit
Video example

See [MI] **mi impute** for a general description and details about options common to all imputation methods, *impute_options*. Also see [MI] **Workflow** for general advice on working with mi.

Univariate imputation using logistic regression

The logistic regression imputation method can be used to fill in missing values of a binary variable (for example, Rubin [1987]; Raghunathan et al. [2001]; and van Buuren [2007]). It is a parametric method that assumes an underlying logistic model for the imputed variable (given other predictors).

Unlike the linear regression method, the logistic imputation method is based on the asymptotic approximation of the posterior predictive distribution of the missing data. The actual posterior distribution of the logistic model parameters, $\boldsymbol{\beta}$, does not have a simple form under the common noninformative prior distribution. Thus a large-sample normal approximation to the posterior distribution of $\boldsymbol{\beta}$ is used instead. Rubin (1987, 169) points out that although the actual posterior distribution may be far from normal (for example, when the number of observed cases is small or when the fraction of ones in the observed data is close to zero or one), the use of the normal approximation is common in practice.

Using mi impute logit

Continuing our heart attack example from [MI] **Intro substantive** and [MI] **mi impute**, suppose that hsgrad, a binary variable recording whether subjects graduated from high school, contains missing values:

```
. use https://www.stata-press.com/data/r19/mheart2
(Fictional heart attack data; hsgrad missing)
. mi set mlong
. mi misstable summarize
```

				Obs<.		
Variable	Obs=.	Obs>.	Obs<.	Unique values	Min	Max
hsgrad	18		136	2	0	1

Thus we want to impute missing values of hsgrad, because hsgrad was one of the predictors in our logistic model (logit attack smokes age bmi female hsgrad). From our previous analysis of the heart attack data, we recall that hsgrad was not a significant predictor. So, we could have omitted hsgrad from the logistic model in the casewise-deletion analysis to avoid the reduction in sample size, and then imputing hsgrad would not have been needed. In general, the imputer rarely has such knowledge, and omitting hsgrad from the imputation model would prevent this predictor from being used in later analysis by the analyst (see, for example, *Imputation modeling* in [MI] **mi impute**). Thus we proceed with imputation.

We use mi impute logit to create 10 imputations of hsgrad:

```
. mi register imputed hsgrad
(18 m=0 obs now marked as incomplete)
. mi impute logit hsgrad attack smokes age bmi female, add(10)
Univariate imputation                       Imputations =       10
Logistic regression                                added =       10
Imputed: m=1 through m=10                        updated =        0
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
hsgrad	136	18	18	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

We can now use the imputed hsgrad in our analysis, for example,

```
. mi estimate: logit attack smokes age bmi female hsgrad
  (output omitted)
```

Video example

Multiple imputation: Setup, imputation, estimation—logistic regression

Stored results

mi impute logit stores the following in r():

Scalars

r(M)	total number of imputations
r(M_add)	number of added imputations
r(M_update)	number of updated imputations
r(k_ivars)	number of imputed variables (always 1)
r(pp)	1 if perfect prediction detected, 0 otherwise
r(N_g)	number of imputed groups (1 if by() is not specified)

Macros

r(method)	name of imputation method (logit)
r(ivars)	names of imputation variables
r(rngstate)	random-number state used
r(by)	names of variables specified within by()

Matrices

r(N)	number of observations in imputation sample in each group
r(N_complete)	number of complete observations in imputation sample in each group
r(N_incomplete)	number of incomplete observations in imputation sample in each group
r(N_imputed)	number of imputed observations in imputation sample in each group

Methods and formulas

Consider a univariate variable $\mathbf{x} = (x_1, x_2, \ldots, x_n)'$ that follows a logistic model

$$\Pr(x_i \neq 0|\mathbf{z}_i) = \frac{\exp(\mathbf{z}_i'\boldsymbol{\beta})}{1 + \exp(\mathbf{z}_i'\boldsymbol{\beta})} \tag{1}$$

where $\mathbf{z}_i = (z_{i1}, z_{i2}, \ldots, z_{iq})'$ records values of predictors of $\mathbf{x}$ for observation i and $\boldsymbol{\beta}$ is the $q \times 1$ vector of unknown regression coefficients. (When a constant is included in the model—the default—$z_{i1} = 1,\ i = 1, \ldots, n$.)

$\mathbf{x}$ contains missing values that are to be filled in. Consider the partition of $\mathbf{x} = (\mathbf{x}_o', \mathbf{x}_m')$ into $n_0 \times 1$ and $n_1 \times 1$ vectors containing the complete and the incomplete observations. Consider a similar partition of $\mathbf{Z} = (\mathbf{Z}_o, \mathbf{Z}_m)$ into $n_0 \times q$ and $n_1 \times q$ submatrices.

mi impute logit follows the steps below to fill in $\mathbf{x}_m$:

1. Fit a logistic model (1) to the observed data $(\mathbf{x}_o, \mathbf{Z}_o)$ to obtain the maximum likelihood estimates, $\widehat{\boldsymbol{\beta}}$, and their asymptotic sampling variance, $\widehat{\mathbf{U}}$.
2. Simulate new parameters, $\boldsymbol{\beta}_\star$, from the large-sample normal approximation, $N(\widehat{\boldsymbol{\beta}}, \widehat{\mathbf{U}})$, to its posterior distribution assuming the noninformative prior $\Pr(\boldsymbol{\beta}) \propto \text{const}$.
3. Obtain one set of imputed values, $\mathbf{x}_m^1$, by simulating from the logistic distribution:

   $$\Pr(x_{i_m} = 1) = \exp(\mathbf{z}_{i_m}'\boldsymbol{\beta}_\star) / \left\{1 + \exp(\mathbf{z}_{i_m}'\boldsymbol{\beta}_\star)\right\}$$

   for every missing observation i_m.
4. Repeat steps 2 and 3 to obtain M sets of imputed values, $\mathbf{x}_m^1, \mathbf{x}_m^2, \ldots, \mathbf{x}_m^M$.

Steps 2 and 3 above correspond to only approximate draws from the posterior predictive distribution of the missing data $\Pr(\mathbf{x}_m|\mathbf{x}_o, \mathbf{Z}_o)$ because $\boldsymbol{\beta}_\star$ is drawn from the asymptotic approximation to its posterior distribution.

If weights are specified, a weighted logistic regression model is fit to the observed data in step 1 (see [R] **logit** for details).

References

Raghunathan, T. E., J. M. Lepkowski, J. Van Hoewyk, and P. Solenberger. 2001. A multivariate technique for multiply imputing missing values using a sequence of regression models. *Survey Methodology* 27: 85–95.

Rubin, D. B. 1987. *Multiple Imputation for Nonresponse in Surveys.* New York: Wiley.

van Buuren, S. 2007. Multiple imputation of discrete and continuous data by fully conditional specification. *Statistical Methods in Medical Research* 16: 219–242. https://doi.org/10.1177/0962280206074463.

Also see

[MI] **mi impute** — Impute missing values

[MI] **mi estimate** — Estimation using multiple imputations

[MI] **Intro** — Introduction to mi

[MI] **Intro substantive** — Introduction to multiple-imputation analysis

mi impute mlogit — Impute using multinomial logistic regression

Description | Menu | Syntax | Options
Remarks and examples | Stored results | Methods and formulas | References
Also see

Description

`mi impute mlogit` fills in missing values of a nominal variable by using the multinomial (polytomous) logistic regression imputation method. You can perform separate imputations on different subsets of the data by specifying the `by()` option. You can also account for frequency, importance, and sampling weights.

Menu

Statistics > Multiple imputation

Syntax

`mi impute mlogit` *ivar* [*indepvars*] [*if*] [*weight*] [, *impute_options options*]

impute_options	Description
Main	
* `add(#)`	specify number of imputations to add; required when no imputations exist
* `replace`	replace imputed values in existing imputations
`rseed(#)`	specify random-number seed
`double`	store imputed values in double precision; the default is to store them as `float`
`by(`*varlist*[, *byopts*]`)`	impute separately on each group formed by *varlist*
Reporting	
`dots`	display dots as imputations are performed
`noisily`	display intermediate output
`nolegend`	suppress all table legends
Advanced	
`force`	proceed with imputation, even when missing imputed values are encountered
`noupdate`	do not perform `mi update`; see [MI] **noupdate option**

*`add(#)` is required when no imputations exist; `add(#)` or `replace` is required if imputations exist.

`noupdate` does not appear in the dialog box.

options	Description
Main	
noconstant	suppress constant term
baseoutcome(#)	specify value of *ivar* that will be the base outcome
augment	perform augmented regression in the presence of perfect prediction
conditional(*if*)	perform conditional imputation
bootstrap	estimate model parameters using sampling with replacement
Maximization	
maximize_options	control the maximization process; seldom used

You must `mi set` your data before using `mi impute mlogit`; see [MI] **mi set**.

You must `mi register` *ivar* as imputed before using `mi impute mlogit`; see [MI] **mi set**.

indepvars may contain factor variables; see [U] **11.4.3 Factor variables**.

`collect` is allowed; see [U] **11.1.10 Prefix commands**.

`fweights`, `iweights`, and `pweights` are allowed; see [U] **11.1.6 weight**.

Options

Main

`noconstant`; see [R] **Estimation options**.

`add()`, `replace`, `rseed()`, `double`, `by()`; see [MI] **mi impute**.

`baseoutcome(#)` specifies the value of *ivar* to be treated as the base outcome. The default is to choose the most frequent outcome.

`augment` specifies that augmented regression be performed if perfect prediction is detected. By default, an error is issued when perfect prediction is detected. The idea behind the augmented-regression approach is to add a few observations with small weights to the data during estimation to avoid perfect prediction. See *The issue of perfect prediction during imputation of categorical data* under *Remarks and examples* in [MI] **mi impute** for more information. `augment` is not allowed with importance weights.

`conditional(`*if*`)` specifies that the imputation variable be imputed conditionally on observations satisfying *exp*; see [U] **11.1.3 if exp**. That is, missing values in a conditional sample, the sample identified by the *exp* expression, are imputed based only on data in that conditional sample. Missing values outside the conditional sample are replaced with a conditional constant, the value of the imputation variable in observations outside the conditional sample. As such, the imputation variable is required to be constant outside the conditional sample. Also, if any conditioning variables (variables involved in the conditional specification `if` *exp*) contain soft missing values (`.`), their missing values must be nested within missing values of the imputation variables. See *Conditional imputation* under *Remarks and examples* in [MI] **mi impute**.

`bootstrap` specifies that posterior estimates of model parameters be obtained using sampling with replacement; that is, posterior estimates are estimated from a bootstrap sample. The default is to sample the estimates from the posterior distribution of model parameters or from the large-sample normal approximation of the posterior distribution. This option is useful when asymptotic normality of parameter estimates is suspect.

Reporting

dots, noisily, nolegend; see [MI] **mi impute**. noisily specifies that the output from the multinomial logistic regression fit to the observed data be displayed. nolegend suppresses all legends that appear before the imputation table. Such legends include a legend about conditional imputation that appears when the conditional() option is specified and group legends that may appear when the by() option is specified.

Maximization

maximize_options; see [R] **mlogit**. These options are seldom used. difficult, technique(), gradient, showstep, hessian, and showtolerance are not allowed when the augment option is used.

Advanced

force; see [MI] **mi impute**.

The following option is available with mi impute but is not shown in the dialog box:

noupdate; see [MI] **noupdate option**.

Remarks and examples

Remarks are presented under the following headings:

Univariate imputation using multinomial logistic regression
Using mi impute mlogit

See [MI] **mi impute** for a general description and details about options common to all imputation methods, *impute_options*. Also see [MI] **Workflow** for general advice on working with mi.

Univariate imputation using multinomial logistic regression

The multinomial logistic regression imputation method can be used to fill in missing values of a nomial variable (for example, Raghunathan et al. [2001] and van Buuren [2007]). It is a parametric method that assumes an underlying multinomial logistic model for the imputed variable (given other predictors). Similarly to the logistic imputation method, this method is based on the asymptotic approximation of the posterior predictive distribution of the missing data.

Using mi impute mlogit

Consider the heart attack data introduced in [MI] **Intro substantive** and discussed in [MI] **mi impute**. Suppose that we want our logistic model of interest to also include information about marital status (categorical variable marstatus)—logit attack smokes age bmi female hsgrad i.marstatus.

We first tabulate values of marstatus:

```
. use https://www.stata-press.com/data/r19/mheart3
(Fictional heart attack data; marstatus missing)
. tabulate marstatus, missing
```

Marital status: single, married, divorced	Freq.	Percent	Cum.
Single	53	34.42	34.42
Married	48	31.17	65.58
Divorced	46	29.87	95.45
.	7	4.55	100.00
Total	154	100.00	

From the output, the marstatus variable has three unique categories and seven missing observations. Because marstatus is a categorical variable, we use the multinomial logistic imputation method to fill in its missing values.

We mi set the data, register marstatus as an imputed variable, and then create 10 imputations by specifying the add(10) option with mi impute mlogit:

```
. mi set mlong
. mi register imputed marstatus
(7 m=0 obs now marked as incomplete)
. mi impute mlogit marstatus attack smokes age bmi female hsgrad, add(10)
Univariate imputation                       Imputations =       10
Multinomial logistic regression                   added =       10
Imputed: m=1 through m=10                       updated =        0
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
marstatus	147	7	7	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

We can now analyze these multiply imputed data using logistic regression via mi estimate:

```
. mi estimate: logit attack smokes age bmi female hsgrad i.marstatus
  (output omitted)
```

Stored results

`mi impute mlogit` stores the following in `r()`:

Scalars

`r(M)`	total number of imputations
`r(M_add)`	number of added imputations
`r(M_update)`	number of updated imputations
`r(k_ivars)`	number of imputed variables (always `1`)
`r(pp)`	`1` if perfect prediction detected, `0` otherwise
`r(N_g)`	number of imputed groups (`1` if `by()` is not specified)

Macros

`r(method)`	name of imputation method (`mlogit`)
`r(ivars)`	names of imputation variables
`r(rngstate)`	random-number state used
`r(by)`	names of variables specified within `by()`

Matrices

`r(N)`	number of observations in imputation sample in each group
`r(N_complete)`	number of complete observations in imputation sample in each group
`r(N_incomplete)`	number of incomplete observations in imputation sample in each group
`r(N_imputed)`	number of imputed observations in imputation sample in each group

Methods and formulas

Consider a univariate variable $\mathbf{x} = (x_1, x_2, \ldots, x_n)'$ that contains K categories (without loss of generality, let $k = 1$ be the base outcome) and follows a multinomial logistic model

$$\Pr(x_i = k|\mathbf{z}_i) = \begin{cases} \dfrac{1}{1 + \sum_{l=2}^{K} \exp(\mathbf{z}_i'\boldsymbol{\beta}_l)}, & \text{if } k = 1 \\ \dfrac{\exp(\mathbf{z}_i'\boldsymbol{\beta}_k)}{1 + \sum_{l=2}^{K} \exp(\mathbf{z}_i'\boldsymbol{\beta}_l)}, & \text{if } k > 1 \end{cases} \tag{1}$$

where $\mathbf{z}_i = (z_{i1}, z_{i2}, \ldots, z_{iq})'$ records values of predictors of $\mathbf{x}$ for observation i and $\boldsymbol{\beta}_l$ is the $q \times 1$ vector of unknown regression coefficients for outcome $l = 2, \ldots, K$. (When a constant is included in the model—the default—$z_{i1} = 1,\ i = 1, \ldots, n$.)

$\mathbf{x}$ contains missing values that are to be filled in. Consider the partition of $\mathbf{x} = (\mathbf{x}_o', \mathbf{x}_m')$ into $n_0 \times 1$ and $n_1 \times 1$ vectors containing the complete and the incomplete observations. Consider a similar partition of $\mathbf{Z} = (\mathbf{Z}_o, \mathbf{Z}_m)$ into $n_0 \times q$ and $n_1 \times q$ submatrices.

`mi impute mlogit` follows the steps below to fill in $\mathbf{x}_m$:

1. Fit a multinomial logistic model (1) to the observed data $(\mathbf{x}_o, \mathbf{Z}_o)$ to obtain the maximum likelihood estimates, $\widehat{\boldsymbol{\beta}} = (\widehat{\boldsymbol{\beta}}_2', \ldots, \widehat{\boldsymbol{\beta}}_K')'$, and their asymptotic sampling variance, $\widehat{\mathbf{U}}$.
2. Simulate new parameters, $\boldsymbol{\beta}_\star$, from the large-sample normal approximation, $N(\widehat{\boldsymbol{\beta}}, \widehat{\mathbf{U}})$, to its posterior distribution assuming the noninformative prior $\Pr(\boldsymbol{\beta}) \propto$ const.
3. Obtain one set of imputed values, $\mathbf{x}_m^1$, by simulating from the multinomial logistic distribution: one of K categories is randomly assigned to a missing category, i_m, using the cumulative probabilities computed from (1) with $\boldsymbol{\beta}_l = \boldsymbol{\beta}_{\star l}$ and $\mathbf{z}_i = \mathbf{z}_{i_m}$.
4. Repeat steps 2 and 3 to obtain M sets of imputed values, $\mathbf{x}_m^1, \mathbf{x}_m^2, \ldots, \mathbf{x}_m^M$.

Steps 2 and 3 above correspond to only approximate draws from the posterior predictive distribution of the missing data $\Pr(\mathbf{x}_m|\mathbf{x}_o, \mathbf{Z}_o)$ because $\boldsymbol{\beta}_\star$ is drawn from the asymptotic approximation to its posterior distribution.

If weights are specified, a weighted multinomial logistic regression model is fit to the observed data in step 1 (see [R] **mlogit** for details).

References

Raghunathan, T. E., J. M. Lepkowski, J. Van Hoewyk, and P. Solenberger. 2001. A multivariate technique for multiply imputing missing values using a sequence of regression models. *Survey Methodology* 27: 85–95.

van Buuren, S. 2007. Multiple imputation of discrete and continuous data by fully conditional specification. *Statistical Methods in Medical Research* 16: 219–242. https://doi.org/10.1177/0962280206074463.

Also see

[MI] **mi impute** — Impute missing values

[MI] **mi impute ologit** — Impute using ordered logistic regression

[MI] **mi estimate** — Estimation using multiple imputations

[MI] **Intro** — Introduction to mi

[MI] **Intro substantive** — Introduction to multiple-imputation analysis

mi impute monotone — Impute missing values in monotone data

Description | Menu | Syntax | Options
Remarks and examples | Stored results | Methods and formulas | References
Also see

Description

`mi impute monotone` fills in missing values in multiple variables by using a sequence of independent univariate conditional imputation methods. Variables to be imputed, *ivars*, must follow a monotone-missing pattern (see [MI] **Intro substantive**). You can perform separate imputations on different subsets of the data by specifying the `by()` option. You can also account for frequency, analytic (with continuous variables only), importance, and sampling weights.

Menu

Statistics > Multiple imputation

Syntax

Default specification of prediction equations, basic syntax

`mi impute monotone (`*uvmethod*`)` *ivars* [`=` *indepvars*] [*if*] [*weight*] [`,` *impute_options options*]

Default specification of prediction equations, full syntax

`mi impute monotone` *lhs* [`=` *indepvars*] [*if*] [*weight*] [`,` *impute_options options*]

Custom specification of prediction equations

`mi impute monotone` *cmodels* [*if*] [*weight*]`, custom` [*impute_options options*]

where *lhs* is *lhs_spec* [*lhs_spec* [...]] and *lhs_spec* is

`(`*uvmethod* [*if*] [`,` *uvspec_options*]`)` *ivars*

cmodels is `(`*cond_spec*`)` [`(`*cond_spec*`)` [...]] and a conditional specification, *cond_spec*, is

uvmethod ivar [*rhs_spec*] [*if*] [`,` *uvspec_options*]

rhs_spec includes *varlist* and expressions of imputation variables bound in parentheses.

ivar(*s*) (or *newivar* if *uvmethod* is `intreg`) is the name(s) of the imputation variable(s).

uvspec_options are `asc`ontinuous, `noi`sily, and the method-specific *options* as described in the manual entry for each univariate imputation method.

uvmethod	Description
regress	linear regression for a continuous variable; [MI] **mi impute regress**
pmm	predictive mean matching for a continuous variable; [MI] **mi impute pmm**
truncreg	truncated regression for a continuous variable with a restricted range; [MI] **mi impute truncreg**
intreg	interval regression for a continuous partially observed (censored) variable; [MI] **mi impute intreg**
logit	logistic regression for a binary variable; [MI] **mi impute logit**
ologit	ordered logistic regression for an ordinal variable; [MI] **mi impute ologit**
mlogit	multinomial logistic regression for a nominal variable; [MI] **mi impute mlogit**
poisson	Poisson regression for a count variable; [MI] **mi impute poisson**
nbreg	negative binomial regression for an overdispersed count variable; [MI] **mi impute nbreg**

impute_options	Description
Main	
* add(#)	specify number of imputations to add; required when no imputations exist
* replace	replace imputed values in existing imputations
rseed(#)	specify random-number seed
double	store imputed values in double precision; the default is to store them as float
by(*varlist*[, *byopts*])	impute separately on each group formed by *varlist*
Reporting	
dots	display dots as imputations are performed
noisily	display intermediate output
nolegend	suppress all table legends
Advanced	
force	proceed with imputation, even when missing imputed values are encountered
noupdate	do not perform mi update; see [MI] **noupdate option**

*add(#) is required when no imputations exist; add(#) or replace is required if imputations exist.

noupdate does not appear in the dialog box.

options	Description
Main	
* custom	customize prediction equations of conditional specifications
augment	perform augmented regression in the presence of perfect prediction for all categorical imputation variables
bootstrap	estimate model parameters using sampling with replacement
Reporting	
dryrun	show conditional specifications without imputing data
verbose	show conditional specifications and impute data; implied when custom prediction equations are not specified
report	show report about each conditional specification
Advanced	
nomonotonechk	do not check whether variables follow a monotone-missing pattern

*custom is required when specifying customized prediction equations.

You must mi set your data before using mi impute monotone; see [MI] **mi set**.

You must mi register *ivars* as imputed before using mi impute monotone; see [MI] **mi set**.

indepvars and *rhs_spec* may contain factor variables; see **[U] 11.4.3 Factor variables**.

collect is allowed; see **[U] 11.1.10 Prefix commands**.

fweights, aweights (regress, pmm, truncreg, and intreg only), iweights, and pweights are allowed; see **[U] 11.1.6 weight**.

Options

Main

custom is required to build customized prediction equations within the univariate conditional specifications. Otherwise, the default specification of prediction equations is assumed.

add(), replace, rseed(), double, by(); see [MI] **mi impute**.

augment specifies that augmented regression be performed if perfect prediction is detected. By default, an error is issued when perfect prediction is detected. The idea behind the augmented-regression approach is to add a few observations with small weights to the data during estimation to avoid perfect prediction. See *The issue of perfect prediction during imputation of categorical data* under *Remarks and examples* in [MI] **mi impute** for more information. augment is not allowed with importance weights. This option is equivalent to specifying augment within univariate specifications of all categorical imputation methods.

bootstrap specifies that posterior estimates of model parameters be obtained using sampling with replacement; that is, posterior estimates are estimated from a bootstrap sample. The default is to sample the estimates from the posterior distribution of model parameters or from the large-sample normal approximation of the posterior distribution. This option is useful when asymptotic normality of parameter estimates is suspect. This option is equivalent to specifying bootstrap within all univariate specifications.

The following options appear on a Specification dialog that appears when you click on the **Create...** button on the **Main** tab.

uvspec_options are options specified within each univariate imputation method, *uvmethod*. *uvspec_options* include ascontinuous, noisily, and the method-specific *options* as described in the manual entry for each univariate imputation method.

ascontinuous specifies that categorical imputation variables corresponding to the current *uvmethod* be included as continuous in all prediction equations. This option is only allowed when *uvmethod* is logit, ologit, or mlogit.

noisily specifies that the output from the current univariate model fit to the observed data be displayed.

Reporting

dots, noisily, nolegend; see [MI] **mi impute**. noisily specifies that the output from all univariate conditional models fit to the observed data be displayed. nolegend suppresses all imputation table legends which include a legend with the titles of the univariate imputation methods used, a legend about conditional imputation when conditional() is used within univariate specifications, and group legends when by() is specified.

dryrun specifies to show the conditional specifications that would be used to impute each variable without actually imputing data. This option is recommended for checking specifications of conditional models prior to imputation.

verbose specifies to show conditional specifications and impute data. verbose is implied when custom prediction equations are not specified.

report specifies to show a report about each univariate conditional specification. This option, in combination with dryrun, is recommended for checking specifications of conditional models prior to imputation.

Advanced

force; see [MI] **mi impute**.

nomonotonechk specifies not to check that imputation variables follow a monotone-missing pattern. This option may be used to avoid potentially time-consuming checks. The monotonicity check may be time consuming when a large number of variables is being imputed. If you use nomonotonechk with a custom specification, make sure that you list the univariate conditional specifications in the order of monotonicity or you might obtain incorrect results.

The following option is available with mi impute but is not shown in the dialog box:

noupdate; see [MI] **noupdate option**.

Remarks and examples

Remarks are presented under the following headings:

Multivariate imputation when a missing-data pattern is monotone
First use
Using mi impute monotone
Default syntax of mi impute monotone
The alternative syntax of mi impute monotone—custom prediction equations
Examples of using default prediction equations
Examples of using custom prediction equations

See [MI] **mi impute** for a general description and details about options common to all imputation methods, *impute_options*. Also see [MI] **Workflow** for general advice on working with mi.

Multivariate imputation when a missing-data pattern is monotone

When a pattern of missingness in multiple variables is monotone (or, more rigorously, when the missingness-modeling structure is monotone distinct), a multivariate imputation can be replaced with a set of conditional univariate imputations (Rubin 1987, 170–178). Let $X_1, X_2, \ldots, X_p$ be ordered such that if X_{1j} is missing, then X_{2j} is also missing, although X_2 may also be missing in other observations; if X_{2j} is missing, then X_{3j} is missing, although X_3 may also be missing in other observations; and so on. Then a simultaneous imputation of variables $X_1, X_2, \ldots, X_p$ according to a model, $f_{\mathbf{X}}(\cdot)$, and complete predictors (independent variables), $\mathbf{Z}$, is equivalent to the sequential conditional imputation

$$
\begin{aligned}
X_1^\star &\sim f_1(X_1|\mathbf{Z}) \\
X_2^\star &\sim f_2(X_2|X_1^\star, \mathbf{Z}) \\
&\ldots \\
X_p^\star &\sim f_p(X_p|X_1^\star, X_2^\star, \ldots, X_{p-1}^\star, \mathbf{Z})
\end{aligned}
\tag{1}
$$

where for brevity we omit conditioning on the model parameters. The univariate conditional imputation models $f_j(\cdot)$ can each be of a different type (normal, logistic, etc.), as is appropriate for imputing X_j.

The specification of a conditional imputation model $f_j(\cdot)$ includes an imputation method and a prediction equation relating an imputation variable to other explanatory variables. In what follows, we distinguish between the default specification in which the identities of the complete explanatory variables are the same for all imputed variables, and the custom specification in which the identities are allowed to differ.

Under the default specification, prediction equations of each imputation variable include all complete independent variables and all preceding imputation variables that have already been imputed. Under the custom specification, each prediction equation may include a subset of the predictors that would be used under the default specification. The custom specification implies nothing more than the assumption of conditional independence between certain imputation variables and certain sets of predictors.

Model (1) corresponds to the default specification. For example, consider imputation variables X_1, X_2, and X_3, ordered from the most observed to the least observed, and complete predictors Z_1 and Z_2. Under the default specification, the individual prediction equations are determined as follows. The most observed variable, X_1, is predicted from Z_1 and Z_2. The next most observed variable, X_2, is predicted from Z_1, Z_2, and previously imputed X_1. The least observed variable, X_3, is predicted from Z_1, Z_2, and previously imputed X_1 and X_2. (A constant is included in all prediction equations, by default.) We use the following notation to refer to the above sequence of prediction equations (imputation sequence): $X_1|Z_1, Z_2 \rightarrow X_2|X_1, Z_1, Z_2 \rightarrow X_3|X_1, X_2, Z_1, Z_2$.

A sequence such as $X_1|Z_1 \rightarrow X_2|X_1, Z_1, Z_2 \rightarrow X_3|X_1, Z_2$ would correspond to a custom specification. Here X_1 is assumed to be independent of Z_2 given Z_1, and X_3 is assumed to be independent of Z_1 and X_2 given X_1 and Z_2.

The monotone-distinct structure offers much flexibility in building a multivariate imputation model. It simplifies the often intractable multivariate imputation task to a set of simpler univariate imputation tasks. In addition, it accommodates imputation of a mixture of types of variables. So, what's the catch? The catch is that the pattern of missingness is rarely monotone in practice. There are types of data for which a monotone-missing data pattern can occur naturally (for example, follow-up measurements). Usually, however, this happens only by chance.

There are several ways to proceed if your data are not monotone missing. You can discard the observations that violate the monotone-missing pattern, especially if there are very few such observations. You can assume independence among the sets of variables to create independent monotone patterns. For example, the missingness pattern for X_1, X_2, X_3, X_4, X_5 may not be monotone, but it may be for X_1, X_3 and for X_2, X_4, X_5. If it is reasonable to assume independence between these two sets of variables, you can then impute each set separately by using monotone imputation. Other alternatives are to use certain techniques to complete the missing-data pattern to monotone (see, for example, Schafer 1997), to use an iterative sequential (fully conditional) imputation (see [MI] **mi impute chained**; Royston 2005, 2007, 2009; van Buuren, Boshuizen, and Knook 1999; Raghunathan et al. 2001), or to assume an explicit multivariate parametric model for the imputation variables (see [MI] **mi impute mvn**; Schafer 1997). Also see *Multivariate imputation* of [MI] **mi impute** for a general discussion of multivariate imputation.

Throughout this entry, we will assume that the considered imputation variables are monotone missing.

First use

Before we describe various uses of `mi impute monotone`, let's look at an example.

Consider the heart attack data examining the relationship between heart attack and smoking. The `age` and `bmi` variables contain missing values and follow a monotone-missing pattern. Recall multivariate imputation of `bmi` and `age` using `mi impute monotone` described in *Multivariate imputation* of [MI] **mi impute**:

```
. use https://www.stata-press.com/data/r19/mheart5s0
(Fictional heart attack data)
. mi impute monotone (regress) bmi age = attack smokes hsgrad female, add(10)
Conditional models:
               age: regress age attack smokes hsgrad female
               bmi: regress bmi age attack smokes hsgrad female

Multivariate imputation                     Imputations =       10
Monotone method                                   added =       10
Imputed: m=1 through m=10                       updated =        0
               bmi: linear regression
               age: linear regression
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
bmi	126	28	28	154
age	142	12	12	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

The `age` and `bmi` variables have monotone missingness, and so `mi impute monotone` is used to fill in missing values. Ten imputations are created (`add(10)` option). The linear regression imputation method (`regress`) is used to impute both continuous variables. The `attack`, `smokes`, `hsgrad`, and `female` variables are used as complete predictors (independent variables).

The conditional models legend shows that `age` (having the least number of missing values) is imputed first using the `regress` method, even though we specified `bmi` before `age` on the `mi impute` command. After that, `bmi` is imputed using the `regress` method and the previously imputed variable `age` and the other predictors.

The header and table output were described in detail in [MI] **mi impute**. The additional information above the imputation table is the legend describing what univariate imputation method was used to impute each variable. (If desired, this legend may be suppressed by specifying the `nolegend` option.)

Using mi impute monotone

Below we summarize general capabilities of `mi impute monotone`.

1. `mi impute monotone` requires that the specified imputation variables follow a monotone-missing pattern. If they do not, it will stop with an error:

```
. mi impute monotone x1 x2 ...
(1 m=0 obs now marked as incomplete)
x1 x2: not monotone;
    imputation variables must have a monotone-missing
    structure; see mi misstable nested
r(459);
```

   As indicated by the error message, we can use `mi misstable nested` to verify for ourselves that the imputation variables are not monotone missing. We could also use other features of `mi misstable` to investigate the pattern.

2. `mi impute monotone` offers two main syntaxes—one using the default prediction equations,

```
. mi impute monotone ...
```

   and the other allowing customization of prediction equations,

```
. mi impute monotone ..., custom ...
```

   We will refer to the two syntaxes as default and custom, respectively.

3. `mi impute monotone` allows specification of a global (outer) `if` condition,

```
. mi impute monotone ... if exp ...
```

   and equation-specific (inner) `if` conditions,

```
. mi impute monotone ... (... if exp ...) ...
```

   A global `if` is applied to all equations (conditional specifications). You may combine global and equation-specific `if` conditions:

```
. mi impute monotone ... (... if exp ...) ... if exp ...
```

4. `mi impute monotone` allows specification of global weights, which are applied to all equations,

```
. mi impute monotone ... [weight] ...
```

Use a combination of options `dryrun` and `report` to check the specification of each univariate imputation model prior to imputing data.

In the next two sections, we describe the use of `mi impute monotone` first using hypothetical situations and then using real examples.

Default syntax of mi impute monotone

We showed in *First use* an example of `mi impute monotone` with default prediction equations using the heart attack data. Here we provide more details about this default specification.

By default, `mi impute monotone` imputes missing values by using the full specification of prediction equations. It builds the corresponding univariate conditional imputation models based on the supplied information: *uvmethod*, the imputation method; *ivars*, the imputation variables; and *indepvars*, the complete predictors or independent variables.

Suppose that continuous variables `x1`, `x2`, and `x3` contain missing values with a monotone-missing pattern. We want to impute these variables, and we decide to use the same univariate imputation method, say, linear regression, for all. We can do this by typing

```
. mi impute monotone (regress) x1 x2 x3 ...
```

The above corresponds to the first syntax diagram of `mi impute monotone`: *uvmethod* is `regress` and *ivars* is `x1 x2 x3`. Relating the above to the model notation used in (1), f_1, f_2, and f_3 represent linear regression imputation models and the prediction sequence is $X_1 \rightarrow X_2|X_1 \rightarrow X_3|X_2, X_1$.

If we have additional covariates containing no missing values (say, `z1` and `z2`) that we want to include in the imputation model, we can do it by typing

```
. mi impute monotone (regress) x1 x2 x3 = z1 z2 ...
```

Now *indepvars* is `z1 z2` and the prediction sequence is $X_1|Z_1, Z_2 \rightarrow X_2|X_1, Z_1, Z_2 \rightarrow X_3|X_2, X_1, Z_1, Z_2$. Independent variables are included in the prediction equations of all conditional models.

Suppose that we want to use a different imputation method for one of the variables—we want to impute `x3` using predictive mean matching. We can do this by typing

```
. mi impute monotone (regress) x1 x2  (pmm, knn(5)) x3  = z1 z2 ...
```

The above corresponds to the second syntax diagram of `mi impute monotone`, a generalization of the first that accommodates differing imputation methods. The right-hand side of the equation is unchanged. `z1` and `z2` are included in all three prediction equations. The left-hand side now has two specifications: `(regress) x1 x2` and `(pmm, knn(5)) x3`. In previous examples, we had only one left-hand-side specification, *lhs_spec*—`(regress) x1 x2 x3`. (Note that the number of left-hand-side specifications does not necessarily correspond to the number of conditional models; the latter is determined by the number of imputation variables.) In this example, `x1` and `x2` are imputed using linear regression, and `x3` is imputed using predictive mean matching with five nearest neighbors specified in `pmm`'s option `knn()`. All method-specific options must be specified within the parentheses surrounding the method:

```
. mi impute monotone (regress) x1 x2 (pmm, knn(5)) x3 = z1 z2 ...
```

Under the default specification, you can list imputation variables in any order and `mi impute monotone` will determine the correct ordering that follows the monotone-missing pattern.

Suppose now we want to restrict the imputation sample for `x2` to observations where `z1` is one; also see *Imputing on subsamples* of [MI] **mi impute**. The corresponding syntax is

```
. mi impute monotone (regress) x1 (regress if z1==1) x2 (pmm, knn(5))
> x3 = z1 z2 ...
```

If, in addition to the above, we want to impute all variables using an overall subsample where `z3` is one, we can specify the global `if z3==1` condition:

```
. mi impute monotone (regress) x1 (regress if z1==1) x2 (pmm, knn(5))
> x3 = z1 z2 if z3==1 ...
```

When any imputation variable is imputed using a categorical method, `mi impute monotone` automatically includes it as a factor variable in the prediction equations of other imputation variables. Suppose that `x1` is a categorical variable and is imputed using the multinomial logistic method:

```
. mi impute monotone (mlogit) x1 (regress) x2 x3 ...
```

The above will result in the prediction sequence $X_1 \rightarrow X_2|\mathtt{i}.X_1 \rightarrow X_3|X_2, \mathtt{i}.X_1$, where $\mathtt{i}.X_1$ denotes the factors of X_1.

If you wish to include factor variables as continuous in prediction equations, you can use the `ascontinuous` option within a specification of the univariate imputation method for that variable:

```
. mi impute monotone (mlogit, ascontinuous) x1 (regress) x2 x3 ...
```

As we discussed in *The issue of perfect prediction during imputation of categorical data* of [MI] **mi impute**, perfect prediction often occurs during imputation of categorical variables. One way of dealing with it is to use the augmented-regression approach (White, Daniel, and Royston 2010), available through the `augment` option. For example, if perfect prediction occurs during imputation of `x1` in the above, you can specify `augment` within the method specification of `x1` to perform augmented regression:

```
. mi impute monotone (mlogit, augment) x1 (regress) x2 x3 ...
```

Alternatively, you can use the `augment` option with `mi impute monotone` to perform augmented regression for all categorical variables for which the issue of perfect prediction arises:

```
. mi impute monotone (mlogit) x1 (logit) x2 (regress) x3 ..., augment ...
```

The above command is equivalent to specifying `augment` within each specification of a univariate categorical imputation method:

```
. mi impute monotone (mlogit, augment) x1 (logit, augment) x2 (regress) x3 ...
```

Also see *Default prediction equations* in [MI] **mi impute chained** for other uses of the default syntax.

The alternative syntax of mi impute monotone—custom prediction equations

Consider the prediction sequence $X_1 \rightarrow X_2|X_1 \rightarrow X_3|X_2, X_1$. Suppose that we want to predict X_3 from X_1 rather than from X_1 and X_2. This could be achieved by simply imputing X_1 and X_2 and then X_3 given X_1 separately because of the implied assumption that X_3 and X_2 are independent given X_1. However, with a larger number of variables and more complicated prediction rules, separate imputations may not be appealing. So customization of the prediction equations is a good alternative.

You customize prediction equations using the custom syntax (the third syntax) of `mi impute monotone`. You must specify the `custom` option to notify `mi impute monotone` that you are specifying custom prediction equations.

Under the custom syntax, you specify a separate conditional imputation model for each imputation variable. The specification of a conditional model is the same as that for the chosen univariate imputation method, but the entire model must be bound in parentheses, for example,

```
. mi impute monotone (regress x1)
                     (regress x2 x1)
                     (regress x3 x1)
                                 , custom ...
```

Here we have three conditional specifications: `(regress x1)`, `(regress x2 x1)`, and `(regress x3 x1)`. The corresponding prediction sequence is $X_1 \rightarrow X_2|X_1 \rightarrow X_3|X_1$. Prediction equations have the syntax *ivar* [*rhs_spec*].

When specifying custom prediction equations, you are required to list the conditional models in the correct order of missing monotonicity. `mi impute monotone` will issue an error if you are wrong:

```
mi impute monotone: incorrect equation order
    equations must be listed in the monotone-missing order of the imputation
    variables (from most observed to least observed); x2(2) -> x1(5) -> x3(10)
r(198);
```

If we have additional covariates `z1` and `z2` containing no missing values, we can include them in the imputation model:

```
. mi impute monotone (regress x1 z1 z2)
                     (regress x2 x1 z1 z2)
                     (regress x3 x1 z1 z2), custom ...
```

To use the predictive mean matching method for `x3`, we simply change the method from `regress` to `pmm` and specify, say, five nearest neighbors in `pmm`'s required option `knn()` in the last conditional specification:

```
. mi impute monotone (regress x1 z1 z2)
                     (regress x2 x1 z1 z2)
                     (pmm x3 x1 z1 z2, knn(5)), custom ...
```

Under the custom syntax, you can also include expressions of previously imputed variables in prediction equations. For example, if you want to model `x3` using main and squared effects of `x1` (ignoring predictors `z1` and `z2`), you can type

```
. mi impute monotone (regress x1)
                     (regress x2 x1)
                     (pmm x3 x1 (x1^2), knn(5)), custom ...
```

Note that we bound the expression `x1^2` in parentheses. Any expression may appear inside the parentheses.

Similar to the default specification, we can include equation-specific `if`s,

```
. mi impute monotone (regress x1)
                     (regress x2 x1 if z1==1)
                     (pmm x3 x1, knn(5)), custom ...
```

and we can specify a global `if`,

```
. mi impute monotone (regress x1 z1 z2)
                     (regress x2 x1 z2 if z1==1)
                     (pmm x3 x1 z1 z2, knn(5))
                                    if z3==1, custom ...
```

Suppose that one of the imputed variables is categorical. We can use the multinomial logistic method to impute its values:

```
. mi impute monotone (mlogit x1)
                     (regress x2 i.x1)
                     (regress x3 i.x1)
                                 , custom ...
```

Also see *Link between mi impute chained and mi impute monotone* in [MI] **mi impute chained** for a discussion of custom syntaxes.

Examples of using default prediction equations

▷ Example 1: Different imputation methods

Recall the heart attack example from *First use*. If we wanted to impute age using predictive mean matching instead of linear regression, we could type

```
. use https://www.stata-press.com/data/r19/mheart5s0, clear
(Fictional heart attack data)
. mi impute monotone (regress) bmi (pmm, knn(3)) age = attack smokes hsgrad
> female, add(10)
Conditional models:
               age: pmm age attack smokes hsgrad female, knn(3)
               bmi: regress bmi age attack smokes hsgrad female

Multivariate imputation                     Imputations =       10
Monotone method                                added =       10
Imputed: m=1 through m=10                    updated =        0
               bmi: linear regression
               age: predictive mean matching
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
bmi	126	28	28	154
age	142	12	12	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

As previously, we listed age and bmi in the reverse order here, and `mi impute monotone` determined the correct order of missing monotonicity.

◁

▷ Example 2: Imputing a variable on a subsample

Consider an `mi set` version of the heart attack data containing the indicator for smoking high-tar cigarettes (variable `hightar`):

```
. use https://www.stata-press.com/data/r19/mheart6s0, clear
(Fictional heart attack data; bmi, age, and hightar missing)
. mi describe
Style: mlong
       last mi update 04feb2025 12:58:57, 11 days ago
Observations:
   Complete          124
   Incomplete         30  (M = 0 imputations)
   ------------------------
   Total             154
Variables:
   Imputed: 3; bmi(24) age(30) hightar(8)
   Passive: 0
   Regular: 4; attack smokes female hsgrad
   System:  3; _mi_m _mi_id _mi_miss
   (there are no unregistered variables)
```

mi describe reports that there are no imputations, three registered imputed variables (hightar is one of them), and four registered regular variables.

Next we use mi misstable nested to examine missing-data patterns in the data.

```
. mi misstable nested
     1.  hightar(8) -> bmi(24) -> age(30)
```

There is one monotone-missing pattern in the data. According to the output, missing values of hightar are nested within bmi, whose missing values are nested within age. So hightar, bmi, and age follow a monotone-missing pattern.

As before, to impute missing values of age and bmi, we use the regression method. The hightar variable is a binary variable, so we choose the logistic method to fill in its values (see [MI] **mi impute logit**). Because hightar records whether a subject smokes high-tar cigarettes, we use only those who smoke to impute its missing values. (If there were any missing values of hightar for the subjects who do not smoke, we would have replaced them with zeros.)

```
. mi impute monotone (reg) age bmi (logit if smokes) hightar
> = attack smokes hsgrad female, add(10)

Conditional models:
           hightar: logit hightar attack smokes hsgrad female if smokes
               bmi: regress bmi i.hightar attack smokes hsgrad female
               age: regress age bmi i.hightar attack smokes hsgrad female

note: smokes omitted because of collinearity.

Multivariate imputation                     Imputations =       10
Monotone method                                    added =       10
Imputed: m=1 through m=10                        updated =        0

               age: linear regression
               bmi: linear regression
           hightar: logistic regression
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
age	124	30	30	154
bmi	130	24	24	154
hightar	56	8	8	64

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

mi impute monotone reports which univariate conditional model was used to impute each variable. Because hightar has the least number of missing observations, it is imputed first using the specified complete predictors and using only observations for smokers. From the output, all incomplete values of each of the variables are imputed in all 10 imputations. Notice that because we restricted the imputation sample of hightar to smokers, the total number of observations reported for hightar is 64 and not 154.

It is safe to use the if restriction in the above because smokes does not contain any missing values and hightar does not contain any missing values in observations with smokes==0. Otherwise, the conditional() option should be used instead; see *Conditional imputation* of [MI] **mi impute** for details.

◁

Examples of using custom prediction equations

▷ Example 3: Using different sets of predictors within individual conditional models

Let's take a closer look at the conditional model for `hightar` used in the above example:

```
hightar: logit hightar attack smokes hsgrad female if (smokes)
```

Notice that predictor `smokes` is redundant in this model because it is collinear with the constant (included in the model by default) on the restricted sample of smokers. In fact, if we specify the `noisily` option (`noi` for short) within the `logit` specification to see the estimation results, we will notice that, as expected, `smokes` was omitted from the estimation model for `hightar`; that is, its coefficient is zero.

```
. mi impute monotone (reg) age bmi (logit if smokes, noi) hightar
> = attack smokes hsgrad female, replace

Conditional models:
           hightar: logit hightar attack smokes hsgrad female if smokes,
                     noisily
               bmi: regress bmi i.hightar attack smokes hsgrad female
               age: regress age bmi i.hightar attack smokes hsgrad female

Running logit on observed data:

note: smokes omitted because of collinearity.
Iteration 0:  Log likelihood = -38.673263
Iteration 1:  Log likelihood = -38.455029
Iteration 2:  Log likelihood = -38.454991
Iteration 3:  Log likelihood = -38.454991
Logistic regression                                     Number of obs =     56
                                                        LR chi2(3)    =   0.44
                                                        Prob > chi2   = 0.9326
Log likelihood = -38.454991                             Pseudo R2     = 0.0056

------------------------------------------------------------------------------
     hightar | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
      attack |   .0773715   .5630513     0.14   0.891    -1.026189    1.180932
      smokes |           0  (omitted)
      hsgrad |  -.1663937   .5977995    -0.28   0.781    -1.338059    1.005272
      female |  -.3331926    .617736    -0.54   0.590    -1.543933    .8775477
       _cons |   .0138334   .6263152     0.02   0.982    -1.213722    1.241389
------------------------------------------------------------------------------

Multivariate imputation                     Imputations =       10
Monotone method                                    added =        0
Imputed: m=1 through m=10                        updated =       10
               age: linear regression
               bmi: linear regression
          hightar: logistic regression

------------------------------------------------------------------------------
                             |                Observations per m
                             |----------------------------------------------
                    Variable |   Complete   Incomplete   Imputed      Total
-----------------------------+----------------------------------------------
                         age |        124           30        30        154
                         bmi |        130           24        24        154
                    hightar |         56            8         8         64
------------------------------------------------------------------------------
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

Although `mi impute` handles collinearity problems for us automatically, we can eliminate redundancy manually by removing `smokes` from the prediction equation for `hightar`. To do that, we need to specify custom prediction equations.

As discussed in *Using mi impute monotone*, custom prediction equations are available with `mi impute monotone` when the `custom` option is used. We also know that within this custom specification, we must fully specify prediction equations within each conditional model and must specify the conditional models in the monotone-missing order of the imputation variables.

Building such conditional models from scratch could be a tedious task except that we can use `mi impute monotone, dryrun` to display the conditional models with default prediction equations without performing the corresponding imputation:

```
. mi impute monotone (reg) age bmi (logit if smokes) hightar
> = attack smokes hsgrad female, dryrun

Conditional models:
           hightar: logit hightar attack smokes hsgrad female if smokes
               bmi: regress bmi i.hightar attack smokes hsgrad female
               age: regress age bmi i.hightar attack smokes hsgrad female
```

We can use these default conditional specifications as the basis for writing our own customized specifications. We will remove `smokes` from the predictor list for `hightar`:

```
. mi impute monotone (logit hightar attack hsgrad female if smokes)
>                    (regress bmi hightar attack smokes hsgrad female)
>                    (regress age bmi hightar attack smokes hsgrad female)
>                                                              , custom replace

Multivariate imputation                     Imputations =       10
Monotone method                                    added =        0
Imputed: m=1 through m=10                        updated =       10

           hightar: logistic regression
               bmi: linear regression
               age: linear regression
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
hightar	56	8	8	64
bmi	130	24	24	154
age	124	30	30	154

(Complete + Incomplete = Total; Imputed is the minimum across *m* of the number of filled-in observations.)

◁

Example 4: Including expressions of imputation variables in prediction equations

The distribution of bmi is slightly skewed. To take this into account, we can either use predictive mean matching to impute bmi or impute bmi on a logarithmic scale. We choose to impute the log of bmi here.

Following the steps described in *Imputing transformations of incomplete variables* of [MI] **mi impute**, we create a new variable, lnbmi, containing the log of bmi and register it as imputed. Here we also reset the number of imputations to zero.

```
. mi set M = 0
(10 imputations dropped; M = 0)
. mi unregister bmi
. generate lnbmi = ln(bmi)
(24 missing values generated)
. mi register imputed lnbmi
```

We are now ready to impute lnbmi. However, although we are imputing the log of bmi, we want to use bmi in the original scale when imputing age. To do that, we include exp(lnbmi) in the prediction equation for age. When including expressions in a custom specification, the expressions must appear in parentheses:

```
. mi impute monotone (logit hightar attack hsgrad female if smokes)
>                    (regress lnbmi hightar attack smokes hsgrad female)
>                    (regress age (exp(lnbmi))
>                        hightar attack smokes hsgrad female)
>                                                          , custom add(10)
Multivariate imputation                     Imputations =       10
Monotone method                                   added =       10
Imputed: m=1 through m=10                       updated =        0
           hightar: logistic regression
             lnbmi: linear regression
               age: linear regression
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
hightar	56	8	8	64
lnbmi	130	24	24	154
age	124	30	30	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

If we also wanted to include a squared term for bmi in the conditional imputation model for age, we would type

```
. mi impute monotone
> (logit hightar attack hsgrad female if smokes)
> (regress lnbmi hightar attack smokes hsgrad female)
> (regress age (exp(lnbmi)) (exp(lnbmi)^2) hightar attack smokes hsgrad female)
>                                                          , custom replace
```

(*output omitted*)

Stored results

mi impute monotone stores the following in r():

Scalars

r(M)	total number of imputations
r(M_add)	number of added imputations
r(M_update)	number of updated imputations
r(k_ivars)	number of imputed variables
r(N_g)	number of imputed groups (1 if by() is not specified)

Macros

r(method)	name of imputation method (monotone)
r(ivars)	names of imputation variables
r(rngstate)	random-number state used
r(uvmethods)	names of univariate conditional imputation methods
r(by)	names of variables specified within by()

Matrices

r(N)	number of observations in imputation sample in each group (per variable)
r(N_complete)	number of complete observations in imputation sample in each group (per variable)
r(N_incomplete)	number of incomplete observations in imputation sample in each group (per variable)
r(N_imputed)	number of imputed observations in imputation sample in each group (per variable)

Methods and formulas

Let $\mathbf{x}_{(i)} = (x_{i1}, x_{i2}, \ldots, x_{ip})$ be the ith observation containing values of the imputation variables ordered from the most observed to the least observed to form a monotone-missing data pattern. Let $\mathbf{z}_{(i)} = (z_{i1}, z_{i2}, \ldots, z_{iq})$ be the corresponding set of predictors of $\mathbf{x}_{(i)}$. Then, if the missingness-modeling structure is monotone distinct (imputation variables have monotone missingness and parameters of the conditional models are distinct as defined in Rubin [1987, 174]), the following decomposition holds:

$$f_{\mathbf{X}}(\mathbf{x}_{(i)}|\mathbf{z}_{(i)}, \boldsymbol{\theta}) = f_1(x_{i1}|\mathbf{z}_{(i)}, \boldsymbol{\theta}_1) f_2(x_{i2}|\mathbf{z}_{(i)}, x_{i1}, \boldsymbol{\theta}_2) \cdots f_p(x_{ip}|\mathbf{z}_{(i)}, x_{i1}, x_{i2}, \ldots, x_{i,p-1}, \boldsymbol{\theta}_p)$$

where the unknown parameters $\boldsymbol{\theta}_1, \ldots, \boldsymbol{\theta}_p$ are distinct, that is, $\Pr(\boldsymbol{\theta}) = \prod_{j=1}^{p} \Pr(\boldsymbol{\theta}_j)$. The monotone-distinct structure ensures that the univariate conditional models f_j do not depend on any unobserved values of variable $\mathbf{x}_j$ and the posterior distributions of $\boldsymbol{\theta}_j$ do not involve the imputed values of the previously filled-in variables $\mathbf{x}_1, \ldots, \mathbf{x}_{j-1}$. See Rubin (1987, 174–178) for a rigorous justification of the above decomposition.

The above allows substituting the imputation of $\mathbf{X}$ using the probability model $f_{\mathbf{X}}(\cdot)$ with a sequence of univariate conditional imputations of $\mathbf{x}_j$ using the probability models $f_j(\cdot)$. Note that f_j can be any proper imputation model (for example, linear regression or logistic regression).

mi impute monotone follows the steps below to fill in missing values in $\mathbf{x}_1, \ldots, \mathbf{x}_p$:

1. If the custom option is not used, mi impute monotone first builds univariate conditional models containing the default prediction equations using the supplied information about imputation methods, imputation variables $\mathbf{X}$, and complete predictors $\mathbf{Z}$. The order in which imputation variables are listed is irrelevant. The prediction equations are constructed as follows. Complete predictors *indepvars* are included first. The imputation variables are included next with each previously imputed variable added to the beginning of the prediction equation previously used.

   If the custom option is used, mi impute monotone uses the specified conditional models in the order supplied. The conditional models must be listed in the monotone-missing order of the corresponding imputation variables.

2. Fit univariate conditional models for each $\mathbf{x}_j$ to the observed data to obtain the estimates of $\boldsymbol{\theta}_j$, $j = 1, \ldots, p$. See step 1 in *Methods and formulas* of each respective univariate imputation method's manual entry for details.
3. Sequentially fill in missing values of $\mathbf{x}_1, \mathbf{x}_2, \ldots, \mathbf{x}_p$ according to the specified imputation model. See step 2 and step 3 in *Methods and formulas* of each respective univariate imputation method's manual entry for details.
4. Repeat step 3 to obtain M multiple imputations.

References

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Rubin, D. B. 1987. *Multiple Imputation for Nonresponse in Surveys.* New York: Wiley.

Schafer, J. L. 1997. *Analysis of Incomplete Multivariate Data.* Boca Raton, FL: Chapman and Hall/CRC.

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White, I. R., R. M. Daniel, and P. Royston. 2010. Avoiding bias due to perfect prediction in multiple imputation of incomplete categorical data. *Computational Statistics and Data Analysis* 54: 2267–2275. https://doi.org/10.1016/j.csda.2010.04.005.

Also see

[MI] **mi impute** — Impute missing values

[MI] **mi impute chained** — Impute missing values using chained equations

[MI] **mi impute mvn** — Impute using multivariate normal regression

[MI] **mi estimate** — Estimation using multiple imputations

[MI] **Intro** — Introduction to mi

[MI] **Intro substantive** — Introduction to multiple-imputation analysis

[MI] **Glossary**

mi impute mvn — Impute using multivariate normal regression

Description | Menu | Syntax | Options
Remarks and examples | Stored results | Methods and formulas | References
Also see

Description

`mi impute mvn` fills in missing values of one or more continuous variables using multivariate normal regression. It accommodates arbitrary missing-value patterns. You can perform separate imputations on different subsets of the data by specifying the `by()` option. `mi impute mvn` uses an iterative Markov chain Monte Carlo (MCMC) method to impute missing values. See *Remarks and examples* for details.

Menu

Statistics > Multiple imputation

Syntax

`mi impute mvn` *ivars* [`=` *indepvars*] [*if*] [`,` *impute_options options*]

impute_options	Description
Main	
* `add(#)`	specify number of imputations to add; required when no imputations exist
* `replace`	replace imputed values in existing imputations
`rseed(#)`	specify random-number seed
`double`	store imputed values in double precision; the default is to store them as `float`
`by(`*varlist*[`,` *byopts*]`)`	impute separately on each group formed by *varlist*
Reporting	
`dots`	display dots as imputations are performed
`noisily`	display intermediate output
`nolegend`	suppress all table legends
Advanced	
`force`	proceed with imputation, even when missing imputed values are encountered
`noupdate`	do not perform `mi update`; see [MI] **noupdate option**

*`add(#)` is required when no imputations exist; `add(#)` or `replace` is required if imputations exist.

`noupdate` does not appear in the dialog box.

options	Description
Main	
noconstant	suppress constant term
MCMC options	
burnin(#)	specify number of iterations for the burn-in period; default is burnin(100)
burnbetween(#)	specify number of iterations between imputations; default is burnbetween(100)
prior(*prior_spec*)	specify a prior distribution; default is prior(uniform)
mcmconly	perform MCMC for the length of the burn-in period without imputing missing values
initmcmc(*init_mcmc*)	specify initial values for the MCMC procedure; default is initmcmc(em) using the EM estimates for initial values
wlfwgt(*matname*)	specify weights for the worst linear function
savewlf(*filename*[, ...])	save the worst linear function from each iteration in *filename*.dta
saveptrace(*fname*[, ...])	save MCMC parameter estimates from each iteration in *fname*.stptrace; see [MI] **mi ptrace**
Reporting	
emlog	display iteration log from EM
emoutput	display intermediate output from EM estimation
mcmcdots	display dots as MCMC iterations are performed
alldots	display dots as intermediate iterations are performed
nolog	do not display information about the EM or MCMC procedures
Advanced	
emonly[(*em_options*)]	perform EM estimation only

You must mi set your data before using mi impute mvn; see [MI] **mi set**.

You must mi register *ivars* as imputed before using mi impute mvn; see [MI] **mi set**.

indepvars may contain factor variables; see **[U] 11.4.3 Factor variables**.

collect is allowed; see **[U] 11.1.10 Prefix commands**.

prior_spec	Description
uniform	use the uniform prior distribution; the default
jeffreys	use the Jeffreys noninformative prior distribution
ridge, df(#)	use a ridge prior distribution with degrees of freedom #

init_mcmc	Description
em[, *em_options*]	use EM to obtain starting values for MCMC; the default
initmatlist	supply matrices containing initial values for MCMC

em_options	Description
iterate(#)	specify the maximum number of iterations; default is iterate(100)
tolerance(#)	specify tolerance for the changes in parameter estimates; default is tolerance(1e-5)
init(*init_em*)	specify initial values for the EM algorithm; default is init(ac)
nolog	do not show EM iteration log
saveptrace(*fname*[, ...])	save EM parameter estimates from each iteration in *fname*.stptrace; see [MI] **mi ptrace**

init_em	Description
ac	use all available cases to obtain initial values for EM; the default
cc	use only complete cases to obtain initial values for EM
initmatlist	supply matrices containing initial values for EM

initmatlist is of the form *initmat* [*initmat* [...]]

initmat	Description
betas(#|*matname*)	specify coefficient vector; default is betas(0)
sds(#|*matname*)	specify standard deviation vector; default is sds(1)
vars(#|*matname*)	specify variance vector; default is vars(1)
corr(#|*matname*)	specify correlation matrix; default is corr(0)
cov(*matname*)	specify covariance matrix

In the above, # is understood to mean a vector containing all elements equal to #.

Options

Main

noconstant; see [R] **Estimation options**.

add(), replace, rseed(), double, by(); see [MI] **mi impute**.

MCMC options

burnin(#) specifies the number of iterations for the initial burn-in period. The default is burnin(100). This option specifies the number of iterations necessary for the MCMC to reach approximate stationarity or, equivalently, to converge to a stationary distribution. The required length of the burn-in period will depend on the starting values used and the missing-data patterns observed in the data. It is important to examine the chain for convergence to determine an adequate length of the burn-in period prior to obtaining imputations; see *Convergence of the MCMC method* and examples 2 and 4. The provided default may be sufficient in many cases, but you are responsible for determining that sufficient iterations are performed.

burnbetween(#) specifies a number of iterations of the MCMC to perform between imputations, the purpose being to reduce correlation between sets of imputed values. The default is burnbetween(100). As with burnin(), you are responsible for determining that sufficient iterations are performed. See *Convergence of the MCMC method* and examples 2 and 4.

`prior(`*prior_spec*`)` specifies a prior distribution to be used by the MCMC procedure. The default is `prior(uniform)`. The alternative prior distributions are useful when the default estimation of the parameters using maximum likelihood becomes unstable (for example, estimates on the boundary of the parameter space) and introducing some prior information about parameters stabilizes the estimation.

prior_spec is

`uniform` | `jeffreys` | `ridge, df(`#`)`

`uniform` specifies the uniform (flat) prior distribution. Under this prior distribution, the posterior distribution is proportional to the likelihood function and thus the estimate of the posterior mode is the same as the maximum likelihood (ML) estimate.

`jeffreys` specifies the Jeffreys, noninformative prior distribution. This prior distribution can be used when there is no strong prior knowledge about the model parameters.

`ridge, df(`#`)` specifies a ridge, informative prior distribution with the degrees of freedom #. This prior introduces some information about the covariance matrix by smoothing the off-diagonal elements (correlations) toward zero. The degrees of freedom, `df()`, which may be noninteger, regulates the amount of smoothness—the larger this number, the closer the correlations are to zero. A ridge prior is useful to stabilize inferences about the mean parameters when the covariance matrix is poorly estimated, for example, when there are insufficient observations to estimate correlations between some variables reliably because of missing data, causing the estimated covariance matrix to become non–positive definite (see Schafer [1997, 155–157] for details).

`mcmconly` specifies that `mi impute mvn` run the MCMC for the length of the burn-in period and then stop. This option is useful in combination with `savewlf()` or `saveptrace()` to examine the convergence of the MCMC prior to imputation. No imputation is performed when `mcmconly` is specified, so `add()` or `replace` is not required with `mi impute mvn, mcmconly`, and they are ignored if specified. The `mcmconly` option is not allowed with `emonly`.

`initmcmc()` may be specified as `initmcmc(em` [`,` *em_options*]`)` or `initmcmc(`*initmatlist*`)`.

`initmcmc()` specifies initial values for the regression coefficients and covariance matrix of the multivariate normal distribution to be used by the MCMC procedure. By default, initial values are obtained from the EM algorithm, `initmcmc(em)`.

`initmcmc(em`[`,` *em_options*]`)` specifies that the initial values for the MCMC procedure be obtained from EM. You can control the EM estimation by specifying *em_options*. If the uniform prior is used, the initial estimates correspond to the ML estimates computed using EM. Otherwise, the initial values are the estimates of the posterior mode computed using EM.

em_options are

`iterate(`#`)` specifies the maximum number of EM iterations to perform. The default is `iterate(100)`.

`tolerance(`#`)` specifies the convergence tolerance for the EM algorithm. The default is `tolerance(1e-5)`. Convergence is declared once the maximum of the relative changes between two successive estimates of all model parameters is less than #.

`init()` may be specified as `init(ac)`, `init(cc)`, or `init(`*matlist*`)`

`init()` specifies initial values for the regression coefficients and covariance matrix of the multivariate normal distribution to be used by the EM algorithm. `init(ac)` is the default.

`init(ac)` specifies that initial estimates be obtained using all available cases. The initial values for regression coefficients are obtained from separate univariate regressions of each imputation variable on the independent variables. The corresponding estimates of the residual mean-squared error are used as the initial values for the diagonal entries of the covariance matrix (variances). The off-diagonal entries (correlations) are set to zero.

`init(cc)` specifies that initial estimates be obtained using only complete cases. The initial values for regression coefficients and the covariance matrix are obtained from a multivariate regression fit to the complete cases only.

`init(`*initmatlist*`)` specifies to use manually supplied initial values for the EM procedure and syntactically is identical to `mcmcinit(`*initmatlist*`)`, described below, except that you specify `init(`*initmatlist*`)`.

`nolog` suppresses the EM iteration log when `emonly` or `emoutput` is used.

`saveptrace(`*fname*`[ , replace ])` specifies to save the parameter trace log from the EM algorithm to a file called *fname*`.stptrace`. If the file already exists, the `replace` suboption specifies to overwrite the existing file. See [MI] **mi ptrace** for details about the saved file and how to read it into Stata.

`initmcmc(`*initmatlist*`)`, where *initmatlist* is

initmat [*initmat* [...]]

specifies manually supplied initial values for the MCMC procedure.

initmat is

`betas(#|`*matname*`)` specifies initial values for the regression coefficients. The default is `betas(0)`, implying a value of zero for all regression coefficients. If you specify `betas(#)`, then # will be used as the initial value for all regression coefficients. Alternatively, you can specify the name of a Stata matrix, *matname*, containing values for each regression coefficient. *matname* must be conformable with the dimensionality of the specified model. That is, it can be one of the following dimensions: $p \times q$, $q \times p$, $1 \times pq$, or $pq \times 1$, where p is the number of imputation variables and q is the number of independent variables.

`sds(#|`*matname*`)` specifies initial values for the standard deviations (square roots of the diagonal elements of the covariance matrix). The default is `sds(1)`, which sets all standard deviations and thus variances to one. If you specify `sds(#)`, then the squared # will be used as the initial value for all variances. Alternatively, you can specify the name of a Stata matrix, *matname*, containing individual values. *matname* must be conformable with the dimensionality of the specified model. That is, it can be one of the following dimensions: $1 \times p$ or $p \times 1$, where p is the number of imputation variables. This option cannot be combined with `cov()` or `vars()`. The `sds()` option can be used in combination with `corr()` to provide initial values for the covariance matrix.

`vars(#|`*matname*`)` specifies initial values for variances (diagonal elements of the covariance matrix). The default is `vars(1)`, which sets all variances to one. If you specify `vars(#)`, then # will be used as the initial value for all variances. Alternatively, you can specify the name of a Stata matrix, *matname*, containing individual values. *matname* must be conformable with the dimensionality of the specified model. That is, it can be one of the following dimensions: $1 \times p$ or $p \times 1$, where p is the number of imputation variables. This option cannot be combined with `cov()` or `sds()`. The `vars()` option can be used in combination with `corr()` to provide initial values for the covariance matrix.

`corr(#|`*matname*`)` specifies initial values for the correlations (off-diagonal elements of the correlation matrix). The default is `corr(0)`, which sets all correlations and, thus, covariances to zero. If you specify `corr(#)`, then all correlation coefficients will be set to #. Alternatively, you can specify the name of a Stata matrix, *matname*, containing individual values. *matname* can be a square $p \times p$ matrix with diagonal elements equal to one or it can contain the corresponding lower (upper) triangular matrix in a vector of dimension $p(p+1)/2$, where p is the number of imputation variables. This option cannot be combined with `cov()`. The `corr()` option can be used in combination with `sds()` or `vars()` to provide initial values for the covariance matrix.

`cov(`*matname*`)` specifies initial values for the covariance matrix. *matname* must contain the name of a Stata matrix. *matname* can be a square $p \times p$ matrix or it can contain the corresponding lower (upper) triangular matrix in a vector of dimension $p(p+1)/2$, where p is the number of imputation variables. This option cannot be combined with `corr()`, `sds()`, or `vars()`.

`wlfwgt(`*matname*`)` specifies the weights (coefficients) to use when computing the worst linear function (WLF). The coefficients must be saved in a Stata matrix, *matname*, of dimension $1 \times d$, where $d = pq + p(p+1)/2$, p is the number of imputation variables, and q is the number of predictors. This option is useful when initial values from the EM estimation are supplied to data augmentation (DA) as matrices. This option can also be used to obtain the estimates of linear functions other than the default WLF. This option cannot be combined with `by()`.

`savewlf(`*filename*`[ , replace ])` specifies to save the estimates of the WLF from each iteration of MCMC to a Stata dataset called *filename*`.dta`. If the file already exists, the `replace` suboption specifies to overwrite the existing file. This option is useful for monitoring convergence of the MCMC. `savewlf()` is allowed with `initmcmc(em)`, when the initial values are obtained using the EM estimation, or with `wlfwgt()`. This option cannot be combined with `by()`.

`saveptrace(`*fname*`[ , replace ])` specifies to save the parameter trace log from the MCMC to a file called *fname*`.stptrace`. If the file already exists, the `replace` suboption specifies to overwrite the existing file. See [MI] **mi ptrace** for details about the saved file and how to read it into Stata. This option is useful for monitoring convergence of the MCMC. This option cannot be combined with `by()`.

Reporting

`dots`, `noisily`, `nolegend`; see [MI] **mi impute**. Also, `noisily` is a synonym for `emoutput`. `nolegend` suppresses group legends that may appear when the `by()` option is used. It is a synonym for `by(, nolegend)`.

`emlog` specifies that the EM iteration log be shown. The EM iteration log is not displayed unless `emonly` or `emoutput` is specified.

`emoutput` specifies that the EM output be shown. This option is implied with `emonly`.

`mcmcdots` specifies to display all MCMC iterations as dots.

`alldots` specifies to display all intermediate iterations as dots in addition to the imputation dots. These iterations include the EM iterations and the MCMC burn-in iterations. This option implies `mcmcdots`.

`nolog` suppresses all output from EM or MCMC that is usually displayed by default.

Advanced

`force`; see [MI] **mi impute**.

`emonly`[(*em_options*)] specifies that `mi impute mvn` perform EM estimation and then stop. You can control the EM process by specifying *em_options*. This option is useful at the preliminary stage to obtain insight about the length of the burn-in period as well as to choose a prior specification. No imputation is performed, so `add()` or `replace` is not required with `mi impute mvn, emonly`, and they are ignored if specified. The `emonly` option is not allowed with `mcmconly`.

The following option is available with `mi impute` but is not shown in the dialog box:

`noupdate`; see [MI] **noupdate option**.

Remarks and examples

Remarks are presented under the following headings:

Incomplete continuous data with arbitrary pattern of missing values
Multivariate imputation using data augmentation
Convergence of the MCMC method
Using mi impute mvn
Examples

See [MI] **mi impute** for a general description and details about options common to all imputation methods, *impute_options*. Also see [MI] **Workflow** for general advice on working with `mi`.

Incomplete continuous data with arbitrary pattern of missing values

As we described in detail in *Multivariate imputation* in [MI] **mi impute**, imputation of multiple variables with an arbitrary pattern of missing values is more challenging than when the missing-data pattern is monotone.

One approach for dealing with an arbitrary missing-value pattern is to assume an explicit tractable parametric model for the data and draw imputed values from the resulting distribution of the missing data given observed data. One of the more popular parametric models is the Gaussian normal model; see Rubin (1987) for other recommendations. Although a multivariate normal model is straightforward, difficulty arises in the simulation from the corresponding, more complicated, distribution of the missing data. One solution is to use one of the Bayesian iterative Markov chain Monte Carlo (MCMC) procedures to approximate the distribution of missing data.

Multivariate imputation using data augmentation

`mi impute mvn` uses data augmentation (DA) —an iterative MCMC procedure—to generate imputed values assuming an underlying multivariate normal model. For details about DA as a general MCMC procedure, see Gelman et al. (2014), Tanner and Wong (1987), and Li (1988), among others. For applications of DA to incomplete multivariate normal data, see, for example, Little and Rubin (2020) and Schafer (1997). Below we briefly describe the idea behind DA; see *Methods and formulas* for details.

Consider multivariate data $\mathbf{X} = (\mathbf{X}_o, \mathbf{X}_m)$, decomposed into the observed part $\mathbf{X}_o$ and the missing part $\mathbf{X}_m$, from a normal distribution $\Pr(\mathbf{X}|\boldsymbol{\theta}) = N(\boldsymbol{\beta}, \boldsymbol{\Sigma})$, where $\boldsymbol{\theta}$ denotes the unknown model parameters (regression coefficients $\boldsymbol{\beta}$ and unique elements of the covariance matrix $\boldsymbol{\Sigma}$). The goal is to replace missing values in $\mathbf{X}_m$ with draws from the distribution (or the predictive distribution in Bayesian terminology) of the missing data given observed data, $\Pr(\mathbf{X}_m|\mathbf{X}_o)$. The actual predictive distribution $\Pr(\mathbf{X}_m|\mathbf{X}_o)$ is difficult to draw from directly because of an underlying dependence on the posterior distribution of the unknown parameters $\boldsymbol{\theta}$, $\Pr(\boldsymbol{\theta}|\mathbf{X}_o)$.

Originally, DA was used to approximate the posterior distribution of the model parameters, $\Pr(\boldsymbol{\theta}|\mathbf{X}_o)$, in Bayesian applications with incomplete data. The idea of DA is to augment the observed data, $\mathbf{X}_o$, with the latent (unobserved) data, $\mathbf{X}_m$, such that the conditional posterior distribution $\Pr(\boldsymbol{\theta}|\mathbf{X}_o, \mathbf{X}_m)$ becomes more tractable and easier to simulate from. Then the procedure becomes as follows. For a current $\boldsymbol{\theta}^{(t)}$, draw $\mathbf{X}_m^{(t+1)}$ from its conditional predictive distribution given the observed data and $\boldsymbol{\theta}$, $\Pr(\mathbf{X}_m|\mathbf{X}_o, \boldsymbol{\theta}^{(t)})$. Next draw $\boldsymbol{\theta}^{(t+1)}$ from its conditional posterior distribution given the augmented data, $\Pr(\boldsymbol{\theta}|\mathbf{X}_o, \mathbf{X}_m^{(t+1)})$. Continue to iterate until the sequence $\{(\mathbf{X}_m^{(t)}, \boldsymbol{\theta}^{(t)}) : t = 1, 2, \dots\}$, an MCMC sequence, converges to a stationary distribution $\Pr(\boldsymbol{\theta}, \mathbf{X}_m|\mathbf{X}_o)$. This way a complicated task of simulating from $\Pr(\boldsymbol{\theta}|\mathbf{X}_o)$ is replaced by a sequence of simpler simulation tasks of iteratively sampling from $\Pr(\boldsymbol{\theta}|\mathbf{X}_o, \mathbf{X}_m)$ and $\Pr(\mathbf{X}_m|\mathbf{X}_o, \boldsymbol{\theta})$. How is this procedure related to imputation? The sequence $\{\mathbf{X}_m^{(t)} : t = 1, 2, \dots\}$ contains draws from an approximate predictive distribution $\Pr(\mathbf{X}_m|\mathbf{X}_o)$, and thus $\mathbf{X}_m^{(t)}$'s are, in fact, imputations. The convergence of this procedure was studied by Li (1988).

The functional forms of the conditional distributions $\Pr(\boldsymbol{\theta}|\mathbf{X}_o, \mathbf{X}_m)$ and $\Pr(\mathbf{X}_m|\mathbf{X}_o, \boldsymbol{\theta})$ are determined from the assumed distribution of the data, $\mathbf{X}$, and a prior distribution for the model parameters, $\boldsymbol{\theta}$, $\Pr(\boldsymbol{\theta})$. `mi impute mvn` assumes a normal distribution for the data and supports three prior distributions: uniform, Jeffreys, and ridge.

The prior distributions are categorized into noninformative (or also vague, diffuse, flat, reference) and informative prior distributions. The noninformative priors provide no extra information about model parameters beyond that already contained in the data. These priors are recommended when no strong prior knowledge is available about the parameters. Informative prior distributions are used when there is some a priori knowledge about the distribution of the parameters. For example, prior information about cancer mortality rates in a Poisson model can be assigned based on the available worldwide estimate. The uniform and Jeffreys priors are noninformative priors. The ridge prior is an informative prior.

The uniform prior assumes that all values of the parameters are equally probable. Under this prior specification, the posterior distribution of the parameters is equivalent to the likelihood function, and so the Bayesian and frequentist methods coincide. The Jeffreys prior is another widely used noninformative prior distribution, and with small samples, it may be preferable to the uniform prior. A ridge prior is often used when the estimated covariance matrix becomes singular (or nearly singular), as may occur with sparse missing data if there are not enough observations to estimate reliably all aspects of the covariance matrix. A ridge prior smooths the estimate of the covariance matrix toward a diagonal structure depending on the chosen degrees of freedom; the larger the degrees of freedom, the closer is the estimated covariance matrix to the diagonal matrix (see Schafer [1997, 155–157] for details).

Convergence of the MCMC method

For a brief overview of convergence of MCMC, see *Convergence of iterative methods* in [MI] **mi impute**.

The MCMC procedure DA is iterated until an MCMC sequence $\{(\mathbf{X}_m^{(t)}, \boldsymbol{\theta}^{(t)}) : t = 1, 2, \dots\}$ converges to a stationary distribution. Unlike maximum likelihood, EM, or other optimization-based procedures, the DA procedure does not have a simple stopping rule that guarantees the convergence of the chain to a stationary distribution. Thus the question of how long to iterate to achieve convergence arises. In addition to determining convergence of MCMC, we must also investigate the serial dependence known to exist among the MCMC draws to obtain independent imputations.

Suppose that after an initial burn-in period, b, the sequence $\{(\mathbf{X}_m^{(b+t)}) : t = 1, 2, \dots\}$ (imputations) can be regarded as an approximate sample from $\Pr(\mathbf{X}_m|\mathbf{X}_o)$. In general, this sample will not contain independent observations because the successive iterates of the MCMC tend to be correlated. To achieve independence among imputations, we can sample the chain. To do that, we need to determine the number of iterations, k, such that $\mathbf{X}_m^{(t)}$ and $\mathbf{X}_m^{(t+k)}$ are approximately independent. Then imputations can be obtained as the chain values of $\mathbf{X}_m$ from iterations $b, b+k, b+2k, \dots, b+mk$, where m is the required number of imputations. In our definition, b is the number of iterations necessary for the chain to achieve stationarity and k is the number of iterations between imputations necessary to achieve independent values of the chain.

Before we proceed, we notice that from the properties of MCMC, the convergence of the chain $\{(\mathbf{X}_m^{(t)}, \boldsymbol{\theta}^{(t)}) : t = 1, 2, \dots\}$ to $\Pr(\boldsymbol{\theta}, \mathbf{X}_m|\mathbf{X}_o)$ is equivalent to the convergence of $\{(\boldsymbol{\theta}^{(t)}) : t = 1, 2, \dots\}$ to $\Pr(\boldsymbol{\theta}|\mathbf{X}_o)$ or, alternatively, of $\{(\mathbf{X}_m^{(t)}) : t = 1, 2, \dots\}$ to $\Pr(\mathbf{X}_m|\mathbf{X}_o)$. Because the parameter series are usually of lower dimension, we examine convergence using the series of parameter estimates rather than the series of imputations.

How to determine convergence and, in particular, to choose values for b and k, has received much attention in the MCMC literature. In practice, convergence is often examined visually from the trace and autocorrelation plots of the estimated parameters. Trace plots are plots of estimated parameters against iteration numbers. Long-term trends in trace plots and high serial dependence in autocorrelation plots are indicative of a slow convergence to stationarity. A value of b can be inferred from a trace plot as the earliest iteration after which the chain does not exhibit a visible trend and the parameter series stabilize, which is to say the fluctuations in values become more regular. A value of k can be chosen from autocorrelation plots as the lag k for which autocorrelations of all parameters decrease to zero. When the initial values are close to the posterior mode, the initial number of iterations, b, and number of iterations between imputations, k, will be similar. When the initial values are far off in the tails of the posterior distribution, the initial number of iterations will generally be larger.

In practice, when the number of parameters in the model is large, it may not be feasible to monitor the convergence of all the individual series. One solution is to find a function of the parameters that would be the slowest to converge to stationarity. The convergence of the series for this function will then be indicative of the convergence of other functions and, in particular, individual parameter series. Schafer (1997, 129–131) suggests the worst linear function (WLF), the function corresponding to the linear combination of the parameter estimates where the coefficients are chosen such that this function has the highest asymptotic rate of missing information; see *Methods and formulas* for computational details. He found that when the observed-data posterior distribution is nearly normal, this function is among the slowest to approach stationarity. Thus we can determine b and k by monitoring the convergence of the WLF. When the observed-data posterior is not normal and some aspects of the model are poorly estimated, the WLF may not be the slowest to converge. In such cases, we recommend exploring convergence of other functions or of individual parameter series.

The number of iterations necessary for DA to converge depends on the rate of convergence of DA. The rate of convergence of DA mainly depends on the fractions of missing information and initial values. The higher the fractions of missing information and the farther the initial values are from the posterior mode, the slower the convergence, and thus the larger the number of iterations required. Initial values for the DA procedure can be obtained from the EM algorithm for incomplete data (for example, Dempster, Laird, and Rubin [1977]). In addition, the number of iterations necessary for the DA procedure to converge can be inferred based on the number of iterations that the EM algorithm took to converge (Schafer 1997).

The convergence of the chain and the required number of iterations can be also inferred by running multiple independent MCMC sequences using overdispersed initial values, that is, initial values from a distribution with greater variability than that of the posterior distribution (Gelman and Rubin 1992; Schafer 1997, 126–128). Then the number of iterations can be taken to be the largest iteration number for which the series in all the chains stabilize.

Although the graphical summaries described above are useful in checking convergence, they must be used with caution. They can be deceptive in cases when the observed-data posterior has an odd shape or has multiple modes, which may happen with small sample sizes or sparse missing data. Examination of the data and missing-data patterns, as well as the behavior of the EM algorithm, are highly recommended when investigating the MCMC convergence. How one checks for convergence will be shown in examples 2 and 4.

Using mi impute mvn

`mi impute mvn` imputes missing data using DA, an iterative MCMC method, assuming the multivariate normal distribution for the data. For the discussion of options, such as `add()` and `replace`, common to all imputation methods, see [MI] **mi impute**. Here we focus on the options and functionality specific to `mi impute mvn`.

The two main options are `burnin()` (which specifies the number of iterations necessary for the MCMC to converge, b) and `burnbetween()` (which specifies the number of iterations between imputations, k). We discussed how to choose these values in the previous section. By default, these values are arbitrarily set to be 100 each.

You can choose from the three prior specifications. You can use `prior(uniform)` (the default) to specify the uniform prior, `prior(jeffreys)` to specify the Jeffreys prior, or `prior(ridge, df())` to specify a ridge prior. You must also choose the degrees of freedom with a ridge prior.

For initial values, `mi impute mvn` uses the estimates from the EM algorithm for incomplete data (`initmcmc(em)`). When the uniform prior distribution is used, the estimates obtained from EM are MLEs. Under other prior specifications, the estimates from EM correspond to the posterior mode of the respective posterior distribution of the model parameters. Using the estimates from EM as initial values in general accelerates the convergence of MCMC. To determine convergence, it may also be useful to try different sets of initial values. You can do this by creating Stata matrices containing the initial values and supplying them in the respective `initmcmc()` suboptions `betas()`, `cov()`, etc.

You can save the estimates of the WLF and parameter series from MCMC iterations by using the `savewlf()` and `saveptrace()` options. These options are useful when examining convergence of MCMC, as we will demonstrate in examples 2 and 4. You can use `mi impute mvn` to run the MCMC without imputing the data if you specify the `mcmconly` option. This option is useful in combination with `savewlf()` or `saveptrace()` when examining convergence of MCMC. When `mcmconly` is specified, the DA procedure is performed for the number of iterations as specified in `burnin()` and no imputations are performed.

You can also perform the EM estimation without MCMC iterations if you specify the `emonly()` option. This option is useful for detecting convergence problems prior to running MCMC. The number of iterations EM takes to converge can be used as an approximation for the burn-in period. Also, slow convergence of the EM algorithm can reveal problems with estimability of certain model parameters.

Examples

▷ Example 1: Monotone-missing data

Recall the heart attack example from *Multivariate imputation* in [MI] **mi impute**, where we used `mi impute mvn` to impute missing values for `age` and `bmi` that follow a monotone-missing pattern:

```
. use https://www.stata-press.com/data/r19/mheart5s0
(Fictional heart attack data)
. mi impute mvn age bmi = attack smokes hsgrad female, add(10)
Performing EM optimization:
note: 12 observations omitted from EM estimation because of all imputation
      variables missing.
  observed log likelihood = -651.75868 at iteration 7
Performing MCMC data augmentation ...
Multivariate imputation                     Imputations =       10
Multivariate normal regression                    added =       10
Imputed: m=1 through m=10                       updated =        0
Prior: uniform                               Iterations =     1000
                                                burn-in =      100
                                                between =      100
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
age	142	12	12	154
bmi	126	28	28	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

In the above, we omitted the `nolog` option that was present in the example in [MI] **mi impute**.

In addition to the output reported by all imputation methods, `mi impute mvn` also provides some specific information.

As we previously explained, `mi impute mvn` uses an iterative MCMC technique to impute missing values. The two phases of `mi impute mvn` are 1) obtaining initial values (unless supplied directly) and 2) performing the MCMC procedure from which imputations are obtained. These two phases are noted in the output header.

In this example, the initial values are obtained using the EM method (the default). We see from the output that EM converged in seven iterations. A note displayed thereafter reports that 12 observations contain missing values for both `bmi` and `age` and were omitted. The note is just explanatory and should not cause you concern. Those 12 observations would contribute nothing to the likelihood function even if they were included, although the algorithm would take longer to converge.

The estimates from EM are used as initial values for DA. The first part of the table header, containing the information about the method used and the number of imputations, was described in detail in [MI] **mi impute**. The second part of the table header is specific to `mi impute mvn`. From the output, a total of 1,000 iterations of MCMC are performed. The first 100 iterations (the default) are used for the burn-in period (`burn-in = 100`), the first imputation calculated from the last iteration; thereafter, each subsequent

imputation is calculated after performing another 100 iterations. The default uniform prior is used for both the EM estimation and the MCMC procedure. Under this prior, the parameter estimates obtained are MLEs.

◁

▷ Example 2: Checking convergence of MCMC

In example 1, the monotone missingness of age and bmi as well as the quick convergence of EM suggest that the MCMC must converge rapidly. In fact, we know that under a monotone-missing pattern, no iterations are needed to obtain imputed values (see [MI] **mi impute monotone**). Let's examine the convergence of the MCMC procedure for the above heart attack data, the point being to see what quick convergence looks like.

As we discussed earlier, convergence is often assessed from the trace plots of the MCMC parameter estimates. Because of a possibly large number of estimated parameters, this approach may be tedious. Alternatively, we can plot the WLF for which the convergence is generally the slowest.

We use the `savewlf(wlf)` option to save estimates of the WLF to a Stata dataset called `wlf.dta`. To examine the convergence of MCMC, we do not need imputation, and so we use the `mcmconly` option to perform the MCMC procedure without subsequent imputation. We use a total of $1000 = 10 \times 100$ iterations (`burnin(1000)` option), corresponding to the length of the MCMC to obtain 10 imputations:

```
. mi impute mvn age bmi = attack smokes hsgrad female, mcmconly burnin(1000)
> rseed(2232) savewlf(wlf)

Performing EM optimization:
note: 12 observations omitted from EM estimation because of all imputation
      variables missing.
  observed log likelihood = -651.75868 at iteration 7

Performing MCMC data augmentation ...

Note: No imputation performed.
```

We also specified the `rseed(2232)` option so that we can reproduce our results.

The created dataset contains three variables: `iter`, `m`, and `wlf`. The `iter` variable records iterations (the burn-in iterations are recorded as negative integers). The `m` variable records imputation numbers to which the iteration sequence corresponds (`m` contains 0 if `mcmconly` is used). The `wlf` variable records the WLF estimates.

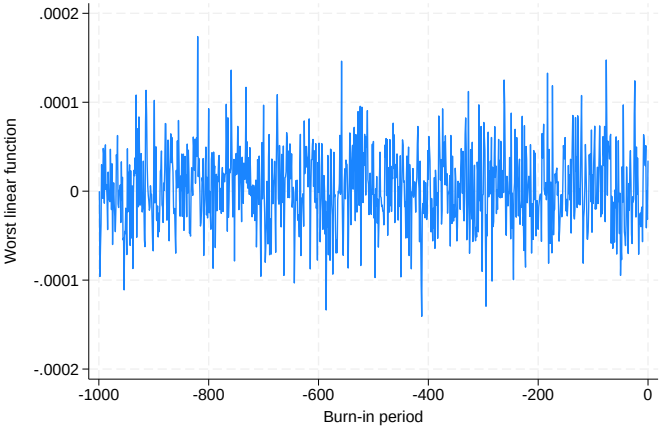
```
. use wlf, clear

. describe

Contains data from wlf.dta
 Observations:         1,000
    Variables:             3                  4 Mar 2025 08:52
-------------------------------------------------------------------------------
Variable      Storage   Display    Value
    name         type    format    label      Variable label
-------------------------------------------------------------------------------
iter            long    %12.0g
m               long    %12.0g
wlf             double  %10.0g
-------------------------------------------------------------------------------
Sorted by:
```

We use the time-series commands `tsline` and `ac` (see [TS] **tsline** and [TS] **corrgram**) to plot the estimates and autocorrelations of `wlf` with respect to the iteration number. We first use `tsset` to set `iter` as the "time" variable and then use `tsline` to obtain a trace plot:

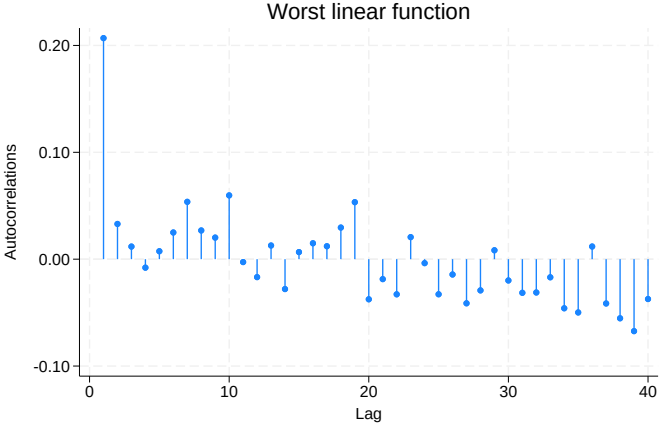
```
. tsset iter
Time variable: iter, -999 to 0
        Delta: 1 unit
. tsline wlf, ytitle(Worst linear function) xtitle(Burn-in period)
```



The graph shows no visible trend in the estimates of the WLF, just as we expected. Convergence of MCMC by the 100th iteration should be assured. In fact, taking into account the declared convergence of the EM algorithm in only seven iterations, we would be comfortable with using a much smaller burn-in period of, say, 10 iterations.

We next examine the autocorrelation in the WLF to obtain an idea of how many iterations to use between imputations to ensure their approximate independence:

```
. ac wlf, title(Worst linear function) ytitle(Autocorrelations)
> ciopts(astyle(none)) note("")
```



From the graphical output, the autocorrelations die off quickly. This suggests that we can use a smaller number, say, 10 or 20, rather than the default 100 iterations for the burn-between period.

◁

We considered an example with a monotone-missing pattern. `mi impute mvn` is designed to accommodate arbitrary missing-data patterns, so let's consider an example with them.

▷ Example 3: Arbitrary missing-data pattern

Consider data on house resale prices provided by the Albuquerque Board of Realtors and distributed by the Data and Story Library. You can find a detailed description of the data at http://www.pmean.com/00files/housing.htm.

```
. use https://www.stata-press.com/data/r19/mhouses1993
(Albuquerque home prices Feb15-Apr30, 1993)
. describe
Contains data from https://www.stata-press.com/data/r19/mhouses1993.dta
 Observations:           117                  Albuquerque home prices
                                                Feb15-Apr30, 1993
    Variables:             8                  19 Jun 2024 10:50
                                              (_dta has notes)
------------------------------------------------------------------------------
Variable      Storage   Display    Value
    name         type    format    label      Variable label
------------------------------------------------------------------------------
price           int     %8.0g                 Sale price (hundreds)
sqft            int     %8.0g                 Square footage of living space
age             byte    %10.0g                Home age (years)
nfeatures       byte    %8.0g                 Number of certain features
ne              byte    %8.0g                 Located in northeast (largest
                                                residential) sector of the city
custom          byte    %8.0g                 Custom build
corner          byte    %8.0g                 Corner location
tax             int     %10.0g                Tax amount (dollars)
------------------------------------------------------------------------------
Sorted by:
```

The dataset includes eight variables. The primary variable of interest is `price`, and other variables are used as its predictors.

We investigate the missing-data patterns of these data using `misstable`:

```
. misstable pattern
  Missing-value patterns
    (1 means complete)

                 |  Pattern
  Percent        |  1  2
-----------------+------
      56%        |  1  1
                 |
      35         |  1  0
       7         |  0  0
       2         |  0  1
-----------------+------
     100%        |
  Variables are  (1) tax  (2) age
. misstable nested
    1.  tax(10)
    2.  age(49)
```

We see from the output only 56% of observations are complete; the remaining 44% contain missing values of `age` or `tax`. The `tax` variable contains 10 missing values, and the `age` variable contains 49 missing values. `misstable nested` reports that missing values of `age` and `tax` are not nested because there are two statements describing the missing-value pattern; see [R] **misstable** for details.

Let's use `mi impute mvn` to impute missing values of `age` and `tax`. Before we do that, a quick examination of the data revealed that the distribution for `age` and `tax` are somewhat skewed. As such, we choose to impute the variables on a log-transformed scale.

Following the steps as described in *Imputing transformations of incomplete variables* of [MI] **mi impute**, we create new variables containing the log values,

```
. generate lnage = ln(age)
(49 missing values generated)
. generate lntax = ln(tax)
(10 missing values generated)
```

and register them as imputed variables,

```
. mi set mlong
. mi register imputed lnage lntax
(51 m=0 obs now marked as incomplete)
. mi register regular price sqft nfeatures ne custom corner
```

We `mi set` our data as mlong and register the complete variables as regular. For the purpose of this analysis, we leave passive variables `age` and `tax` unregistered. (Note that all missing values of the created `lnage` and `lntax` variables are eligible for imputation; see [MI] **mi impute** for details.)

We now use `mi impute mvn` to impute values of `lnage` and `lntax`:

```
. mi impute mvn lnage lntax = price sqft nfeatures ne custom corner, add(20)
Performing EM optimization:
note: 8 observations omitted from EM estimation because of all imputation
      variables missing.
  observed log likelihood =   112.1464 at iteration 48
Performing MCMC data augmentation ...
Multivariate imputation                     Imputations =       20
Multivariate normal regression                    added =       20
Imputed: m=1 through m=20                       updated =        0
Prior: uniform                               Iterations =     2000
                                                burn-in =      100
                                                between =      100
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
lnage	68	49	49	117
lntax	107	10	10	117

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

◁

▷ Example 4: Checking convergence of MCMC

In the above example, we arbitrarily created 20 imputations. The output is similar to that of the earlier example. Here the EM algorithm converges by the 48th iteration. This suggests that, again, the default 100 iterations for the burn-in period should be sufficient for the convergence of MCMC. Nevertheless, we choose to confirm this visually by repeating the steps from example 2.

We run the MCMC for a total of 2,000 iterations (as would be necessary to obtain 20 imputations) without imputing data and set the seed for reproducibility. We overwrite the existing `wlf.dta` file to contain the new estimates of the WLF by specifying `replace` within `savelwf()`:

```
. mi impute mvn lnage lntax = price sqft nfeatures ne custom corner,
> mcmconly burnin(2000) rseed(23) savewlf(wlf, replace)

Performing EM optimization:
note: 8 observations omitted from EM estimation because of all imputation
      variables missing.
  observed log likelihood =   112.1464 at iteration 48

Performing MCMC data augmentation ...

Note: No imputation performed.
```

We generate the same graphs as in example 2, this time using the new estimates of the WLF:

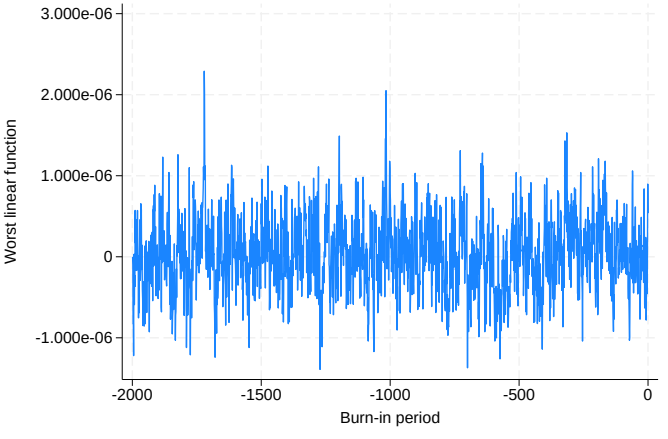
```
. preserve

. use wlf, clear

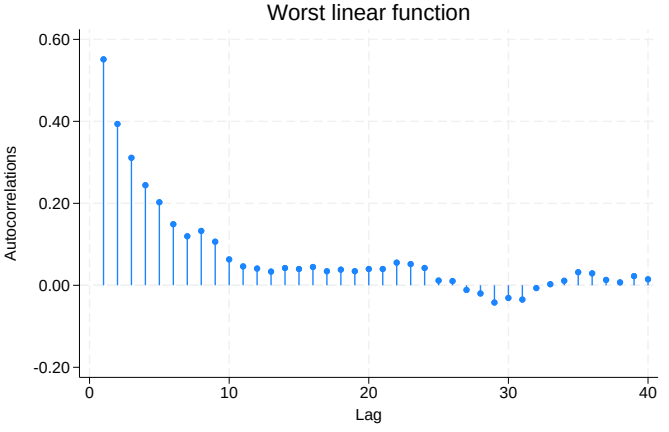
. tsset iter

Time variable: iter, -1999 to 0
        Delta: 1 unit

. tsline wlf, ytitle(Worst linear function) xtitle(Burn-in period)
```



```
. ac wlf, title(Worst linear function) ytitle(Autocorrelations)
> ciopts(astyle(none)) note("")
```



Compared with the earlier graphs, the time-series graphs do not reveal any apparent trend, but the autocorrelation dies out more slowly. The default values of 100 for the initial burn-in and between-imputation iterations should be sufficient.

◁

▷ Example 5: Alternative prior distribution

Consider some hypothetical data:

```
. use https://www.stata-press.com/data/r19/mvnexample0
(Fictional data for -mi impute mvn-)
. mi describe
Style: mlong
       last mi update 04feb2025 12:58:57, 11 days ago
Observations:
   Complete             3
   Incomplete          17  (M = 0 imputations)
   ---------------------
   Total               20
Variables:
   Imputed: 3; x1(16) x2(5) x3(17)
   Passive: 0
   Regular: 0
   System:  3; _mi_m _mi_id _mi_miss
   (there are no unregistered variables)
```

Continuous normally distributed variables `x1`, `x2`, and `x3` contain missing values. For illustration purposes, we consider an extreme case when some variables (`x1` and `x3` here) contain only a few complete observations.

We use `mi impute mvn` to impute missing values and create 30 imputations. Notice that in this example, we do not have complete predictors, and so the right-hand-side specification is empty:

```
. mi imp mvn x1-x3, add(30) rseed(332247)

Performing EM optimization:
note: 4 observations omitted from EM estimation because of all imputation
      variables missing.
  observed log likelihood =  6.5368927 at iteration 100
  (EM did not converge)

Performing MCMC data augmentation ...
Iteration 145: variance-covariance matrix (Sigma) became not
positive definite posterior distribution is not proper
error occurred during imputation of x1 x2 x3 on m = 2
r(498);
```

`mi impute mvn` terminates with an error reporting that the estimated variance–covariance matrix became non–positive definite. `mi impute mvn` terminated because the posterior predictive distribution of missing data is not proper, but notice also that EM did not converge after the default 100 iterations.

There are two issues here. First, because EM did not converge after 100 iterations, we suspect that the default 100 iterations used for the burn-in period may not be large enough for MCMC to converge. Second, the observed missing-data pattern presents difficulties with estimating the covariance matrix reliably, which leads to a non–positive-definite estimate during the MCMC iteration.

The first issue may be resolved by increasing the maximum number of iterations for EM by using EM's `iterate()` suboption. Convergence of EM, however, does not guarantee convergence of the MCMC by the same number of iterations. For one, the convergence of EM is relative to the specified tolerance, and more stringent conditions may lead to a nonconvergent result. As such, we recommend that you always examine the obtained MCMC results.

The second issue is not surprising. Recall that `x1` and `x3` have very few complete observations. So the aspects of the covariance structure involving those variables (for example, the covariance between `x1` and `x2`) are difficult to estimate reliably based on the information from the observed data only. The default uniform prior may not be viable here.

One solution is to introduce prior information to stabilize the estimation of the covariance matrix. We can do this by specifying a ridge prior using the `prior()` option. We introduce only a small amount of information by using a degrees of freedom value of 0.1:

```
. mi imp mvn x1-x3, add(30) prior(ridge, df(0.1)) rseed(332247)

Performing EM optimization:
note: 4 observations omitted from EM estimation because of all imputation
      variables missing.
  observed log posterior =   -1.13422 at iteration 100
  (EM did not converge)

Performing MCMC data augmentation ...

Multivariate imputation                     Imputations =       30
Multivariate normal regression                    added =       30
Imputed: m=1 through m=30                       updated =        0

Prior: ridge, df=.1                          Iterations =     3000
                                                burn-in =      100
                                                between =      100
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
x1	4	16	16	20
x2	15	5	5	20
x3	3	17	17	20

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

This appears to be enough to alleviate the problem of a non–positive-definite estimate of the covariance matrix. Still, EM did not converge.

We will fix that and examine the resulting MCMC sequence. We will use the same random-number seed and this time save the WLF. Rather than imputing the data as before, we will simply run the MCMC for the same number of iterations it takes to obtain 30 imputations using the default settings, namely, $30 \times 100 = 3000$.

```
. mi imp mvn x1-x3, mcmconly prior(ridge, df(0.1))
> initmcmc(em, iter(200) nolog) burnin(3000) savewlf(wlf, replace)
> rseed(332242)

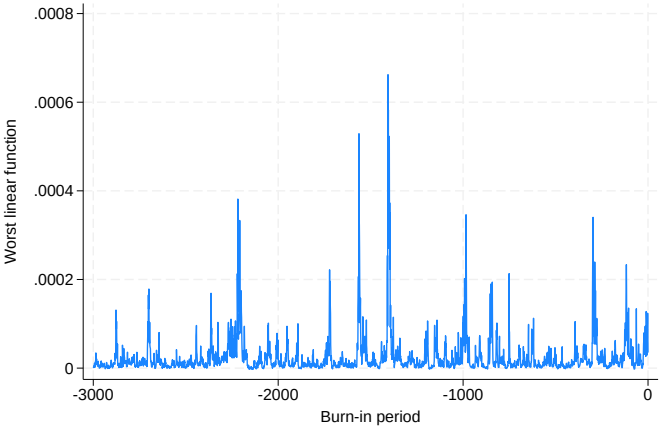
Performing EM optimization:
note: 4 observations omitted from EM estimation because of all imputation
      variables missing.
  observed log posterior = -1.1341806 at iteration 152

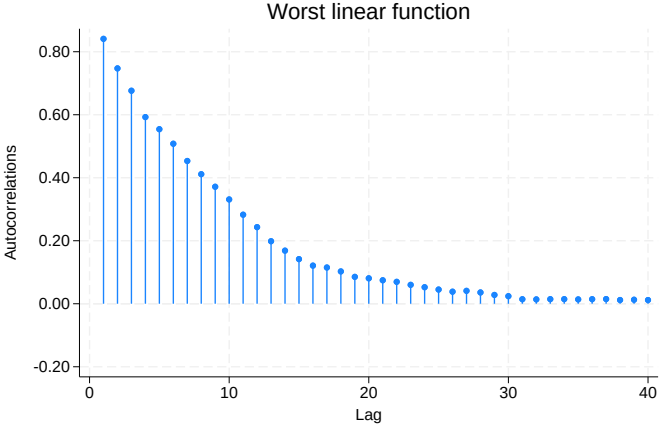
Performing MCMC data augmentation ...

Note: No imputation performed.
```

We increased the maximum number of iterations for the EM algorithm to 200; it converged in iteration 152.

We use the results from `wlf.dta` to obtain the trace and autocorrelation plots as we did in the earlier examples:





The serial correlation decreases slowly. There is no obvious trend in the WLF estimates, but we notice high variability and several spikes, some distinctive. The high variability and spikes are not surprising considering that certain model parameters could not be estimated reliably from the observed data and considering that we did not introduce enough prior information to obtain less variable estimates; we introduced only enough to achieve nonsingularity.

We could decrease the variability of the estimates by obtaining more data or introducing stronger prior information. For example, we could increase the number of degrees of freedom with a ridge prior to constrain the covariance matrix toward a diagonal structure:

```
. mi imp mvn x1-x3, replace prior(ridge, df(10)) burnin(300) rseed(332247)
```

If we create and examine the trace plots and autocorrelations of the WLF under the new prior specification, we find that variability of the estimates and serial dependence decrease greatly at a cost of bias if the prior assumptions are false.

◁

▷ Example 6: Saving all parameter series

The examples above used the WLF to monitor convergence of MCMC because in most applications it is sufficient. Although the WLF series often behave as the worst-case scenario, exceptions exist in practice. Sometimes, examining individual parameter series may be necessary.

We can save all parameter series from MCMC by using the `saveptrace()` option. These parameter series are saved in a parameter-trace file, a special file with extension `.stptrace`. Although the resulting file is not a Stata dataset, it can easily be loaded into Stata using `mi ptrace use`; see [MI] **mi ptrace** for details.

Let's look at several parameter series from the above example.

```
. use https://www.stata-press.com/data/r19/mvnexample0, clear
. mi imp mvn x1-x3, mcmconly prior(ridge, df(0.1)) initmcmc(em, iter(200) nolog)
> burnin(3000) rseed(332247) saveptrace(parms)
```

We save all parameter series to a file called `parms` by using `stptrace(parms)`.

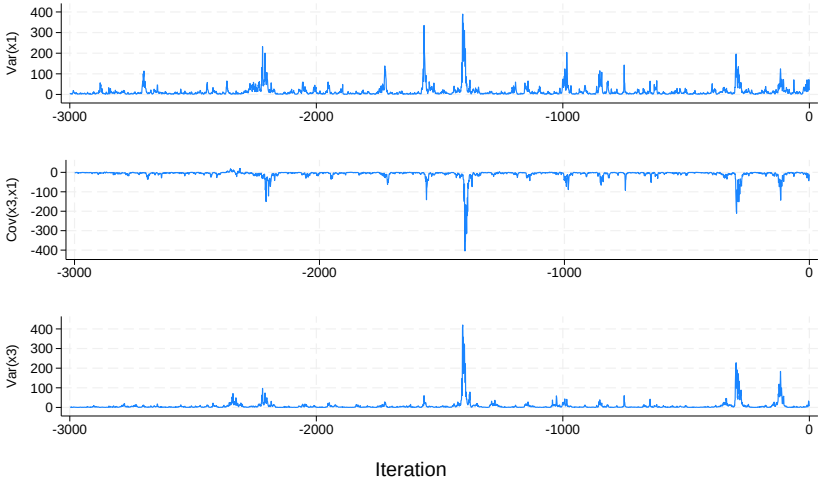
We first describe the contents of the `parms` file and then read it into Stata:

```
. mi ptrace describe parms
  file parms.stptrace created on 4 Mar 2025 08:52 contains 3,000 records
  (obs) on
      m                       1 variable
      iter                    1 variable
      b[y, x]                 3 variables (3 x 1)
      v[y, y]                 6 variables (3 x 3, symmetric)
  where y and x are
      y: (1) x1  (2) x2  (3) x3
      x: (1) _cons
. mi ptrace use parms, clear
```

The output from `mi ptrace describe` reports that the file contains imputation numbers, iteration numbers, estimates of three regression coefficients (`b[x1,_cons]`, `b[x2,_cons]`, and `b[x3,_cons]`, which are effectively the means of `x1`, `x2`, and `x3`), and estimates of six covariances (`v[x1,x1]`, `v[x2,x1]`, `v[x2,x2]`, and so on).

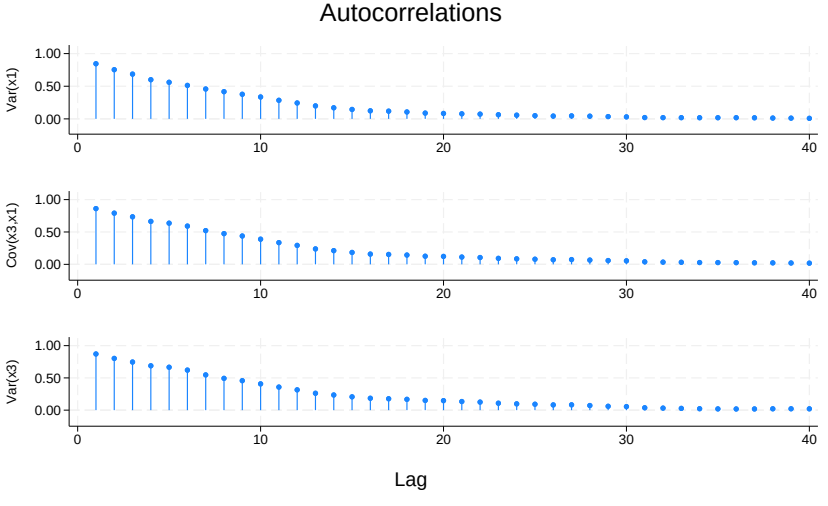
Because `x1` and `x3` contain the least number of complete observations, we examine the series containing their variance and covariance estimates. We generate graphs separately for each series and then combine them in one graph by using `graph combine`; see [G-2] **graph combine**.

```
. tsset iter
Time variable: iter, -2999 to 0
        Delta: 1 unit
. tsline v_y1y1, name(gr1) nodraw ytitle(Var(x1)) xtitle("") ylabel(#4)
. tsline v_y3y1, name(gr2) nodraw ytitle(Cov(x3,x1)) xtitle("") ylabel(#4)
. tsline v_y3y3, name(gr3) nodraw ytitle(Var(x3)) xtitle("") ylabel(#4)
. graph combine gr1 gr2 gr3, xcommon cols(1) b1title(Iteration)
```



We repeat the same for the autocorrelation graphs:

```
. ac v_y1y1, ytitle(Var(x1)) xtitle("") ciopts(astyle(none)) note("")
> name(gr1, replace) nodraw ylabel(#4)
. ac v_y3y1, ytitle(Cov(x3,x1)) xtitle("") ciopts(astyle(none)) note("")
> name(gr2, replace) nodraw ylabel(#4)
. ac v_y3y3, ytitle(Var(x3)) xtitle("") ciopts(astyle(none)) note("")
> name(gr3, replace) nodraw ylabel(#4)
. graph combine gr1 gr2 gr3, xcommon cols(1) title(Autocorrelations) b1title(Lag)
```



We can see that the trace plot and autocorrelations corresponding to the variance of `x1` resemble the patterns of the earlier WLF estimates. We also notice that all series have high serial dependence within the first 20 iterations.

Again, if we switch to using a ridge prior with 10 degrees of freedom and repeat the steps above, the obtained trace plots will be more precise and more regular. The serial dependence in the series will be lower.

◁

Stored results

`mi impute mvn` stores the following in `r()`:

Scalars

`r(M)`	total number of imputations
`r(M_add)`	number of added imputations
`r(M_update)`	number of updated imputations
`r(k_ivars)`	number of imputed variables
`r(burnin)`	number of burn-in iterations
`r(burnbetween)`	number of burn-between iterations
`r(df_prior)`	prior degrees of freedom (stored only with `prior(ridge)`)
`r(N_em)`	number of observations used by EM (including omitted missing observations)
`r(N_e_em)`	number of observations used by EM in estimation (excluding omitted missing observations)
`r(N_mis_em)`	number of incomplete observations within the EM estimation sample
`r(N_S_em)`	number of unique missing-value patterns
`r(niter_em)`	number of iterations EM takes to converge
`r(llobs_em)`	observed log likelihood (stored with `prior(uniform)`)
`r(lpobs_em)`	observed log posterior (stored with priors other than `uniform`)
`r(converged_em)`	convergence flag for EM
`r(emonly)`	`1` if performed EM estimation only, `0` otherwise
`r(mcmconly)`	`1` if performed MCMC only without imputing data, `0` otherwise
`r(N_g)`	number of imputed groups (`1` if `by()` is not specified)

Macros

`r(method)`	name of imputation method (`mvn`)
`r(ivars)`	names of imputation variables
`r(rngstate)`	random-number state used
`r(prior)`	prior distribution
`r(init_mcmc)`	type of initial values (`em` or `user`)
`r(ivarsorder)`	names of imputation variables in the order used in the computation
`r(init_em)`	type of initial values used by EM (`ac`, `cc`, or `user`)
`r(by)`	names of variables specified within `by()`

Matrices

`r(N)`	number of observations in imputation sample in each group (per variable)
`r(N_complete)`	number of complete observations in imputation sample in each group (per variable)
`r(N_incomplete)`	number of incomplete observations in imputation sample in each group (per variable)
`r(N_imputed)`	number of imputed observations in imputation sample in each group (per variable)
`r(Beta0)`	initial values for regression coefficients used by DA
`r(Sigma0)`	initial variance–covariance matrix used by DA
`r(wlf_wgt)`	coefficients for the WLF (stored with `initmcmc(em)` or if `wlfwgt()` is used)
`r(Beta_em)`	estimated regression coefficients from EM
`r(Sigma_em)`	estimated variance–covariance matrix from EM
`r(Beta0_em)`	initial values for regression coefficients used by EM
`r(Sigma0_em)`	initial variance–covariance matrix used by EM
`r(N_pat)`	minimum, average, and maximum numbers of observations per missing-value pattern

`r(N_pat)` and results with the `_em` suffix are stored only when the EM algorithm is used (with `emonly` or `initmcmc(em)`).

Methods and formulas

Let $\mathbf{x}_1, \mathbf{x}_2, \ldots, \mathbf{x}_N$ be a random sample from a p-variate normal distribution recording values of p imputation variables. Consider a multivariate normal regression

$$\mathbf{x}_i = \boldsymbol{\Theta}'\mathbf{z}_i + \boldsymbol{\epsilon}_i,\ i = 1, \ldots, N$$

where $\mathbf{z}_i$ is a $q \times 1$ vector of independent (complete) variables from observation i, $\boldsymbol{\Theta}$ is a $q \times p$ matrix of regression coefficients, and $\boldsymbol{\epsilon}_i$ is a $p \times 1$ vector of random errors from a p-variate normal distribution with a zero mean vector and a $p \times p$ positive-definite covariance matrix $\boldsymbol{\Sigma}$. We refer to $\boldsymbol{\Theta}$ and $\boldsymbol{\Sigma}$ as model parameters. Consider the partition $\mathbf{x}_i = (\mathbf{x}_{i(m)}, \mathbf{x}_{i(o)})$ corresponding to missing and observed values of imputation variables in observation i for $i = 1, \ldots, N$.

Methods and formulas are presented under the following headings:

Data augmentation
Prior distribution
Initial values: EM algorithm
Worst linear function

Data augmentation

`mi impute mvn` uses data augmentation (DA) to fill in missing values in $\mathbf{x}_i$ independently for each observation $i = 1, \ldots, N$. Data augmentation consists of two steps, an I step (imputation step) and a P step (posterior step), performed at each iteration $t = 0, 1, \ldots, T$. At iteration t of the I step, missing values in $\mathbf{x}_i$ are replaced with draws from the conditional posterior distribution of $\mathbf{x}_{i(m)}$ given observed data and current values of model parameters independently for each $i = 1, \ldots, N$. During the P step, new values of model parameters are drawn from their conditional posterior distribution given the observed data and the data imputed in the previous I step. Mathematically, this process can be described as follows:

I step:

$$\mathbf{x}_{i(m)}^{(t+1)} \sim P\left(\mathbf{x}_{i(m)} | \mathbf{z}_i, \mathbf{x}_{i(o)}, \boldsymbol{\Theta}^{(t)}, \boldsymbol{\Sigma}^{(t)}\right),\ i = 1, \ldots, N \tag{1}$$

P step:

$$\begin{aligned} \boldsymbol{\Sigma}^{(t+1)} &\sim P\left(\boldsymbol{\Sigma} | \mathbf{z}_i, \mathbf{x}_{i(o)}, \mathbf{x}_{i(m)}^{(t+1)}\right) \\ \boldsymbol{\Theta}^{(t+1)} &\sim P\left(\boldsymbol{\Theta} | \mathbf{z}_i, \mathbf{x}_{i(o)}, \mathbf{x}_{i(m)}^{(t+1)}, \boldsymbol{\Sigma}^{(t+1)}\right) \end{aligned} \tag{2}$$

The above two steps are repeated until the specified number of iterations, T, is reached. The total number of iterations, T, is determined by the length of the initial burn-in period, b, and the number of iterations between imputations, k. Specifically, $T = b + M_{new} \times k$, where M_{new} contains the number of added and updated imputations. `mi impute mvn` saves imputed values $\mathbf{x}_{i(m)}^{(t_1)}, \mathbf{x}_{i(m)}^{(t_2)}, \ldots, \mathbf{x}_{i(m)}^{(t_{M_{\text{new}}})}$ as final imputations, where iteration $t_i = b + (i-1)k$.

By default, `mi impute mvn` uses default values of 100 for b and k. These values may be adequate in some applications and may be too low in others. In general, b and k must be determined based on the properties of the observed Markov chain $\left(\mathbf{X}_m^{(1)}, \boldsymbol{\Theta}^{(1)}, \boldsymbol{\Sigma}^{(1)}\right), \left(\mathbf{X}_m^{(2)}, \boldsymbol{\Theta}^{(2)}, \boldsymbol{\Sigma}^{(2)}\right), \ldots$, where $\mathbf{X}_m^{(t)}$ denotes all values imputed at iteration t. b must be large enough so that the above chain converges to the stationary distribution $P(\mathbf{X}_m, \boldsymbol{\Theta}, \boldsymbol{\Sigma} | \mathbf{Z}, \mathbf{X}_o)$ by iteration $t = b$. k must be large enough so that random draws (imputations) $\mathbf{x}_{i(m)}^{(t_1)}, \mathbf{x}_{i(m)}^{(t_2)}, \ldots$ are approximately independent. See *Convergence of the MCMC method* for more details.

The functional form of the conditional posterior distributions (1) and (2) depends on the distribution of the data and a prior distribution of the model parameters. `mi impute mvn` assumes an improper uniform prior distribution for $\boldsymbol{\Theta}$ and an inverted Wishart distribution (Mardia, Kent, and Taylor 2024, 92) $W_p^{-1}(\Lambda, \lambda)$ for $\boldsymbol{\Sigma}$ under which the prior joint density function is

$$f(\boldsymbol{\Theta}, \boldsymbol{\Sigma}) \propto |\boldsymbol{\Sigma}|^{-\left(\frac{\lambda+p+1}{2}\right)} \exp\left(-\frac{1}{2}\text{tr}\Lambda^{-1}\boldsymbol{\Sigma}^{-1}\right)$$

Under the multivariate normal model and the above prior distribution, the I and P steps become (Schafer 2008; Schafer 1997, 181–185) the following:

$$\begin{aligned}
\text{I step:} \quad & \mathbf{x}_{i(m)}^{(t+1)} \sim N_{p_i}\left(\boldsymbol{\mu}_{m\cdot o}^{(t)}, \boldsymbol{\Sigma}_{mm\cdot o}^{(t)}\right),\ i = 1, \ldots, N \\
\text{P step:} \quad & \boldsymbol{\Sigma}^{(t+1)} \sim W^{-1}(\Lambda_\star^{(t+1)}, \lambda_\star) \\
& \text{vec}\left(\boldsymbol{\Theta}^{(t+1)}\right) \sim N_{pq}\left\{\text{vec}\left(\widehat{\boldsymbol{\Theta}}^{(t+1)}\right), \boldsymbol{\Sigma}^{(t+1)} \otimes (\mathbf{Z}'\mathbf{Z})^{-1}\right\}
\end{aligned}$$

where p_i is the number of imputation variables containing missing values in observation i and $\otimes$ is the Kronecker product. Submatrices $\boldsymbol{\mu}_{m\cdot o}^{(t)}$ and $\boldsymbol{\Sigma}_{mm\cdot o}^{(t)}$ are the mean and variance of the conditional normal distribution of $\mathbf{x}_{i(m)}$ given $\mathbf{x}_{i(o)}$ based on $(\mathbf{x}_{i(m)}, \mathbf{x}_{i(o)}|\mathbf{z}_i) \sim N_p\left(\boldsymbol{\Theta}^{(t)\prime}\mathbf{z}_i, \boldsymbol{\Sigma}^{(t)}\right)$. See, for example, Mardia, Kent, and Taylor (2024, 74–75) for the corresponding formulas of the conditional mean and variance of the multivariate normal distribution. The matrix $\widehat{\boldsymbol{\Theta}}^{(t+1)} = (\mathbf{Z}'\mathbf{Z})^{-1}\mathbf{Z}'\mathbf{X}^{(t+1)}$ is the OLS estimate of the regression coefficients based on the augmented data $\mathbf{X}^{(t+1)} = (\mathbf{X}_o, \mathbf{X}_m^{(t+1)})$ from iteration t. The posterior cross-product matrix $\Lambda_\star^{(t+1)}$ and the posterior degrees of freedom $\lambda_\star$ are defined as follows:

$$\Lambda_\star^{(t+1)} = \left\{\Lambda^{-1} + (\mathbf{X}^{(t+1)} - \mathbf{Z}\widehat{\boldsymbol{\Theta}}^{(t+1)})'(\mathbf{X}^{(t+1)} - \mathbf{Z}\widehat{\boldsymbol{\Theta}}^{(t+1)})\right\}^{-1}$$

and

$$\lambda_\star = \lambda + N - q$$

Prior distribution

As we already mentioned, `mi impute mvn` assumes an improper uniform prior distribution for $\boldsymbol{\Theta}$ and an inverted Wishart distribution for $\boldsymbol{\Sigma}$ under which the prior joint density function is

$$f(\boldsymbol{\Theta}, \boldsymbol{\Sigma}) \propto |\boldsymbol{\Sigma}|^{-\left(\frac{\lambda+p+1}{2}\right)} \exp\left(-\frac{1}{2}\text{tr}\Lambda^{-1}\boldsymbol{\Sigma}^{-1}\right)$$

Parameters of the inverted Wishart prior distribution, the prior cross-product matrix Λ, and the prior degrees of freedom λ are determined based on the requested prior distribution.

By default, `mi impute mvn` uses the uniform prior distribution under which $\lambda = -(p+1)$ and $\Lambda^{-1} = \mathbf{0}_{p\times p}$. Under the uniform prior, the log-likelihood and log-posterior functions are equivalent, and so the ML estimates of the parameters are equal to the posterior mode.

Under the noninformative Jeffreys prior distribution, $\lambda = 0$ and $\Lambda^{-1} = \mathbf{0}_{p\times p}$.

Under a ridge prior distribution, λ is equal to the user-specified value, and $\Lambda^{-1} = \lambda\boldsymbol{\Sigma}_\star$, where the diagonal matrix $\boldsymbol{\Sigma}_\star$ contains the diagonal elements of the estimate of the covariance matrix using all available cases. The variances (diagonal estimates) are the estimates of the mean squared error from regression of each imputation variable on the complete predictors. See Schafer (1997, 155–157) for details. With $\lambda = 0$, this prior specification reduces to the Jeffreys prior.

Initial values: EM algorithm

Initial values $\boldsymbol{\Theta}^{(0)}$ and $\boldsymbol{\Sigma}^{(0)}$ for DA are obtained from the EM algorithm for the incomplete multivariate normal data (for example, Dempster, Laird, and Rubin [1977], Little and Rubin [2020], Schafer [1997]). The EM algorithm iterates between the expectation step (E step) and the maximization step (M step) to maximize the log-likelihood (or log-posterior) function.

The observed-data log likelihood is

$$l_l(\boldsymbol{\Theta},\boldsymbol{\Sigma}|\mathbf{X}_o)=\sum_{s=1}^{S}\sum_{i\in I(s)}\left\{-0.5\ln(|\boldsymbol{\Sigma}_s|)-0.5(\mathbf{x}_{i(o)}-\boldsymbol{\Theta}_s'\mathbf{z}_i)'\boldsymbol{\Sigma}_s^{-1}(\mathbf{x}_{i(o)}-\boldsymbol{\Theta}_s'\mathbf{z}_i)\right\}$$

where S is the number of unique missing-value patterns, $I(s)$ is the set of observations from the same missing-value pattern s, and $\boldsymbol{\Theta}_s$ and $\boldsymbol{\Sigma}_s$ are the submatrices of $\boldsymbol{\Theta}$ and $\boldsymbol{\Sigma}$ that correspond to the imputation variables, which are observed in pattern s.

The observed-data log posterior is

$$l_p(\boldsymbol{\Theta},\boldsymbol{\Sigma}|\mathbf{X}_o)=l_l(\boldsymbol{\Theta},\boldsymbol{\Sigma}|\mathbf{X}_o)+\ln\{f(\boldsymbol{\Theta},\boldsymbol{\Sigma})\}=l_l(\boldsymbol{\Theta},\boldsymbol{\Sigma}|\mathbf{X}_o)-\frac{\lambda+p+1}{2}\ln(|\boldsymbol{\Sigma}|)-\mathrm{tr}(\Lambda^{-1}\boldsymbol{\Sigma}^{-1})$$

The E step and M step of the EM algorithm are defined as follows (see Schafer [2008; 1997, 163–175] for details).

Let $T_1=\sum_{i=1}^{N}\mathbf{z}_i\mathbf{x}_i'$ and $T_2=\sum_{i=1}^{N}\mathbf{x}_i\mathbf{x}_i'$ denote the sufficient statistics for the multivariate normal model. Consider the submatrices $\boldsymbol{\Theta}_{i(o)}$ and $\boldsymbol{\Theta}_{i(m)}$ of $\boldsymbol{\Theta}$, and the submatrices $\boldsymbol{\Sigma}_{i(mm)}$, $\boldsymbol{\Sigma}_{i(mo)}$, and $\boldsymbol{\Sigma}_{i(oo)}$ of $\boldsymbol{\Sigma}$ corresponding to the observed and missing columns of $\mathbf{x}_i$. Let $O(s)$ and $M(s)$ correspond to the column indexes of the observed and missing parts of $\mathbf{x}_i$ for each missing-values pattern s.

During the E step, the expectations $E(T_1)$ and $E(T_2)$ are computed with respect to the conditional distribution $\Pr(\mathbf{X}_m|\mathbf{X}_o,\boldsymbol{\Theta}^{(t)},\boldsymbol{\Sigma}^{(t)})$ using the following relations:

$$E(x_{ij}|\mathbf{X}_o,\boldsymbol{\Theta}^{(t)},\boldsymbol{\Sigma}^{(t)})=\begin{cases}x_{ij}, & \text{for } j\in O(s)\\ x_{ij}^{\star}, & \text{for } j\in M(s)\end{cases}$$

and

$$E(x_{ij}x_{il}|\mathbf{X}_o,\boldsymbol{\Theta}^{(t)},\boldsymbol{\Sigma}^{(t)})=\begin{cases}x_{ij}x_{il}, & \text{for } j,l\in O(s)\\ x_{ij}^{\star}x_{il}, & \text{for } j\in M(s), l\in O(s)\\ c_{ij}+x_{ij}^{\star}x_{il}^{\star}, & \text{for } j,l\in M(s)\end{cases}$$

where $x_{ij}^{\star}$ is the jth element of the vector $\boldsymbol{\Theta}_{i(m)}'\mathbf{z}_i+\boldsymbol{\Sigma}_{i(mo)}\boldsymbol{\Sigma}_{i(oo)}^{-1}\left(\mathbf{x}_{i(o)}-\boldsymbol{\Theta}_{i(o)}'\mathbf{z}_i\right)$, and c_{ij} is the element of the matrix $\boldsymbol{\Sigma}_{i(mm)}-\boldsymbol{\Sigma}_{i(mo)}\boldsymbol{\Sigma}_{i(oo)}^{-1}\boldsymbol{\Sigma}_{i(mo)}'$.

During the M step, the model parameters are updated using the computed expectations of the sufficient statistics:

$$\boldsymbol{\Theta}^{(t+1)}=(\mathbf{Z}'\mathbf{Z})^{-1}E(T_1)$$

$$\boldsymbol{\Sigma}^{(t+1)}=\frac{1}{N+\lambda+p+1}\left\{E(T_2)-E(T_1)'(\mathbf{Z}'\mathbf{Z})^{-1}E(T_1)+\Lambda^{-1}\right\}$$

EM iterates between the E step and the M step until the maximum relative difference between the two successive values of all parameters is less than the default tolerance of 1e–5 (or the specified `tolerance()`).

Worst linear function

The worst linear function (WLF) is defined as follows (Schafer 1997, 129–131):

$$\xi(\theta) = \widehat{v}_1'(\theta - \widehat{\theta})$$

where θ and $\widehat{\theta}$ are column vectors of the unique model parameters and their respective EM estimates; $\widehat{v}_1 = \theta^{(t)} - \theta^{(t-1)}$, where $\theta^{(t)} = \widehat{\theta}$ and $\theta^{(t-1)}$ are the estimates from the last and one before the last iterations of the EM algorithm. This function is regarded to be the WLF because it has the highest asymptotic rate of missing information among all linear functions. This function is derived based on the convergence properties of the EM algorithm (see Schafer [1997, 55–59] for details).

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Also see

[MI] **mi impute** — Impute missing values

[MI] **mi impute chained** — Impute missing values using chained equations

[MI] **mi impute monotone** — Impute missing values in monotone data

[MI] **mi estimate** — Estimation using multiple imputations

[MI] **Intro** — Introduction to mi

[MI] **Intro substantive** — Introduction to multiple-imputation analysis

[MI] **Glossary**

mi impute nbreg — Impute using negative binomial regression

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Description

`mi impute nbreg` fills in missing values of an overdispersed count variable using a negative binomial regression imputation method. You can perform separate imputations on different subsets of the data by specifying the `by()` option. You can also account for frequency, importance, and sampling weights.

Menu

Statistics > Multiple imputation

Syntax

`mi impute nbreg` *ivar* [*indepvars*] [*if*] [*weight*] [, *impute_options options*]

impute_options	Description
Main	
* `add(#)`	specify number of imputations to add; required when no imputations exist
* `replace`	replace imputed values in existing imputations
`rseed(#)`	specify random-number seed
`double`	store imputed values in double precision; the default is to store them as `float`
`by(`*varlist*[, *byopts*]`)`	impute separately on each group formed by *varlist*
Reporting	
`dots`	display dots as imputations are performed
`noisily`	display intermediate output
`nolegend`	suppress all table legends
Advanced	
`force`	proceed with imputation, even when missing imputed values are encountered
`noupdate`	do not perform `mi update`; see [MI] **noupdate option**

*`add(#)` is required when no imputations exist; `add(#)` or `replace` is required if imputations exist.
`noupdate` does not appear in the dialog box.

options	Description
Main	
noconstant	suppress constant term
dispersion(mean)	parameterization of dispersion; the default
dispersion(constant)	constant dispersion for all observations
exposure(*varname*$_e$)	include ln(*varname*$_e$) in model with coefficient constrained to 1
offset(*varname*$_o$)	include *varname*$_o$ in model with coefficient constrained to 1
conditional(*if*)	perform conditional imputation
bootstrap	estimate model parameters using sampling with replacement
Maximization	
maximize_options	control the maximization process; seldom used

You must `mi set` your data before using `mi impute nbreg`; see [MI] **mi set**.

You must `mi register` *ivar* as imputed before using `mi impute nbreg`; see [MI] **mi set**.

indepvars may contain factor variables; see [U] **11.4.3 Factor variables**.

`collect` is allowed; see [U] **11.1.10 Prefix commands**.

`fweights`, `iweights`, and `pweights` are allowed; see [U] **11.1.6 weight**.

Options

Main

`noconstant`; see [R] **Estimation options**.

`add()`, `replace`, `rseed()`, `double`, `by()`; see [MI] **mi impute**.

`dispersion(mean | constant)`; see [R] **nbreg**.

`exposure(`*varname*$_e$`)`, `offset(`*varname*$_o$`)`; see [R] **Estimation options**.

`conditional(`*if*`)` specifies that the imputation variable be imputed conditionally on observations satisfying *exp*; see [U] **11.1.3 if exp**. That is, missing values in a conditional sample, the sample identified by the *exp* expression, are imputed based only on data in that conditional sample. Missing values outside the conditional sample are replaced with a conditional constant, the value of the imputation variable in observations outside the conditional sample. As such, the imputation variable is required to be constant outside the conditional sample. Also, if any conditioning variables (variables involved in the conditional specification `if` *exp*) contain soft missing values (`.`), their missing values must be nested within missing values of the imputation variables. See *Conditional imputation* under *Remarks and examples* in [MI] **mi impute**.

`bootstrap` specifies that posterior estimates of model parameters be obtained using sampling with replacement; that is, posterior estimates are estimated from a bootstrap sample. The default is to sample the estimates from the posterior distribution of model parameters or from the large-sample normal approximation of the posterior distribution. This option is useful when asymptotic normality of parameter estimates is suspect.

Reporting

`dots`, `noisily`, `nolegend`; see [MI] **mi impute**. `noisily` specifies that the output from the negative binomial regression fit to the observed data be displayed. `nolegend` suppresses all legends that appear before the imputation table. Such legends include a legend about conditional imputation that appears when the `conditional()` option is specified and group legends that may appear when the `by()` option is specified.

Maximization

maximize_options; see [R] **nbreg**. These options are seldom used.

Advanced

`force`; see [MI] **mi impute**.

The following option is available with `mi impute` but is not shown in the dialog box:

`noupdate`; see [MI] **noupdate option**.

Remarks and examples

Remarks are presented under the following headings:

Univariate imputation using negative binomial regression
Using mi impute nbreg

See [MI] **mi impute** for a general description and details about options common to all imputation methods, *impute_options*. Also see [MI] **Workflow** for general advice on working with `mi`.

Univariate imputation using negative binomial regression

The negative binomial regression imputation method can be used to fill in missing values of an overdispersed count variable (Royston 2009). It is a parametric method that assumes an underlying negative binomial model (see [R] **nbreg**) for the imputed variable (given other predictors). This method is based on the asymptotic approximation of the posterior predictive distribution of the missing data.

Using mi impute nbreg

In [MI] **mi impute poisson**, we considered a version of the heart attack data containing a count variable, `npreg`, which records the number of pregnancies and is the only variable containing missing values. We imputed its missing values using `mi impute poisson`.

A Poisson model assumes that the mean and the variance are the same. In the presence of overdispersion, when the variance exceeds the mean, a negative binomial model is more appropriate. We can fit a negative binomial model for `npreg` to the observed data to see if there is any indication of overdispersion in the data.

```
. use https://www.stata-press.com/data/r19/mheartpois
(Fictional heart attack data; npreg missing)
. nbreg npreg attack smokes age bmi hsgrad if female==1, nolog
Negative binomial regression                          Number of obs =     35
                                                      LR chi2(5)    =   1.69
Dispersion: mean                                      Prob > chi2   = 0.8903
Log likelihood = -54.638875                           Pseudo R2     = 0.0152
```

npreg	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
attack	.0551929	.4214484	0.13	0.896	-.7708309	.8812166
smokes	.0521987	.4182004	0.12	0.901	-.7674591	.8718565
age	-.0105877	.0174661	-0.61	0.544	-.0448206	.0236452
bmi	.0194787	.0489883	0.40	0.691	-.0765367	.115494
hsgrad	.5338139	.4972872	1.07	0.283	-.4408511	1.508479
_cons	-.0736959	1.551417	-0.05	0.962	-3.114417	2.967025
/lnalpha	-.7956602	.7987311			-2.361144	.769824
alpha	.4512832	.3604539			.0943122	2.159386

```
LR test of alpha=0: chibar2(01) = 3.00                Prob >= chibar2 = 0.042
```

The estimate of the overdispersion parameter `alpha` is 0.45 with a 95% confidence interval of [0.094, 2.16]. The confidence interval does not include a value of 0 (no overdispersion), so there is slight overdispersion in the conditional distribution of `nbreg` in the observed data.

We now impute `npreg` using `mi impute nbreg`:

```
. mi set mlong
. mi register imputed npreg
(10 m=0 obs now marked as incomplete)
. mi impute nbreg npreg attack smokes age bmi hsgrad, add(20)
> conditional(if female==1)
Univariate imputation                       Imputations =       20
Negative binomial regression                      added =       20
Imputed: m=1 through m=20                         updated =      0
Dispersion: mean
Conditional imputation:
  npreg: incomplete out-of-sample obs replaced with value 0
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
npreg	144	10	10	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

We specify the `conditional()` option to restrict imputation of `npreg` only to females; see *Conditional imputation* in [MI] **mi impute** for details.

We can analyze these multiply imputed data using logistic regression with `mi estimate`:

```
. mi estimate: logit attack smokes age bmi female hsgrad npreg
```

Stored results

`mi impute nbreg` stores the following in `r()`:

Scalars

`r(M)`	total number of imputations
`r(M_add)`	number of added imputations
`r(M_update)`	number of updated imputations
`r(k_ivars)`	number of imputed variables (always `1`)
`r(N_g)`	number of imputed groups (`1` if `by()` is not specified)

Macros

`r(method)`	name of imputation method (`nbreg`)
`r(ivars)`	names of imputation variables
`r(rngstate)`	random-number state used
`r(by)`	names of variables specified within `by()`

Matrices

`r(N)`	number of observations in imputation sample in each group
`r(N_complete)`	number of complete observations in imputation sample in each group
`r(N_incomplete)`	number of incomplete observations in imputation sample in each group
`r(N_imputed)`	number of imputed observations in imputation sample in each group

Methods and formulas

Consider a univariate variable $\mathbf{x} = (x_1, x_2, \ldots, x_n)'$ that follows a negative binomial model

$$\Pr(x_i = x|\mathbf{z}_i) = \frac{\Gamma(m_i + x)}{\Gamma(x+1)\Gamma(m_i)}\, p_i^{m_i}(1-p_i)^x,\ x = 0, 1, 2, \ldots \tag{1}$$

where $m_i = m = 1/\alpha$, $p_i = 1/(1+\alpha\mu_i)$ under mean-dispersion model and $m_i = \mu_i/\delta$, $p_i = p = 1/(1+\delta)$ under constant-dispersion model, $\mu_i = \exp(\mathbf{z}_i'\boldsymbol{\beta} + \text{offset}_i)$, and $\alpha > 0$ and $\delta > 0$ are unknown dispersion parameters; see [R] **nbreg** for details. $\mathbf{z}_i = (z_{i1}, z_{i2}, \ldots, z_{iq})'$ records values of predictors of $\mathbf{x}$ for observation i and $\boldsymbol{\beta}$ is the $q \times 1$ vector of unknown regression coefficients. (When a constant is included in the model—the default—$z_{i1} = 1,\ i = 1, \ldots, n$.)

$\mathbf{x}$ contains missing values that are to be filled in. Consider the partition of $\mathbf{x} = (\mathbf{x}_o', \mathbf{x}_m')$ into $n_0 \times 1$ and $n_1 \times 1$ vectors containing the complete and the incomplete observations. Consider a similar partition of $\mathbf{Z} = (\mathbf{Z}_o, \mathbf{Z}_m)$ into $n_0 \times q$ and $n_1 \times q$ submatrices.

`mi impute nbreg` follows the steps below to fill in $\mathbf{x}_m$:

1. Fit a negative binomial regression model (1) to the observed data $(\mathbf{x}_o, \mathbf{Z}_o)$ to obtain the maximum likelihood estimates, $\hat{\boldsymbol{\theta}} = (\widehat{\boldsymbol{\beta}}', \ln\hat{\alpha})'$ under a mean-dispersion model or $\hat{\boldsymbol{\theta}} = (\widehat{\boldsymbol{\beta}}', \ln\hat{\delta})'$ under a constant-dispersion model, and their asymptotic sampling variance, $\widehat{\mathbf{U}}$.
2. Simulate new parameters, $\boldsymbol{\theta}_\star$, from the large-sample normal approximation, $N(\hat{\boldsymbol{\theta}}, \widehat{\mathbf{U}})$, to its posterior distribution, assuming the noninformative prior $\Pr(\boldsymbol{\theta}) \propto \text{const}$.
3. Obtain one set of imputed values, $\mathbf{x}_m^1$, by simulating from a negative binomial distribution (1) with parameters set to their simulated values from step 2.
4. Repeat steps 2 and 3 to obtain M sets of imputed values, $\mathbf{x}_m^1, \mathbf{x}_m^2, \ldots, \mathbf{x}_m^M$.

Steps 2 and 3 above correspond to only approximate draws from the posterior predictive distribution of the missing data, $\Pr(\mathbf{x}_m|\mathbf{x}_o, \mathbf{Z}_o)$, because $\boldsymbol{\theta}_\star$ is drawn from the asymptotic approximation to its posterior distribution.

If weights are specified, a weighted negative binomial regression model is fit to the observed data in step 1 (see [R] **nbreg** for details).

Reference

Royston, P. 2009. Multiple imputation of missing values: Further update of ice, with an emphasis on categorical variables. *Stata Journal* 9: 466–477.

Also see

[MI] **mi impute** — Impute missing values

[MI] **mi impute poisson** — Impute using Poisson regression

[MI] **mi estimate** — Estimation using multiple imputations

[MI] **Intro** — Introduction to mi

[MI] **Intro substantive** — Introduction to multiple-imputation analysis

mi impute ologit — Impute using ordered logistic regression

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Description

`mi impute ologit` fills in missing values of an ordinal variable using an ordered logistic regression imputation method. You can perform separate imputations on different subsets of the data by specifying the `by()` option. You can also account for frequency, importance, and sampling weights.

Menu

Statistics > Multiple imputation

Syntax

`mi impute ologit` *ivar* [*indepvars*] [*if*] [*weight*] [, *impute_options options*]

impute_options	Description
Main	
* `add(#)`	specify number of imputations to add; required when no imputations exist
* `replace`	replace imputed values in existing imputations
`rseed(#)`	specify random-number seed
`double`	store imputed values in double precision; the default is to store them as `float`
`by(`*varlist*[, *byopts*]`)`	impute separately on each group formed by *varlist*
Reporting	
`dots`	display dots as imputations are performed
`noisily`	display intermediate output
`nolegend`	suppress all table legends
Advanced	
`force`	proceed with imputation, even when missing imputed values are encountered
`noupdate`	do not perform `mi update`; see [MI] **noupdate option**

*`add(#)` is required when no imputations exist; `add(#)` or `replace` is required if imputations exist.
`noupdate` does not appear in the dialog box.

options	Description
Main	
offset(*varname*)	include *varname* in model with coefficient constrained to 1
augment	perform augmented regression in the presence of perfect prediction
conditional(*if*)	perform conditional imputation
bootstrap	estimate model parameters using sampling with replacement
Maximization	
maximize_options	control the maximization process; seldom used

You must `mi set` your data before using `mi impute ologit`; see [MI] **mi set**.

You must `mi register` *ivar* as imputed before using `mi impute ologit`; see [MI] **mi set**.

indepvars may contain factor variables; see [U] **11.4.3 Factor variables**.

`collect` is allowed; see [U] **11.1.10 Prefix commands**.

`fweights`, `iweights`, and `pweights` are allowed; see [U] **11.1.6 weight**.

Options

Main

`add()`, `replace`, `rseed()`, `double`, `by()`; see [MI] **mi impute**.

`offset(`*varname*`)`; see [R] **Estimation options**.

`augment` specifies that augmented regression be performed if perfect prediction is detected. By default, an error is issued when perfect prediction is detected. The idea behind the augmented-regression approach is to add a few observations with small weights to the data during estimation to avoid perfect prediction. See *The issue of perfect prediction during imputation of categorical data* under *Remarks and examples* in [MI] **mi impute** for more information. `augment` is not allowed with importance weights.

`conditional(`*if*`)` specifies that the imputation variable be imputed conditionally on observations satisfying *exp*; see [U] **11.1.3 if exp**. That is, missing values in a conditional sample, the sample identified by the *exp* expression, are imputed based only on data in that conditional sample. Missing values outside the conditional sample are replaced with a conditional constant, the value of the imputation variable in observations outside the conditional sample. As such, the imputation variable is required to be constant outside the conditional sample. Also, if any conditioning variables (variables involved in the conditional specification `if` *exp*) contain soft missing values (`.`), their missing values must be nested within missing values of the imputation variables. See *Conditional imputation* under *Remarks and examples* in [MI] **mi impute**.

`bootstrap` specifies that posterior estimates of model parameters be obtained using sampling with replacement; that is, posterior estimates are estimated from a bootstrap sample. The default is to sample the estimates from the posterior distribution of model parameters or from the large-sample normal approximation of the posterior distribution. This option is useful when asymptotic normality of parameter estimates is suspect.

Reporting

dots, noisily, nolegend; see [MI] **mi impute**. noisily specifies that the output from the ordered logistic regression fit to the observed data be displayed. nolegend suppresses all legends that appear before the imputation table. Such legends include a legend about conditional imputation that appears when the conditional() option is specified and group legends that may appear when the by() option is specified.

Maximization

maximize_options; see [R] **ologit**. These options are seldom used. difficult, technique(), gradient, showstep, hessian, and showtolerance are not allowed when the augment option is used.

Advanced

force; see [MI] **mi impute**.

The following option is available with mi impute but is not shown in the dialog box:

noupdate; see [MI] **noupdate option**.

Remarks and examples

Remarks are presented under the following headings:

Univariate imputation using ordered logistic regression
Using mi impute ologit

See [MI] **mi impute** for a general description and details about options common to all imputation methods, *impute_options*. Also see [MI] **Workflow** for general advice on working with mi.

Univariate imputation using ordered logistic regression

The ordered logistic regression imputation method can be used to fill in missing values of an ordinal variable (for example, Raghunathan et al. [2001] and van Buuren [2007]). It is a parametric method that assumes an underlying logistic model for the imputed variable (given other predictors). Similarly to the logistic imputation method, this method is based on the asymptotic approximation of the posterior predictive distribution of the missing data.

Using mi impute ologit

Following the example from [MI] **mi impute mlogit**, we consider the heart attack data (for example, [MI] **Intro substantive**, [MI] **mi impute**), where a logistic model of interest now includes information about alcohol consumption, variable alcohol—logit attack smokes age bmi female hsgrad i.alcohol.

```
. use https://www.stata-press.com/data/r19/mheart4
(Fictional heart attack data; alcohol missing)
. tabulate alcohol, missing
```

Alcohol consumption: none, <2 drinks/day, >=2 drinks/day	Freq.	Percent	Cum.
Do not drink	18	11.69	11.69
Less than 3 drinks/day	83	53.90	65.58
Three or more drinks/day	44	28.57	94.16
.	9	5.84	100.00
Total	154	100.00	

From the output, the `alcohol` variable has three unique ordered categories and nine missing observations. We use the ordered logistic imputation method to impute missing values of `alcohol`. We create 10 imputations by specifying the `add(10)` option:

```
. mi set mlong
. mi register imputed alcohol
(9 m=0 obs now marked as incomplete)
. mi impute ologit alcohol attack smokes age bmi female hsgrad, add(10)
Univariate imputation                       Imputations =       10
Ordered logistic regression                        added =       10
Imputed: m=1 through m=10                        updated =        0
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
alcohol	145	9	9	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

We can now analyze these multiply imputed data with logistic regression via `mi estimate`:

```
. mi estimate: logit attack smokes age bmi female hsgrad i.alcohol
```

Stored results

`mi impute ologit` stores the following in `r()`:

Scalars

`r(M)`	total number of imputations
`r(M_add)`	number of added imputations
`r(M_update)`	number of updated imputations
`r(k_ivars)`	number of imputed variables (always 1)
`r(pp)`	1 if perfect prediction detected, 0 otherwise
`r(N_g)`	number of imputed groups (1 if `by()` is not specified)

Macros

`r(method)`	name of imputation method (`ologit`)
`r(ivars)`	names of imputation variables
`r(rngstate)`	random-number state used
`r(by)`	names of variables specified within `by()`

Matrices

r(N)	number of observations in imputation sample in each group
r(N_complete)	number of complete observations in imputation sample in each group
r(N_incomplete)	number of incomplete observations in imputation sample in each group
r(N_imputed)	number of imputed observations in imputation sample in each group

Methods and formulas

Consider a univariate variable $\mathbf{x} = (x_1, x_2, \ldots, x_n)'$ that contains K ordered categories and follows an ordered logistic model

$$\begin{aligned}\Pr(x_i = k|\mathbf{z}_i) &= \Pr(\gamma_{k-1} < \mathbf{z}_i'\boldsymbol{\beta} + u \leq \gamma_k) \\ &= \frac{1}{1 + \exp(-\gamma_k + \mathbf{z}_i'\boldsymbol{\beta})} - \frac{1}{1 + \exp(-\gamma_{k-1} + \mathbf{z}_i'\boldsymbol{\beta})}\end{aligned} \tag{1}$$

where $\mathbf{z}_i = (z_{i1}, z_{i2}, \ldots, z_{iq})'$ records values of predictors of $\mathbf{x}$ for observation i, $\boldsymbol{\beta}$ is the $q \times 1$ vector of unknown regression coefficients, and $\boldsymbol{\gamma} = (\gamma_1, \ldots, \gamma_{K-1})'$ are the unknown cutpoints with $\gamma_0 = -\infty$ and $\gamma_K = \infty$. (There is no constant in this model because its effect is absorbed into the cutpoints; see [R] **ologit** for details.)

$\mathbf{x}$ contains missing values that are to be filled in. Consider the partition of $\mathbf{x} = (\mathbf{x}_o', \mathbf{x}_m')$ into $n_0 \times 1$ and $n_1 \times 1$ vectors containing the complete and the incomplete observations. Consider a similar partition of $\mathbf{Z} = (\mathbf{Z}_o, \mathbf{Z}_m)$ into $n_0 \times q$ and $n_1 \times q$ submatrices.

`mi impute ologit` follows the steps below to fill in $\mathbf{x}_m$:

1. Fit an ordered logistic model (1) to the observed data $(\mathbf{x}_o, \mathbf{Z}_o)$ to obtain the maximum likelihood estimates, $\hat{\boldsymbol{\theta}} = (\widehat{\boldsymbol{\beta}}', \widehat{\boldsymbol{\gamma}}')'$, and their asymptotic sampling variance, $\widehat{\mathbf{U}}$.
2. Simulate new parameters, $\boldsymbol{\theta}_\star$, from the large-sample normal approximation, $N(\hat{\boldsymbol{\theta}}, \widehat{\mathbf{U}})$, to its posterior distribution assuming the noninformative prior $\Pr(\boldsymbol{\theta}) \propto$ const.
3. Obtain one set of imputed values, $\mathbf{x}_m^1$, by simulating from an ordered logistic distribution as defined by (1): one of K categories is randomly assigned to a missing category, i_m, using the cumulative probabilities computed from (1) with $\boldsymbol{\beta} = \boldsymbol{\beta}_\star$, $\boldsymbol{\gamma} = \boldsymbol{\gamma}_\star$, and $\mathbf{z}_i = \mathbf{z}_{i_m}$.
4. Repeat steps 2 and 3 to obtain M sets of imputed values, $\mathbf{x}_m^1, \mathbf{x}_m^2, \ldots, \mathbf{x}_m^M$.

Steps 2 and 3 above correspond to only approximate draws from the posterior predictive distribution of the missing data, $\Pr(\mathbf{x}_m|\mathbf{x}_o, \mathbf{Z}_o)$, because $\boldsymbol{\theta}_\star$ is drawn from the asymptotic approximation to its posterior distribution.

If weights are specified, a weighted ordered logistic regression model is fit to the observed data in step 1 (see [R] **ologit** for details).

References

Raghunathan, T. E., J. M. Lepkowski, J. Van Hoewyk, and P. Solenberger. 2001. A multivariate technique for multiply imputing missing values using a sequence of regression models. *Survey Methodology* 27: 85–95.

van Buuren, S. 2007. Multiple imputation of discrete and continuous data by fully conditional specification. *Statistical Methods in Medical Research* 16: 219–242. https://doi.org/10.1177/0962280206074463.

Also see

[MI] **mi impute** — Impute missing values

[MI] **mi impute mlogit** — Impute using multinomial logistic regression

[MI] **mi estimate** — Estimation using multiple imputations

[MI] **Intro** — Introduction to mi

[MI] **Intro substantive** — Introduction to multiple-imputation analysis

mi impute pmm — Impute using predictive mean matching

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Description

`mi impute pmm` fills in missing values of a continuous variable by using the predictive mean matching imputation method. You can perform separate imputations on different subsets of the data by specifying the `by()` option. You can also account for analytic, frequency, importance, and sampling weights.

Menu

Statistics > Multiple imputation

Syntax

`mi impute pmm` *ivar* [*indepvars*] [*if*] [*weight*], `knn(#)` [*impute_options* *options*]

impute_options	Description
Main	
* `add(#)`	specify number of imputations to add; required when no imputations exist
* `replace`	replace imputed values in existing imputations
`rseed(#)`	specify random-number seed
`double`	store imputed values in double precision; the default is to store them as `float`
`by(`*varlist*[, *byopts*]`)`	impute separately on each group formed by *varlist*
Reporting	
`dots`	display dots as imputations are performed
`noisily`	display intermediate output
`nolegend`	suppress all table legends
Advanced	
`force`	proceed with imputation, even when missing imputed values are encountered
`noupdate`	do not perform `mi update`; see [MI] **noupdate option**

*`add(#)` is required when no imputations exist; `add(#)` or `replace` is required if imputations exist.
`noupdate` does not appear in the dialog box.

options	Description
Main	
noconstant	suppress constant term
* knn(#)	specify # of closest observations (nearest neighbors) to draw from
conditional(*if*)	perform conditional imputation
bootstrap	estimate model parameters using sampling with replacement

*knn(#) is required.

You must mi set your data before using mi impute pmm; see [MI] **mi set**.

You must mi register *ivar* as imputed before using mi impute pmm; see [MI] **mi set**.

indepvars may contain factor variables; see **[U] 11.4.3 Factor variables**.

collect is allowed; see **[U] 11.1.10 Prefix commands**.

aweights, fweights, iweights, and pweights are allowed; see **[U] 11.1.6 weight**.

Options

Main

noconstant; see [R] **Estimation options**.

add(), replace, rseed(), double, by(); see [MI] **mi impute**.

knn(#) specifies the number of closest observations (nearest neighbors) from which to draw imputed values. This option is required. The closeness is determined based on the absolute difference between the linear prediction for the missing value and that for the complete values. The closest observation is the observation with the smallest difference. This option regulates the correlation among multiple imputations that affects the bias and the variability of the resulting multiple-imputation point estimates; see *Remarks and examples* for details.

conditional(*if*) specifies that the imputation variable be imputed conditionally on observations satisfying *exp*; see **[U] 11.1.3 if exp**. That is, missing values in a conditional sample, the sample identified by the *exp* expression, are imputed based only on data in that conditional sample. Missing values outside the conditional sample are replaced with a conditional constant, the value of the imputation variable in observations outside the conditional sample. As such, the imputation variable is required to be constant outside the conditional sample. Also, if any conditioning variables (variables involved in the conditional specification if *exp*) contain soft missing values (.), their missing values must be nested within missing values of the imputation variables. See *Conditional imputation* under *Remarks and examples* in [MI] **mi impute**.

bootstrap specifies that posterior estimates of model parameters be obtained using sampling with replacement; that is, posterior estimates are estimated from a bootstrap sample. The default is to sample the estimates from the posterior distribution of model parameters or from the large-sample normal approximation of the posterior distribution. This option is useful when asymptotic normality of parameter estimates is suspect.

Reporting

dots, noisily, nolegend; see [MI] **mi impute**. noisily specifies that the output from the linear regression fit to the observed data be displayed. nolegend suppresses all legends that appear before the imputation table. Such legends include a legend about conditional imputation that appears when the conditional() option is specified and group legends that may appear when the by() option is specified.

Advanced

`force`; see [MI] **mi impute**.

The following option is available with `mi impute` but is not shown in the dialog box:

`noupdate`; see [MI] **noupdate option**.

Remarks and examples

Remarks are presented under the following headings:

Univariate imputation using predictive mean matching
Using mi impute pmm
Video example

See [MI] **mi impute** for a general description and details about options common to all imputation methods, *impute_options*. Also see [MI] **Workflow** for general advice on working with `mi`.

Univariate imputation using predictive mean matching

Either predictive mean matching (`pmm`) or normal linear regression (`regress`) imputation methods can be used to fill in missing values of a continuous variable (Rubin 1987; Schenker and Taylor 1996). Predictive mean matching may be preferable to linear regression when the normality of the underlying model is suspect.

Predictive mean matching (PMM) is a partially parametric method that matches the missing value to the observed value with the closest predicted mean (or linear prediction). It was introduced by Little (1988) based on Rubin's (1986) ideas applied to statistical file matching. PMM combines the standard linear regression and the nearest-neighbor imputation approaches. It uses the normal linear regression to obtain linear predictions. It then uses the linear prediction as a distance measure to form the set of nearest neighbors (possible donors) consisting of the complete values. Finally, it randomly draws an imputed value from this set. By drawing from the observed data, PMM preserves the distribution of the observed values in the missing part of the data, which makes it more robust than the fully parametric linear regression approach.

With PMM, you need to decide how many nearest neighbors to include in the set of possible donors. The number of nearest neighbors must be specified in `mi impute pmm`'s option `knn()`. The number of nearest neighbors affects the correlation among imputations—the smaller the number, the higher the correlation. High correlation in turn increases the variability of the MI point estimates. Including too many possible donors may result in increased bias of the MI point estimates. Thus the number of nearest neighbors regulates the tradeoff between the bias and the variance of the point estimators in repeated sampling. The literature does not provide a definitive recommendation on how to choose this number in practice; see Schenker and Taylor (1996) and Morris, White, and Royston (2014) for some insight into this issue.

Using mi impute pmm

Recall the heart attack data from *Univariate imputation* in [MI] **mi impute**. We wish to fit a logistic regression of `attack` on some predictors, one of which, `bmi`, has missing values. To avoid losing information contained in complete observations of the other predictors, we impute `bmi`.

We showed one way of imputing bmi in [MI] **mi impute regress**. Suppose, however, that we want to restrict the imputed values of bmi to be within the range observed for bmi. We can use the PMM imputation method to restrict the values. This method may also be preferable to the regression imputation of bmi because the distribution of bmi is slightly skewed.

```
. use https://www.stata-press.com/data/r19/mheart0
(Fictional heart attack data; BMI missing)
. mi set mlong
. mi register imputed bmi
(22 m=0 obs now marked as incomplete)
. mi impute pmm bmi attack smokes age hsgrad female, add(20) knn(1)
Univariate imputation                       Imputations =       20
Predictive mean matching                           added =       20
Imputed: m=1 through m=20                        updated =        0
                                       Nearest neighbors =        1
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
bmi	132	22	22	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

In the above, mi impute pmm used one nearest neighbor to draw from. That is, it replaced missing values with an observed value whose linear prediction was the closest to that of the missing value. Using only one nearest neighbor will typically result in high variability of the MI estimates. You can increase the number of nearest neighbors from which the imputed value is drawn. For example, we use 5 below:

```
. mi impute pmm bmi attack smokes age hsgrad female, replace knn(5)
Univariate imputation                       Imputations =       20
Predictive mean matching                           added =        0
Imputed: m=1 through m=20                        updated =       20
                                       Nearest neighbors =        5
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
bmi	132	22	22	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

See Morris, White, and Royston (2014) for recommendations on choosing the number of nearest neighbors with predictive mean matching.

You can now refit the logistic model and examine the effect of using more neighbors:

```
. mi estimate: logit attack smokes age bmi hsgrad female
```

See [MI] **mi impute**, [MI] **mi impute regress**, and [MI] **mi estimate** for more details.

Video example

Multiple imputation: Setup, imputation, estimation—predictive mean matching

Stored results

mi impute pmm stores the following in r():

Scalars

r(M)	total number of imputations
r(M_add)	number of added imputations
r(M_update)	number of updated imputations
r(knn)	number of k nearest neighbors
r(k_ivars)	number of imputed variables (always 1)
r(N_g)	number of imputed groups (1 if by() is not specified)

Macros

r(method)	name of imputation method (pmm)
r(ivars)	names of imputation variables
r(rngstate)	random-number state used
r(by)	names of variables specified within by()

Matrices

r(N)	number of observations in imputation sample in each group
r(N_complete)	number of complete observations in imputation sample in each group
r(N_incomplete)	number of incomplete observations in imputation sample in each group
r(N_imputed)	number of imputed observations in imputation sample in each group

Methods and formulas

mi impute pmm follows the steps as described in *Methods and formulas* of [MI] **mi impute regress** with the exception of step 3.

Consider a univariate variable $\mathbf{x} = (x_1, x_2, \ldots, x_n)'$ that follows a normal linear regression model

$$x_i|\mathbf{z}_i \sim N(\mathbf{z}_i'\boldsymbol{\beta}, \sigma^2) \tag{1}$$

where $\mathbf{z}_i = (z_{i1}, z_{i2}, \ldots, z_{iq})'$ records values of predictors of $\mathbf{x}$ for observation i, $\boldsymbol{\beta}$ is the $q \times 1$ vector of unknown regression coefficients, and σ^2 is the unknown scalar variance. (Note that when a constant is included in the model—the default—$z_{i1} = 1,\ i = 1, \ldots, n$.)

$\mathbf{x}$ contains missing values that are to be filled in. Consider the partition of $\mathbf{x} = (\mathbf{x}_o', \mathbf{x}_m')$ into $n_0 \times 1$ and $n_1 \times 1$ vectors containing the complete and the incomplete observations. Consider a similar partition of $\mathbf{Z} = (\mathbf{Z}_o, \mathbf{Z}_m)$ into $n_0 \times q$ and $n_1 \times q$ submatrices.

mi impute pmm follows the steps below to fill in $\mathbf{x}_m$ (for simplicity, we omit the conditioning on the observed data in what follows):

1. Fit a regression model (1) to the observed data $(\mathbf{x}_o, \mathbf{Z}_o)$ to obtain estimates $\widehat{\boldsymbol{\beta}}$ and $\hat{\sigma}^2$ of the model parameters.
2. Simulate new parameters $\boldsymbol{\beta}_\star$ and $\sigma^2_\star$ from their joint posterior distribution under the conventional noninformative improper prior $\Pr(\boldsymbol{\beta}, \sigma^2) \propto 1/\sigma^2$. This is done in two steps:

$$\begin{aligned} \sigma^2_\star &\sim \hat{\sigma}^2(n_0 - q)/\chi^2_{n_0-q} \\ \boldsymbol{\beta}_\star|\sigma^2_\star &\sim N\left\{\widehat{\boldsymbol{\beta}},\ \sigma^2_\star(\mathbf{Z}_o'\mathbf{Z}_o)^{-1}\right\} \end{aligned}$$

3. Generate the imputed values, $\mathbf{x}_m^1$, as follows. Let $\hat{x}_i = \mathbf{z}_i'\boldsymbol{\beta}_\star$ be the linear prediction of $\mathbf{x}$ based on predictors $\mathbf{Z}$ for observation i. Then for any missing observation i of $\mathbf{x}$, $x_i = x_{j_{\text{min}}}$, where j_{min} is randomly drawn from the set of indices $\{i_1, i_2, \ldots, i_k\}$ corresponding to the first k minimums determined based on the absolute differences between the linear prediction for incomplete observation i and linear predictions for all complete observations, $|\hat{x}_i - \hat{x}_j|$, $j \in obs$. For example, if $k = 1$ (the default), j_{min} is determined based on $|\hat{x}_i - \hat{x}_{j_{\text{min}}}| = \min_{j \in \text{obs}} |\hat{x}_i - \hat{x}_j|$.

4. Repeat steps 2 and 3 to obtain M sets of imputed values, $\mathbf{x}_m^1, \mathbf{x}_m^2, \ldots, \mathbf{x}_m^M$.

If weights are specified, a weighted linear regression model is fit to the observed data in step 1 (see [R] **regress** for details).

References

Little, R. J. A. 1988. Missing-data adjustments in large surveys. *Journal of Business and Economic Statistics* 6: 287–296. https://doi.org/10.2307/1391878.

Morris, T. P., I. R. White, and P. Royston. 2014. Tuning multiple imputation by predictive mean matching and local residual draws. *BMC Medical Research Methodology* 14: art. 75. https://doi.org/10.1186/1471-2288-14-75.

Rubin, D. B. 1986. Statistical matching using file concatenation with adjusted weights and multiple imputations. *Journal of Business and Economic Statistics* 4: 87–94. https://doi.org/10.2307/1391390.

———. 1987. *Multiple Imputation for Nonresponse in Surveys*. New York: Wiley.

Schenker, N., and J. M. G. Taylor. 1996. Partially parametric techniques for multiple imputation. *Computational Statistics and Data Analysis* 22: 425–446. https://doi.org/10.1016/0167-9473(95)00057-7.

Also see

[MI] **mi impute** — Impute missing values

[MI] **mi impute intreg** — Impute using interval regression

[MI] **mi impute regress** — Impute using linear regression

[MI] **mi impute truncreg** — Impute using truncated regression

[MI] **mi estimate** — Estimation using multiple imputations

[MI] **Intro** — Introduction to mi

[MI] **Intro substantive** — Introduction to multiple-imputation analysis

mi impute poisson — Impute using Poisson regression

Description | Menu | Syntax | Options
Remarks and examples | Stored results | Methods and formulas | References
Also see

Description

`mi impute poisson` fills in missing values of a count variable using a Poisson regression imputation method. You can perform separate imputations on different subsets of the data by specifying the `by()` option. You can also account for frequency, importance, and sampling weights.

Menu

Statistics > Multiple imputation

Syntax

`mi impute poisson` *ivar* [*indepvars*] [*if*] [*weight*] [, *impute_options options*]

impute_options	Description
Main	
* `add(#)`	specify number of imputations to add; required when no imputations exist
* `replace`	replace imputed values in existing imputations
`rseed(#)`	specify random-number seed
`double`	store imputed values in double precision; the default is to store them as `float`
`by(`*varlist*[, *byopts*]`)`	impute separately on each group formed by *varlist*
Reporting	
`dots`	display dots as imputations are performed
`noisily`	display intermediate output
`nolegend`	suppress all table legends
Advanced	
`force`	proceed with imputation, even when missing imputed values are encountered
`noupdate`	do not perform `mi update`; see [MI] **noupdate option**

*`add(#)` is required when no imputations exist; `add(#)` or `replace` is required if imputations exist.
`noupdate` does not appear in the dialog box.

options	Description
Main	
noconstant	suppress constant term
exposure(*varname*$_e$)	include ln(*varname*$_e$) in model with coefficient constrained to 1
offset(*varname*$_o$)	include *varname*$_o$ in model with coefficient constrained to 1
conditional(*if*)	perform conditional imputation
bootstrap	estimate model parameters using sampling with replacement
Maximization	
maximize_options	control the maximization process; seldom used

You must `mi set` your data before using `mi impute poisson`; see [MI] **mi set**.

You must `mi register` *ivar* as imputed before using `mi impute poisson`; see [MI] **mi set**.

indepvars may contain factor variables; see [U] **11.4.3 Factor variables**.

`collect` is allowed; see [U] **11.1.10 Prefix commands**.

`fweights`, `iweights`, and `pweights` are allowed; see [U] **11.1.6 weight**.

Options

Main

`noconstant`; see [R] **Estimation options**.

`add()`, `replace`, `rseed()`, `double`, `by()`; see [MI] **mi impute**.

`exposure(`*varname*$_e$`)`, `offset(`*varname*$_o$`)`; see [R] **Estimation options**.

`conditional(`*if*`)` specifies that the imputation variable be imputed conditionally on observations satisfying *exp*; see [U] **11.1.3 if exp**. That is, missing values in a conditional sample, the sample identified by the *exp* expression, are imputed based only on data in that conditional sample. Missing values outside the conditional sample are replaced with a conditional constant, the value of the imputation variable in observations outside the conditional sample. As such, the imputation variable is required to be constant outside the conditional sample. Also, if any conditioning variables (variables involved in the conditional specification `if` *exp*) contain soft missing values (`.`), their missing values must be nested within missing values of the imputation variables. See *Conditional imputation* under *Remarks and examples* in [MI] **mi impute**.

`bootstrap` specifies that posterior estimates of model parameters be obtained using sampling with replacement; that is, posterior estimates are estimated from a bootstrap sample. The default is to sample the estimates from the posterior distribution of model parameters or from the large-sample normal approximation of the posterior distribution. This option is useful when asymptotic normality of parameter estimates is suspect.

Reporting

`dots`, `noisily`, `nolegend`; see [MI] **mi impute**. `noisily` specifies that the output from the Poisson regression fit to the observed data be displayed. `nolegend` suppresses all legends that appear before the imputation table. Such legends include a legend about conditional imputation that appears when the `conditional()` option is specified and group legends that may appear when the `by()` option is specified.

Maximization

maximize_options; see [R] **poisson**. These options are seldom used.

Advanced

`force`; see [MI] **mi impute**.

The following option is available with `mi impute` but is not shown in the dialog box:

`noupdate`; see [MI] **noupdate option**.

Remarks and examples

Remarks are presented under the following headings:

Univariate imputation using Poisson regression
Using mi impute poisson

See [MI] **mi impute** for a general description and details about options common to all imputation methods, *impute_options*. Also see [MI] **Workflow** for general advice on working with `mi`.

Univariate imputation using Poisson regression

The Poisson regression imputation method can be used to fill in missing values of a count variable (for example, Raghunathan et al. [2001] and van Buuren [2007]). It is a parametric method that assumes an underlying Poisson model for the imputed variable (given other predictors). For imputation of overdispersed count variables, see [MI] **mi impute nbreg**. The Poisson method is based on the asymptotic approximation of the posterior predictive distribution of the missing data.

Using mi impute poisson

To illustrate the use of `mi impute poisson`, we continue with our heart attack data analysis example in [MI] **Intro substantive** and consider an additional predictor, `npreg`, which records the number of pregnancies:

```
. use https://www.stata-press.com/data/r19/mheartpois
(Fictional heart attack data; npreg missing)
. misstable summarize
```

				Obs<.		
Variable	Obs=.	Obs>.	Obs<.	Unique values	Min	Max
npreg	10		144	6	0	5

```
. tab female if npreg==.
```

Gender	Freq.	Percent	Cum.
Male	7	70.00	70.00
Female	3	30.00	100.00
Total	10	100.00	

According to misstable summarize, npreg is the only variable containing missing values, and it has 10 out of 154 observations missing. The tabulation of missing values of npreg by gender reveals that most missing values (7) correspond to males.

In this example, we could replace missing npreg for males with 0 and proceed with complete-data analysis, disregarding the remaining three missing observations. Instead, as an illustration, we use mi impute poisson to impute missing values of npreg. Our dataset is not declared yet, so we use mi set to declare it. We also use mi register to register npreg as the imputed variable before using mi impute poisson:

```
. mi set mlong
. mi register imputed npreg
(10 m=0 obs now marked as incomplete)
. mi impute poisson npreg attack smokes age bmi hsgrad, add(20)
> conditional(if female==1)
Univariate imputation                       Imputations =       20
Poisson regression                                added =       20
Imputed: m=1 through m=20                         updated =        0
Conditional imputation:
  npreg: incomplete out-of-sample obs replaced with value 0
```

	Observations per m			
Variable	Complete	Incomplete	Imputed	Total
npreg	144	10	10	154

(Complete + Incomplete = Total; Imputed is the minimum across m of the number of filled-in observations.)

The npreg variable is relevant to females only, so we used the conditional() option to restrict imputation to observations with female==1; see *Conditional imputation* in [MI] **mi impute**.

We can analyze these multiply imputed data using logistic regression with mi estimate:

```
. mi estimate: logit attack smokes age bmi female hsgrad npreg
```

Stored results

mi impute poisson stores the following in r():

Scalars

r(M)	total number of imputations
r(M_add)	number of added imputations
r(M_update)	number of updated imputations
r(k_ivars)	number of imputed variables (always 1)
r(N_g)	number of imputed groups (1 if by() is not specified)

Macros

r(method)	name of imputation method (poisson)
r(ivars)	names of imputation variables
r(rngstate)	random-number state used
r(by)	names of variables specified within by()

Matrices

r(N)	number of observations in imputation sample in each group
r(N_complete)	number of complete observations in imputation sample in each group
r(N_incomplete)	number of incomplete observations in imputation sample in each group
r(N_imputed)	number of imputed observations in imputation sample in each group

Methods and formulas

Consider a univariate variable $\mathbf{x} = (x_1, x_2, \ldots, x_n)'$ that follows a Poisson model

$$\Pr(x_i = x|\mathbf{z}_i) = \frac{e^{-\lambda_i}\lambda_i^x}{x!},\ x = 0, 1, 2, \ldots \tag{1}$$

where $\lambda_i = \exp(\mathbf{z}_i'\boldsymbol{\beta} + \text{offset}_i)$ (see [R] **poisson**), $\mathbf{z}_i = (z_{i1}, z_{i2}, \ldots, z_{iq})'$ records values of predictors of $\mathbf{x}$ for observation i and $\boldsymbol{\beta}$ is the $q \times 1$ vector of unknown regression coefficients. (When a constant is included in the model—the default—$z_{i1} = 1,\ i = 1, \ldots, n$.)

$\mathbf{x}$ contains missing values that are to be filled in. Consider the partition of $\mathbf{x} = (\mathbf{x}_o', \mathbf{x}_m')$ into $n_0 \times 1$ and $n_1 \times 1$ vectors containing the complete and the incomplete observations. Consider a similar partition of $\mathbf{Z} = (\mathbf{Z}_o, \mathbf{Z}_m)$ into $n_0 \times q$ and $n_1 \times q$ submatrices.

`mi impute poisson` follows the steps below to fill in $\mathbf{x}_m$:

1. Fit a Poisson regression model (1) to the observed data $(\mathbf{x}_o, \mathbf{Z}_o)$ to obtain the maximum likelihood estimates, $\widehat{\boldsymbol{\beta}}$, and their asymptotic sampling variance, $\widehat{\mathbf{U}}$.
2. Simulate new parameters, $\boldsymbol{\beta}_\star$, from the large-sample normal approximation, $N(\widehat{\boldsymbol{\beta}}, \widehat{\mathbf{U}})$, to its posterior distribution assuming the noninformative prior $\Pr(\boldsymbol{\beta}) \propto \text{const}$.
3. Obtain one set of imputed values, $\mathbf{x}_m^1$, by simulating from a Poisson distribution (1) with $\lambda_i = \lambda_{i_m} = \exp(\mathbf{z}_{i_m}'\boldsymbol{\beta}_\star + \text{offset}_{i_m})$.
4. Repeat steps 2 and 3 to obtain M sets of imputed values $\mathbf{x}_m^1, \mathbf{x}_m^2, \ldots, \mathbf{x}_m^M$.

Steps 2 and 3 above correspond to only approximate draws from the posterior predictive distribution of the missing data, $\Pr(\mathbf{x}_m|\mathbf{x}_o, \mathbf{Z}_o)$, because $\boldsymbol{\beta}_\star$ is drawn from the asymptotic approximation to its posterior distribution.

If weights are specified, a weighted Poisson regression model is fit to the observed data in step 1 (see [R] **poisson** for details).

References

Raghunathan, T. E., J. M. Lepkowski, J. Van Hoewyk, and P. Solenberger. 2001. A multivariate technique for multiply imputing missing values using a sequence of regression models. *Survey Methodology* 27: 85–95.

van Buuren, S. 2007. Multiple imputation of discrete and continuous data by fully conditional specification. *Statistical Methods in Medical Research* 16: 219–242. https://doi.org/10.1177/0962280206074463.

Also see

[MI] **mi impute** — Impute missing values

[MI] **mi impute nbreg** — Impute using negative binomial regression

[MI] **mi estimate** — Estimation using multiple imputations

[MI] **Intro** — Introduction to mi

[MI] **Intro substantive** — Introduction to multiple-imputation analysis

mi impute regress — Impute using linear regression

Description | Menu | Syntax | Options
Remarks and examples | Stored results | Methods and formulas | References
Also see

Description

`mi impute regress` fills in missing values of a continuous variable using the Gaussian normal regression imputation method. You can perform separate imputations on different subsets of the data by specifying the `by()` option. You can also account for analytic, frequency, importance, and sampling weights.

Menu

Statistics > Multiple imputation

Syntax

`mi impute regress` *ivar* [*indepvars*] [*if*] [*weight*] [, *impute_options options*]

impute_options	Description
Main	
* `add(#)`	specify number of imputations to add; required when no imputations exist
* `replace`	replace imputed values in existing imputations
`rseed(#)`	specify random-number seed
`double`	store imputed values in double precision; the default is to store them as `float`
`by(`*varlist*[, *byopts*]`)`	impute separately on each group formed by *varlist*
Reporting	
`dots`	display dots as imputations are performed
`noisily`	display intermediate output
`nolegend`	suppress all table legends
Advanced	
`force`	proceed with imputation, even when missing imputed values are encountered
`noupdate`	do not perform `mi update`; see [MI] **noupdate option**

*`add(#)` is required when no imputations exist; `add(#)` or `replace` is required if imputations exist.

`noupdate` does not appear in the dialog box.

options	Description
Main	
noconstant	suppress constant term
conditional(*if*)	perform conditional imputation
bootstrap	estimate model parameters using sampling with replacement

You must mi set your data before using mi impute regress; see [MI] **mi set**.

You must mi register *ivar* as imputed before using mi impute regress; see [MI] **mi set**.

indepvars may contain factor variables; see [U] **11.4.3 Factor variables**.

collect is allowed; see [U] **11.1.10 Prefix commands**.

aweights, fweights, iweights, and pweights are allowed; see [U] **11.1.6 weight**.

Options

Main

noconstant; see [R] **Estimation options**.

add(), replace, rseed(), double, by(); see [MI] **mi impute**.

conditional(*if*) specifies that the imputation variable be imputed conditionally on observations satisfying *exp*; see [U] **11.1.3 if exp**. That is, missing values in a conditional sample, the sample identified by the *exp* expression, are imputed based only on data in that conditional sample. Missing values outside the conditional sample are replaced with a conditional constant, the value of the imputation variable in observations outside the conditional sample. As such, the imputation variable is required to be constant outside the conditional sample. Also, if any conditioning variables (variables involved in the conditional specification if *exp*) contain soft missing values (.), their missing values must be nested within missing values of the imputation variables. See *Conditional imputation* under *Remarks and examples* in [MI] **mi impute**.

bootstrap specifies that posterior estimates of model parameters be obtained using sampling with replacement; that is, posterior estimates are estimated from a bootstrap sample. The default is to sample the estimates from the posterior distribution of model parameters or from the large-sample normal approximation of the posterior distribution. This option is useful when asymptotic normality of parameter estimates is suspect.

Reporting

dots, noisily, nolegend; see [MI] **mi impute**. noisily specifies that the output from a linear regression fit to the observed data be displayed. nolegend suppresses all legends that appear before the imputation table. Such legends include a legend about conditional imputation that appears when the conditional() option is specified and group legends that may appear when the by() option is specified.

Advanced

force; see [MI] **mi impute**.

The following option is available with mi impute but is not shown in the dialog box:

noupdate; see [MI] **noupdate option**.

Remarks and examples

Remarks are presented under the following headings:

Univariate imputation using linear regression
Using mi impute regress
Video example

See [MI] **mi impute** for a general description and details about options common to all imputation methods, *impute_options*. Also see [MI] **Workflow** for general advice on working with `mi`.

Univariate imputation using linear regression

When a continuous variable contains missing values, a linear regression imputation method (or predictive mean matching; see [MI] **mi impute pmm**) can be used to fill in missing values (Rubin 1987; Schenker and Taylor 1996). The linear regression method is a fully parametric imputation method that relies on the normality of the model. Thus the imputation variable may need to be transformed from the original scale to meet the normality assumption prior to using `mi impute regress`.

The linear regression method is perhaps the most popular method for imputing quantitative variables. It is superior to other imputation methods when the underlying normal model holds. However, it can be more sensitive to violations of this assumption than other nonparametric and partially parametric imputation methods, such as predictive mean matching. For example, Schenker and Taylor (1996) studied the sensitivity of the regression method to the misspecification of the regression function and error distribution. They found that this method still performs well in the presence of heteroskedasticity and when the error distribution is heavier-tailed than the normal. However, it resulted in increased bias and variances under a misspecified regression function.

Using mi impute regress

Recall the heart attack data from *Univariate imputation* of [MI] **mi impute**. We wish to fit a logistic regression of `attack` on some predictors, one of which (`bmi`) has missing values. To avoid losing information contained in complete observations of the other predictors, we impute `bmi`.

The distribution of BMI is slightly skewed to the right, so we choose to fill in missing values of BMI on a log-transformed scale here. To do that, we need to create a new variable, `lnbmi`, containing the log of `bmi` and impute it:

```
. use https://www.stata-press.com/data/r19/mheart0
(Fictional heart attack data; BMI missing)
. generate lnbmi = ln(bmi)
(22 missing values generated)
. mi set mlong
. mi register imputed lnbmi
(22 m=0 obs now marked as incomplete)
```

Following the steps in *Imputing transformations of incomplete variables* of [MI] **mi impute**, we create the imputed variable `lnbmi` containing the log of `bmi` and register it as imputed. We omitted the step of eliminating possible ineligible missing values in `lnbmi` because `bmi` ranges from 17 to 38 and we do not anticipate any extra (algebraic) missing from the operation `ln(bmi)`.

We now use `mi impute` to impute missing values of `lnbmi`. We create 20 imputations and specify a random-number seed for reproducibility:

```
. mi impute regress lnbmi attack smokes age hsgrad female, add(20) rseed(2232)
Univariate imputation                       Imputations =       20
Linear regression                                 added =       20
Imputed: m=1 through m=20                       updated =        0
```

Variable	Observations per *m*			
	Complete	Incomplete	Imputed	Total
lnbmi	132	22	22	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

From the output, all 22 incomplete values of `lnbmi` are imputed.

We want to use BMI in its original scale in the analysis. To do that, we need to replace `bmi` with exponentiated `lnbmi`. Because `bmi` now is a function of the imputed variable, it becomes a passive variable:

```
. mi register passive bmi
. quietly mi passive: replace bmi = exp(lnbmi)
```

Finally, we fit the logistic regression:

```
. mi estimate, dots: logit attack smokes age bmi hsgrad female
Imputations (20):
  .........10.........20 done
Multiple-imputation estimates                   Imputations       =         20
Logistic regression                             Number of obs     =        154
                                                Average RVI       =     0.0636
                                                Largest FMI       =     0.2619
DF adjustment:   Large sample                   DF:     min       =     288.05
                                                        avg       = 121,496.74
                                                        max       = 215,505.49
Model F test:       Equal FMI                   F(   5,18140.5)   =       3.51
Within VCE type:          OIM                   Prob > F          =     0.0036
```

attack	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
smokes	1.222696	.3606843	3.39	0.001	.5157605	1.929631
age	.0358906	.0154728	2.32	0.020	.0055643	.0662169
bmi	.1092684	.0522189	2.09	0.037	.0064894	.2120473
hsgrad	.1733616	.405482	0.43	0.669	-.621373	.9680961
female	-.0987609	.4186695	-0.24	0.814	-.9193435	.7218218
_cons	-5.625106	1.791905	-3.14	0.002	-9.143989	-2.106223

We obtain results comparable with those from [MI] **Intro substantive**.

Video example

Multiple imputation: Setup, imputation, estimation—regression imputation

Stored results

mi impute regress stores the following in r():

Scalars

r(M)	total number of imputations
r(M_add)	number of added imputations
r(M_update)	number of updated imputations
r(k_ivars)	number of imputed variables (always 1)
r(N_g)	number of imputed groups (1 if by() is not specified)

Macros

r(method)	name of imputation method (regress)
r(ivars)	names of imputation variables
r(rngstate)	random-number state used
r(by)	names of variables specified within by()

Matrices

r(N)	number of observations in imputation sample in each group
r(N_complete)	number of complete observations in imputation sample in each group
r(N_incomplete)	number of incomplete observations in imputation sample in each group
r(N_imputed)	number of imputed observations in imputation sample in each group

Methods and formulas

Consider a univariate variable $\mathbf{x} = (x_1, x_2, \ldots, x_n)'$ that follows a normal linear regression model

$$x_i|\mathbf{z}_i \sim N(\mathbf{z}_i'\boldsymbol{\beta}, \sigma^2) \tag{1}$$

where $\mathbf{z}_i = (z_{i1}, z_{i2}, \ldots, z_{iq})'$ records values of predictors of $\mathbf{x}$ for observation i, $\boldsymbol{\beta}$ is the $q \times 1$ vector of unknown regression coefficients, and σ^2 is the unknown scalar variance. (Note that when a constant is included in the model—the default—$z_{i1} = 1,\ i = 1, \ldots, n$.)

$\mathbf{x}$ contains missing values that are to be filled in. Consider the partition of $\mathbf{x} = (\mathbf{x}_o', \mathbf{x}_m')$ into $n_0 \times 1$ and $n_1 \times 1$ vectors containing the complete and the incomplete observations. Consider a similar partition of $\mathbf{Z} = (\mathbf{Z}_o, \mathbf{Z}_m)$ into $n_0 \times q$ and $n_1 \times q$ submatrices.

mi impute regress follows the steps below to fill in $\mathbf{x}_m$ (for simplicity, we omit the conditioning on the observed data in what follows):

1. Fit a regression model (1) to the observed data $(\mathbf{x}_o, \mathbf{Z}_o)$ to obtain estimates $\widehat{\boldsymbol{\beta}}$ and $\hat{\sigma}^2$ of the model parameters.
2. Simulate new parameters $\boldsymbol{\beta}_\star$ and $\sigma^2_\star$ from their joint posterior distribution under the conventional noninformative improper prior $\Pr(\boldsymbol{\beta}, \sigma^2) \propto 1/\sigma^2$. This is done in two steps:

$$\begin{aligned} \sigma^2_\star &\sim \hat{\sigma}^2(n_0 - q)/\chi^2_{n_0-q} \\ \boldsymbol{\beta}_\star|\sigma^2_\star &\sim N\left\{\widehat{\boldsymbol{\beta}},\ \sigma^2_\star(\mathbf{Z}_o'\mathbf{Z}_o)^{-1}\right\} \end{aligned}$$

3. Obtain one set of imputed values, $\mathbf{x}_m^1$, by simulating from $N(\mathbf{Z}_m\boldsymbol{\beta}_\star,\ \sigma^2_\star I_{n_1 \times n_1})$.
4. Repeat steps 2 and 3 to obtain M sets of imputed values, $\mathbf{x}_m^1, \mathbf{x}_m^2, \ldots, \mathbf{x}_m^M$.

Steps 2 and 3 above correspond to simulating from the posterior predictive distribution of the missing data $\Pr(\mathbf{x}_m|\mathbf{x}_o, \mathbf{Z}_o)$ (for example, see Gelman et al. [2014, 354–357]).

If weights are specified, a weighted linear regression model is fit to the observed data in step 1 (see [R] **regress** for details). Also, in the case of `aweights`, $\sigma^2_\star I_{n_1\times n_1}$ is replaced with $\sigma^2_\star \mathbf{W}^{-1}_{n_1\times n_1}$ in step 3, where $\mathbf{W} = \text{diag}(w_i)$ and w_i is the analytic weight for observation i.

References

Gelman, A., J. B. Carlin, H. S. Stern, D. B. Dunson, A. Vehtari, and D. B. Rubin. 2014. *Bayesian Data Analysis*. 3rd ed. Boca Raton, FL: Chapman and Hall/CRC.

Rubin, D. B. 1987. *Multiple Imputation for Nonresponse in Surveys*. New York: Wiley.

Schenker, N., and J. M. G. Taylor. 1996. Partially parametric techniques for multiple imputation. *Computational Statistics and Data Analysis* 22: 425–446. https://doi.org/10.1016/0167-9473(95)00057-7.

Also see

[MI] **mi impute** — Impute missing values

[MI] **mi impute intreg** — Impute using interval regression

[MI] **mi impute pmm** — Impute using predictive mean matching

[MI] **mi impute truncreg** — Impute using truncated regression

[MI] **mi estimate** — Estimation using multiple imputations

[MI] **Intro** — Introduction to mi

[MI] **Intro substantive** — Introduction to multiple-imputation analysis

mi impute truncreg — Impute using truncated regression

Description | Menu | Syntax | Options
Remarks and examples | Stored results | Methods and formulas | References
Also see

Description

`mi impute truncreg` fills in missing values of a continuous variable with a restricted range using a truncated regression imputation method. You can perform separate imputations on different subsets of the data by specifying the `by()` option. You can also account for analytic, frequency, importance, and sampling weights.

Menu

Statistics > Multiple imputation

Syntax

`mi impute truncreg` *ivar* [*indepvars*] [*if*] [*weight*] [, *impute_options options*]

impute_options	Description
Main	
* `add(#)`	specify number of imputations to add; required when no imputations exist
* `replace`	replace imputed values in existing imputations
`rseed(#)`	specify random-number seed
`double`	store imputed values in double precision; the default is to store them as `float`
`by(`*varlist*[, *byopts*]`)`	impute separately on each group formed by *varlist*
Reporting	
`dots`	display dots as imputations are performed
`noisily`	display intermediate output
`nolegend`	suppress all table legends
Advanced	
`force`	proceed with imputation, even when missing imputed values are encountered
`noupdate`	do not perform `mi update`; see [MI] **noupdate option**

*`add(#)` is required when no imputations exist; `add(#)` or `replace` is required if imputations exist.

`noupdate` does not appear in the dialog box.

options	Description
Main	
noconstant	suppress constant term
ll(*varname* | #)	lower limit for left-truncation
ul(*varname* | #)	upper limit for right-truncation
offset(*varname*$_o$)	include *varname*$_o$ in model with coefficient constrained to 1
conditional(*if*)	perform conditional imputation
bootstrap	estimate model parameters using sampling with replacement
Maximization	
maximize_options	control the maximization process; seldom used

You must `mi set` your data before using `mi impute truncreg`; see [MI] **mi set**.

You must `mi register` *ivar* as imputed before using `mi impute truncreg`; see [MI] **mi set**.

indepvars may contain factor variables; see [U] **11.4.3 Factor variables**.

`collect` is allowed; see [U] **11.1.10 Prefix commands**.

`aweights`, `fweights`, `iweights`, and `pweights` are allowed; see [U] **11.1.6 weight**.

Options

Main

`noconstant`; see [R] **Estimation options**.

`add()`, `replace`, `rseed()`, `double`, `by()`; see [MI] **mi impute**.

`ll(`*varname* | #`)` and `ul(`*varname* | #`)` indicate the lower and upper limits for truncation, respectively. You may specify one or both. Observations with *ivar* $\leq$ `ll()` are left-truncated, observations with *ivar* $\geq$ `ul()` are right-truncated, and the remaining observations are not truncated.

`offset(`*varname*$_o$`)`; see [R] **Estimation options**.

`conditional(`*if*`)` specifies that the imputation variable be imputed conditionally on observations satisfying *exp*; see [U] **11.1.3 if exp**. That is, missing values in a conditional sample, the sample identified by the *exp* expression, are imputed based only on data in that conditional sample. Missing values outside the conditional sample are replaced with a conditional constant, the value of the imputation variable in observations outside the conditional sample. As such, the imputation variable is required to be constant outside the conditional sample. Also, if any conditioning variables (variables involved in the conditional specification `if` *exp*) contain soft missing values (`.`), their missing values must be nested within missing values of the imputation variables. See *Conditional imputation* under *Remarks and examples* in [MI] **mi impute**.

`bootstrap` specifies that posterior estimates of model parameters be obtained using sampling with replacement; that is, posterior estimates are estimated from a bootstrap sample. The default is to sample the estimates from the posterior distribution of model parameters or from the large-sample normal approximation of the posterior distribution. This option is useful when asymptotic normality of parameter estimates is suspect.

Reporting

dots, noisily, nolegend; see [MI] **mi impute**. noisily specifies that the output from the truncated regression fit to the observed data be displayed. nolegend suppresses all legends that appear before the imputation table. Such legends include a legend about conditional imputation that appears when the conditional() option is specified and group legends that may appear when the by() option is specified.

Maximization

maximize_options; see [R] **truncreg**. These options are seldom used.

Advanced

force; see [MI] **mi impute**.

The following option is available with mi impute but is not shown in the dialog box:

noupdate; see [MI] **noupdate option**.

Remarks and examples

Remarks are presented under the following headings:

Univariate imputation using truncated regression
Using mi impute truncreg

See [MI] **mi impute** for a general description and details about options common to all imputation methods, *impute_options*. Also see [MI] **Workflow** for general advice on working with mi.

Univariate imputation using truncated regression

The truncated regression imputation method can be used to fill in missing values of a continuous variable with a restricted range (for example, Raghunathan et al. [2001] and Schafer [1997, 203]). It is a parametric method that assumes an underlying truncated normal model for the imputed variable (given other predictors). This method is based on the asymptotic approximation of the posterior predictive distribution of the missing data.

Similar to estimation, it is important to distinguish between truncation and censoring when imputing continuous variables with a limited range. Truncation arises when the distribution of a variable of interest is restricted to a certain range—a truncated distribution. The probability that the variable takes on values outside that range is zero. Truncated data may arise naturally (for example, SAT section scores may not exceed 800) or may be the result of a particular study design (for example, only subjects with income below a certain threshold are of interest in the study). See [R] **truncreg** for more details.

Use mi impute intreg (see [MI] **mi impute intreg**) to impute continuous partially observed (censored) variables.

Using mi impute truncreg

In [MI] **mi impute pmm**, we used predictive mean matching to impute missing values of bmi (used as a predictor in the logistic analysis of heart attacks as described in [MI] **Intro substantive**), restricting imputed values to be within the observed range of bmi.

`mi impute pmm` imputes missing values of `bmi`, replacing them only with values already observed in the data. Suppose that, instead, we want to allow imputed `bmi` values to take on any value within a certain range. We can achieve this by using `mi impute truncreg`.

```
. use https://www.stata-press.com/data/r19/mheart0
(Fictional heart attack data; BMI missing)
. summarize bmi
```

Variable	Obs	Mean	Std. dev.	Min	Max
bmi	132	25.24136	4.027137	17.22643	38.24214

The observed range of `bmi` in our data is between roughly 17 and 39.

We impute `bmi` from a normal distribution truncated at (17, 39):

```
. mi set mlong
. mi register imputed bmi
(22 m=0 obs now marked as incomplete)
. mi impute truncreg bmi attack smokes age hsgrad female, add(20) ll(17) ul(39)
Univariate imputation                       Imputations =       20
Truncated regression                               added =       20
Imputed: m=1 through m=20                        updated =        0
Limit: lower =          17              Number truncated =        0
       upper =          39                          left =        0
                                                    right =        0
```

Variable	Observations per *m*			
	Complete	Incomplete	Imputed	Total
bmi	132	22	22	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

`mi impute truncreg` reports in the output header the truncation limits used (17 and 39 in our example). If the `ll()` and `ul()` options are not specified, the truncation limits are displayed as `-inf` and `+inf`, respectively, and the imputation model becomes equivalent to that using (unrestricted) normal linear regression.

`mi impute truncreg` also reports numbers of truncated observations. In our example, all values of `bmi` lie between 17 and 39, so there are no truncated observations. Truncated observations are not used during estimation; see [R] **truncreg**.

Rather than restricting `bmi` to the observed range during imputation, it may be reasonable to assume a wider range that is still consistent with the observed dataset. It may also be reasonable to use different ranges for males and females. For example, considering the observed ages, suppose that we assume a normal distribution for `bmi` truncated at (14, 55) for females and at (17, 50) for males.

To accommodate varying ranges, we first create variables containing gender-specific truncation limits:

```
. quietly mi xeq: generate lbmi = cond(female==1, 14, 17)
. quietly mi xeq: generate ubmi = cond(female==1, 55, 50)
```

The declared style of our `mi` data is `mlong`, so it is not necessary to use the `mi xeq` prefix for generating new variables. It is good practice, however, to use `mi`-specific commands so that your data manipulation is appropriate no matter what the `mi` style is; see [MI] **mi xeq** and [MI] **Styles** for details.

We now replace the existing imputations with new ones, which account for varying ranges of bmi among males and females:

```
. mi impute truncreg bmi attack smokes age hsgrad female, replace ll(lbmi)
> ul(ubmi)
Univariate imputation                       Imputations =       20
Truncated regression                              added =        0
Imputed: m=1 through m=20                       updated =       20
Limit: lower =         lbmi            Number truncated =        0
       upper =         ubmi                        left =        0
                                                   right =        0
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
bmi	132	22	22	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

We can analyze these multiply imputed data using logistic regression with mi estimate:

```
. mi estimate: logit attack smokes age bmi female hsgrad
```

Stored results

mi impute truncreg stores the following in r():

Scalars

r(M)	total number of imputations
r(M_add)	number of added imputations
r(M_update)	number of updated imputations
r(k_ivars)	number of imputed variables (always 1)
r(N_trunc)	number of truncated observations
r(N_ltrunc)	number of left-truncated observations
r(N_rtrunc)	number of right-truncated observations
r(ll)	lower truncation limit (if ll(#) is specified)
r(ul)	upper truncation limit (if ul(#) is specified)
r(N_g)	number of imputed groups (1 if by() is not specified)

Macros

r(method)	name of imputation method (truncreg)
r(ivars)	names of imputation variables
r(llopt)	contents of ll(), if specified
r(ulopt)	contents of ul(), if specified
r(rngstate)	random-number state used
r(by)	names of variables specified within by()

Matrices

r(N)	number of observations in imputation sample in each group
r(N_complete)	number of complete observations in imputation sample in each group
r(N_incomplete)	number of incomplete observations in imputation sample in each group
r(N_imputed)	number of imputed observations in imputation sample in each group

Methods and formulas

Consider a univariate variable $\mathbf{x} = (x_1, x_2, \ldots, x_n)'$ that follows a truncated normal model with the density

$$f_{(a,b)}(x|\mathbf{z}_i) = \frac{\frac{1}{\sigma}\phi\left(\frac{x-\mu_i}{\sigma}\right)}{\Phi\left(\frac{b-\mu_i}{\sigma}\right) - \Phi\left(\frac{a-\mu_i}{\sigma}\right)}, \; a < x < b \tag{1}$$

where $\phi(\cdot)$ and $\Phi(\cdot)$ are the standard normal density and cumulative distribution functions, respectively, $\mu_i = \mathbf{z}_i'\boldsymbol{\beta}$, $\mathbf{z}_i = (z_{i1}, z_{i2}, \ldots, z_{iq})'$ records values of predictors of $\mathbf{x}$ for observation i, $\boldsymbol{\beta}$ is the $q \times 1$ vector of unknown regression coefficients, σ^2 is the unknown scalar variance, and a and b are the respective known lower and upper truncation limits; also see [R] **truncreg**. (When a constant is included in the model—the default—$z_{i1} = 1, \; i = 1, \ldots, n$.)

$\mathbf{x}$ contains missing values that are to be filled in. Consider the partition of $\mathbf{x} = (\mathbf{x}_o', \mathbf{x}_m')$ into $n_0 \times 1$ and $n_1 \times 1$ vectors containing the complete and the incomplete observations. Consider a similar partition of $\mathbf{Z} = (\mathbf{Z}_o, \mathbf{Z}_m)$ into $n_0 \times q$ and $n_1 \times q$ submatrices.

`mi impute truncreg` follows the steps below to fill in $\mathbf{x}_m$:

1. Fit a truncated regression (1) to the observed data $(\mathbf{x}_o, \mathbf{Z}_o)$ to obtain the maximum likelihood estimates, $\hat{\boldsymbol{\theta}} = (\widehat{\boldsymbol{\beta}}', \ln\hat{\sigma})'$, and their asymptotic sampling variance, $\widehat{\mathbf{U}}$.
2. Simulate new parameters, $\boldsymbol{\theta}_\star$, from the large-sample normal approximation, $N(\hat{\boldsymbol{\theta}}, \widehat{\mathbf{U}})$, to its posterior distribution assuming the noninformative prior $\Pr(\boldsymbol{\theta}) \propto \text{const}$.
3. Obtain one set of imputed values, $\mathbf{x}_m^1$, by simulating from a truncated normal model (1) with parameters set to their simulated values from step 2: $\boldsymbol{\beta} = \boldsymbol{\beta}_\star$ and $\sigma = \sigma_\star$.
4. Repeat steps 2 and 3 to obtain M sets of imputed values, $\mathbf{x}_m^1, \mathbf{x}_m^2, \ldots, \mathbf{x}_m^M$.

Steps 2 and 3 above correspond to only approximate draws from the posterior predictive distribution of the missing data, $\Pr(\mathbf{x}_m|\mathbf{x}_o, \mathbf{Z}_o)$, because $\boldsymbol{\theta}_\star$ is drawn from the asymptotic approximation to its posterior distribution.

If weights are specified, a weighted regression model is fit to the observed data in step 1 (see [R] **truncreg** for details). Also, in the case of `aweights`, $\sigma_\star$ is replaced with $\sigma_\star w_i^{-1/2}$ in step 3, where w_i is the analytic weight for observation i.

References

Raghunathan, T. E., J. M. Lepkowski, J. Van Hoewyk, and P. Solenberger. 2001. A multivariate technique for multiply imputing missing values using a sequence of regression models. *Survey Methodology* 27: 85–95.

Schafer, J. L. 1997. *Analysis of Incomplete Multivariate Data.* Boca Raton, FL: Chapman and Hall/CRC.

Also see

[MI] **mi impute** — Impute missing values

[MI] **mi impute intreg** — Impute using interval regression

[MI] **mi impute pmm** — Impute using predictive mean matching

[MI] **mi impute regress** — Impute using linear regression

[MI] **mi estimate** — Estimation using multiple imputations

[MI] **Intro** — Introduction to mi

[MI] **Intro substantive** — Introduction to multiple-imputation analysis

mi impute usermethod — User-defined imputation methods

Description Syntax Options Remarks and examples
Stored results Acknowledgment Also see

Description

This entry describes how to add your own imputation methods to the `mi impute` command.

Syntax

`mi impute` *usermethod userspec* [, *options*]

usermethod is the name of the method you would like to add to the `mi impute` command. When naming an `mi impute` method, you should follow the same convention as for naming the programs you add to Stata—do not pick "nice" names that may later be used by Stata's official methods.

userspec is a specification of an imputation model as supported by the user-defined method *usermethod*. It must include imputation variables *ivars*. It may also include independent variables *indepvars*, weights, and an *if* qualifier if those things are also supported by *usermethod*. The actual syntax of *userspec* will be specific to *usermethod*. We encourage users who are adding their own methods to `mi impute` to follow `mi impute`'s syntax or Stata's general syntax when designing their methods.

options	Description
impute_options	any option of `mi impute` except `noupdate` and `by()`
`orderasis`	impute variables in the specified order
user_options	additional options supported by *usermethod*

You must `mi set` your data before using `mi impute` *usermethod*; see [MI] **mi set**.

You must `mi register` imputation variables as `imputed` before using `mi impute` *usermethod*; see [MI] **mi set**.

Options

impute_options include `add()`, `replace`, `rseed()`, `double`, `dots`, `noisily`, `nolegend`, `force`; see [MI] **mi impute** for details.

`orderasis` requests that the variables be imputed in the specified order. By default, variables are imputed in order from the most observed to the least observed.

user_options specify any additional options supported by *usermethod*.

Remarks and examples

Adding your own methods to `mi impute` is rather straightforward. Suppose that you want to add a method called `mymethod` to `mi impute`.

1. Write an ado-file that contains a program called `mi_impute_cmd_mymethod_parse` to parse your imputation model.
2. Write an ado-file that contains a program called `mi_impute_cmd_mymethod`, which will perform a single imputation on all of your imputation variables.

3. Place the ado-files where Stata can find them.

You are done. You can now use `mymethod` within `mi impute` like any other official `mi impute` method. `mi impute` will take care of performing your imputation step multiple times and will do it properly for any `mi` style.

Remarks are presented under the following headings:

Toy example: Naive regression imputation
Steps for adding a new method to mi impute
Writing an imputation parser
Writing an initializer
Writing an imputer
Storing additional results
Writing a cleanup program
Examples
Naive regression imputation
Univariate regression imputation
Multivariate monotone imputation
Global macros

Toy example: Naive regression imputation

As a quick example, let's write a method called `naivereg` to perform a naive regression imputation, also known as stochastic regression imputation, of a single variable *ivar* based on independent variables *xvars*.

First, let's describe our imputation procedure.

1. Regress *ivar* on *xvars* using the observed data.
2. Obtain the linear predictor, *xb*.
3. Replace missing values in *ivar* with *xb* plus a random error generated from $N(0, sigma_mle)$, where *sigma_mle* is the estimated error standard deviation.

Let's now write our imputation program. We create an ado-file called `mi_impute_cmd_naivereg.ado` that contains the following Stata program:

```
// imputer
program mi_impute_cmd_naivereg
        version 19.5      // (or version 19 if you do not have StataNow)
        /* step 1: run regression on observed data */
        quietly regress $MI_IMPUTE_user_ivar $MI_IMPUTE_user_xvars
        /* step 2: compute linear prediction */
        tempvar xb
        quietly predict double `xb', xb
        /* step 3: replace missing values */
        quietly replace $MI_IMPUTE_user_ivar = `xb' + rnormal(0,e(rmse)) ///
              if $MI_IMPUTE_user_miss==1
end
```

Global macros `MI_IMPUTE_user_ivar` and `MI_IMPUTE_user_xvars` contain the names of the imputation and independent variables, respectively, and `MI_IMPUTE_user_miss` contains the indicator for missing values in the imputation variable. `ereturn` scalar `e(rmse)` contains the estimated error standard deviation from the `regress` command used in step 1. The `rnormal()` function is used to generate values from a normal distribution.

In addition to the imputer, we also need to write a parser program that passes the imputation model specification to `mi impute`. We create an ado-file called `mi_impute_cmd_naivereg_parse.ado` that contains the following simple program:

```
// parser
program mi_impute_cmd_naivereg_parse
        version 19.5      // (or version 19 if you do not have StataNow)
        syntax anything [, * ]
        gettoken ivar xvars : anything
        u_mi_impute_user_setup, ivars(‘ivar’) xvars(‘xvars’) ‘options’
end
```

The parser retrieves the information about imputation and independent variables to be supplied by the user and passes it to `mi impute` via the utility program `u_mi_impute_user_setup`, which will be discussed later.

We can now use `naivereg` with `mi impute`. For demonstration purposes only, let's use our new method to impute missing values of variable `rep78` from the `auto` dataset. We will use complete variables `mpg` and `weight` as predictors.

We load the data, declare the `mi` style, and register `rep78` as an imputation variable.

```
. sysuse auto, clear
(1978 automobile data)
. mi set wide
. mi register imputed rep78
```

We now use our new method `naivereg` within `mi impute`.

```
. mi impute naivereg rep78 mpg weight, add(2)
Multiple imputation                             Imputations =        2
User method naivereg                                  added =        2
Imputed: m=1 through m=2                            updated =        0
```

Variable	Observations per *m*			
	Complete	Incomplete	Imputed	Total
rep78	69	5	5	74

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

We created two imputations using `mi impute`'s option `add()` and obtained the standard output from `mi impute`. We imputed all five missing values of variable `rep78` using the new `naivereg` method.

This is just a simple example. Your imputation model can be as complicated as you would like. See *Examples* for more complicated imputation models.

Steps for adding a new method to mi impute

Suppose you want to add your own method, *usermethod*, to the `mi impute` command. Here is an outline of the steps to follow:

1. Create a *parser*, a program called `mi_impute_cmd_`*usermethod*`_parse` and defined by the ado-file `mi_impute_cmd_`*usermethod*`_parse.ado` that parses the imputation model and checks the syntax of user-specific options, *user_options*. See *Writing an imputation parser*.

2. Optionally, create an *initializer*, a program called `mi_impute_cmd_`*usermethod*`_init` and defined by the ado-file `mi_impute_cmd_`*usermethod*`_init.ado` that performs certain tasks to be executed once on the observed data. For example, during monotone imputation, the estimation of model parameters can be done just once using the observed data. See *Writing an initializer*.
3. Create an *imputer*, a program called `mi_impute_cmd_`*usermethod* and defined by the ado-file `mi_impute_cmd_`*usermethod*`.ado` that performs one round of imputation for all imputation variables. See *Writing an imputer*.
4. Optionally, create a program for storing additional `r()` results called `mi_impute_cmd_`*usermethod*`_return` and defined by the ado-file `mi_impute_cmd_`*usermethod*`_return.ado`. See *Storing additional results*.
5. Optionally, create a *cleanup* program (or garbage collector), a program called `mi_impute_cmd_`*usermethod*`_cleanup` and defined by the ado-file `mi_impute_cmd_`*usermethod*`_cleanup.ado` that removes all the intermediate variables, global macros, etc., you created during parsing, initialization, or imputation. See *Writing a cleanup program*.
6. Place all of your programs where Stata can find them.

You can now use your *usermethod* with `mi impute`,

```
. mi impute usermethod ...
```

and access any of `mi impute`'s options (except `by()` and `noupdate`).

Writing an imputation parser

A parser is a program that parses the imputation model specification *userspec*, passes the necessary information to `mi impute`, and checks user-specified options. It must be defined within an ado file with the name `mi_impute_cmd_`*usermethod*`_parse.ado`. You can use any of Stata's parsing utilities such as the `syntax` command to write your parser. It may be more convenient for users if you follow the syntax of `mi impute` when designing your imputation methods.

At a minimum, your parser must supply information about the imputation variables to `mi impute`. This is done via the `ivars()` option of the utility command `u_mi_impute_user_setup`:

```
u_mi_impute_user_setup, ivars(varlist) ...
```

You may supply other information such as independent variables (complete predictors) in option `xvars()`, weights, an *if* qualifier, and so on.

A simple univariate parser may look as follows.

```
program mi_impute_cmd_usermethod_parse
        version ...
        syntax anything [if] [fw iw] [, * ]
        gettoken ivar xvars : anything
        u_mi_impute_user_setup `if' [`weight'`exp'],   ///
                ivars(`ivar') xvars(`xvars') `options'
end
```

The above parser corresponds to the following *userspec*,

ivar [*indepvars*] [*if*] [*weight*]

where only `fweights` and `iweights` are allowed.

A simple multivariate parser may look as follows.

```
program mi_impute_cmd_usermethod_parse
        version ...
        syntax anything(equalok) [if] [fw iw] [, * ]
        gettoken ivars xvars : anything, parse("=")
        gettoken eq xvars : xvars, parse("=")
        u_mi_impute_user_setup `if' [`weight'`exp'],   ///
                ivars(`ivars') xvars(`xvars') `options'
end
```

This parser corresponds to the following *userspec*,

ivars [= *indepvars*] [*if*] [*weight*]

where only `fweights` and `iweights` are allowed.

You may also supply complete predictors, *if* qualifiers, and weights specific to each imputation variable or control the order in which variables are imputed. Here is the full syntax of the utility program.

`u_mi_impute_user_setup` [*if*] [*weight*] [, *setup_options*]

setup_options	Description
Main	
* `ivars(`*varlist*`)`	specify imputation variables
`xvars(`*varlist*`)`	specify complete predictors for all imputation variables
`xvars#(`*varlist*`)`	specify complete predictors for the #th imputation variable; overrides `xvars()`
`if#(`*if*`)`	specify an *if* qualifier for the #th imputation variable (in addition to the global *if*)
`weight#(`*weight*`)`	specify weights for the #th imputation variable; overrides global weights
`orderasis`	impute variables in the specified order
[`no`]`fillmissing`	do not replace current imputed data with missing values
`title1(string)`	specify the main title
`title2(string)`	specify the secondary title

* `ivars(`*varlist*`)` is required.

`ivars(`*varlist*`)` specifies the names of the imputation variables. This option is required.

`xvars(`*varlist*`)` specifies the names of the independent variables (complete predictors) for all imputation variables. You may use `xvars#()` to override the complete predictors for the #th imputation variable.

`xvars#(`*varlist*`)` specifies the names of the independent variables for the #th imputation variable. This option overrides the `xvars()` option for that variable. If `xvars#()` is not specified, then `xvars()` (if specified) is assumed for that variable.

`if#(`*if*`)` specifies an *if* qualifier for the #th imputation variable. This option is used in conjunction with the global *if* qualifier specified with the program to define an imputation sample for that variable.

`weight#(`*weight*`)` specifies weights for the #th imputation variable. This option overrides the global weight specified with the program. If `weight#()` is not specified, then the global weight (if specified) is used for that variable.

`orderasis` requests that the variables be imputed in the specified order. By default, variables are imputed in order from the most observed to the least observed.

`fillmissing` or `nofillmissing` requests that the imputed data be filled in or not filled in with missing values prior to the imputation. The default is `fillmissing`. This option is rarely used.

`title1(`*string*`)` specifies the main title. The default is "Multiple imputation".

`title2(`*string*`)` specifies the secondary title. The default is "User method: *usermethod*".

`u_mi_impute_user_setup` sets certain global macros used by `mi impute`; see *Global macros* for details.

Writing an initializer

An initializer (in the context of `mi impute`) is a program that is executed once on the observed data, $m = 0$, before imputation. This program is optional. If you choose to write an initializer, it must be defined within an ado-file with the name `mi_impute_cmd_`*usermethod*`_init.ado`. This program is useful if you have an estimation task that needs to be performed only once on the observed data.

For example, a univariate regression imputation requires that the regression be performed on the observed data prior to imputation. A simple initializer for such imputation may look as follows.

```
program mi_impute_cmd_usermethod_init
        version ...
        quietly regress $MI_IMPUTE_user_ivar $MI_IMPUTE_user_xvars ///
                if $MI_IMPUTE_user_touse
end
```

Writing an imputer

An imputer is a program that imputes missing values of all specified imputation variables once. This program is required and must be defined within an ado-file with the name `mi_impute_cmd_`*usermethod*`.ado`. `mi impute` will execute this program multiple times to produce multiply imputed datasets.

A simple univariate imputer may look as follows.

```
program mi_impute_cmd_usermethod
        version ...
        quietly replace $MI_IMPUTE_user_ivar = ...  ///
                if $MI_IMPUTE_user_miss
end
```

Storing additional results

To store results in addition to those provided by `mi impute` (see *Stored results*), you need to create a r-class program called `mi_impute_cmd_`*usermethod*`_return`. Here is an example.

```
program mi_impute_cmd_ usermethod_return, rclass
        version ...
        syntax [, myopt(real 0) * ]
        return scalar myopt = `myopt'
end
```

Writing a cleanup program

A "cleanup" program or garbage collector is a program that is called at the end of the imputation process to remove any intermediate results you created in your parser, initializer, or imputer that will not be removed automatically upon program completion. For example, such results may include new

variables (except temporary variables), global macros, global names for estimation results, and so on. This program is optional but highly recommended when you have intermediate results that need to be cleared manually.

Examples

Naive regression imputation

Recall our introductory example from *Toy example: Naive regression imputation* of a naive (or stochastic) regression imputation.

Initializer. We can make our imputer more computationally efficient by separating the estimation and imputation tasks. Currently, regression is performed in each imputation. We can move this step into the initializer.

```
// initializer (naivereg)
program mi_impute_cmd_naivereg_init
        version 19.5      // (or version 19 if you do not have StataNow)
        /* step 1: run regression on observed data */
        quietly regress $MI_IMPUTE_user_ivar $MI_IMPUTE_user_xvars
end
```

Here is the updated imputer.

```
// imputer (naivereg)
program mi_impute_cmd_naivereg
        version 19.5      // (or version 19 if you do not have StataNow)
        /* step 2: compute linear prediction */
        tempvar xb
        quietly predict double `xb', xb
        /* step 3: replace missing values */
        quietly replace $MI_IMPUTE_user_ivar = `xb'+rnormal(0,e(rmse)) ///
            if $MI_IMPUTE_user_miss==1
end
```

If we now run `mi impute naivereg`, the `regress` command will be run only once, on the observed data $m = 0$.

If qualifier and weights. We can also extend our method to allow the specification of an *if* qualifier and, say, frequency weights.

```
// parser (naivereg, if and weights)
program mi_impute_cmd_naivereg_parse
        version 19.5      // (or version 19 if you do not have StataNow)
        syntax anything [if] [fw] [, * ]
        gettoken ivar xvars : anything
        u_mi_impute_user_setup `if' [`weight'`exp'] ,  ///
                        ivars(`ivar') xvars(`xvars') `options'
end
```

We updated the `syntax` statement to allow *if* and frequency weights and passed that information to the utility program `u_mi_impute_user_setup`.

```
// initializer (naivereg, if and weights)
program mi_impute_cmd_naivereg_init
        version 19.5      // (or version 19 if you do not have StataNow)
        step 1: run regression on observed data */
        quietly regress $MI_IMPUTE_user_ivar $MI_IMPUTE_user_xvars  ///
                    $MI_IMPUTE_user_weight if $MI_IMPUTE_user_touse
end
```

We included the global macros containing the information about weights and the imputation sample in our `regress` command.

```
// imputer (naivereg, if and weights)
program mi_impute_cmd_naivereg
        version 19.5      // (or version 19 if you do not have StataNow)
        /* step 2: compute linear prediction */
        tempvar xb
        quietly predict double `xb' if $MI_IMPUTE_user_touse, xb
        /* step 3: replace missing values */
        quietly replace $MI_IMPUTE_user_ivar = `xb'+rnormal(0,e(rmse)) ///
                 if $MI_IMPUTE_user_miss==1
end
```

We restricted the computation of the linear predictor for the sample determined by the specified *if* qualifier. A more efficient approach would be to also restrict the computation of the linear predictor for missing values only. This can be done by replacing `if $MI_IMPUTE_user_touse` in the `predict` line above with `if $MI_IMPUTE_user_miss`.

For example, we can now impute `rep78` separately for foreign and domestic cars and incorporate frequency weights. For the purpose of demonstration, we will use `turn` as a frequency weight.

```
. sysuse auto, clear
(1978 automobile data)
. mi set wide
. mi register imputed rep78
. mi impute naivereg rep78 mpg weight [fweight=turn] if foreign==1, add(2)
Multiple imputation                             Imputations =        2
User method naivereg                                  added =        2
Imputed: m=1 through m=2                            updated =        0
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
rep78	741	38	38	779

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

```
. mi impute naivereg rep78 mpg weight [fweight=turn] if foreign==0, replace
Multiple imputation                          Imputations =        2
User method naivereg                               added =        0
Imputed: m=1 through m=2                         updated =        2
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
rep78	2005	150	150	2155

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

Univariate regression imputation

In *Naive regression imputation*, we added a new method, `naivereg`. The reason we called this imputation method naive is that it did not incorporate the uncertainty about the estimates of coefficients and error standard deviation when computing the linear predictor and simulating the imputed values.

Let's add a new method, `myregress`, that improves the `naivereg` method. The parser and the initializer stay the same (except they need to be renamed to `mi_impute_cmd_myregress_parse` and `mi_impute_cmd_myregress_init`, respectively). The imputer, however, changes substantially. Before we move on to the programming task, let's revisit the imputation procedure described in *Toy example: Naive regression imputation*.

The linear predictor from step 2 is computed using the maximum likelihood estimates of regression coefficients, *beta_mle*, from step 1. Also, the random normal variates are generated using the maximum likelihood estimate of the error standard deviation, *sigma_mle*. The proper regression imputation simulates a new set of parameters, *beta* and *sigma*, from their respective posterior distributions and uses them to compute results in steps 2 and 3. Let's update our imputation procedure.

1. Regress *ivar* on *xvars* using the observed data.
2. Simulate new regression coefficients *beta* and error standard deviation *sigma* from their respective posterior distributions, which are based on their maximum likelihood estimates, *beta_mle* and *sigma_mle*.
3. Obtain the linear predictor, *xb*, using the new regression coefficients *beta*.
4. Replace missing values in *ivar* with *xb* plus a random error generated from $N(0, sigma)$.

Let's now update our imputer.

```
// imputer (myregress)
program mi_impute_cmd_myregress, eclass
        version 19.5      // (or version 19 if you do not have StataNow)
        /* step 2: simulate new beta and sigma */
        tempname sigma beta sigma_mle beta_mle vce_chol rnorm
        matrix `beta_mle'  = e(b)
        scalar `sigma_mle' = e(rmse)
        matrix `vce_chol'  = cholesky(e(V))/`sigma_mle'
        local ncols        = colsof(`beta_mle')
        /* draw beta and sigma from the posterior distribution */
        scalar `sigma' = `sigma_mle'*sqrt(e(df_r)/rchi2(e(df_r)))
        mata: st_matrix("`rnorm'", rnormal(`ncols',1,0,1))
        matrix `beta' = `beta_mle'+(`sigma'*(`vce_chol'*`rnorm'))'
```

```
        /* step 3: compute linear prediction */
        ereturn repost b = `beta' // repost new beta
        tempvar xb
        quietly predict double `xb' if $MI_IMPUTE_user_miss, xb
        ereturn repost b = `beta_mle' // repost back beta_mle
        /* step 4: replace missing values */
        quietly replace $MI_IMPUTE_user_ivar = `xb'+`sigma'*rnormal() ///
                if $MI_IMPUTE_user_miss==1
end
```

Our new imputer is much more involved. In step 2, we generate a new (temporary) matrix of coefficients, `beta`, and a temporary scalar containing new error standard deviation. The new parameters are simulated from their posterior distribution. In step 3, we repost new coefficients to `e()` results to obtain the proper linear predictor, and we repost the old coefficients back to be used in the next imputation. In step 4, we use a new `sigma` to generate random errors.

We can check that we obtain the same imputed values as Stata's official `mi impute regress` command, provided that we use the same random-number seed. For example,

```
. sysuse auto, clear
(1978 automobile data)
. mi set wide
. mi register imputed rep78
. mi impute myregress rep78 mpg weight, add(1) rseed(234)
Multiple imputation                             Imputations =        1
User method myregress                                 added =        1
Imputed: m=1                                        updated =        0

------------------------------------------------------------------------
                                Observations per m
                  ----------------------------------------------
        Variable |   Complete   Incomplete    Imputed      Total
-----------------+------------------------------------------------------
           rep78 |         69            5          5         74
------------------------------------------------------------------------
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
. mi impute regress rep78 mpg weight, add(1) rseed(234)
Univariate imputation                           Imputations =        2
Linear regression                                     added =        1
Imputed: m=2                                        updated =        0

------------------------------------------------------------------------
                                Observations per m
                  ----------------------------------------------
        Variable |   Complete   Incomplete    Imputed      Total
-----------------+------------------------------------------------------
           rep78 |         69            5          5         74
------------------------------------------------------------------------
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

```
. mi xeq 1 2: summarize rep78
m=1 data:
-> summarize rep78
    Variable |        Obs        Mean    Std. dev.       Min        Max
-------------+---------------------------------------------------------
       rep78 |         74     3.37852    .9965215         1          5
m=2 data:
-> summarize rep78
    Variable |        Obs        Mean    Std. dev.       Min        Max
-------------+---------------------------------------------------------
       rep78 |         74     3.37852    .9965215         1          5
```

Multivariate monotone imputation

Our previous examples demonstrated univariate imputation—imputation of a single variable. Here we demonstrate an example of multivariate imputation for variables with a monotone missing-value pattern. For simplicity, we will consider imputation of two variables using a new method, `mymonreg`.

We start with a parser.

```
// imputer (mymonreg)
program mi_impute_cmd_mymonreg_parse
        version 19.5      // (or version 19 if you do not have StataNow)
        syntax anything(equalok) [if] [, * ]
        gettoken ivars xvars : anything, parse("=")
        gettoken eq xvars : xvars, parse("=")
        u_mi_impute_user_setup `if', ivars(`ivars') xvars(`xvars') `options'
end
```

We separate multiple-imputation variables from the complete predictors with the equality (`=`) sign. The same set of complete predictors will be used to impute all imputation variables.

```
// initializer (mymonreg)
program mi_impute_cmd_mymonreg_init
        version 19.5      // (or version 19 if you do not have StataNow)
        /* run regression on observed data for each imputation variable and
            store estimation results */
        quietly regress $MI_IMPUTE_user_ivar1               ///
              $MI_IMPUTE_user_xvars1 if $MI_IMPUTE_user_touse1
        quietly estimates store myreg1
        quietly regress $MI_IMPUTE_user_ivar2               ///
              $MI_IMPUTE_user_ivar1 $MI_IMPUTE_user_xvars2 ///
              if $MI_IMPUTE_user_touse2
        quietly estimates store myreg2
end
```

With multiple imputation variables, `mi impute` automatically orders them from the least missing to the most missing. In our example, `MI_IMPUTE_user_ivar1` will contain the name of the imputation variable with the least number of missing values, and `MI_IMPUTE_user_ivar2` with the most number. You can use the `orderasis` option to prevent `mi impute` from ordering the variables. Notice that during monotone imputation, the previously imputed variables are used as predictors of the subsequent imputation variables in addition to the complete predictors. So we used `MI_IMPUTE_user_ivar1` as an additional predictor of `MI_IMPUTE_user_ivar2`.

To avoid refitting models on each imputed dataset, we store estimation results as `myreg1` and `myreg2`. It is our responsibility to drop these estimation results from memory at the end of the imputation.

During imputation, we will need to apply the steps of the regression imputation described in *Univariate regression imputation* to each imputation variable. To simplify this task, we can create a subprogram within our imputer that performs these steps, `ImputeIvar`. Then, our imputer may look like this.

```
// imputer (mymonreg)
program mi_impute_cmd_mymonreg
        version 19.5      // (or version 19 if you do not have StataNow)
        ImputeIvar 1 myreg1
        ImputeIvar 2 myreg2
end
// subprogram defined within mi_impute_cmd_mymonreg.ado
program ImputeIvar, eclass
        args index estres
        /* load the appropriate estimation results */
        quietly estimates restore `estres'
        /* step 2: simulate new beta and sigma */
        tempname sigma beta sigma_mle beta_mle vce_chol rnorm
        matrix `beta_mle' = e(b)
        scalar `sigma_mle' = e(rmse)
        matrix `vce_chol' = cholesky(e(V))/`sigma_mle'
        local ncols = colsof(`beta_mle')
        /* draw beta and sigma from the posterior distribution */
        scalar `sigma' = `sigma_mle'*sqrt(e(df_r)/rchi2(e(df_r)))
        mata: st_matrix("`rnorm'", rnormal(`ncols',1,0,1))
        matrix `beta' = `beta_mle'+(`sigma'*(`vce_chol'*`rnorm'))'
        /* step 3: compute linear prediction */
        ereturn repost b = `beta' // repost new beta
        tempvar xb
        quietly predict double `xb' if ${MI_IMPUTE_user_miss`index'}, xb
        ereturn repost b = `beta_mle' // repost back beta_mle
        /* step 4: replace missing values */
        quietly replace ${MI_IMPUTE_user_ivar`index'} = `xb' +  ///
                    rnormal(0,`sigma') if ${MI_IMPUTE_user_miss`index'}==1
end
```

The `ImputeIvar` subprogram is almost the same as the imputer from the univariate regression imputation, except we replaced global macros with their analogs specific to each imputation variable. For example, we replaced `MI_IMPUTE_user_ivar` with `MI_IMPUTE_user_ivar`index'`, where local macro `index'` will contain a value of 1 or 2. We also passed to the subprogram the corresponding names of the estimation results.

Finally, we write a cleanup program to drop the estimation results we created during initialization from memory.

```
// cleanup program (mymonreg)
program mi_impute_cmd_mymonreg_cleanup
        version 19.5      // (or version 19 if you do not have StataNow)
        capture estimates drop myreg1 myreg2
end
```

Returning to our `auto` example, we can replace missing values in `rep78` and `mpg`.

```
. sysuse auto, clear
(1978 automobile data)
. quietly replace mpg = . in 3
. mi set wide
. mi register imputed rep78 mpg
. mi impute mymonreg rep78 mpg = weight, add(1)
Multiple imputation                             Imputations =        1
User method mymonreg                                  added =        1
Imputed: m=1                                        updated =        0
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
rep78	69	5	5	74
mpg	73	1	1	74

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

Global macros

`mi impute` *usermethod* stores global macros that can be consumed by the programmers of imputation methods. The global macros are `MI_IMPUTE_user_`*name*, where *name* is defined below. Global macro `MI_IMPUTE_user` is set to 1 for all user-defined imputation methods and to 0 for all official imputation methods.

name	Description
`method`	name of the imputation method
`user_options`	method-specific options
`k_ivars`	total number of specified imputation variables (complete and incomplete)
`allivars`	names of all specified imputation variables (complete and incomplete)
`k_ivarsinc`	number of incomplete imputation variables
`ivarsinc`	names of incomplete imputation variables in the original order
`ivars`	synonym for `ivarsinc`
`ivarscomplete`	names of complete imputation variables in the original order
`ivarsincord`	names of incomplete imputation variables ordered from the least missing to the most missing
`ordind`	indices of ordered imputation variables
`incordind`	indices for ordered incomplete imputation variables
`pattern`	`monotone` or `nonmonotone` pattern among all specified imputation variables with respect to the global imputation sample
`ivar`#	name of the #th incomplete imputation variable
`ivar`	synonym for `ivar1`; stored only with one imputation variable
`xvars`	names of complete predictors for all incomplete imputation variables
`xvars`#	names of the complete predictors for the #th incomplete imputation variable
`weight`	global weight expression
`weight`#	weight expression for the #th imputation variable
`touse`	indicator for the global imputation sample
`touse`#	indicator for the imputation sample for the #th imputation variable
`tousevars`	names of all imputation-sample indicators
`miss`#	missing-value indicator for the #th imputation variable
`miss`	synonym for `miss1`; stored only with one imputation variable
`missvars`	names of all missing-value indicators
`m`	current imputation number
`quietly`	contains `quietly` unless `mi impute`'s option `noisily` was specified
`opt_add`	content of option `add()`
`opt_replace`	content of option `replace`
`opt_rseed`	content of option `rseed()`
`opt_double`	content of option `double`
`opt_dots`	content of option `dots`
`opt_noisily`	content of option `noisily`
`opt_nolegend`	content of option `nolegend`
`opt_force`	content of option `force`
`opt_orderasis`	content of option `orderasis`

You may need to define your own global macros. In that case, you need to use the prefix `MI_IMPUTE_userdef_` for all of your global macros to avoid collision with `mi impute`'s internal global macros.

Stored results

`mi impute` *usermethod* stores the following in `r()`:

Scalars

`r(M)`	total number of imputations
`r(M_add)`	number of added imputations
`r(M_update)`	number of updated imputations
`r(k_ivars)`	number of imputed variables
`r(N_g)`	number of imputed groups

Macros

`r(method)`	name of imputation method (*usermethod*)
`r(ivars)`	names of imputation variables
`r(rngstate)`	random-number state used

Matrices

`r(N)`	number of observations in imputation sample
`r(N_complete)`	number of complete observations in imputation sample
`r(N_incomplete)`	number of incomplete observations in imputation sample
`r(N_imputed)`	number of imputed observations in imputation sample

You may also store your own results; see *Storing additional results* for details.

Acknowledgment

The development of this functionality was partially supported by the World Bank.

Also see

[MI] **mi impute** — Impute missing values

[MI] **mi estimate** — Estimation using multiple imputations

[MI] **Intro** — Introduction to mi

[MI] **Intro substantive** — Introduction to multiple-imputation analysis

mi merge — Merge mi data

Description Menu Syntax Options
Remarks and examples Stored results Also see

Description

`mi merge` is `merge` for `mi` data; see [D] **merge** for a description of merging datasets.

It is recommended that the match variables (*varlist* in the syntax diagram) not include imputed or passive variables, or any varying or super-varying variables. If they do, the values of the match variables in $m = 0$ will be used to control the merge even in $m = 1$, $m = 2$, …, $m = M$. Thus $m = 0$, $m = 1$, …, $m = M$ will all be merged identically, and there will continue to be a one-to-one correspondence between the observations in $m = 0$ with the observations in each of $m > 0$.

Menu

Statistics > Multiple imputation

Syntax

`mi merge 1:1` *varlist* `using` *filename* [, *options*]

`mi merge m:1` *varlist* `using` *filename* [, *options*]

`mi merge 1:m` *varlist* `using` *filename* [, *options*]

`mi merge m:m` *varlist* `using` *filename* [, *options*]

options	Description
Options	
`generate(`*newvar*`)`	create *newvar* recording how observations matched
`nolabel`	do not copy value-label definitions from using
`nonotes`	do not copy notes from using
`noreport`	do not display result summary table
`force`	allow string/numeric variable type mismatch without error
Results	
`assert(`*results*`)`	require observations to match as specified
`keep(`*results*`)`	results to keep
`noupdate`	see [MI] **noupdate option**

`collect` is allowed; see **[U] 11.1.10 Prefix commands**.

Notes:

1. Jargon:
   match variables = *varlist*, variables on which match performed
   master = data in memory
   using = data on disk (*filename*)
2. Master must be `mi set`; using may be `mi set`.
3. `mi merge` is syntactically and logically equivalent to `merge` (see [D] **merge**).
4. `mi merge` syntactically differs from `merge` in that the `nogenerate`, `sorted`, `keepusing()`, `update`, and `replace` options are not allowed. Also, no `_merge` variable is created unless the `generate()` option is specified.
5. *filename* must be enclosed in double quotes if *filename* contains blanks or other special characters.

Options

Options

`generate(`*newvar*`)` creates new variable *newvar* containing the match status of each observation in the resulting data. The codes are `1`, `2`, and `3` from the table below.

`nolabel` prevents copying the value-label definitions from the using data to the master. Even if you do not specify this option, label definitions from the using never replace those of the master.

`nonotes` prevents any notes in the using from being incorporated into the master; see [D] **notes**.

`noreport` suppresses the report that `mi merge` ordinarily presents.

`force` allows string/numeric variable type mismatches, resulting in missing values from the using dataset. If omitted, `mi merge` issues an error message; if specified, `mi merge` issues a warning message.

Results

`assert(`*results*`)` specifies how observations should match. If results are not as you expect, an error message will be issued and the master data left unchanged.

Code	Word	Description
1	master	observation appeared in master only
2	using	observation appeared in using only
3	match	observation appeared in both

(Numeric codes and words are equivalent; you may use either.)

`assert(match)` specifies that all observations in both the master and the using are expected to match, and if that is not so, an error message is to be issued. `assert(match master)` means that all observations match or originally appeared only in the master. See [D] **merge** for more information.

`keep(`*results*`)` specifies which observations are to be kept from the merged dataset. `keep(match)` would specify that only matches are to be kept.

`noupdate` in some cases suppresses the automatic `mi update` this command might perform; see [MI] **noupdate option**.

Remarks and examples

Use mi merge when you would use merge if the data were not mi.

Remarks are presented under the following headings:

Merging with non-mi data
Merging with mi data
Merging with mi data containing overlapping variables

Merging with non-mi data

Assume that file ipats.dta contains data on the patients in the ICU of a local hospital. The data are mi set, $M = 5$, and missing values have been imputed. File nurses.dta contains information on nurses and is not mi data. You wish to add the relevant nurse information to each patient. Type

```
. use ipats, clear
. mi merge m:1 nurseid using nurses, keep(master)
```

The resulting data are still mi set with $M = 5$. The new variables are unregistered.

Merging with mi data

Now assume the same situation as above except this time nurses.dta is mi data. Some of the nurse variables have missing values, and those values have been imputed. M is 6. To combine the datasets, you type the same as you would have typed before:

```
. use ipats, clear
. mi merge m:1 nurseid using nurses, keep(master)
```

Remember, $M = 5$ in ipats.dta and $M = 6$ in nurses.dta. The resulting data have $M = 6$, the larger value. There are missing values in the patient variables in $m = 6$, so we need to either impute them or drop the extra imputation by typing mi set M = 5.

Merging with mi data containing overlapping variables

Now assume the situation as directly above but this time nurses.dta contains variables other than nurseid that also appear in ipats.dta. Such variables—variables in common that are not used as matching variables—are called overlapping variables. Assume seniornurse is such a variable. Let's imagine that seniornurse has no missing values and is unregistered in ipats.dta, but does have missing values and is registered as imputed in nurses.dta.

You will want seniornurse registered as imputed if merging nurses.dta adds new observations that have seniornurse equal to missing. On the other hand, if none of the added observations has seniornurse equal to missing, then you will want the variable left unregistered. And that is exactly what mi merge does. That is,

- Variables unique to the master will be registered according to how they were registered in the master.
- Variables unique to the using will be registered according to how they were registered in the using.
- Variables that overlap will be registered according to how they were in the master if there are no unmatched using observations in the final result.

- If there are such unmatched using observations in the final result, then the unique variables that do not contain missing in the unmatched-and-kept observations will be registered according to how they were registered in the master. So will all variables registered as imputed in the master.
- Variables that do contain missing in the unmatched-and-kept observations will be registered as imputed if they were registered as imputed in the using data or as passive if they were registered as passive in the using data.

Thus variables might be registered differently if we typed

```
. mi merge m:1 nurseid using nurses, keep(master)
```

rather than

```
. mi merge m:1 nurseid using nurses, gen(howmatch)
. keep if howmatch==3
```

If you want to keep the matched observations, it is better to specify `merge`'s `keep()` option.

Stored results

`mi merge` stores the following in `r()`:

Scalars

`r(N_master)`	number of observations in $m = 0$ in master
`r(N_using)`	number of observations in $m = 0$ in using
`r(N_result)`	number of observations in $m = 0$ in result
`r(M_master)`	number of imputations (M) in master
`r(M_using)`	number of imputations (M) in using
`r(M_result)`	number of imputations (M) in result

Macros

`r(newvars)`	new variables added

Thus values in the resulting data are

N = # of observations in $m = 0$
= `r(N_result)`

k = # of variables
= *k_master* + `` `:word count `r(newvars)' ``

M = # of imputations
= `max(r(M_master), r(M_using))`
= `r(M_result)`

Also see

[MI] **Intro** — Introduction to mi

[D] **merge** — Merge datasets

[MI] **mi append** — Append mi data

mi misstable — Tabulate pattern of missing values

Description Menu Syntax Options
Remarks and examples Stored results Also see

Description

`mi misstable` runs `misstable` on $m = 0$ or on $m = \#$ if the `m(#)` option is specified. `misstable` makes tables to help in understanding the pattern of missing values in your data; see [R] **misstable**.

Menu

Statistics > Multiple imputation

Syntax

`mi misstable summarize` [*varlist*] [*if*] [, *options*]

`mi misstable patterns` [*varlist*] [*if*] [, *options*]

`mi misstable tree` [*varlist*] [*if*] [, *options*]

`mi misstable nested` [*varlist*] [*if*] [, *options*]

options	Description
Main	
`exmiss`	treat `.a`, `.b`, …, `.z` as missing
`m(#)`	run `misstable` on $m = \#$; default $m = 0$
other_options	see [R] **misstable** (`generate()` is not allowed; `exok` is assumed)
`nopreserve`	programmer's option; see [P] **nopreserve option**

Options

Main

`exmiss` specifies that the extended missing values, `.a`, `.b`, …, `.z`, are to be treated as missing. `misstable` treats them as missing by default and has the `exok` option to treat them as nonmissing. `mi misstable` turns that around and has the `exmiss` option.

In the `mi` system, extended missing values that are recorded in imputed variables indicate values not to be imputed and thus are, in a sense, not missing, or more accurately, missing for a good and valid reason.

The `exmiss` option is intended for use with the `patterns`, `tree`, and `nested` subcommands. You may specify `exmiss` with the `summarize` subcommand, but the option is ignored because `summarize` reports both extended and system missing in separate columns.

`m(#)` specifies the imputation dataset on which `misstable` is to be run. The default is $m = 0$, the original data.

other_options are allowed; see [R] **misstable**.

Remarks and examples

See [R] **misstable**.

Stored results

See [R] **misstable**.

Also see

[MI] **Intro** — Introduction to mi

[R] **misstable** — Tabulate missing values

[MI] **mi varying** — Identify variables that vary across imputations

mi passive — Generate/replace and register passive variables

Description Menu Syntax Options
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Description

`mi passive` creates and registers passive variables or replaces the contents of existing passive variables.

More precisely, `mi passive` executes the specified `generate`, `egen`, or `replace` command on each of $m = 0$, $m = 1$, …, $m = M$. If the command is `generate` or `egen`, then `mi passive` registers the new variable as passive. If the command is `replace`, then `mi passive` verifies that the variable is already registered as passive.

Menu

Statistics > Multiple imputation

Syntax

```
mi passive: { generate | egen | replace } ...

mi passive: by varlist: { generate | egen | replace } ...
```

The full syntax is

```
mi passive[ , options ]: [ by varlist [ (varlist) ]: ] { generate | egen | replace } ...
```

options	Description
`noupdate`	see [MI] **noupdate option**
`nopreserve`	do not first `preserve`

Also see [D] **generate** and [D] **egen**.

Options

`noupdate` in some cases suppresses the automatic `mi update` this command might perform; see [MI] **noupdate option**.

`nopreserve` is a programmer's option. It specifies that `mi passive` is not to `preserve` the data if it ordinarily would. This is used by programmers who have already preserved the data before calling `mi passive`.

Remarks and examples

Remarks are presented under the following headings:

mi passive basics
mi passive works with the by prefix
mi passive works fastest with the wide style
mi passive and super-varying variables
Renaming passive variables
Dropping passive variables
Update passive variables when imputed values change
Alternatives to mi passive

mi passive basics

A passive variable is a variable that is a function of imputed variables or of other passive variables. For instance, if variable `age` were imputed and you created `lnage` from it, the `lnage` variable would be passive. The right way to create `lnage` is to type

```
. mi passive: generate lnage = ln(age)
```

Simply typing

```
. generate lnage = ln(age)
```

is not sufficient because that would create `lnage` in the $m = 0$ data, and `age`, being imputed, varies across m. There are situations where omitting the `mi passive` prefix would be almost sufficient, namely, when the data are mlong or flong style, but even then you would need to follow up by typing `mi register passive lnage`.

To create passive variables or to change the values of existing passive variables, use `mi passive`. Passive variables cannot be super-varying; see *mi passive and super-varying variables*.

mi passive works with the by prefix

You can use `mi passive` with the `by` prefix. For instance, you can type

```
. mi passive: by person: generate totaltodate = sum(amount)
```

You do not need to sort the data before issuing either of these commands, nor are you required to specify `by`'s `sort` option. `mi passive` handles sorting issues for you.

Use `by`'s parenthetical syntax to specify the order within `by`, if that is necessary. For instance,

```
. mi passive: by person (time): generate lastamount = amount[_n-1]
```

Do not omit the parenthetical `time` and instead attempt to sort the data yourself:

```
. sort person time
. mi passive: by person: generate lastamount = amount[_n-1]
```

Sorting the data yourself will work if your data happen to be wide style; it will not work in general.

mi passive works fastest with the wide style

`mi passive` works with any style, but it works fastest when the data are wide style. If you are going to issue multiple `mi passive` commands, you can usually speed execution by first converting your data to the wide style; see [MI] **mi convert**.

mi passive and super-varying variables

You should be careful not to mistakenly use `mi passive` to create super-varying variables. Super-varying variables cannot be passive variables because the values of a super-varying variable differ not only in the incomplete observations but also in the complete observations across imputations.

As noted in [MI] **mi set**, super-varying variables should never be registered. If a super-varying variable is registered as passive, it will be converted to a varying variable. All complete observations of the super-varying variable in each imputation will be replaced with their values from $m = 0$.

`mi passive` registers the created variable as passive. Even if the command you use with `mi passive` creates a super-varying variable, `mi passive` will convert it to varying, as described above.

You can use `mi passive` with any function that produces values that solely depend on values within the observation. In general, you cannot use `mi passive` with functions that produce values that depend on groups of observations.

For example, most `egen` functions result in super-varying variables. In such cases, you should use `mi xeq: egen` to create them and leave them unregistered; see [MI] **mi xeq**. You might thus conclude that you should never use `mi passive` with `egen`. That is not true, but it is nearly true. You may use `mi passive` with `egen`'s `rowmean()` function, for instance, because it produces values that depend only on one observation at a time.

Renaming passive variables

Use `mi rename` (see [MI] **mi rename**) to rename all variables, not just passive variables:

```
. mi rename oldname newname
```

`rename` (see [D] **rename**) is insufficient for renaming passive variables regardless of the style of your data.

Dropping passive variables

Use `drop` (see [D] **drop**) to drop variables (or observations), but run `mi update` (see [MI] **mi update**) afterward.

```
. drop var_or_vars
. mi update
```

This advice applies for all variables, not just passive ones.

Update passive variables when imputed values change

Passive variables are not automatically updated when the values of the underlying imputed variables change.

If imputed values change or if you add more imputations, you must update or re-create the passive variables. If you have several passive variables, we suggest you make a do-file to create them. You can run the do-file again whenever necessary. A do-file to create `lnage` and `totaltodate` might read

begin `cr_passive.do`

```
use mydata, clear
capture drop lnage
capture drop totaltodate
mi update
mi passive: generate lnage = ln(age)
mi passive: by person (time): generate totaltodate = sum(amount)
```

end `cr_passive.do`

Alternatives to mi passive

`mi passive` can run any `generate`, `replace`, or `egen` command. If that is not sufficient to create the variable you need, you will have to create the variable for yourself. Here is how you do that:

1. If your data are wide or mlong, use `mi convert` (see [MI] **mi convert**) to convert them to one of the fully long styles, flong or flongsep, and then continue with the appropriate step below.
2. If your data are flong, `mi` system variable `_mi_m` records m. Create your new variable by using standard Stata commands, but do that `by _mi_m`. After creating the variable, `mi register` it as passive; see [MI] **mi set**.
3. If your data are flongsep, create the new variable in each of the $m = 0$, $m = 1$, …, $m = M$ datasets, and then register the result. Start by working with a copy of your data:

   . `mi copy` *newname*

   The data in memory at this point correspond to $m = 0$. Create the new variable and then save the data:

   . *(create new_variable)*

   . `save` *newname*`, replace`

   Now use the $m = 1$ data and repeat the process:

   . `use _1_`*newname*

   . *(create new_variable)*

   . `save _1_`*newname*`, replace`

   Repeat for $m = 2$, $m = 3$, …, $m = M$.

At this point, the new variable is created but not yet registered. Reload the original $m = 0$ data, register the new variable as passive, and run `mi update` (see [MI] **mi update**):

```
. use newname
. register passive new_variable
. mi update
```

Finally, copy the result back to your original flongsep data,

```
. mi copy name, replace
```

or if you started with mlong, flong, or wide data, then convert the data back to your preferred style:

```
. mi convert original_style
```

Either way, erase the *newname* flongsep dataset collection:

```
. mi erase newname
```

The third procedure can be tedious and error-prone if M is large. We suggest that you make a do-file to create the variable and then run it on each of the $m = 0$, $m = 1$, …, $m = M$ datasets:

```
. mi copy newname
. do mydofile
. save newname, replace
. forvalues m=1(1)20 {        // we assume M=20
>   use _'m'_newname
>   do mydofile
>   save _'m'_newname, replace
> }
. use newname
. register passive new_variable
. mi update
```

Also see

[MI] **Intro** — Introduction to mi

[MI] **mi reset** — Reset imputed or passive variables

[MI] **mi xeq** — Execute command(s) on individual imputations

mi predict — Obtain multiple-imputation predictions

Description | Menu | Syntax | Options
Remarks and examples | Methods and formulas | References | Also see

Description

`mi predict using` *miestfile* is for use after `mi estimate, saving(`*miestfile*`):` ... to obtain multiple-imputation (MI) linear predictions or their standard errors.

`mi predictnl using` *miestfile* is for use after `mi estimate, saving(`*miestfile*`):` ... to obtain MI (possibly) nonlinear predictions, their standard errors, and other statistics, including statistics specific to MI.

MI predictions, their standard errors, and other statistics are obtained by applying Rubin's combination rules observationwise to the completed-data predictions, predictions computed for each imputation (White, Royston, and Wood 2011). The results are stored in the original data ($m = 0$). See [R] **predict** and [R] **predictnl** for details about the computation of the completed-data predictions.

`mi predict` and `mi predictnl` may change the sort order of the data.

Menu

Statistics > Multiple imputation

Syntax

Obtain multiple-imputation linear predictions

`mi predict` [*type*] *newvar* [*if*] `using` *miestfile* [, *predict_options options*]

Obtain multiple-imputation nonlinear predictions

`mi predictnl` [*type*] *newvar* = *pnl_exp* [*if*] `using` *miestfile* [, *pnl_options options*]

miestfile`.ster` contains estimation results previously saved by `mi estimate, saving(`*miestfile*`)`; see [MI] **mi estimate**.

pnl_exp is any valid Stata expression and may also contain calls to two special functions unique to `predictnl`: `predict()` and `xb()`; see [R] **predictnl** for details.

predict_options	Description
Predict options	
`xb`	calculate linear prediction; the default
`stdp`	calculate standard error of the prediction
`nooffset`	ignore any `offset()` or `exposure()` variable
`equation(`*eqspec*[, *eqspec*]`)`	specify equation(s) for which predictions are to be made

pnl_options	Description
Predict options	
`se(`*newvar*`)`	create *newvar* containing standard errors
`variance(`*newvar*`)`	create *newvar* containing variances
`wald(`*newvar*`)`	create *newvar* containing the Wald test statistic
`p(`*newvar*`)`	create *newvar* containing the significance level (*p*-value) of the Wald test
`ci(`*newvars*`)`	create *newvars* containing lower and upper confidence intervals
`level(`#`)`	set confidence level; default is `level(95)`
`bvariance(`*newvar*`)`	create *newvar* containing between-imputation variances
`wvariance(`*newvar*`)`	create *newvar* containing within-imputation variances
`df(`*newvar*`)`	create *newvar* containing MI degrees of freedom
`nosmall`	do not apply small-sample correction to degrees of freedom
`rvi(`*newvar*`)`	create *newvar* containing relative variance increases
`fmi(`*newvar*`)`	create *newvar* containing fractions of missing information
`re(`*newvar*`)`	create *newvar* containing relative efficiencies
Advanced	
`iterate(`#`)`	maximum iterations for finding optimal step size to compute completed-data numerical derivatives of *pnl_exp*; default is 100
`force`	calculate completed-data standard errors, etc., even when possibly inappropriate

options	Description
MI options	
`nimputations(`#`)`	specify number of imputations to use in computation; default is to use all existing imputations
`imputations(`*numlist*`)`	specify which imputations to use in computation
`estimations(`*numlist*`)`	specify which estimation results to use in computation
`esample(`*varname*`)`	restrict the prediction to the estimation subsample identified by a binary variable *varname*
`storecompleted`	store completed-data predictions in the imputed data; available only in the flong and flongsep styles
Reporting	
`replay`	replay command-specific results from each individual estimation in *miestfile*`.ster`
`cmdlegend`	display the command legend
`noupdate`	do not perform `mi update`; see [MI] **noupdate option**
`noerrnotes`	suppress error notes associated with failed estimation results in *miestfile*`.ster`
`showimputations`	show imputations saved in *miestfile*`.ster`

`noupdate`, `noerrnotes`, and `showimputations` do not appear in the dialog box.

Options

Predict options

xb, stdp, nooffset, equation(*eqspec*[, *eqspec*]); see [R] **predict**.

se(*newvar*), variance(*newvar*), wald(*newvar*), p(*newvar*), ci(*newvars*), level(#); see [R] **predictnl**. These options store the specified MI statistics in variable *newvar* in the original data ($m = 0$). level() is relevant in combination with ci() only. If storecompleted is specified, then *newvar* contains the respective completed-data estimates in the imputed data ($m > 0$). Otherwise, *newvar* is missing in the imputed data.

bvariance(*newvar*) adds *newvar* of storage type *type*, where for each i in the prediction sample, *newvar*[i] contains the estimated between-imputation variance of *pnl_exp*[i]. storecompleted has no effect on bvariance().

wvariance(*newvar*) adds *newvar* of storage type *type*, where for each i in the prediction sample, *newvar*[i] contains the estimated within-imputation variance of *pnl_exp*[i]. storecompleted has no effect on wvariance().

df(*newvar*) adds *newvar* of storage type *type*, where for each i in the prediction sample, *newvar*[i] contains the estimated MI degrees of freedom of *pnl_exp*[i]. If storecompleted is specified, then *newvar* in the imputed data will contain the complete-data degrees of freedom as saved by mi estimate. In the absence of the complete-data degrees of freedom or if nosmall is used, then *newvar* is missing in the imputed data, even if storecompleted is specified.

nosmall specifies that no small-sample correction be made to the degrees of freedom. By default, the small-sample correction of Barnard and Rubin (1999) is used. This option has an effect on the results stored by p(), ci(), df(), fmi(), and re().

rvi(*newvar*) adds *newvar* of storage type *type*, where for each i in the prediction sample, *newvar*[i] contains the estimated relative variance increase of *pnl_exp*[i]. storecompleted has no effect on rvi().

fmi(*newvar*) adds *newvar* of storage type *type*, where for each i in the prediction sample, *newvar*[i] contains the estimated fraction of missing information of *pnl_exp*[i]. storecompleted has no effect on fmi().

re(*newvar*) adds *newvar* of storage type *type*, where for each i in the prediction sample, *newvar*[i] contains the estimated relative efficiency of *pnl_exp*[i]. storecompleted has no effect on re().

MI options

nimputations(#) specifies that the first # imputations be used; # must be $2 \leq \# \leq M$. The default is to use all imputations, M. Only one of nimputations(), imputations(), or estimations() may be specified.

imputations(*numlist*) specifies which imputations to use. The default is to use all of them. *numlist* must contain at least two numbers corresponding to the imputations saved in *miestfile*.ster. You can use the showimputations option to display imputations currently saved in *miestfile*.ster. Only one of nimputations(), imputations(), or estimations() may be specified.

estimations(*numlist*) does the same thing as imputations(*numlist*), but this time the imputations are numbered differently. Say that *miestfile*.ster was created by mi estimate and mi estimate was told to limit itself to imputations 1, 3, 5, and 9. With imputations(), the imputations are still numbered 1, 3, 5, and 9. With estimations(), they are numbered 1, 2, 3, and 4. Usually, one does

not specify a subset of imputations when using mi estimate, and so usually, the imputations() and estimations() options are identical. The specified *numlist* must contain at least two numbers. Only one of nimputations(), imputations(), or estimations() may be specified.

esample(*varname*) restricts the prediction to the estimation sample identified by a binary variable *varname*. By default, predictions are obtained for all observations in the original data. Variable *varname* cannot be registered as imputed or passive and cannot vary across imputations.

storecompleted stores completed-data predictions in the newly created variables in each imputation. By default, the imputed data contain missing values in the newly created variables. The storecompleted option may be specified only if the data are flong or flongsep; see [MI] **mi convert** to convert to one of those styles.

Reporting

replay replays estimation results from *miestfile*.ster, previously saved by mi estimate, saving(*miestfile*).

cmdlegend requests that the command line corresponding to the estimation command used to produce the estimation results saved in *miestfile*.ster be displayed.

Advanced

iterate(#), force; see [R] **predictnl**.

The following options are available with mi predict and mi predictnl but are not shown in the dialog box:

noupdate in some cases suppresses the automatic mi update this command might perform; see [MI] **noupdate option**. This option is rarely used.

noerrnotes suppresses notes about failed estimation results. These notes appear when *miestfile*.ster contains estimation results, previously saved by mi estimate, saving(*miestfile*), from imputations for which the estimation command used with mi estimate failed to estimate parameters.

showimputations displays imputation numbers corresponding to the estimation results saved in *miestfile*.ster.

Remarks and examples

Remarks are presented under the following headings:

Introduction
Using mi predict and mi predictnl
Example 1: Obtain MI linear predictions and other statistics
Example 2: Obtain MI linear predictions for the estimation sample
Example 3: Obtain MI estimates of probabilities
Example 4: Obtain other MI predictions
Example 5: Obtain MI predictions after multiple-equation commands

Introduction

Various predictions are often of interest after estimation. Within the MI framework, one must first decide what prediction means. There is no single dataset with respect to which prediction is made. Rather, there are multiple datasets in which values of imputed predictors vary from one dataset to another.

One definition is simply to consider an observation-specific prediction to be a parameter of interest and apply Rubin's combination rules to it as to any other estimand (White, Royston, and Wood 2011). The next thing to decide is what types of predictions are appropriate for pooling. For any parameter, the applicability of combination rules is subject to a number of conditions that the parameter must satisfy. One of them is asymptotic normality of the completed-data estimates of the parameter; see, for example, *Theory underlying multiple imputation* under *Remarks and examples* of [MI] **Intro substantive** for a full set of conditions.

It is safe to apply combination rules to the linear predictor, as computed by `mi predict`. It is also safe to apply combination rules to functions, possibly nonlinear, of the linear predictor, provided the sampling distribution of that function is asymptotically normal. This can be done by using `mi predictnl`. `mi predictnl` also provides, with the `predict()` specification, a way of obtaining MI estimates for various types of predictions specific to each estimation command used with `mi estimate`. Care should be taken when using this functionality. Some predictions may require preliminary transformation to a scale that improves normality, which is more appropriate for pooling. The obtained MI estimates of predictions may then be back-transformed to obtain final predictions in the original metric. For example, one can obtain MI estimates of probabilities of a positive outcome after logistic estimation by pooling the completed-data estimates of the actual probabilities. A better approach is to pool the completed-data estimates of the linear predictor and then apply an inverse-logit transformation to obtain the probability of a positive outcome. Other available predictions, such as standard errors, may not even be applicable for pooling.

The MI predictions should be treated as a final result; they should not be used as intermediate results in computations. For example, MI estimates of the linear predictor cannot be used to compute residuals as is done in non-MI analysis. Instead, completed-data residuals should be calculated for each imputed dataset, and these can be obtained by using the `mi xeq:` command. For example,

```
. mi xeq: regress ...; predict resid, r
```

Because completed-data predictions are super varying, they should only be computed in the flong or flongsep styles.

Using mi predict and mi predictnl

`mi predict` and `mi predictnl` require that completed-data estimation results saved by `mi estimate, saving()` are supplied with the `using` specification and that the `mi` data used to obtain these results are in memory. Apart from this, the use of these commands is similar to that of their non-`mi` counterparts, `predict` and `predictnl` (see [R] **predict** and [R] **predictnl**).

By default, `mi predict` computes MI linear predictions. If the `stdp` option is specified, `mi predict` computes standard errors of the MI linear predictions. As with `predict`, the `equation()` option can be used with `mi predict` after multiple-equation commands to obtain linear predictions or their standard errors from a specific equation.

Similarly to `predictnl`, a number of statistics associated with predictions can be obtained with `mi predictnl`, such as confidence intervals and p-values. Additionally, a number of MI statistics, such as relative variance increases and fractions of missing information, are available with `mi predictnl`. As we mentioned in *Introduction*, the `predict()` function of `mi predictnl` offers a variety of predictions. However, you should carefully consider whether the requested prediction is applicable for pooling or, perhaps, needs a preliminary transformation to improve normality.

Unlike `predict`, `mi predict` always defaults to the linear prediction. It supports only the linear prediction or its standard error and does not support any other command-specific predictions. Command-specific predictions appropriate for pooling may be obtained with the `predict()` function

of mi predictnl. Also unlike predict after some multiple-equation commands, mi predict does not allow specification of multiple new variables to store predictions from all equations. For each equation *eqspec*, you should use mi predict, equation(*eqspec*) to obtain predictions from equation *eqspec*.

To obtain estimation-sample predictions, the if e(sample) restriction is usually used with predict and predictnl. This restriction is not allowed with mi predict and mi predictnl. mi estimate does not set an estimation sample. There is no single estimation sample within the MI framework; there are M of them, and they may vary across imputed datasets. To obtain estimation-sample predictions with mi predict and mi predictnl, you must first store the estimation sample in a variable and then specify this variable in the esample() option. For example, you may use mi estimate's esample(*newvar*) option to store the estimation sample in *newvar*. To use mi estimate, esample(), you must be in flong or flongsep style; use [MI] **mi convert** to convert to one of these styles.

mi predict and mi predictnl store MI predictions and statistics associated with them in the original data ($m = 0$). If your data are flong or flongsep, you may additionally store the corresponding completed-data estimates in the imputed data ($m > 0$) by specifying the storecompleted option. This option only affects results for which completed-data counterparts are available, such as predictions, standard errors, and confidence intervals. It has no effect on statistics specific to MI, such as relative variance increases and fractions of missing information.

When you restrict predictions to a subsample, mi predict and mi predictnl verify that the prediction samples are the same across imputed datasets. If varying prediction samples are detected, the commands terminate with an error. If such a situation occurs, you may consider modifying your restriction to define a sample common to all imputations. If there are a few imputations violating the consistency of the prediction sample, you may obtain MI predictions over a selected set of imputations using, for example, the imputations() option.

Example 1: Obtain MI linear predictions and other statistics

Recall the analysis of house resale prices from *Example 2: Completed-data linear regression analysis* in [MI] **mi estimate**:

```
. use https://www.stata-press.com/data/r19/mhouses1993s30
(Albuquerque home prices Feb15-Apr30, 1993)
. mi estimate, saving(miest): regress price tax sqft age nfeatures ne custom
> corner
Multiple-imputation estimates                   Imputations       =         30
Linear regression                               Number of obs     =        117
                                                Average RVI       =     0.0648
                                                Largest FMI       =     0.2533
                                                Complete DF       =        109
DF adjustment:   Small sample                   DF:     min       =      69.12
                                                        avg       =      94.02
                                                        max       =     105.51
Model F test:       Equal FMI                   F(   7,  106.5)   =      67.18
Within VCE type:          OLS                   Prob > F          =     0.0000
```

price	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
tax	.6768015	.1241568	5.45	0.000	.4301777	.9234253
sqft	.2118129	.069177	3.06	0.003	.0745091	.3491168
age	.2471445	1.653669	0.15	0.882	-3.051732	3.546021
nfeatures	9.288033	13.30469	0.70	0.487	-17.12017	35.69623
ne	2.518996	36.99365	0.07	0.946	-70.90416	75.94215
custom	134.2193	43.29755	3.10	0.002	48.35674	220.0818
corner	-68.58686	39.9488	-1.72	0.089	-147.7934	10.61972
_cons	123.9118	71.05816	1.74	0.085	-17.19932	265.0229

We saved complete-data estimation results to `miest.ster` using `mi estimate`'s `saving()` option.

We store MI linear predictions in variable `xb_mi`:

```
. mi predict xb_mi using miest
(option xb assumed; linear prediction)
. mi xeq 0: summarize price xb_mi
m=0 data:
-> summarize price xb_mi
```

Variable	Obs	Mean	Std. dev.	Min	Max
price	117	1062.735	380.437	540	2150
xb_mi	117	1062.735	344.2862	523.0295	2042.396

MI predictions are stored in the original data ($m = 0$). The predictions of `price` seem reasonable.

We compute standard errors of MI linear predictions by using the `stdp` option:

```
. mi predict stdp_mi using miest, stdp
```

To obtain other statistics, such as confidence intervals and Wald test statistics, we can use `mi predictnl`. For example, we compute linear predictions, 95% confidence intervals, and fractions of missing information of the linear predictions as follows:

```
. mi predictnl xb1_mi = predict(xb) using miest, ci(cil_mi ciu_mi) fmi(fmi)
```

Unlike confidence intervals produced by `predictnl`, confidence intervals from `mi predictnl` are based on observation-specific degrees of freedom. Recall from [MI] **mi estimate** that the degrees of freedom used for MI inference is inversely related to relative variance increases due to missing data, which are

parameter-specific. The prediction for each observation is viewed as a separate parameter, so it has its own degrees of freedom. If desired, you may obtain observation-specific MI degrees of freedom by specifying the `df()` option with `mi predictnl`.

Example 2: Obtain MI linear predictions for the estimation sample

To obtain MI linear predictions for the estimation sample, we must first store the estimation sample in a variable. To store the estimation sample with `mi estimate`, the `mi` data must be flong or flongsep.

Continuing our house resale prices example, the data are mlong:

```
. use https://www.stata-press.com/data/r19/mhouses1993s30, clear
(Albuquerque home prices Feb15-Apr30, 1993)

. mi query
data mi set mlong, M = 30
last mi update 04feb2025 12:58:57, 11 days ago
```

We switch to the flong style by using the `mi convert` command (see [MI] **mi convert**) and store the estimation sample in variable `touse` by using `mi estimate, esample()`:

```
. mi convert flong

. mi estimate, esample(touse): regress price tax sqft age nfeatures ne custom
> corner
Multiple-imputation estimates                   Imputations       =         30
Linear regression                               Number of obs     =        117
                                                Average RVI       =     0.0648
                                                Largest FMI       =     0.2533
                                                Complete DF       =        109
DF adjustment:   Small sample                   DF:     min       =      69.12
                                                        avg       =      94.02
                                                        max       =     105.51
Model F test:       Equal FMI                   F(   7,  106.5)   =      67.18
Within VCE type:          OLS                   Prob > F          =     0.0000
```

price	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
tax	.6768015	.1241568	5.45	0.000	.4301777	.9234253
sqft	.2118129	.069177	3.06	0.003	.0745091	.3491168
age	.2471445	1.653669	0.15	0.882	-3.051732	3.546021
nfeatures	9.288033	13.30469	0.70	0.487	-17.12017	35.69623
ne	2.518996	36.99365	0.07	0.946	-70.90416	75.94215
custom	134.2193	43.29755	3.10	0.002	48.35674	220.0818
corner	-68.58686	39.9488	-1.72	0.089	-147.7934	10.61972
_cons	123.9118	71.05816	1.74	0.085	-17.19932	265.0229

Because we use the same regression model, we do not need to resave estimation results and we can use the previously saved `miest.ster` from *Example 1: Obtain MI linear predictions and other statistics* with `mi predict`.

To restrict the linear prediction to the estimation sample identified by the `touse` variable, we use `esample(touse)` with `mi predict`:

```
. mi predict xb_mi using miest, esample(touse)
(option xb assumed; linear prediction)
. mi xeq 0: summarize xb_mi
m=0 data:
-> summarize xb_mi
    Variable |        Obs        Mean    Std. dev.       Min        Max
-------------+---------------------------------------------------------
       xb_mi |        117    1062.735    344.2862   523.0295   2042.396
```

The estimation sample includes all observations, so we obtain the same predictions as we did in example 1.

We could simply use an `if` restriction instead of the `esample()` option to obtain the same results:

```
. mi predict xb_mi if touse using miest
```

But if you use the `esample()` option, `mi predict` and `mi predictnl` perform additional checks to verify that the supplied variable is a proper estimation-sample variable.

By default, the MI linear prediction is only stored in the original data ($m = 0$) and the imputed data contain missing values in the corresponding variable. In the flong and flongsep styles, we can also store completed-data predictions in the imputed data ($m > 0$) by specifying the `storecompleted` option:

```
. mi predict xb_mi_all using miest, esample(touse) storecompleted
(option xb assumed; linear prediction)
. mi xeq 0 1 2: summarize xb_mi_all
m=0 data:
-> summarize xb_mi_all
    Variable |        Obs        Mean    Std. dev.       Min        Max
-------------+---------------------------------------------------------
   xb_mi_all |        117    1062.735    344.2862   523.0295   2042.396
m=1 data:
-> summarize xb_mi_all
    Variable |        Obs        Mean    Std. dev.       Min        Max
-------------+---------------------------------------------------------
   xb_mi_all |        117    1062.735    346.1095   529.5227   2042.942
m=2 data:
-> summarize xb_mi_all
    Variable |        Obs        Mean    Std. dev.       Min        Max
-------------+---------------------------------------------------------
   xb_mi_all |        117    1062.735    344.8446   515.5598   2040.374
```

Variable `xb_mi_all` contains MI linear predictions in $m = 0$; completed-data linear predictions from imputation 1 in $m = 1$; completed-data linear predictions from imputation 2 in $m = 2$; and so on.

Example 3: Obtain MI estimates of probabilities

Recall the analysis of heart attacks from *Example 1: Completed-data logistic analysis* in [MI] **mi estimate**:

```
. use https://www.stata-press.com/data/r19/mheart1s20, clear
(Fictional heart attack data; BMI missing)
. mi estimate, saving(miest, replace): logit attack smokes age bmi hsgrad female
Multiple-imputation estimates                   Imputations       =         20
Logistic regression                             Number of obs     =        154
                                                Average RVI       =     0.0312
                                                Largest FMI       =     0.1355
DF adjustment:   Large sample                   DF:     min       =   1,060.38
                                                        avg       = 223,362.56
                                                        max       = 493,335.88
Model F test:       Equal FMI                   F(   5,71379.3)   =       3.59
Within VCE type:          OIM                   Prob > F          =     0.0030
------------------------------------------------------------------------------
      attack | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
      smokes |   1.198595   .3578195     3.35   0.001     .4972789    1.899911
         age |   .0360159   .0154399     2.33   0.020     .0057541    .0662776
         bmi |   .1039416   .0476136     2.18   0.029      .010514    .1973692
      hsgrad |   .1578992   .4049257     0.39   0.697    -.6357464    .9515449
      female |  -.1067433   .4164735    -0.26   0.798    -.9230191    .7095326
       _cons |  -5.478143   1.685075    -3.25   0.001    -8.782394   -2.173892
------------------------------------------------------------------------------
```

We could have used a different estimation file to store the completed-data estimation results from `logit`. Instead, we replaced the existing estimation file `miest.ster` with new results by specifying `saving()`'s `replace` option.

Following the discussion in *Introduction*, we first obtain MI estimates of the probabilities of a positive outcome by using the transformation-based approach. We obtain MI estimates of linear predictions and apply the inverse-logit transformation to obtain the probabilities:

```
. mi predict xb_mi using miest
(option xb assumed; linear prediction)
. quietly mi xeq: generate phat = invlogit(xb_mi)
```

Unlike `predict` after `logit`, `mi predict` after `mi estimate: logit` defaults to the linear prediction and not to the probability of a positive outcome. `mi predict` always assumes the linear prediction.

Alternatively, we can apply Rubin's combination rules directly to probabilities. Unlike `predict`, `mi predict` does not allow the `pr` option. You can obtain only linear predictions or standard errors using `mi predict`. We can use the `predict()` function of `mi predictnl` to obtain MI estimates of the probabilities by directly pooling completed-data probabilities:

```
. mi predictnl phat_mi = predict(pr) using miest
. mi xeq 0: summarize phat phat_mi
m=0 data:
-> summarize phat phat_mi
    Variable |        Obs        Mean    Std. dev.       Min        Max
-------------+---------------------------------------------------------
        phat |        154    .4478198    .1820425   .1410432   .8923041
     phat_mi |        154    .4480519    .1812098    .141361   .8912111
```

Although the first approach is preferable, we can see that we obtain similar estimates of the probabilities of a positive outcome with both approaches.

Example 4: Obtain other MI predictions

Consider the cancer data from *Example 3: Completed-data survival analysis* in [MI] **mi estimate**:

```
. use https://www.stata-press.com/data/r19/mdrugtrs25, clear
(Patient survival in drug trial)
. mi stset studytime, failure(died)
Survival-time data settings
         Failure event: died!=0 & died<.
Observed time interval: (0, studytime]
     Exit on or before: failure
------------------------------------------------------------------------------
         48  total observations
          0  exclusions
------------------------------------------------------------------------------
         48  observations remaining, representing
         31  failures in single-record/single-failure data
        744  total analysis time at risk and under observation
                                                At risk from t =         0
                                     Earliest observed entry t =         0
                                          Last observed exit t =        39
```

In this example, we fit a parametric Weibull regression to the survival data and as before replace the estimation results in `miest.ster` with new ones from `mi estimate: streg`:

```
. mi estimate, saving(miest, replace): streg drug age, dist(weibull)
Multiple-imputation estimates                   Imputations       =         25
Weibull PH regression                           Number of obs     =         48
                                                Average RVI       =     0.0927
                                                Largest FMI       =     0.1847
DF adjustment:   Large sample                   DF:     min       =     721.15
                                                        avg       =   6,014.48
                                                        max       =  11,383.09
Model F test:       Equal FMI                   F(   2, 2910.0)   =      14.94
Within VCE type:          OIM                   Prob > F          =     0.0000
------------------------------------------------------------------------------
          _t | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
        drug |  -2.093333   .4091925    -5.12   0.000    -2.895422   -1.291243
         age |    .126931   .0403526     3.15   0.002     .0477084    .2061536
       _cons |  -11.14588   2.584909    -4.31   0.000    -16.22013   -6.071634
-------------+----------------------------------------------------------------
      /ln_p |   .5524239   .1434973     3.85   0.000     .2711445    .8337033
-------------+----------------------------------------------------------------
           p |   1.737459   .2493207                      1.311465    2.301827
         1/p |    .575553   .0825903                      .4344374    .7625063
------------------------------------------------------------------------------
```

Suppose that we want to estimate median survival time. After `streg`, median survival time can be obtained by using `predict, median time`. `mi predict` does not support these options, but we can use the `predict(median time)` function with `mi predictnl` to obtain MI estimates of the median survival time.

To improve normality, we perform pooling in a log scale and then exponentiate results back to the original scale:

```
. mi predictnl p50_lntime_mi = ln(predict(median time)) using miest
. quietly mi xeq: generate p50_time_mi = exp(p50_lntime_mi)
```

Above, we demonstrated the use of expressions with the `predict()` function by computing median log-survival time by using `ln(predict(median time))`. Alternatively, we can compute median log-survival time directly with `predict(median lntime)`:

```
. mi predictnl p50_lntime1_mi = predict(median lntime) using miest
. quietly mi xeq: generate p50_time1_mi = exp(p50_lntime1_mi)
```

We verify that we obtain identical results:

```
. mi xeq 0: summarize p50_time_mi p50_time1_mi
m=0 data:
-> summarize p50_time_mi p50_time1_mi
```

Variable	Obs	Mean	Std. dev.	Min	Max
p50_time_mi	48	21.74607	14.60662	3.707896	53.10997
p50_time1_mi	48	21.74607	14.60662	3.707896	53.10997

Example 5: Obtain MI predictions after multiple-equation commands

For illustrative purposes, let's use `mlogit` instead of `logit` to analyze the heart-attack data from *Example 3: Obtain MI estimates of probabilities*:

```
. use https://www.stata-press.com/data/r19/mheart1s20, clear
(Fictional heart attack data; BMI missing)
. mi estimate, saving(miest, replace): mlogit attack smokes age bmi hsgrad female
Multiple-imputation estimates                   Imputations       =         20
Multinomial logistic regression                 Number of obs     =        154
                                                Average RVI       =     0.0312
                                                Largest FMI       =     0.1355
DF adjustment:   Large sample                   DF:     min       =   1,060.38
                                                        avg       = 223,362.56
                                                        max       = 493,335.88
Model F test:       Equal FMI                   F(   5,71379.3)   =       3.59
Within VCE type:          OIM                   Prob > F          =     0.0030
```

attack	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
0	(base outcome)					
1						
smokes	1.198595	.3578195	3.35	0.001	.4972789	1.899911
age	.0360159	.0154399	2.33	0.020	.0057541	.0662776
bmi	.1039416	.0476136	2.18	0.029	.010514	.1973692
hsgrad	.1578992	.4049257	0.39	0.697	-.6357464	.9515449
female	-.1067433	.4164735	-0.26	0.798	-.9230191	.7095326
_cons	-5.478143	1.685075	-3.25	0.001	-8.782394	-2.173892

We obtain the same results as with `mi estimate: logit`.

To obtain predictions after multiple-equation commands such as `mlogit`, we need to use the `equation()` option of `mi predict` or `mi predictnl` to obtain a prediction from a specific equation. By default, the first equation is assumed:

```
. mi predict xb_0_mi using miest
(option xb assumed; linear prediction)
. mi xeq 0: summarize xb_0_mi
m=0 data:
-> summarize xb_0_mi
    Variable |        Obs        Mean    Std. dev.       Min        Max
-------------+---------------------------------------------------------
     xb_0_mi |        154           0           0           0          0
```

In our example, the first equation corresponds to the base category, so the linear prediction is zero for this equation.

To obtain the linear prediction from the second equation, we specify the `equation(`*eqspec*`)` option. *eqspec* can refer to the equation number, `#2`, or to the equation name, `income`. For example,

```
. mi predict xb_1_mi using miest, equation(#2)
(option xb assumed; linear prediction)
```

Suppose we want to compute observation-specific odds of a heart attack. Knowing that the odds of a disease is the exponentiated linear predictor, we can compute the odds simply as

```
. quietly mi xeq: generate odds_mi = exp(xb_1_mi)
```

Instead, to illustrate a more advanced syntax of `mi predictnl`, we compute the odds using their definition as the ratio of a probability of a heart attack (`attack==1`) to the probability of no heart attack (`attack==0`). Log odds are asymptotically normally distributed, so we apply combination rules to log odds and then exponentiate the result to obtain odds:

```
. mi predictnl lnodds_mi = ln(predict(pr equation(1))/predict(pr equation(0)))
> using miest
. quietly mi xeq: generate odds_mi = exp(lnodds_mi)
```

In the above, we used the names of the equations, `0` and `1`, within `equation()` to obtain probabilities of no heart attack and a heart attack, respectively.

We can see, for example, that for older subjects or subjects who smoke, the odds of having a heart attack are noticeably higher:

```
. quietly mi xeq: generate byte atrisk = smokes==1 | age>50
. mi xeq 0: by atrisk, sort: summ odds_mi
m=0 data:
-> by atrisk, sort: summ odds_mi
-------------------------------------------------------------------------------
-> atrisk = 0
    Variable |        Obs        Mean    Std. dev.       Min        Max
-------------+---------------------------------------------------------
     odds_mi |         30    .3472545    .1451144   .1642029    .818259
-------------------------------------------------------------------------------
-> atrisk = 1
    Variable |        Obs        Mean    Std. dev.       Min        Max
-------------+---------------------------------------------------------
     odds_mi |        124    1.327598    1.228176   .2198672   8.285403
```

Methods and formulas

Multiple-imputation predictions are obtained by considering an observation-specific prediction as an estimand and by applying Rubin's combination rules to it (White, Royston, and Wood 2011).

Let $\eta_i(\cdot)$ be a prediction of interest for subject i and $\hat{\eta}_{i,m}(\cdot)$ be a completed-data estimate of the prediction for subject i, $i = 1, \ldots, N$, from imputation m, $m = 1, \ldots, M$. In what follows, we omit the functional argument of $\eta_i(\cdot)$ for brevity.

The MI estimate of prediction η_i is

$$\overline{\eta}_{i,M} = \frac{1}{M}\sum_{m=1}^{M}\hat{\eta}_{i,m},\ i = 1, \ldots, N$$

Let $\widehat{\text{Var}}(\hat{\eta}_{i,m})$ be the completed-data variance of the completed-data prediction $\hat{\eta}_{i,m}$ for subject i from imputation m. The standard error of the MI prediction $\overline{\eta}_{i,M}$ is the square root of the total MI variance $T_{\overline{\eta}_{i,M}}$,

$$T_{\overline{\eta}_{i,M}} = \overline{U}_i + \left(1 + \frac{1}{M}\right) B_i,\ i = 1, \ldots, N$$

where $\overline{U}_i = \sum_{m=1}^{M} \widehat{\text{Var}}(\hat{\eta}_{i,m})/M$ is the within-imputation variance and

$B_i = \sum_{m=1}^{M} (\hat{\eta}_{i,m} - \overline{\eta}_{i,M})^2/(M-1)$ is the between-imputation variance.

Other statistics such as test statistics, confidence intervals, and relative variance increases are obtained by applying to η_i the same formulas as described in *Univariate case* under *Methods and formulas* of [MI] **mi estimate** for parameter Q. Also see Rubin (1987, 76–77).

As for any other parameter, the validity of applying Rubin's combination rules to η_i is subject to η_i satisfying a set of conditions as described, for example, in *Theory underlying multiple imputation* under *Remarks and examples* of [MI] **Intro substantive**. In particular, the combination rules should be applied to η_i in the metric for which the sampling distribution is closer to the normal distribution.

References

Barnard, J., and D. B. Rubin. 1999. Small-sample degrees of freedom with multiple imputation. *Biometrika* 86: 948–955. https://doi.org/10.1093/biomet/86.4.948.

Rubin, D. B. 1987. *Multiple Imputation for Nonresponse in Surveys*. New York: Wiley.

White, I. R., P. Royston, and A. M. Wood. 2011. Multiple imputation using chained equations: Issues and guidance for practice. *Statistics in Medicine* 30: 377–399. https://doi.org/10.1002/sim.4067.

Also see

[MI] **mi estimate postestimation** — Postestimation tools for mi estimate

[MI] **mi estimate** — Estimation using multiple imputations

[MI] **Intro** — Introduction to mi

[MI] **Intro substantive** — Introduction to multiple-imputation analysis

[MI] **Glossary**

mi ptrace — Load parameter-trace file into Stata

Description Syntax Options Remarks and examples
Stored results Also see

Description

Parameter-trace files, files with suffix `.stptrace`, are created by the `saveptrace()` option of `mi impute mvn`; see [MI] **mi impute mvn**. These are not Stata datasets, but they can be loaded as if they were by using `mi ptrace use`. Their contents can be described without loading them by using `mi ptrace describe`.

Syntax

`mi ptrace describe [using]` *filename*

`mi ptrace use` *filename* [, *use_options*]

use_options	Description
`clear`	okay to replace existing data in memory
`double`	load variables as doubles (default is floats)
`select(`*selections*`)`	what to load (default is all)

`collect` is allowed; see **[U] 11.1.10 Prefix commands**.

where *selections* is a space-separated list of individual selections. Individual selections are of the form

`b[`*yname*`,` *xname*`]`
`v[`*yname*`,` *yname*`]`

where *yname*s and *xname*s are displayed by `mi ptrace describe`. You may also specify

`b[`*#_y*`,` *#_x*`]`
`v[`*#_y*`,` *#_y*`]`

where *#_y* and *#_x* are the variable numbers associated with *yname* and *xname*, and those too are shown by `mi ptrace describe`.

For `b`, you may also specify `*` to mean all possible index elements. For instance,

`b[*,*]`	all elements of `b`
`b[`*yname*`,*]`	row corresponding to *yname*
`b[*,`*xname*`]`	column corresponding to *xname*

Similarly, `b[#_y,*]` and `b[*,#_x]` are allowed. The same is allowed for `v`, and also, the second element can be specified as `<`, `<=`, `=`, `>=`, or `>`. For instance,

`v[`*yname*`,=]`	variance of *yname*
`v[*,=]`	all variances (diagonal elements)
`v[*,<]`	lower triangle
`v[*,<=]`	lower triangle and diagonal
`v[*,>=]`	upper triangle and diagonal
`v[*,>]`	upper triangle

In `mi ptrace describe` and in `mi ptrace use`, *filename* must be specified in quotes if it contains special characters or blanks. *filename* is assumed to be *filename*`.stptrace` if the suffix is not specified.

Options

`clear` specifies that it is okay to clear the dataset in memory, even if it has not been saved to disk since it was last changed.

`double` specifies that elements of `b` and `v` are to be loaded as doubles; they are loaded as floats by default.

`select(`*selections*`)` allows you to load subsets of `b` and `v`. If the option is not specified, all of `b` and `v` are loaded. That result is equivalent to specifying `select(b[*,*] v[*,<=])`. The `<=` specifies that just the diagonal and lower triangle of symmetric matrix `v` be loaded.

Specifying `select(b[*,*])` would load just `b`.

Specifying `select(v[*,<=])` would load just `v`.

Specifying `select(b[*,*] v[*,=])` would load `b` and the diagonal elements of `v`.

Remarks and examples

Say that we impute the values of y_1 and y_2 assuming that they are multivariate normal distributed, with their means determined by a linear combination of x_1, x_2, and x_3, and their variance constant. Writing this more concisely, $\mathbf{y} = (y_1, y_2)'$ is distributed MVN($\mathbf{XB}$, $\mathbf{V}$), where $\mathbf{B}$: 2×3 and $\mathbf{V}$: 2×2. If we use MCMC or EM procedures to produce values of $\mathbf{B}$ and $\mathbf{V}$ to be used to generate values for $\mathbf{y}$, we must ensure that we use sufficient iterations so that the iterative procedure stabilizes. `mi impute mvn` (see [MI] **mi impute mvn**) provides the worst linear combination (WLC) of the elements of $\mathbf{B}$ and $\mathbf{V}$. If we want to perform other checks, we can specify `mi impute mvn`'s `saveptrace(`*filename*`)` option. `mi impute` then produces a file containing `m` (imputation number), `iter` (overall iteration number), and the corresponding `B` and `V`. The last `iter` for each `m` is the `B` and `V` that `mi impute mvn` used to impute the missing values.

When we used `mi impute mvn`, we specified burn-in and burn-between numbers, say, `burnin(300)` and `burnbetween(100)`. If we also specified `saveptrace()`, the file produced is organized as follows:

Record #	m	iter	B	V	
1	1	-299	...	...	
2	1	-298	...	...	
.	.	.	.	.	
.	.	.	.	.	
299	1	-1	...	...	
300	1	0	...	...	<- used to impute *m*=1
301	2	1	.	.	
302	2	2	.	.	
.	.	.	.	.	
.	.	.	.	.	
399.	1	99	...	...	
400.	1	100	...	...	<- used to impute *m*=2
401.	2	101	...	...	
.	.	.	.	.	
.	.	.	.	.	

The file is not a Stata dataset, but `mi ptrace use` can load the file and convert it into Stata format, and then it will look just like the above except for the following:

- The record number will become the Stata observation number.
- `B` will become variables `b_y1x1`, `b_y1x2`, and `b_y1x3`; and `b_y2x1`, `b_y2x2`, and `b_y2x3`. (Remember, we had 2 y variables and 3 x variables.)
- `V` will become variables `v_y1y1`, `v_y2y1`, and `v_y2y2`. (This is the diagonal and lower triangle of **V**; variable `v_y1y2` is not created because it would be equal to `v_y2y1`.)
- Variable labels will be filled in with the underlying names of the variables. For instance, the variable label for `b_y1x1` might be "experience, age", and that would remind us that `b_y1x1` contains the coefficient on age used to predict experience. `v_y2y1` might be "education, experience", and that would remind us that `v_y2y1` contains the covariance between education and experience.

Stored results

`mi ptrace describe` stores the following in `r()`:

Scalars

`r(tc)`	`%tc` date-and-time file created
`r(nx)`	number of x variables (columns of `B`)
`r(ny)`	number of y variables (rows of `B`)

Macros

`r(x)`	space-separated [*op.*]*varname* of x
`r(y)`	space-separated [*op.*]*varname* of y

Also see

[MI] **Intro** — Introduction to mi

[MI] **mi impute mvn** — Impute using multivariate normal regression

mi rename — Rename variable

Description Menu Syntax Option
Remarks and examples Also see

Description

`mi rename` renames variables.

Menu

Statistics > Multiple imputation

Syntax

`mi rename` *oldname newname* [`, noupdate`]

Option

`noupdate` in some cases suppresses the automatic `mi update` this command might perform; see [MI] **noupdate option**.

Remarks and examples

Remarks are presented under the following headings:

Specifying the noupdate option
What to do if you accidentally use rename
What to do if you accidentally use rename on wide data
What to do if you accidentally use rename on mlong data
What to do if you accidentally use rename on flong data
What to do if you accidentally use rename on flongsep data

Specifying the noupdate option

If you are renaming more than one variable, you can speed execution with no loss of safety by specifying the `noupdate` option after the first `mi rename`:

```
. mi rename ageyears age
. mi rename timeinstudy studytime, noupdate
. mi rename personid id, noupdate
```

The above is generally good advice. When giving one `mi` command after another, you may specify `noupdate` after the first command to speed execution.

What to do if you accidentally use rename

Assume that you just typed

```
. rename ageyears age
```

rather than typing

```
. mi rename ageyears age
```

as you should have. No damage has been done yet, but if you give another `mi` command and it runs `mi update` (see [MI] **mi update**), real damage will be done. We will discuss that and what to do about it in the sections that follow, but first, if you have given no additional `mi` commands, use `rename` (not `mi rename`) to rename the variable back to how it was:

```
. rename age ageyears
```

Then use `mi rename` as you should have in the first place:

```
. mi rename ageyears age
```

The sections below handle the case where `mi update` has run. You will know that `mi update` has run because since the rename, you gave some `mi` command—perhaps even `mi update` itself—and you saw a message like one of these:

(variable `ageyears` dropped in $m > 0$)

(imputed variable `ageyears` unregistered because not in $m = 0$)

(passive variable `ageyears` unregistered because not in $m = 0$)

(regular variable `ageyears` unregistered because not in $m = 0$)

What to do if you accidentally use rename on wide data

If `ageyears` was unregistered, no damage was done, and no additional action needs to be taken.

If `ageyears` was registered as regular, no damage was done. However, your renamed variable is no longer registered. Reregister the variable under its new name by typing `mi register regular age`; see [MI] **mi set**.

If `ageyears` was registered as imputed or passive, you just lost all values for $m > 0$. Passive variables are usually not too difficult to re-create; see [MI] **mi passive**. If the variable was imputed, well, hope that you will have saved your data recently when you make this error and, before that, learn good computing habits.

What to do if you accidentally use rename on mlong data

If `ageyears` was unregistered, no damage was done, and no additional action needs to be taken.

If `ageyears` was registered as regular, no damage was done. However, your renamed variable is no longer registered. Reregister the variable under its new name by typing `mi register regular age`; see [MI] **mi set**.

If ageyears was registered as imputed or passive, you just lost all values for $m > 0$. We offer the same advice as we offered when the data were wide: Passive variables are usually not too difficult to re-create—see [MI] **mi passive**—and otherwise hope that you will have saved your data recently when you make this error. It is always a good idea to save your data periodically.

What to do if you accidentally use rename on flong data

The news is better in this case; no matter how your variables were registered, you have not lost data.

If ageyears was unregistered, no further action is required.

If ageyears was registered as regular, you need to reregister the variable under its new name by typing mi register regular age; see [MI] **mi set**.

If ageyears was registered as passive or imputed, you need to reregister the variable under its new name by typing mi register passive age or mi register imputed age.

What to do if you accidentally use rename on flongsep data

The news is not as good in this case.

If ageyears was unregistered, no damage was done. When mi update ran, it noticed that old variable ageyears no longer appeared in $m > 0$ and that new variable age now appeared in $m = 0$, so mi update dropped the first and added the second to $m > 0$, thus undoing any damage. There is nothing more that needs to be done.

If ageyears was registered as regular, no damage was done, but you need to reregister the variable by typing mi register regular age; see [MI] **mi set**.

If ageyears was registered as passive or imputed, you have lost the values in $m > 0$. Now would probably be a good time for us to mention how you should work with a copy of your flongsep data; see [MI] **mi copy**.

Also see

[MI] **Intro** — Introduction to mi

mi replace0 — Replace original data

Description Menu Syntax Option
Remarks and examples Also see

Description

`mi replace0` provides a mechanism for using standard data management commands on an `mi` dataset. The process involves three steps:

1. Use `mi extract` to extract $m = 0$ data into a standard dataset.
2. Modify the extracted dataset using standard data management commands.
3. Use `mi replace0` to replace $m = 0$ with the modified dataset and make all imputations consistent with the changes.

Menu

Statistics > Multiple imputation

Syntax

`mi replace0 using` *filename*`, id(`*varlist*`)`

Typical use is

```
. mi extract 0
. (perform data management commands)
. mi replace0 using origfile, id(idvar)
```

Option

`id(`*varlist*`)` is required; it specifies the variable or variables to use to match the observations in $m = 0$ of the `mi` data to the observations of the non-`mi` dataset. The ID variables must uniquely identify the observations in each dataset, and equal values across datasets must indicate corresponding observations, but one or both datasets can have observations found (or not found) in the other.

Remarks and examples

It is often easier to perform data management on $m = 0$ and then let `mi replace0` duplicate the results for $m = 1$, $m = 2$, …, $m = M$ rather than perform the data management on all m's simultaneously. It is easier because $m = 0$ by itself is a non-`mi` dataset, so you can use any of the general Stata commands (that is, non-`mi` commands) with it.

You use `mi extract` to extract $m = 0$; see [MI] **mi extract**. The extracted dataset is just a regular Stata dataset; it is not `mi set`, nor does it have any secret complexities.

You use mi replace0 to recombine the datasets after you have modified the $m = 0$ data. mi replace0 can deal with the following changes to $m = 0$:

- changes to the values of existing variables,
- removal of variables,
- addition of new variables,
- dropped observations, and
- added observations.

For instance, you could use mi extract and mi replace0 to do the following:

```
. use my_midata, clear
. mi extract 0
. replace age = 26 if age==6
. replace age = 32 if pid==2088
. merge 1:1 pid using newvars, keep(match) nogen
. by location: egen avgrate = mean(rate)
. drop proxyrate
. mi replace0 using my_midata, id(pid)
```

In the above,

1. we extract $m = 0$;
2. we update existing variable age (we fix a typo and the age of pid 2088);
3. we merge $m = 0$ with newvars.dta to obtain some new variables and, in the process, keep only the observations that were found in both $m = 0$ and newvars.dta;
4. we create new variable avgrate equal to the mean rate by location; and
5. we drop previously existing variable proxyrate.

We then take that result and use it to replace $m = 0$ in our original mi dataset. We leave it to mi replace0 to carry out the changes to $m = 1$, $m = 2$, …, $m = M$ to account for what we did to $m = 0$.

By the way, it turns out that age in my_midata.dta is registered as imputed. We changed one nonmissing value to another nonmissing value and changed one missing value to a nonmissing value. mi replace0 will deal with the implications of that. It would even deal with us having changed a nonmissing value to a missing value.

There is no easier way to do data management than by using mi extract and mi replace0.

Also see

[MI] **Intro** — Introduction to mi

[MI] **mi extract** — Extract original or imputed data from mi data

mi reset — Reset imputed or passive variables

Description Menu Syntax Options
Remarks and examples Also see

Description

`mi reset` resets the imputed or passive variables specified. Values are reset to the values in $m = 0$, which are typically missing, but if you specify `=` *exp*, they are reset to the value specified.

Menu

Statistics > Multiple imputation

Syntax

`mi reset` *varlist* [`=` *exp*] [*if*] [`,` *options*]

options	Description
Main	
`m(`*numlist*`)`	values of m to be reset; default all
`noupdate`	see [MI] **noupdate option**

Options

Main

`m(`*numlist*`)` specifies the values of m that are to be reset; the default is to update all values of m. If M were equal to 3, the default would be equivalent to specifying `m(1/3)` or `m(1 2 3)`. If you wished to update the specified variable(s) in just $m = 2$, you could specify `m(2)`.

`noupdate` in some cases suppresses the automatic `mi update` this command might perform; see [MI] **noupdate option**.

Remarks and examples

Remarks are presented under the following headings:

Using mi reset
Technical notes and relation to mi update

Using mi reset

Resetting an imputed or passive variable means setting its values in $m > 0$ equal to the values recorded in $m = 0$. For instance, if variable inc were imputed, typing

```
. mi reset inc
(15 values reset)
```

would reset its incomplete values back to missing in all m. In the sample output shown, we happen to have $M = 5$ and reset back to missing the three previously imputed values in each imputation.

It is rare that you would want to reset an imputed variable, but one can imagine cases. Your coworker Joe sent you the data and just buzzed you on the telephone. "There is one value wrong in the data I sent you," he says. "There is an imputed value for inc that is 15,000, which is obviously absurd. Just reset it back to missing until I find out what happened." So you type

```
. mi reset inc if inc==15000
(1 value reset)
```

Later Joe calls back. "It is a long and very stupid story," he begins, and you can hear him settling into his chair to tell it. As you finish your second cup of coffee, he is wrapping up. "So the value of inc for pid 1433 should be 0.725." You type

```
. mi reset inc = .725 if pid=1433
(1 value reset)
```

It is common to need to reset passive variables if imputed values change. For instance, you have variables age and lnage in your data. You imputed lnage; age is passive. You recently updated the imputed values for lnage. One way to update the values for age would be to type

```
. mi passive: replace age = exp(lnage)
m=0:
m=1:
(10 real changes made)
m=2:
(10 real changes made)
m=3:
(8 real changes made)
```

Alternatively, you could type

```
. mi reset age = exp(lnage)
(28 values reset)
```

Technical notes and relation to mi update

mi reset, used with an imputed variable, changes only the values for which the variable contains hard missing (.) in $m = 0$. The other values are, by definition, already equal to their $m = 0$ values.

mi reset, used with a passive variable, changes only the values in incomplete observations, observations in which any imputed variable contains hard missing. The other values of the passive variable are, by definition, already equal to their $m = 0$ values.

mi update can be used to ensure that values that are supposed to be equal to their $m = 0$ values in fact are equal to them; see [MI] **mi update**.

Also see

[MI] **Intro** — Introduction to mi

[MI] **mi update** — Ensure that mi data are consistent

mi reshape — Reshape mi data

Description Menu Syntax Options Remarks and examples Also see

Description

`mi reshape` is Stata's `reshape` for `mi` data; see [D] **reshape**.

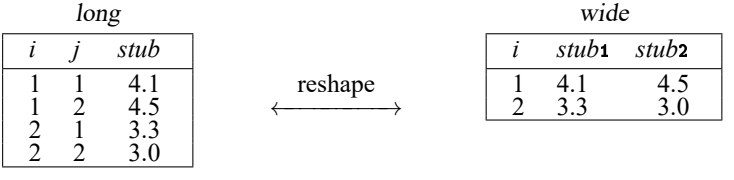
Menu

Statistics > Multiple imputation

Syntax

Overview

(The words long *and* wide *in what follows have nothing to do with mi styles mlong, flong, flongsep, and wide; they have to do with reshape's concepts.)*



To go from long to wide:

j existing variable
/
`mi reshape wide` *stub*`, i(`*i*`) j(`*j*`)`

To go from wide to long:

`mi reshape long` *stub*`, i(`*i*`) j(`*j*`)`
\
j new variable

Basic syntax

Convert mi data from long form to wide form

`mi reshape wide` *stubnames*`, i(`*varlist*`) j(`*varname*`)` [*options*]

Convert mi data from wide form to long form

`mi reshape long` *stubnames*`, i(`*varlist*`) j(`*varname*`)` [*options*]

options	Description
`i(`*varlist*`)`	i variable(s)
`j(`*varname* [*values*]`)`	long→wide: j, existing variable wide→long: j, new variable optionally specify values to subset j
`string`	j is string variable (default is numeric)

where *values* is `#[-#] [...]` if j is numeric (the default)
`"`*string*`" ["`*string*`" ...]` if j is string

and where *stubnames* are variable names (long→wide), or stubs of variable names (wide→long). Unlike `reshape` (see [D] **reshape**), *stubnames* may not contain `@` to denote where j appears in the name; all *stubnames* must follow the style *stub#*.

Options

See [D] **reshape** for descriptions of the other options.

Remarks and examples

The `reshape` command you specify is carried out on the $m = 0$ data, and then the result is duplicated in $m = 1$, $m = 2$, ..., $m = M$.

In `mi reshape`, all variables corresponding to the same *stubnames* must be registered of the same `mi` type: `imputed`, `passive`, or `regular`.

Also see

[MI] **Intro** — Introduction to mi

[MI] **mi replace0** — Replace original data

[D] **reshape** — Convert data from wide to long form and vice versa

mi select — Programmer's alternative to mi extract

Description Syntax Option Remarks and examples
Stored results Also see

Description

`mi select` is a programmer's command. It is a faster, more dangerous version of `mi extract`; see [MI] **mi extract**. Before using `mi select`, the `mi` data must be preserved; see [P] **preserve**.

`mi select init` initializes `mi select #` and must be used before the first call to `mi select #`.

`mi select #` replaces the data in memory with a copy of the data for $m = \#$. The data are not `mi set`.

Syntax

```
mi select init [ , fast ]

mi select #
```

where $0 \leq \# \leq M$, and where typical usage is

```
quietly mi query
local M = r(M)

preserve
mi select init
local priorcmd "`r(priorcmd)'"

forvalues m=1(1)`M' {
    mi select `m'
    ...
    `priorcmd'
}

restore
```

`collect` is allowed; see **[U] 11.1.10 Prefix commands**.

Option

`fast`, specified with `mi select init`, specifies that the data delivered by `mi select #` commands not be changed except for sort order. Then `mi select` can operate more quickly. `fast` is allowed with all styles but currently affects the performance with the wide style only.

If `fast` is not specified, the data delivered by `mi select #` may be modified freely before the next `mi select #` call. However, the data may not be dropped. `mi select` uses characteristics (see [P] **char**) stored in `_dta[]` to know its state.

Remarks and examples

The two mi select commands work in tandem. mi select init initializes mi select #.

mi select init returns macro r(priorcmd), which you are to issue as a command between each mi select # call. r(priorcmd) is not required to be issued before the first call to mi select #, although you may issue it if that is convenient. mi select # calls can be made in any order, and the same m may be selected repeatedly.

The data delivered by mi select # differ from those delivered by mi extract in that there may be extra variables in the dataset. One of the extra variables, _mi_id, is a unique observation identifier.

If you want to post changes made in the selected data back to the mi data, you can write a file containing mi_id and the updated variables and then use _mi_id to match that to the mi data after your final restore. By default, changes to the selected data will not be posted back to the underlying mi data.

In the case of wide data, the mi data have no _mi_id variable. _mi_id in the selected data is reflected in the current order of the mi data.

Stored results

mi select init returns the following in r():

Macros

r(priorcmd) command to be issued prior to calling mi select #; this command will be either restore, preserve or nothing

Also see

[MI] **Intro** — Introduction to mi

[MI] **mi extract** — Extract original or imputed data from mi data

[MI] **Technical** — Details for programmers

mi set — Declare multiple-imputation data

Description Menu Syntax Option for mi unset Remarks and examples
Also see

Description

`mi set` is used to set a regular Stata dataset to be an `mi` dataset. `mi set` is also used to modify the attributes of an already set dataset. An `mi set` dataset has the following attributes:

- The data are recorded in a *style*: `wide`, `mlong`, `flong`, or `flongsep`; see [MI] **Styles**.
- Variables are registered as `imputed`, `passive`, or `regular`, or they are left unregistered.
- In addition to $m = 0$, the data with missing values, the data include $M \geq 0$ imputations of the imputed variables.

`mi set` *style* begins the setting process by setting the desired style. `mi set` *style* sets all variables as unregistered and sets $M = 0$.

`mi register` registers variables as `imputed`, `passive`, or `regular`. Variables can be registered one at a time or in groups and can be registered and reregistered.

`mi unregister` unregisters registered variables, which is useful if you make a mistake. Exercise caution. Unregistering an imputed or passive variable can cause loss of the filled-in missing values in $m > 0$ if your data are recorded in the wide or mlong styles. In such cases, just `mi register` the variable correctly without `mi unregister`ing it first.

`mi set M` modifies M, the total number of imputations. M may be increased or decreased. M may be set before or after imputed variables are registered.

`mi set m` drops selected imputations from the data.

`mi unset` is a rarely used command to unset the data. Better alternatives include `mi extract` and `mi export` (see [MI] **mi extract** and [MI] **mi export**, respectively).

Menu

Statistics > Multiple imputation

Syntax

```
mi set style

    where style is wide
                   mlong
                   flong
                   flongsep name

mi register { imputed | passive | regular } varlist

mi unregister varlist

mi set M { = | += | -= } #

mi set m -= (numlist)

mi unset [ , asis ]
```

The mi suite of commands does not allow alias variables; see [D] **frunalias** for advice on how to get around this restriction.

Option for mi unset

asis is rarely used and is intended for programmers. mi unset, asis unsets the mi data as is. This means that it will not rename the _mi_* system variables and the _#_* variables (wide mi style). By default, mi unset renames the _mi_* variables as mi_* and the _#_* variables as *_#_. Most mi commands, including mi unset without option asis, will not work without the _mi_* system variables. mi unset, asis, however, will work even without those variables (in case they are accidentally dropped); it will simply unset the data as is. The resulting dataset may not always be usable; for instance, without the _mi_m variable, you may not be able to identify imputations, and without the _mi_id variable, you may not be able to identify the imputed observations. You should exercise caution when using this option.

Remarks and examples

Data must be mi set before they can be used with the other mi commands. There are two ways data can become mi set: direct use of mi set *style* or use of mi import (see [MI] **mi import**).

The mi register, mi set M, and mi set m commands are for use with already set data and are useful even with imported data.

Remarks are presented under the following headings:

mi set style
mi register and mi unregister
mi set M and mi set m
mi unset

mi set style

`mi set` *style* begins the setting process. `mi set` *style* has the following forms:

```
mi set wide
mi set mlong
mi set flong
mi set flongsep name
```

It does not matter which style you choose because you can always use `mi convert` (see [MI] **mi convert**) to change the style later. We typically choose `wide` to begin.

If your data are large, you may have to use `flongsep`. `mi set flongsep` requires you to specify a name for the flongsep dataset collection. See *Advice for using flongsep* in [MI] **Styles**.

If you intend to have super-varying variables, you need to choose either `flong` or `flongsep`, or you will need to `mi convert` to flong or flongsep style later.

The current style of the data is shown by the `mi query` and `mi describe` commands; see [MI] **mi describe**.

mi register and mi unregister

`mi register` has three forms:

```
mi register imputed varlist
mi register passive varlist
mi register regular varlist
```

See [MI] **Glossary** for a definition of imputed, passive, and regular variables.

You are required to register imputed variables. If you intend to use `mi impute` (see [MI] **mi impute**) to impute missing values, you must still register the variables first.

Concerning passive variables, we recommend that you register them, and if your data are style wide, you are required to register them. If you create passive variables by using `mi passive` (see [MI] **mi passive**), that command automatically registers them for you.

Whether you register regular variables is up to you. Registering them is safer in all styles except wide, where it does not matter. We say registering is safer because regular variables should not vary across m, and in the long styles, you can unintentionally create variables that vary. If variables are registered, `mi` will detect and fix mistakes for you.

The names of imputation and passive variables may not exceed 29 characters. In the wide style, the names of these variables may be restricted to less than 29 characters depending on the number of imputations. In the flongsep style, the names of regular variables in addition to the names of imputation and passive variables also may not exceed 29 characters.

Super-varying variables—see [MI] **Glossary**—rarely occur, but if you have them, be aware that they can be stored only in flong and flongsep data and that they never should be registered.

The registration status of variables is listed by `mi describe` (see [MI] **mi describe**).

Use mi unregister if you accidentally register a variable incorrectly, with one exception: if you mistakenly register a variable as imputed but intended to register it as passive, or vice versa, use mi register directly to reregister the variable. The mere act of unregistering a passive or imputed variable can cause values in $m > 0$ to be replaced with those from $m = 0$ if the data are wide or mlong.

That exception aside, you first mi unregister variables before reregistering them.

mi set M and mi set m

mi set M is seldom used, and mi set m is sometimes used.

mi set M sets M, the total number of imputations. The syntax is

```
mi set M = #
mi set M += #
mi set M -= #
```

mi set M = # sets $M = \#$. Imputations are added or deleted as necessary. If imputations are added, the new imputations obtain their values of imputed and passive variables from $m = 0$, which means that the missing values are not yet replaced in the new imputations. It is not necessary to increase M if you intend to use mi impute to impute values; see [MI] **mi impute**.

mi set M += # increments M by #.

mi set M -= # decrements M by #.

mi set m -= (*numlist*) deletes the specified imputations. For instance, if you had $M = 5$ imputations and wanted to delete imputation 2, leaving you with $M = 4$, you would type mi set m -= (2).

mi unset

If you wish to unset your data, your best choices are mi extract and mi export; see [MI] **mi extract** and [MI] **mi export**. The mi extract 0 command replaces the data in memory with the data from $m = 0$, unset. The mi export command replaces the data in memory with unset data in a form that can be sent to a non–Stata user.

mi unset is included for completeness, and if it has any use at all, it would be by programmers.

Also see

[MI] **Intro** — Introduction to mi

[MI] **mi convert** — Change style of mi data

[MI] **mi describe** — Describe mi data

[MI] **mi export** — Export mi data

[MI] **mi extract** — Extract original or imputed data from mi data

[MI] **mi import** — Import data into mi

[MI] **mi XXXset** — Declare mi data to be svy, st, ts, xt, etc.

[MI] **Styles** — Dataset styles

[D] **frunalias** — Change storage type of alias variables

mi stsplit — Split and join time-span records for mi data

Description Menu Syntax Options
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Description

`mi stsplit` and `mi stjoin` are `stsplit` and `stjoin` for `mi` data; see [ST] **stsplit**. Except for the addition of the `noupdate` option, the syntax is identical. Except for generalization across m, the results are identical.

Your `mi` data must be `stset` to use these commands. If your data are not already `stset`, use `mi stset` rather than the standard `stset`; see [MI] **mi XXXset**.

Menu

Statistics > Multiple imputation

Syntax

To split at designated times

```
mi stsplit newvar [ if ], { at(numlist) | every(#) } [ options ]
```

options	Description
Main	
* `at(`*numlist*`)`	split at specified analysis times
* `every(#)`	split when analysis time is a multiple of #
`after(`*spec*`)`	use time since *spec* instead of analysis time for `at()` or `every()`
`trim`	exclude observations outside of range
`noupdate`	see [MI] **noupdate option**
`nopreserve`	programmer's option

* `at()` or `every()` is required.

`nopreserve` is not included in the dialog box.

To split at failure times

```
mi stsplit [ if ], at(failures) [ options ]
```

options	Description
Main	
* `at(failures)`	split at times of observed failures
`strata(`*varlist*`)`	perform splitting by failures within stratum, strata defined by *varlist*
`riskset(`*newvar*`)`	create risk-set ID variable
`noupdate`	see [MI] **noupdate option**
`nopreserve`	programmer's option

* `at()` is required.

`nopreserve` is not included in the dialog box.

To join episodes

```
mi stjoin [ , options ]
```

options	Description
Main	
`censored(`*numlist*`)`	values of failure that indicate no event
`noupdate`	see [MI] **noupdate option**

Options

`noupdate` in some cases suppresses the automatic `mi update` this command might perform; see [MI] **noupdate option**.

See [ST] **stsplit** for documentation on the remaining options.

Remarks and examples

You should never use `stsplit`, `stjoin`, or any other heavyweight data management command with `mi` data. Instead, you should use their `mi` counterparts, such as `mi stsplit`. Heavyweight commands are commands that make sweeping changes to the data rather than simply deleting some observations, adding or dropping some variables, or changing some values of existing variables. `stsplit` and `stjoin` are examples of heavyweight commands (see [ST] **stsplit**).

Also see

[MI] **Intro** — Introduction to mi

[ST] **stsplit** — Split and join time-span records

[MI] **mi XXXset** — Declare mi data to be svy, st, ts, xt, etc.

mi test — Test hypotheses after mi estimate

Description Menu Syntax Options
Remarks and examples Stored results Methods and formulas References
Also see

Description

`mi test` performs joint tests of coefficients.

`mi testtransform` performs joint tests of transformed coefficients as specified with `mi estimate` or `mi estimate using` (see [MI] **mi estimate** or [MI] **mi estimate using**).

Menu

Statistics > Multiple imputation

Syntax

Test that coefficients are zero

```
mi test coeflist
```

Test that coefficients within a single equation are zero

```
mi test [ eqspec ] [ : coeflist ]
```

Test that subsets of coefficients are zero (full syntax)

```
mi test (spec) [(spec) ...] [ , test_options ]
```

Test that subsets of transformed coefficients are zero

```
mi testtransform name [ (name) ... ] [ , transform_options ]
```

test_options	Description
Test	
ufmitest	perform unrestricted FMI model test
nosmall	do not apply small-sample correction to degrees of freedom
constant	include the constant in coefficients to be tested

transform_options	Description
Test	
ufmitest	perform unrestricted FMI model test
nosmall	do not apply small-sample correction to degrees of freedom
nolegend	suppress transformation legend

coeflist may contain factor variables and time-series operators; see **[U] 11.4.3 Factor variables** and **[U] 11.4.4 Time-series varlists**.
`collect` is allowed with `mi test`; see **[U] 11.1.10 Prefix commands**.

coeflist is

coef [*coef* ...]
[*eqspec*]*coef* [[*eqspec*]*coef* ...]
[*eqspec*] _b[*coef*] [[*eqspec*] _b[*coef*] ...]

eqspec is

\# #
eqname

spec is

coeflist
[*eqspec*] [: *coeflist*]

coef identifies a coefficient in the model; see the description in [R] **test** for details. *eqname* is an equation name.
name is an expression name as specified with `mi estimate` or `mi estimate using` (see [MI] **mi estimate** or [MI] **mi estimate using**).

Options

Test

`ufmitest` specifies that the unrestricted fraction missing information (FMI) model test be used. The default test performed assumes equal fractions of information missing due to nonresponse for all coefficients. This is equivalent to the assumption that the between-imputation and within-imputation variances are proportional. The unrestricted test may be preferable when this assumption is suspect provided that the number of imputations is large relative to the number of estimated coefficients.

`nosmall` specifies that no small-sample adjustment be made to the degrees of freedom. By default, individual tests of coefficients (and transformed coefficients) use the small-sample adjustment of Barnard and Rubin (1999), and the overall model test uses the small-sample adjustment of Reiter (2007).

`constant` specifies that `_cons` be included in the list of coefficients to be tested when using the [*eqspec*] form of *spec* with `mi test`. The default is to not include `_cons`.

`nolegend`, specified with `mi testtransform`, suppresses the transformation legend.

Remarks and examples

Remarks are presented under the following headings:

Introduction
Overview
Example 1: Testing subsets of coefficients equal to zero
Example 2: Testing linear hypotheses
Example 3: Testing nonlinear hypotheses

Introduction

The major issue arising when performing tests after MI estimation is the validity of the variance–covariance estimator (VCE) of the MI estimates. MI variance consists of two sources of variation: within-imputation variation and between-imputation variation. With a small number of imputations, the estimate of the between-imputation variance–covariance matrix is imprecise. In fact, when the number of imputations is less than or equal to the number of estimated parameters, the between-imputation matrix does not even have a full rank. As such, the estimated VCE may not be a valid variance–covariance matrix and thus not suitable for joint inference.

One solution to this problem was proposed by Rubin (1987) and Li et al. (1991). The idea is to assume that the between-imputation variance is proportional to the within-imputation variance. This assumption implies equal FMIs for all jointly tested parameters. Li et al. (1991) found that the procedure performs well in terms of power and maintaining the significance level even with moderately variable FMIs. `mi test` and `mi testtransform`, by default, perform tests using this procedure.

When the number of imputations is large enough relative to the number of tested parameters so that the corresponding VCE is trustworthy, you can request the unrestricted FMI test by specifying the `ufmitest` option. The unrestricted FMI test is the conventional test described by Rubin (1987, 77).

For testing nonlinear hypotheses, direct application of the conventional delta method to the estimated coefficients may not be feasible when the number of imputations is small enough that the VCE of the MI estimates cannot be used for inference. To test these hypotheses, one can first obtain MI estimates of the transformed coefficients by applying Rubin's combination rules to the transformed completed-data estimates and then apply the above MI-specific hypotheses tests to the combined transformed estimates.

The first step can be done by specifying expressions with mi estimate (or mi estimate using). The second step is performed with mi testtransform. mi testtransform uses the same method to test transformed coefficients as mi test uses to test coefficients.

Overview

Use mi test to perform joint tests that coefficients are equal to zero:

```
. mi estimate: regress y x1 x2 x3 x4
. mi test x2 x3 x4
```

Use mi testtransform, however, to perform tests of more general linear hypotheses, such as _b[x1]=_b[x2], or _b[x1]=_b[x2] and _b[x1]=_b[x3]. Testing general linear hypotheses requires estimation of between and within variances corresponding to the specific hypotheses and requires recombining the imputation-specific estimation results. One way you could do that would be to refit the model and include the additional parameters during the estimation step. To test _b[x1]=_b[x2], you could type

```
. mi estimate (diff: _b[x1]-_b[x2]): regress y x1 x2 x3 x4
. mi testtransform diff
```

A better approach, however, is to save each of the imputation-specific results at the time the original model is fit and then later recombine results using mi estimate using. To save the imputation-specific results, specify mi estimate's saving() option when the model is originally fit:

```
. mi estimate, saving(myresults): regress y x1 x2 x3 x4
```

To test _b[x1]=_b[x2], you type

```
. mi estimate (diff: _b[x1]-_b[x2]) using myresults
. mi testtransform diff
```

The advantage of this approach is that you can test additional hypotheses without refitting the model. For instance, if we now wanted to test _b[x1]=_b[x2] and _b[x1]=_b[x3], we could type

```
. mi estimate (diff1: _b[x1]-_b[x2]) (diff2: _b[x1]=_b[x3]) using myresults
. mi testtransform diff1 diff2
```

To test nonlinear hypotheses, such as _b[x1]/_b[x2]=_b[x3]/_b[x4], we could then type

```
. mi estimate (diff: _b[x1]/_b[x2]-_b[x3]/_b[x4]) using myresults
. mi testtransform diff
```

Example 1: Testing subsets of coefficients equal to zero

We are going to test that tax, sqft, age, nfeatures, ne, custom, and corner are in the regression analysis of house resale prices we performed in *Example 1: Completed-data logistic analysis* of [MI] **mi estimate**. Following the advice above, when we fit the model, we are going to save the imputation-specific results even though we will not need them in this example; we will need them in the following examples.

```
. use https://www.stata-press.com/data/r19/mhouses1993s30
(Albuquerque home prices Feb15-Apr30, 1993)
. mi estimate, saving(miest): regress price tax sqft age nfeatures ne custom
> corner
Multiple-imputation estimates                   Imputations       =         30
Linear regression                               Number of obs     =        117
                                                Average RVI       =     0.0648
                                                Largest FMI       =     0.2533
                                                Complete DF       =        109
DF adjustment:   Small sample                   DF:     min       =      69.12
                                                        avg       =      94.02
                                                        max       =     105.51
Model F test:       Equal FMI                   F(   7,  106.5)   =      67.18
Within VCE type:          OLS                   Prob > F          =     0.0000
```

price	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
tax	.6768015	.1241568	5.45	0.000	.4301777	.9234253
sqft	.2118129	.069177	3.06	0.003	.0745091	.3491168
age	.2471445	1.653669	0.15	0.882	-3.051732	3.546021
nfeatures	9.288033	13.30469	0.70	0.487	-17.12017	35.69623
ne	2.518996	36.99365	0.07	0.946	-70.90416	75.94215
custom	134.2193	43.29755	3.10	0.002	48.35674	220.0818
corner	-68.58686	39.9488	-1.72	0.089	-147.7934	10.61972
_cons	123.9118	71.05816	1.74	0.085	-17.19932	265.0229

In the above `mi estimate` command, we use the `saving()` option to create a Stata estimation file called `miest.ster`, which contains imputation-specific estimation results.

`mi estimate` reports the joint test of all coefficients equal to zero in the header. We can reproduce this test with `mi test` by typing

```
. mi test tax sqft age nfeatures ne custom corner
note: assuming equal fractions of missing information.
 ( 1)  tax = 0
 ( 2)  sqft = 0
 ( 3)  age = 0
 ( 4)  nfeatures = 0
 ( 5)  ne = 0
 ( 6)  custom = 0
 ( 7)  corner = 0
       F(  7, 106.5) =   67.18
            Prob > F =    0.0000
```

We obtain results identical to those from `mi estimate`.

We can test that a subset of coefficients, say, `sqft` and `tax`, are equal to zero by typing

```
. mi test sqft tax
note: assuming equal fractions of missing information.
 ( 1)  sqft = 0
 ( 2)  tax = 0
       F(  2, 105.7) =  114.75
            Prob > F =    0.0000
```

Example 2: Testing linear hypotheses

Now we want to test the equality of the coefficients for sqft and tax. Following our earlier suggestion, we use mi estimate using to estimate the difference between coefficients (and avoid refitting the models) and then use mi testtransform to test that the difference is zero:

```
. mi estimate (diff: _b[tax]-_b[sqft]) using miest, nocoef
Multiple-imputation estimates                   Imputations       =         30
Linear regression                               Number of obs     =        117
                                                Average RVI       =     0.1200
                                                Largest FMI       =     0.1100
                                                Complete DF       =        109
DF adjustment:   Small sample                   DF:     min       =      92.10
                                                        avg       =      92.10
Within VCE type:          OLS                           max       =      92.10
      command: regress price tax sqft age nfeatures ne custom corner
         diff: _b[tax]-_b[sqft]
------------------------------------------------------------------------------
       price | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
        diff |   .4649885   .1863919     2.49   0.014     .0948037    .8351733
------------------------------------------------------------------------------

. mi testtransform diff
note: assuming equal fractions of missing information.
         diff: _b[tax]-_b[sqft]
 ( 1)  diff = 0
       F(  1,  92.1) =    6.22
            Prob > F =    0.0144
```

We suppress the display of the coefficient table by specifying the nocoef option with mi estimate using. We obtain the same results from the F test as those of the t test reported in the transformation table.

Similarly, we can test whether three coefficients are jointly equal:

```
. mi estimate (diff1: _b[tax]-_b[sqft]) (diff2: _b[custom]-_b[tax]) using miest,
> nocoef
Multiple-imputation estimates                   Imputations       =         30
Linear regression                               Number of obs     =        117
                                                Average RVI       =     0.0748
                                                Largest FMI       =     0.1100
                                                Complete DF       =        109
DF adjustment:   Small sample                   DF:     min       =      92.10
                                                        avg       =      97.95
Within VCE type:          OLS                           max       =     103.80
      command: regress price tax sqft age nfeatures ne custom corner
        diff1: _b[tax]-_b[sqft]
        diff2: _b[custom]-_b[tax]
------------------------------------------------------------------------------
       price | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
       diff1 |   .4649885   .1863919     2.49   0.014     .0948037    .8351733
       diff2 |   133.5425   43.30262     3.08   0.003     47.66984    219.4151
------------------------------------------------------------------------------

. mi testtr diff1 diff2
note: assuming equal fractions of missing information.
        diff1: _b[tax]-_b[sqft]
        diff2: _b[custom]-_b[tax]
 ( 1)  diff1 = 0
 ( 2)  diff2 = 0
       F(  2, 105.6) =    7.34
            Prob > F =    0.0010
```

We estimate two differences, `_b[tax]-_b[sqft]` and `_b[custom]-_b[tax]`, using `mi estimate using` and test whether they are jointly equal to zero by using `mi testtransform`.

We can perform tests of other hypotheses similarly by reformulating the hypotheses of interest such that we are testing equality to zero.

Example 3: Testing nonlinear hypotheses

In the examples above, we tested linear hypotheses. Testing nonlinear hypotheses is no different. We simply replace the specification of linear expressions in `mi estimate using` with the nonlinear expressions corresponding to the tests of interest.

For example, let's test that the ratio of the coefficients for `tax` and `sqft` is one, an equivalent but less efficient way of testing whether the two coefficients are the same. Similarly to the earlier example, we specify the corresponding nonlinear expression with `mi estimate using` and then use `mi testtransform` to test that the ratio is one:

```
. mi estimate (rdiff: _b[tax]/_b[sqft] - 1) using miest, nocoef
Multiple-imputation estimates                   Imputations       =         30
Linear regression                               Number of obs     =        117
                                                Average RVI       =     0.0951
                                                Largest FMI       =     0.0892
                                                Complete DF       =        109
DF adjustment:   Small sample                   DF:     min       =      95.33
                                                        avg       =      95.33
Within VCE type:          OLS                           max       =      95.33
      command: regress price tax sqft age nfeatures ne custom corner
       rdiff: _b[tax]/_b[sqft] - 1
------------------------------------------------------------------------------
       price | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
       rdiff |      2.2359   1.624546     1.38   0.172    -.9890876    5.460888
------------------------------------------------------------------------------

. mi testtr rdiff
note: assuming equal fractions of missing information.
        rdiff: _b[tax]/_b[sqft] - 1
 ( 1)  rdiff = 0
       F(  1,  95.3) =    1.89
            Prob > F =    0.1719
```

We do not need to use `mi testtransform` (or `mi test`) to test one transformation (or coefficient) because the corresponding test is provided in the output from `mi estimate using`.

Stored results

`mi test` and `mi testtransform` store the following in `r()`:

Scalars

`r(df)`	test constraints degrees of freedom
`r(df_r)`	residual degrees of freedom
`r(p)`	two-sided p-value
`r(F)`	F statistic
`r(drop)`	1 if constraints were dropped, 0 otherwise
`r(dropped_i)`	index of ith constraint dropped

Methods and formulas

`mi test` and `mi testtransform` use the methodology described in *Multivariate case* under *Methods and formulas* of [MI] **mi estimate**, where we replace $\mathbf{q}$ with $\mathbf{Rq} - \mathbf{r}$ and $\mathbf{q}_0 = \mathbf{0}$ for the test H_0: $\mathbf{Rq} = \mathbf{r}$.

References

Barnard, J., and D. B. Rubin. 1999. Small-sample degrees of freedom with multiple imputation. *Biometrika* 86: 948–955. https://doi.org/10.1093/biomet/86.4.948.

Li, K.-H., X.-L. Meng, T. E. Raghunathan, and D. B. Rubin. 1991. Significance levels from repeated p-values with multiply-imputed data. *Statistica Sinica* 1: 65–92.

Reiter, J. P. 2007. Small-sample degrees of freedom for multi-component significance tests with multiple imputation for missing data. *Biometrika* 94: 502–508. https://doi.org/10.1093/biomet/asm028.

Rubin, D. B. 1987. *Multiple Imputation for Nonresponse in Surveys.* New York: Wiley.

Also see

[MI] **mi estimate postestimation** — Postestimation tools for mi estimate

[MI] **mi estimate** — Estimation using multiple imputations

[MI] **mi estimate using** — Estimation using previously saved estimation results

[MI] **Intro** — Introduction to mi

[MI] **Intro substantive** — Introduction to multiple-imputation analysis

[MI] **Glossary**

mi update — Ensure that mi data are consistent

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Description

`mi update` verifies that `mi` data are consistent. If the data are not consistent, `mi update` reports the inconsistencies and makes the necessary changes to make the data consistent.

`mi update` can change the sort order of the data.

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Syntax

```
mi update
```

Remarks and examples

Remarks are presented under the following headings:

Purpose of mi update
What mi update does
mi update is run automatically

Purpose of mi update

`mi update` allows you to

- change the values of existing variables, whether imputed, passive, regular, or unregistered;
- add or remove missing values from imputed variables (or from any variables);
- drop variables;
- create new variables;
- drop observations; and
- duplicate observations (but not add observations in other ways).

You can make any of or all the above changes and then type

```
. mi update
```

and `mi update` will handle making whatever additional changes are required to keep the data consistent. For instance,

```
. drop if sex==1
(75 observations deleted)
. mi update
(375 m>0 obs dropped because of dropped obs in m=0)
```

In this example, we happen to have five imputations and are working with flongsep data. We dropped 75 observations in $m = 0$, and that still left $5 \times 75 = 375$ observations to be dropped in $m > 0$.

The messages mi update produces vary according to the style of the data because the changes required to make the data consistent are determined by the style. Had we been working with flong data, we might have seen

```
. drop if sex==1
(450 observations deleted)
. mi update
(system variable _mi_id updated because of changed number of obs)
```

With flong data in memory, when we dropped if sex==1, we dropped all $75 + 5 \times 75 = 450$ observations, so no more observations needed to be dropped; but here mi update needed to update one of its system variables because of the change we made.

Had we been working with mlong data, we might have seen

```
. drop if sex==1
(90 observations deleted)
. mi update
(system variable _mi_id updated because of changed number of obs)
```

The story here is very much like the story in the flong case. In mlong data, dropping if sex==1 drops the 75 observations in $m = 0$ and also drops the incomplete observations among the 75 in $m = 1$, $m = 2, \ldots, m = 5$. In this example, there are three such observations, so a total of $75 + 5 \times 3 = 90$ were dropped, and because of the change, mi update needed to update its system variable.

Had we been using wide data, we might have seen

```
. drop if sex==1
(75 observations deleted)
. mi update
```

mi update's silence indicates that mi update did nothing, because after dropping observations in wide data, nothing more needs to be done. We could have skipped typing mi update here, but do not think that way because changing values, dropping variables, creating new variables, dropping observations, or creating new observations can have unanticipated consequences.

For instance, in our data is variable farmincome, and it seems obvious that farmincome should be 0 if the person does not have a farm, so we type

```
. replace farmincome = 0 if !farm
(15 real changes made)
```

After changing values, you should type mi update even if you do not suspect that it is necessary. Here is what happens when we do that with these data:

```
. mi update
(12 m=0 obs now marked as complete)
```

Typing mi update was indeed necessary! We forgot that the farmincome variable was imputed, and it turns out that the variable contained missing in 12 nonfarm observations; mi needed to deal with that.

Running mi update is so important that mi itself is constantly running it just in case you forget. For instance, let's "forget" to type mi update and then convert our data to wide:

```
. replace farmincome = 0 if !farm
(15 real changes made)
. mi convert wide, clear
(12 m=0 obs now marked as complete)
```

The parenthetical message was produced because `mi convert` ran `mi update` for us. For more information on this, see [MI] **noupdate option**.

What mi update does

- `mi update` checks whether you have changed N, the number of observations in $m = 0$, and resets N if necessary.
- `mi update` checks whether you have changed M, the number of imputations, and adjusts the data if necessary.
- `mi update` checks whether you have added, dropped, registered, or unregistered any variables and takes the appropriate action.
- `mi update` checks whether you have added or deleted any observations. If you have, it then checks whether you carried out the operation consistently for $m = 0$, $m = 1$, …, $m = M$. If you have not carried it out consistently, `mi update` carries it out consistently for you.
- In the mlong, flong, and flongsep styles, `mi update` checks system variable `_mi_id`, which links observations across m, and reconstructs the variable if necessary.
- `mi update` checks that the system variable `_mi_miss`, which marks the incomplete observations, is correct and, if not, updates it and makes any other changes required by the change.
- `mi update` verifies that the values recorded in imputed variables in $m > 0$ are equal to the values in $m = 0$ when they are nonmissing and updates any that differ.
- `mi update` verifies that the values recorded in passive variables in $m > 0$ are equal to the values recorded in $m = 0$'s complete observations and updates any that differ.
- `mi update` verifies that the values recorded in regular variables in $m > 0$ equal the values in $m = 0$ and updates any that differ.
- `mi update` adds any new variables in $m = 0$ to $m > 0$.
- `mi update` drops any variables from $m > 0$ that do not appear in $m = 0$.

mi update is run automatically

As we mentioned before, running `mi update` is so important that many `mi` commands simply run it as a matter of course. This is discussed in [MI] **noupdate option**. In a nutshell, the `mi` commands that run `mi update` automatically have a `noupdate` option, so you can identify them, and you can specify the option to skip running the update and so speed execution, but only with the adrenaline rush caused by a small amount of danger.

Whether you specify `noupdate` or not, we advise you to run `mi update` periodically and to always run `mi update` after dropping or adding variables or observations, or changing values.

Also see

[MI] **Intro** — Introduction to mi

[MI] **noupdate option** — The noupdate option

mi varying — Identify variables that vary across imputations

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Description

`mi varying` lists the names of variables that are unexpectedly varying and super varying; see [MI] **Glossary** for a definition of varying and super-varying variables.

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Syntax

`mi varying` [*varlist*] [, `noupdate`]

`mi varying, unregistered` [`noupdate`]

`collect` is allowed; see **[U] 11.1.10 Prefix commands**.

Options

`unregistered` specifies that the listing be made only for unregistered variables. Specifying this option saves time, especially when the data are flongsep.

`noupdate` in some cases suppresses the automatic `mi update` this command might perform; see [MI] **noupdate option**.

Remarks and examples

A variable is said to be varying if it varies over m in the complete observations. A variable is said to be super varying if it varies over m in the incomplete observations.

Remarks are presented under the following headings:

Detecting problems
Fixing problems

Detecting problems

`mi varying` looks for five potential problems:

1. *Imputed nonvarying.* Variables that are registered as imputed and are nonvarying either
   a. do not have their missing values in $m > 0$ filled in yet, in which case you should use `mi impute` (see [MI] **mi impute**) to impute them, or
   b. have no missing values in $m = 0$, in which case you should `mi unregister` the variables and perhaps use `mi register` to register the variables as regular (see [MI] **mi set**).

2. *Passive nonvarying.* Variables that are registered as passive and are nonvarying either

    a. have missing values in the incomplete observations in $m > 0$, in which case after you have filled in the missing values of your imputed variables, you should use `mi passive` (see [MI] **mi passive**) to update the values of these variables, or

    b. have no missing values in $m = 0$, in which case you should `mi unregister` the variables and perhaps use `mi register` to register the variables as regular (see [MI] **mi set**).

3. *Unregistered varying.*

    a. It is most likely that such variables should be registered as imputed or as passive.

    b. If the variables are varying but should not be, use `mi register` to register them as regular. That will fix the problem; values from $m = 0$ will be copied to $m > 0$.

    c. It is possible that this is just like potential problem 5, below, and it just randomly turned out that the only observations in which variation occurred were the incomplete observations. In that case, leave the variable unregistered.

4. *Unregistered super/varying.* These are variables that are super varying but would have been categorized as varying if they were registered as imputed. This is to say that while they have varying values in the complete observations as complete is defined this instant—which is based on the variables currently registered as imputed—these variables merely vary in observations for which they themselves contain missing in $m = 0$, and thus they could be registered as imputed without loss of information. Such variables should be registered as imputed.

5. *Unregistered super varying.* These variables really do super vary and could not be registered as imputed without loss of information. These variables either contain true errors or they are passive variables that are functions of groups of observations. Fix the errors by registering the variables as regular and leave unregistered those intended to be super varying. If you intentionally have super-varying variables in your data, remember never to convert to the wide or mlong styles. Super-varying variables can appear only in the flong and flongsep styles.

`mi varying` output looks like this:

```
             Possible problem   Variable names
------------------------------------------------------------------------------
         imputed nonvarying: (none)
         passive nonvarying: (none)
       unregistered varying: (none)
*unregistered super/varying: (none)
 unregistered super varying: (none)
------------------------------------------------------------------------------
* super/varying means super varying but would be varying if registered as
  imputed; variables vary only where equal to soft missing in m=0.
```

If there are possible problems, variable names are listed in the table.

Super-varying variables can arise only in flong and flongsep data, so the last two categories are omitted when `mi varying` is run on wide or mlong data. If there are no imputed variables, or no passive variables, or no unregistered variables, the corresponding categories are omitted from the table.

Fixing problems

If mi varying detects problems, register all imputed variables before registering passive variables. Rerun mi varying as you register new imputed variables. Registering new variables as imputed can change which observations are classified as complete and incomplete, and that classification in turn can change the categories to which the other variables are assigned. After registering a variable as imputed, another variable previously listed as super varying might now be merely varying.

Stored results

mi varying stores the following in r():

Macros

r(ivars)	nonvarying imputed variables
r(pvars)	nonvarying passive variables
r(uvars_v)	varying unregistered variables
r(uvars_s_v)	(super) varying unregistered variables
r(uvars_s_s)	super-varying unregistered variables

Also see

[MI] **Intro** — Introduction to mi

[MI] **mi misstable** — Tabulate pattern of missing values

mi xeq — Execute command(s) on individual imputations

Description Syntax Remarks and examples Stored results Also see

Description

`mi xeq:` *XXX* executes *XXX* on $m = 0, m = 1, \ldots, m = M$.

`mi xeq` *numlist*`:` *XXX* executes *XXX* on $m =$ *numlist*.

XXX can be any single command or it can be multiple commands separated by a semicolon. If specifying multiple commands, the delimiter must not be set to semicolon; see [P] **#delimit**.

Syntax

`mi xeq` [*numlist*]`:` *command* [`;` *command* [`;` ...]]

Remarks and examples

Remarks are presented under the following headings:

Using mi xeq with reporting commands
Using mi xeq with data-modification commands
Using mi xeq with data-modification commands on flongsep data

Using mi xeq with reporting commands

By reporting commands, we mean any general Stata command that reports results but leaves the data unchanged. `summarize` (see [R] **summarize**) is an example. `mi xeq` is especially useful with such commands. If you wanted to see the summary statistics for variables `outcome` and `age` among the females in your `mi` data, you could type

```
. mi xeq: summarize outcome age if sex=="female"

m=0 data:
-> summarize outcome age if sex=="female"
     (output omitted)

m=1 data:
-> summarize outcome age if sex=="female"
     (output omitted)

m=2 data:
-> summarize outcome age if sex=="female"
     (output omitted)
```

$M = 2$ in the data above.

If you wanted to see a particular regression run on the $m = 2$ data, you could type

```
. mi xeq 2: regress outcome age bp

m=2 data:
-> regress outcome age bp
     (output omitted)
```

In both cases, once the command executes, the entire `mi` dataset is brought back into memory.

Using mi xeq with data-modification commands

You can use data-modification commands with `mi xeq` but doing that is not especially useful unless you are using flongsep data.

If variable `lnage` were registered as passive and you wanted to update its values, you could type

```
. mi xeq: replace lnage = ln(age)
  (output omitted)
```

That would work regardless of style, although it is just as easy to update the variable using `mi passive` (see [MI] **mi passive**):

```
. mi passive: replace lnage = ln(age)
  (output omitted)
```

If what you are doing depends on the sort order of the data, include the `sort` command among the commands to be executed; do not assume that the individual datasets will be sorted the way the data in memory are sorted. For instance, if you have passive variable `totalx`, do not type

```
. sort id time
. mi xeq: by id: replace totalx = sum(x)
```

That will not work. Instead, type

```
. mi xeq: sort id time;  by id: replace totalx = sum(x)

m=0 data:
-> sort id time
-> by id: replace total x = sum(x)
(8 changes made)

m=1 data:
-> sort id time
-> by id: replace total x = sum(x)
(8 changes made)

m=2 data:
-> sort id time
-> by id: replace total x = sum(x)
(8 changes made)
```

Again we note that it would be just as easy to update this variable with `mi passive`:

```
. mi passive: by id (time): replace totalx = sum(x)
m=0:
(8 changes made)
m=1:
(8 changes made)
m=2:
(8 changes made)
```

With the wide, mlong, and flong styles, there is always another way to proceed, and often the other way is easier.

Using mi xeq with data-modification commands on flongsep data

With flongsep data, `mi xeq` is especially useful. Consider the case where you want to add new variable `lnage` = `ln(age)` to your data, and `age` is just a regular or unregistered variable. With flong, mlong, or wide data, you would just type

```
. generate lnage = ln(age)
```

and be done with it.

With flongsep data, you have multiple datasets to update. Of course, you could `mi convert` (see [MI] **mi convert**) your data to one of the other styles, but we will assume that if you had sufficient memory to do that, you would have done that long ago and so would not be using flongsep data.

The easy way to create `lnage` with flongsep data is by typing

```
. mi xeq: generate lnage = ln(age)
(output omitted)
```

You could use the `mi xeq` approach with any of the styles, but with flong, mlong, or wide data, it is not necessary. With flongsep, it is.

Stored results

`mi xeq` stores in `r()` whatever the last command run on the last imputation or specified imputation returns. For instance,

```
. mi xeq: tabulate g ; summarize x
```

returns the stored results for `summarize x` run on $m = M$.

```
. mi xeq 1 2: tabulate g ; summarize x
```

returns the stored results for `summarize x` run on $m = 2$.

```
. mi xeq 0: summarize x
```

returns the stored results for `summarize x` run on $m = 0$.

Also see

[MI] **Intro** — Introduction to mi

[MI] **mi passive** — Generate/replace and register passive variables

mi XXXset — Declare mi data to be svy, st, ts, xt, etc.

Description Syntax Remarks and examples Also see

Description

Using some features of Stata requires setting your data. The commands listed below allow you to do that with `mi` data. The `mi` variants have the same syntax and work the same way as the original commands.

Syntax

`mi fvset ...`	see [R] **fvset**
`mi svyset ...`	see [SVY] **svyset**
`mi stset ...`	see [ST] **stset**
`mi streset ...`	
`mi st ...`	
`mi tsset ...`	see [TS] **tsset**
`mi xtset ...`	see [XT] **xtset**

Remarks and examples

If you have set your data with any of the above commands before you `mi set` them, there is no problem; the settings were automatically imported. Once you `mi set` your data, however, you will discover that Stata's other set commands no longer work. For instance, here is the result of typing `stset` on an `mi set` dataset:

```
. stset ...
no; data are mi set
    Use mi stset to set or query these data; mi stset has the same
    syntax as stset.
    Perhaps you did not type stset.  Some commands call stset to obtain
    information about the settings.  In that case, that command is not appropriate
    for running directly on mi data.  Use mi extract to select the data on which
    you want to run the command, which is probably m=0.
r(119);
```

Also, you might sometimes see an error like the one above when you give a command that depends on the data being set by one of Stata's other set commands. In general, it is odd that you would be running such a command directly on `mi` data because what you will get will depend on the `mi` style of data. Perhaps, however, you are using `mi` wide data, where the structure of the data more or less corresponds to the structure of non-`mi` data, or perhaps you have smartly specified the appropriate `if` statement to account for the `mi` style of data you are using. In any case, the result might be

```
. some_other_command
no; data are mi set
    Use mi XXXset to set or query these data; mi XXXset has the same syntax as
    XXXset.

    Perhaps you did not type stset.  Some commands call stset to obtain
    information about the settings.  In that case, that command is not appropriate
    for running directly on mi data.  Use mi extract to select the data on which
    you want to run the command, which is probably m=0.
r(119);
```

Substitute one of the set commands listed above for XXXset, and then understand what just happened. You correctly used `mi XXXset` to set your data, you thought your data were set, yet when you tried to use a command that depended on the data being XXXset, you received this error.

If this happens to you, the solution is to use `mi extract` (see [MI] **mi extract**) to obtain the data on which you want to run the command—which is probably $m = 0$, so you would type `mi extract 0`—and then run the command.

Also see

[MI] **Intro** — Introduction to mi

Description Syntax Option Remarks and examples Also see

Description

Many `mi` commands allow the `noupdate` option. This entry describes the purpose of that option.

Syntax

```
mi ... [ , ... noupdate ... ]
```

Option

`noupdate` specifies that the `mi` command in question need not perform an `mi update` because you are certain that there are no inconsistencies that need fixing; see [MI] **mi update**. `noupdate` is taken as a suggestion; `mi update` will still be performed if the command sees evidence that it needs to be. Not specifying the option does not mean that an `mi update` will be performed.

Remarks and examples

Some `mi` commands perform modifications to the data, and those modifications will go very poorly—even to the point of corrupting your data—if certain assumptions about your data are not true. Usually, those assumptions are true, but to be safe, the commands check the assumptions. They do this by calling `mi update`; see [MI] **mi update**. `mi update` checks the assumptions and, if they are not true, corrects the data so that the assumptions are true. `mi update` always reports the data corrections it makes.

All of this reflects an abundance of caution, with the result that some commands spend more time running `mi update` than they spend performing their intended task.

Commands that use `mi update` to verify assumptions have a `noupdate` option. When you specify that option, the command skips checking the assumptions, which is to say it skips calling `mi update`. More correctly, the command skips calling `mi update` if the command sees no obvious evidence that `mi update` needs to be called.

You can make commands run faster by specifying `noupdate`. Should you? Unless you are noticing poor performance, we would say no. It is, however, absolutely safe to specify `noupdate` if the only commands executed since the last `mi update` are `mi` commands. The following would be perfectly safe:

```
. mi update
. mi passive, noupdate: generate agesq = age*age
. mi rename age age_at_admission, noupdate
. mi ...
```

The following would be safe, too:

```
. mi update
. mi passive, noupdate: generate agesq = age*age
. summarize agesq
. mi rename age age_at_admission, noupdate
. mi ...
```

It would be safe because `summarize` is a reporting command that does not change the data; see [R] **summarize**.

The problem `mi` has is that it is not in control of your session and data. Between `mi` commands, `mi` does not know what you have done to the data. The following would not be recommended and has the potential to go very poorly:

```
. mi update
. mi passive, noupdate: generate agesq = age*age
. drop if female
. drop agesq
. mi ..., noupdate          // do not do this
```

By the rules for using `mi`, you should perform an `mi update` yourself after a `drop` command, or any other command that changes the data, but it usually does not matter whether you follow that rule because `mi` will check eventually, when it matters. That is, `mi` will check if you do not specify the `noupdate` option.

The `noupdate` option is recommended for use by programmers in programs that code a sequence of `mi` commands.

Also see

[MI] **Intro** — Introduction to mi

[MI] **mi update** — Ensure that mi data are consistent

Styles — Dataset styles

Description Syntax Remarks and examples Also see

Description

The purpose of this entry is to familiarize you with the four styles in which `mi` data can be stored.

Syntax

There are four dataset styles available for storing `mi` data:

`wide`

`mlong`

`flong`

`flongsep`

Remarks and examples

Remarks are presented under the following headings:

The four styles
Style wide
Style flong
Style mlong
Style flongsep
How we constructed this example
Using mi system variables
Advice for using flongsep

The four styles

We have highly artificial data, which we will first describe verbally and then show to you in each of the styles. The original data have two observations on two variables:

a	b
1	2
4	.

Variable `b` has a missing value. We have two imputed values for `b`, namely, 4.5 and 5.5. There will also be a third variable, `c`, in our dataset, where `c` = `a` + `b`.

Thus, in the jargon of mi, we have $M = 2$ imputations, and the datasets $m = 0$, $m = 1$, and $m = 2$ are

m=0:

a	b	c
1	2	3
4	.	.

m=1:

a	b	c
1	2	3
4	4.5	8.5

m=2:

a	b	c
1	2	3
4	5.5	9.5

Continuing with jargon, a is a regular variable, b is an imputed variable, and c is a passive variable.

Style wide

The above data have been stored in miproto.dta in the wide style.

```
. use https://www.stata-press.com/data/r19/miproto
(mi prototype)
. list
```

	a	b	c	_1_b	_2_b	_1_c	_2_c	_mi_miss
1.	1	2	3	2	2	3	3	0
2.	4	.	.	4.5	5.5	8.5	9.5	1

There is no significance to the order in which the variables appear.

On the left, under variables a, b, and c, you can see the original data.

The imputed values for b appear under the variables named _1_b and _2_b; $m = 1$ appears under _1_b, and $m = 2$ appears under _2_b. Note that in the first observation, the observed value of b is simply repeated in _1_b and _2_b. In the second observation, however, _1_b and _2_b show the replacement values for the missing value of b.

The passive values for c appear under the variables named _1_c and _2_c in the same way that the imputed values appeared under the variables named _1_b and _2_b.

Finally, one extra variable appears: _mi_miss. This is an example of an mi system variable. You are never to change mi system variables; they take care of themselves. The wide style has only one system variable. _mi_miss contains 0 for complete observations and 1 for incomplete observations.

Style flong

Let's convert this dataset to style flong:

```
. mi convert flong, clear
. list, separator(2)
```

	a	b	c	_mi_miss	_mi_m	_mi_id
1.	1	2	3	0	0	1
2.	4	.	.	1	0	2
3.	1	2	3	.	1	1
4.	4	4.5	8.5	.	1	2
5.	1	2	3	.	2	1
6.	4	5.5	9.5	.	2	2

We listed these data with a separator line after every two rows so that they would be easier to understand. Ignore the `mi` system variables and focus on variables `a`, `b`, and `c`. Observations 1 and 2 contain $m = 0$; observations 3 and 4 contain $m = 1$; observations 5 and 6 contain $m = 2$.

We will now explain the system variables, but you do not need to remember this.

1. We again see `_mi_miss`, just as we did in the wide style. It marks the incomplete observations in $m = 0$. It contains missing in $m > 0$.
2. `_mi_m` records m. The first two observations are $m = 0$; the next two, $m = 1$; and the last two, $m = 2$.
3. `_mi_id` records an arbitrarily coded observation-identification variable. It is 1 and 2 in $m = 0$, and then repeats in $m = 1$ and $m = 2$. Observations `_mi_id` $= 1$ correspond to each other for all m. The same applies to `_mi_id` $= 2$.

   Warning: Do not use `_mi_id` as your own ID variable. You might look one time, see that a particular observation has `_mi_id` $= 8$, and look a little later, and see that the observation has changed from `_mi_id` $= 8$ to `_mi_id` $= 5$. `_mi_id` belongs to `mi`. If you want your own ID variable, make your own. All that is true of `_mi_id` is that, at any instant, it uniquely identifies, and ties together, the observations.

There is no significance to the order of the variables or, for that matter, to the order of the observations.

Style mlong

Let's convert this dataset to the mlong style:

```
. mi convert mlong, clear
. list
```

	a	b	c	_mi_miss	_mi_m	_mi_id
1.	1	2	3	0	0	1
2.	4	.	.	1	0	2
3.	4	4.5	8.5	.	1	2
4.	4	5.5	9.5	.	2	2

This listing will be easier to read if we add some carefully chosen blank lines:

	a	b	c	_mi_miss	_mi_m	_mi_id
1.	1	2	3	0	0	1
2.	4	.	.	1	0	2
3.	4	4.5	8.5	.	1	2
4.	4	5.5	9.5	.	2	2

The mlong style is just like flong except that the complete observations—observations for which `_mi_miss` $= 0$ in $m = 0$—are omitted in $m > 0$.

Observations 1 and 2 are the original, $m = 0$ data.

Observation 3 is the $m = 1$ replacement observation for observation 2.

Observation 4 is the $m = 2$ replacement observation for observation 2.

Style flongsep

Let's look at these data in the flongsep style:

```
. mi convert flongsep example, clear
(files example.dta _1_example.dta _2_example.dta created)
. list
```

	a	b	c	_mi_miss	_mi_id
1.	1	2	3	0	1
2.	4	.	.	1	2

The flongsep style stores $m = 0$, $m = 1$, and $m = 2$ in separate files. When we converted to the flongsep style, we had to specify a name for these files, and we chose `example`. This resulted in $m = 0$ being stored in `example.dta`, $m = 1$ being stored in `_1_example.dta`, and $m = 2$ being stored in `_2_example.dta`.

In the listing above, we see the original, $m = 0$ data.

After conversion, $m = 0$ (`example.dta`) was left in memory. When working with flongsep data, you always work with $m = 0$ in memory. Nothing can stop us, however, from taking a brief peek:

```
. save example, replace
file example.dta saved
. use _1_example, clear
(mi prototype)
. list
```

	a	b	c	_mi_id
1.	1	2	3	1
2.	4	4.5	8.5	2

There are the data for $m = 1$. As previously, system variable `_mi_id` ties together observations. In the $m = 1$ data, however, `_mi_miss` is not repeated.

Let's now look at _2_example.dta:

```
. use _2_example, clear
(mi prototype)
. list
```

	a	b	c	_mi_id
1.	1	2	3	1
2.	4	5.5	9.5	2

And there are the data for $m = 2$.

We have an aside, but an important one. Review the commands we just gave, stripped of their output:

```
. mi convert flongsep example, clear
. list
. save example, replace
. use _1_example, clear
. list
. use _2_example, clear
. list
```

What we want you to notice is the line `save example, replace`. After converting to flongsep, for some reason we felt obligated to save the dataset. We will explain below. Now look farther down the history. After using _1_example.dta, we did not feel obligated to resave that dataset before using _2_example.dta. We will explain that below, too.

The flongsep style data are a matched set of datasets. You work with the $m = 0$ dataset in memory. It is your responsibility to save that dataset. Sometimes `mi` will have already saved the dataset for you. That was true here after `mi convert`, but it is impossible for you to know that in general, and it is your responsibility to save the dataset just as you would save any other dataset.

The $m > 0$ datasets, _#_*name*.dta, are `mi`'s responsibility. We do not have to concern ourselves with saving them. Obviously, it was not necessary to save them here because we had just used the data and made no changes. The point is that, in general, the $m > 0$ datasets are not our responsibility. The $m = 0$ dataset, however, is our responsibility.

We are done with the demonstration:

```
. drop _all
. mi erase example
```

How we constructed this example

You might be curious as to how we constructed miproto.dta. Here is what we did:

```
. drop _all
. input a b
              a          b
  1. 1 2
  2. 4 .
  3. end
. mi set wide
. mi set M = 2
(2 imputations added; M = 2)
```

```
. mi register regular a
. mi register imputed b
. replace _1_b = 4.5 in 2
(1 real change made)
. replace _2_b = 5.5 in 2
(1 real change made)
. mi passive: generate c = a + b
m=0:
(1 missing value generated)
m=1:
m=2:
. order a b c _1_b _2_b _1_c _2_c _mi_miss
```

Using mi system variables

You can use `mi`'s system variables to make some tasks easier. For instance, if you wanted to know the overall number of complete and incomplete observations, you could type

```
. tabulate _mi_miss
```

because in all styles, the `_mi_miss` variable is created in $m = 0$ containing 0 if complete and 1 if incomplete.

If you wanted to know the summary statistics for `weight` in $m = 1$, the general solution is

```
. mi xeq 1: summarize weight
```

If you were using wide data, however, you could instead type

```
. summarize _1_weight
```

If you were using flong data, you could type

```
. summarize weight if _mi_m==1
```

If you were using mlong data, you could type

```
. summarize weight if (_mi_m==0 & !_mi_miss) | _mi_m==1
```

Well, that last is not so convenient.

What is convenient to do directly depends on the style you are using. Remember, however, you can always switch between styles by using `mi convert` (see [MI] **mi convert**). If you were using mlong data and wanted to compare summary statistics of the `weight` variable in the original data and in all imputations, you could type

```
. mi convert wide
. summarize *weight
```

Advice for using flongsep

Use the flongsep style when your data are too big to fit into any of the other styles. If you already have flongsep data, you can try to convert it to another style. If you get the error "no room to add more observations" or "no room to add more variables", then you need to increase the amount of memory Stata is allowed to use (see [D] **memory**) or resign yourself to using the flongsep style.

There is nothing wrong with the flongsep style except that you need to learn some new habits. Usually, in Stata, you work with a copy of the data in memory, and the changes you make are not reflected in the underlying disk file until and unless you explicitly save the data. If you want to change the name of the data, you merely save them in a file of a different name. None of that is true when working with flongsep data. Flongsep data are a collection of datasets; you work with the one corresponding to $m = 0$ in memory, and `mi` handles keeping the others in sync. As you make changes, the datasets on disk change.

Think of the collection of datasets as having one name. That name is established when the flongsep data are created. There are three ways that can happen. You might start with a non-`mi` dataset in memory and `mi set` it; you might import a dataset into Stata and the result be flongsep; or you might convert another `mi` dataset to flongsep. Here are all the corresponding commands:

```
. mi set flongsep name                    (1)
. mi import flongsep name                 (2)
. mi import nhanes1 name
. mi convert flongsep name                (3)
```

In each command, you specify a name and that name becomes the name of the flongsep dataset collection. In particular, *name*`.dta` becomes $m = 0$, `_1_`*name*`.dta` becomes $m = 1$, `_2_`*name*`.dta` becomes $m = 2$, and so on. You `use` flongsep data by typing `use` *name*, just as you would any other dataset. As we said, you work with $m = 0$ in memory and `mi` handles the rest.

Flongsep data are stored in the current (working) directory. Learn about `pwd` to find out where you are and about `cd` to change that; see [D] **cd**.

As you work with flongsep data, it is your responsibility to `save` *name*`.dta` almost as it would be with any Stata dataset. The difference is that `mi` might and probably has saved *name*`.dta` along the way without mentioning the fact, and `mi` has doubtlessly updated the `_#_`*name*`.dta` datasets, too. Nevertheless, it is still your responsibility to `save` *name*`.dta` when you are done because you do not know whether `mi` has saved *name*`.dta` recently enough. It is not your responsibility to worry about `_#_`*name*`.dta`.

It is a wonderful feature of Stata that you can usually work with a dataset in memory without modifying the original copy on disk except when you intend to update it. It is an unpleasant feature of flongsep that the same is not true. We therefore recommend working with a copy of the data, and `mi` provides an `mi copy` command (see [MI] **mi copy**) for just that purpose:

```
. mi copy newname
```

With flongsep data in memory, when you type `mi copy` *newname*, the current flongsep files are saved in their existing name (this is one case where you are not responsible for saving *name*`.dta`), and then the files are copied to *newname*, meaning that $m = 0$ is copied to *newname*`.dta`, $m = 1$ is copied to `_1_`*newname*`.dta`, and so on. You are now working with the same data, but with the new name *newname*.

As you work, you may reach a point where you would like to save the data collection under *name* and continue working with *newname*. Do the following:

```
. mi copy name, replace
. use newname
```

When you are done for the day, if you want your data saved, do not forget to save them by using `mi copy`. It is also a good idea to erase the flongsep *newname* dataset collection:

```
. mi copy name, replace
. mi erase newname
```

By the way, *name*`.dta`, `_1_`*name*`.dta`, ... are just ordinary Stata datasets. By using general (non-`mi`) Stata commands, you can look at them and even make changes to them. Be careful about doing the latter; see [MI] **Technical**.

See [MI] **mi copy** to learn more about `mi copy`.

Also see

[MI] **Intro** — Introduction to mi

[MI] **mi copy** — Copy mi flongsep data

[MI] **mi erase** — Erase mi datasets

[MI] **Technical** — Details for programmers

Description Remarks and examples Also see

Description

Technical information for programmers who wish to extend `mi` is provided below.

Remarks and examples

Remarks are presented under the following headings:

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Definition of styles
  Style all
  Style wide
  Style mlong
  Style flong
  Style flongsep
  Style flongsep_sub
Adding new commands to mi
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  u_mi_assert_set
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  u_mi_save and u_mi_use
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  u_mi_fixchars
  mata: u_mi_cpchars_get() and mata: u_mi_cpchars_put()
  mata: u_mi_get_mata_instanced_var()
  mata: u_mi_ptrace_*()
How to write other set commands to work with mi

Notation

$M = \#$ of imputations

$m =$ imputation number
  0. original data with missing values
  1. first imputation dataset
  .
  .
  M. last imputation dataset

$N =$ number of observations in $m = 0$

Definition of styles

Style describes how the mi data are stored. There are four styles: wide, mlong, flong, and flongsep.

Style all

Characteristics:

_dta[_mi_marker]	"_mi_ds_1"

Description: _dta[_mi_marker] is set with all styles, including flongsep_sub. The definitions below apply only if "‘_dta[_mi_marker]’" = "_mi_ds_1".

Style wide

Characteristics:

_dta[_mi_style]	"wide"
_dta[_mi_M]	M
_dta[_mi_ivars]	imputed variables; variable list
_dta[_mi_pvars]	passive variables; variable list
_dta[_mi_rvars]	regular variables; variable list
_dta[_mi_update]	time last updated; %tc_value/1000

Variables:

_mi_miss	whether incomplete; 0 or 1
_#_*varname*	*varname* for $m = \#$, defined for each ‘_dta[_mi_ivars]’ and ‘_dta[_mi_pvars]’

Description: $m = 0$, $m = 1$, …, $m = M$ are stored in one dataset with $_N = N$ observations. Each imputed and passive variable has M additional variables associated with it. If variable bp contains the values in $m = 0$, then values for $m = 1$ are contained in variable _1_bp, values for $m = 2$ in _2_bp, and so on. wide stands for *wide*.

Style mlong

Characteristics:

_dta[_mi_style]	"mlong"
_dta[_mi_M]	M
_dta[_mi_N]	N
_dta[_mi_n]	# of observations in marginal
_dta[_mi_ivars]	imputed variables; variable list
_dta[_mi_pvars]	passive variables; variable list
_dta[_mi_rvars]	regular variables; variable list
_dta[_mi_update]	time last updated; %tc_value/1000

Variables:

_mi_m	m; 0, 1, …, M
_mi_id	ID; 1, …, N
_mi_miss	whether incomplete; 0 or 1 if _mi_m = 0, else .

Description: $m = 0$, $m = 1$, …, $m = M$ are stored in one dataset with $_N = N + M \times n$ observations, where n is the number of incomplete observations in $m = 0$. mlong stands for *marginal long*.

Style flong

Characteristics:

_dta[_mi_style]	"flong"
_dta[_mi_M]	M
_dta[_mi_N]	N
_dta[_mi_ivars]	imputed variables; variable list
_dta[_mi_pvars]	passive variables; variable list
_dta[_mi_rvars]	regular variables; variable list
_dta[_mi_update]	time last updated; %tc_value/1000

Variables:

_mi_m	m; 0, 1, …, M
_mi_id	ID; 1, …, N
_mi_miss	whether incomplete; 0 or 1 if _mi_m = 0, else .

Description: $m = 0$, $m = 1, \ldots, m = M$ are stored in one dataset with $_N = N + M \times N$ observations, where N is the number of observations in $m = 0$. flong stands for *full long*.

Style flongsep

Characteristics:

_dta[_mi_style]	"flongsep"
_dta[_mi_name]	*name*
_dta[_mi_M]	M
_dta[_mi_N]	N
_dta[_mi_ivars]	imputed variables; variable list
_dta[_mi_pvars]	passive variables; variable list
_dta[_mi_rvars]	regular variables; variable list
_dta[_mi_update]	time last updated; %tc_value/1000

Variables:

_mi_id	ID; 1, …, N
_mi_miss	whether incomplete; 0 or 1

Description: $m = 0$, $m = 1, \ldots, m = M$ are each separate .dta datasets. If $m = 0$ data are stored in pat.dta, then $m = 1$ data are stored in _1_pat.dta, $m = 2$ in _2_pat.dta, and so on.

The definitions above apply only to $m = 0$, the dataset named '_dta[_mi_name]'.dta. See *Style flongsep_sub* directly below for $m > 0$. flongsep stands for *full long and separate*.

Style flongsep_sub

Characteristics:

_dta[_mi_style]	"flongsep_sub"
_dta[_mi_name]	*name*
_dta[_mi_m]	m; 0, 1, …, M

Variables:

_mi_id	ID; 1, …, N

Description: The description above applies to the _'_dta[_mi_m]'_'_dta[_mi_name]'.dta datasets. There are M such datasets recording $m = 1, \ldots, M$ used by the flongsep style directly above.

Adding new commands to mi

New commands are written in ado. Name the new command `mi_cmd_`*newcmd* and store it in `mi_cmd_`*newcmd*`.ado`. When the user types `mi` *newcmd* ..., `mi_cmd_`*newcmd*`.ado` will be executed.

See *Writing programs for use with mi* of [P] **program properties** for details on how to write estimation commands for use with the `mi estimate` prefix.

Outline for new commands

```
program mi_cmd_newcmd, rclass                                    (1)
        version 19.5      // (or version 19 if you do not have StataNow)

        u_mi_assert_set                                          (2)

        syntax ... [, ... noUPdate ...]                          (3)

        ...

        u_mi_certify_data, acceptable                            (4)

        ...

        if ("`update'"=="") {
                u_mi_certify_data, proper                        (5)
        }

        ...
end
```

Notes:

1. The command may be `rclass`; that is not required. It may be `eclass` instead if you wish.
2. `u_mi_assert_set` verifies that the data are `mi` data; see *u_mi_assert_set* below.
3. If you intend for your command to use `mi update` to update the data before performing its intended task, include a `noupdate` option; see [MI] **noupdate option**. Some commands instead or in addition run `mi update` to perform cleanup after performing their task. Such use does not require a `noupdate` option.
4. `u_mi_certify_data` is the internal routine that performs `mi update`. An update is divided into two parts, called acceptable and proper. All commands should verify that the data are acceptable; see *u_mi_certify_data* below.
5. `u_mi_certify_data, proper` performs the second step of `mi update`; it verifies that acceptable data are proper. Whether you verify properness is up to you, but if you do, you are supposed to include a `noupdate` option to skip running the check.

Utility routines

The only information you absolutely need to know is that already revealed. Using the utility routines described below, however, will simplify your programming task and make your code appear more professional to the end user.

As you read what follows, remember that you may review the source code for the routines by using viewsource; see [P] **viewsource**. If you wanted to see the source for u_mi_assert_set, you would type viewsource u_mi_assert_set.ado. If you do this, you will sometimes see that the routines allow options not documented below. Ignore those options; they may not appear in future releases.

Using viewsource, you may also review examples of the utility commands being used by viewing the source of the mi commands we have written. Each mi command appears in the file mi_cmd_*command*.ado. Also remember that other mi commands make useful utility routines. For instance, if your new command makes passive variables, use mi register to register them. Always call existing mi commands through mi; code mi passive and not mi_cmd_passive.

u_mi_assert_set

u_mi_assert_set [*desired_style*]

This utility verifies that data are mi and optionally of the desired style; it issues the appropriate error message and stops execution if not. The optional argument *desired_style* can be wide, mlong, flong, or flongsep, but is seldom specified. When not specified, any style is allowed.

u_mi_certify_data

u_mi_certify_data [, acceptable proper noupdate sortok]

This command performs mi update. mi update is equivalent to u_mi_certify_data, acceptable proper sortok.

Specify one or both of acceptable and proper. If the noupdate option is specified, then proper is specified. The sortok option specifies that u_mi_certify_data need not spend extra time to preserve and restore the original sort order of the data.

An update is divided into two parts. In the first part, called acceptable, $m = 0$ and the _dta[_mi_*] characteristics are certified. Your program will use the information recorded in those characteristics, and before that information can be trusted, the data must be certified as acceptable. Do not trust any _dta[_mi_*] characteristics until you have run u_mi_certify_data, acceptable.

u_mi_certify_data, proper verifies that data known to be acceptable are proper. In practice, this means that in addition to trusting $m = 0$, you can trust $m > 0$.

Running u_mi_certify_data, acceptable might actually result in the data being certified as proper, although you cannot depend on that. When you run u_mi_certify_data, acceptable and certain problems are observed in $m = 0$, they are fixed in all m, which can lead to other problems being detected, and by the time the whole process is through, the data are proper.

u_mi_no_sys_vars and u_mi_no_wide_vars

u_mi_no_sys_vars "*variable_list*" ["*word*"]

u_mi_no_wide_vars "*variable_list*" ["*word*"]

These routines are for use in parsing user input.

u_mi_no_sys_vars verifies that the specified list of variable names does not include any mi system variables such as _mi_m, _mi_id, _mi_miss, etc.

u_mi_no_wide_vars verifies that the specified list of variable names does not include any style wide $m > 0$ variables of the form _#_*varname*. u_mi_no_wide_vars may be called with any style of data but does nothing if the style is not wide.

Both functions issue appropriate error messages if problems are found. If *word* is specified, the error message will be "*word* may not include …". Otherwise, the error message is "may not specify …".

u_mi_zap_chars

u_mi_zap_chars

u_mi_zap_chars deletes all _dta[_mi_*] characteristics from the data in memory.

u_mi_xeq_on_tmp_flongsep

u_mi_xeq_on_tmp_flongsep [, nopreserve]: *command*

u_mi_xeq_on_tmp_flongsep executes *command* on the data in memory, said data converted to style flongsep, and then converts the flongsep result back to the original style. If the data already are flongsep, a temporary copy is made and, at the end, posted back to the original. Either way, *command* is run on a temporary copy of the data. If anything goes wrong, the user's original data are restored; that is, they are restored unless nopreserve is specified. If *command* completes without error, the flongsep data in memory are converted back to the original style and the original data are discarded.

It is not uncommon to write commands that can deal only with flongsep data, and yet these seem to users as if they work with all styles. That is because the routines use u_mi_xeq_on_tmp_flongsep. They start by allowing any style, but the guts of the routine are written assuming flongsep. mi stjoin is implemented in this way. There are two parts to mi stjoin: mi_cmd_stjoin.ado and mi_sub_stjoin_flongsep.ado. mi_cmd_stjoin.ado ends with

```
u_mi_xeq_on_tmp_flongsep: mi_sub_stjoin_flongsep `if', `options'
```

mi_sub_stjoin_flongsep does all the work, while u_mi_xeq_on_tmp_flongsep handles the issue of converting to flongsep and back again. The mi_sub_stjoin_flongsep subroutine must appear in its own ado-file because u_mi_xeq_on_tmp_flongsep is itself implemented as an ado-file. u_mi_xeq_on_tmp_flongsep would be unable to find the subroutine otherwise.

u_mi_get_flongsep_tmpname

u_mi_get_flongsep_tmpname *macname* : *basename*

u_mi_get_flongsep_tmpname creates a temporary flongsep name based on *basename* and stores it in the local macro *macname*. u_mi_xeq_on_tmp_flongsep, for your information, obtains the temporary name it uses from this routine.

u_mi_get_flongsep_tmpname is seldom used directly because u_mi_xeq_on_tmp_flongsep works well for shifting temporarily into flongsep mode, and u_mi_xeq_on_tmp_flongsep does a lot more than just getting a name under which the data should be temporarily stored. There are instances, however, when one needs to be more involved in the conversion. For examples, see the source mi_cmd_append.ado and mi_cmd_merge.ado. The issue these two routines face is that they need to shift two input datasets to flongsep, then they create a third from them, and that is the only one that needs to be shifted back to the original style. So these two commands handle the conversions themselves using u_mi_get_flongsep_tmpname and mi convert (see [MI] **mi convert**).

For instance, they start with something like

```
u_mi_get_flongsep_tmpname master : __mimaster
```

That creates a temporary name suitable for use with `mi convert` and stores it in `‘master’`. The suggested name is `__mimaster`, but if that name is in use, then `u_mi_get_flongsep_tmpname` will form from it `__mimaster1`, or `__mimaster2`, etc. We recommend that you specify a *basename* that begins with `__mi`, which is to say, two underscores followed by `mi`.

Next you must appreciate that it is your responsibility to eliminate the temporary files. You do that by coding something like

```
...
local origstyle "‘_dta[_mi_style]’"
if ("‘origstyle’"=="flongsep") {
        local origstyle "‘origstyle’ ‘_dta[_mi_name]’"
}
u_mi_get_flongsep_tmpname master : __mimaster
capture {
        quietly mi convert flongsep ‘master’
        ...
        ...
        quietly mi convert ‘origstyle’, clear replace
{
nobreak {
        local rc = _rc
        mata: u_mi_flongsep_erase("‘master’", 0, 0)
        if (‘rc’) {
                exit ‘rc’
        }
}
```

The other thing to note above is our use of `mi convert ‘master’` to convert our data to flongsep under the name `‘master’`. What, you might wonder, happens if our data already is flongsep? A nice feature of `mi convert` is that when run on data that are already flongsep, it performs an `mi copy`; see [MI] **mi copy**.

mata: u_mi_flongsep_erase()

`mata: u_mi_flongsep_erase("`*name*`",` *from* `[ ,` *output* `])`

where

name	*string*; flongsep name
from	#; where to begin erasing
output	0|1; whether to produce output

`mata: u_mi_flongsep_erase()` is the internal version of `mi erase` (see [MI] **mi erase**); use whichever is more convenient.

Input *from* is usually specified as 0 and then `mata: u_mi_flongsep_erase()` erases *name*`.dta`, `_1_`*name*`.dta`, `_2_`*name*`.dta`, and so on. *from* may be specified as a number greater than zero, however, and then erased are `_<`*from*`>_`*name*`.dta`, `_<`*from+1*`>_`*name*`.dta`, `_<`*from+2*`>_`*name*`.dta`, ...

If *output* is 0, no output is produced; otherwise, the erased files are also listed. If *output* is not specified, files are listed.

See `viewsource u_mi.mata` for the source code for this routine.

u_mi_sortback

`u_mi_sortback` *varlist*

`u_mi_sortback` removes dropped variables from *varlist* and sorts the data on the remaining variables. The routine is for dealing with sort-preserve problems when `program` *name*`,` `sortpreserve` is not adequate, such as when the data might be subjected to substantial editing between the preserving of the sort order and the restoring of it. To use `u_mi_sortback`, first record the order of the data:

```
local sortedby : sortedby
tempvar recnum
gen long ‘recnum’ = _n
quietly compress ‘recnum’
```

Later, when you want to restore the sort order, you code

```
u_mi_sortback ‘sortedby’ ‘recnum’
```

u_mi_save and u_mi_use

`u_mi_save` *macname* `:` *filename* [`,` *save_options*]

`u_mi_use` `‘"‘`*macname*`’"’` *filename* [`,` `clear` `nolabel`]

save_options are as described in [D] **save**. `clear` and `nolabel` are as described in [D] **use**. In both commands, *filename* must be specified in quotes if it contains any special characters or blanks.

It is sometimes necessary to save data in a temporary file and reload them later. In such cases, when the data are reloaded, you would like to have the original `c(filename)`, `c(filedate)`, and `c(changed)` restored. `u_mi_save` saves that information in *macname*. `u_mi_use` restores the information from the information saved in *macname*. Note the use of compound quotes around ‘*macname*’ in `u_mi_use`; they are not optional.

mata: u_mi_wide_swapvars()

`mata: u_mi_wide_swapvars(`*m*`,` *tmpvarname*`)`

where

m	#; $1 \leq \# \leq M$
tmpvarname	*string*; name from `tempvar`

This utility is for use with wide data only. For each variable name contained in `_dta[_mi_ivars]` and `_dta[_mi_pvars]`, `mata: u_mi_wide_swapvars()` swaps the contents of *varname* with *_m_varname*. Argument *tmpvarname* must be the name of a temporary variable obtained from command `tempvar`, and the variable must not exist. `mata: u_mi_wide_swapvars()` will use this variable while swapping. See [P] **macro** for more information on `tempvar`.

This function is its own inverse, assuming `_dta[_mi_ivars]` and `_dta[_mi_pvars]` have not changed.

See `viewsource u_mi.mata` for the source code for this routine.

u_mi_fixchars

`u_mi_fixchars` [, `acceptable` `proper`]

`u_mi_fixchars` makes the data and variable characteristics the same in $m = 1, m = 2, \ldots, m = M$ as they are in $m = 0$. The options specify what is already known to be true about the data, that the data are known to be acceptable or known to be proper. If neither is specified, you are stating that you do not know whether the data are even acceptable. That is okay. `u_mi_fixchars` handles performing whatever certification is required. Specifying the options makes `u_mi_fixchars` run faster.

This stabilizing of the characteristics is not about `mi`'s characteristics; that is handled by `u_mi_certify_data`. Other commands of Stata set and use characteristics, while `u_mi_fixchars` ensures that those characteristics are the same across all m.

mata: u_mi_cpchars_get() and mata: u_mi_cpchars_put()

`mata: u_mi_cpchars_get(`*matavar*`)`

`mata: u_mi_cpchars_put(`*matavar*`, {0|1|2})`

where *matavar* is a Mata transmorphic variable. Obtain *matavar* from `u_mi_get_mata_instanced_var()` when using these functions from Stata.

These routines replace the characteristics in one dataset with those of another. They are used to implement `u_mi_fixchars`.

`mata: u_mi_cpchars_get(`*matavar*`)` stores in *matavar* the characteristics of the data in memory. The data in memory remain unchanged.

`mata: u_mi_cpchars_put(`*matavar*`, #)` replaces the characteristics of the data in memory with those previously recorded in *matavar*. The second argument specifies the treatment of `_dta[_mi_*]` characteristics:

0	delete them in the destination data
1	copy them from the source just like any other characteristic
2	retain them as-is from the destination data.

mata: u_mi_get_mata_instanced_var()

`mata: u_mi_get_mata_instanced_var("`*macname*`", "`*basename*`" [ , `*i_value*` ])`

where

macname	name of local macro
basename	suggested name for instanced variable
i_value	initial value for instanced variable

`mata: u_mi_get_mata_instanced_var()` creates a new Mata global variable, initializes it with *i_value* or as a 0×0 real, and places its name in local macro *macname*. Typical usage is

```
local var
capture noisily {
        mata: u_mi_get_mata_instanced_var("var", "myvar")
        ...
        ... use `var' however you wish ...
        ...
}
nobreak {
        local rc = _rc
        capture mata: mata drop `var'
        if (`rc') {
                exit `rc'
        }
}
```

mata: u_mi_ptrace_*()

h = `u_mi_ptrace_open(`"*filename*"`, {"r"|"w"} [, {0|1}])`

`u_mi_ptrace_write_stripes(`*h*`, `*id*`, `*ynames*`, `*xnames*`)`

`u_mi_ptrace_write_iter(`*h*`, `*m*`, `*iter*`, `*B*`, `*V*`)`

`u_mi_ptrace_close(`*h*`)`

`u_mi_ptrace_safeclose(`*h*`)`

The above are Mata functions, where

h, if it is declared, should be declared transmorphic
id is a string scalar
ynames and *xnames* are string scalars
m and *iter* are real scalars
B and *V* are real matrices; *V* must be symmetric

These routines write parameter-trace files; see [MI] **mi ptrace**. The procedure is 1) open the file; 2) write the stripes; 3) repeatedly write iteration information; and 4) close the file.

1. Open the file: *filename* may be specified with or without a file suffix. Specify the second argument as `"w"`. The third argument should be `1` if the file may be replaced when it exists, and `0` otherwise.
2. Write the stripes: Specify *id* as the name of your routine or as `""`; `mi ptrace describe` will show this string as the creator of the file if the string is not `""`. *ynames* and *xnames* are both string scalars containing space-separated names or, possibly, *op.names*.
3. Repeatedly write iteration information: Written are m, the imputation number; *iter*, the iteration number; B, the matrix of coefficients; and V, the variance matrix. B must be $ny \times nx$ and V must be $ny \times ny$ and symmetric, where $nx =$ `length(tokens(`*xnames*`))` and $ny =$ `length(tokens(`*ynames*`))`.

4. Close the file: In Mata, use `u_mi_ptrace_close(`*h*`)`. It is highly recommended that, before step 1, *h* be obtained from inside Stata (not Mata) using `mata: u_mi_get_mata_instanced_var("h", "`*myvar*`")`. If you follow this advice, include a `mata: u_mi_ptrace_safeclose(‘h’)` in the ado-file cleanup code. This will ensure that open files are closed if the user presses *Break* or something else causes your routine to exit before the file is closed. A correctly written program will have two closes, one in Mata and another in the ado-file, although you could omit the one in Mata. See *mata: u_mi_get_mata_instanced_var()* directly above.

Also included in `u_mi_ptrace_*()` are routines to read parameter-trace files. You should not need these routines because users will use Stata command `mi ptrace use` to load the file you have written. If you are interested, however, then type `viewsource u_mi_ptrace.mata`.

How to write other set commands to work with mi

This section concerns the writing of other set commands such as [ST] **stset** or [XT] **xtset**—set commands having nothing to do with `mi`—so that they properly work with `mi`.

The definition of a set command is any command that creates characteristics in the data, and possibly creates variables in the data, that other commands in the suite will subsequently access. Making such set commands work with `mi` is mostly `mi`’s responsibility, but there is a little you need to do to assist `mi`. Before dealing with that, however, write and debug your set command ignoring `mi`. Once that is done, go back and add a few lines to your code. We will pretend your set command is named `mynewset` and your original code looks something like this:

```
program mynewset
    ...
    syntax ... [, ... ]
    ...
end
```

Our goal is to make it so that `mynewset` will not run on `mi` data while simultaneously making it so that `mi` can call it (the user types `mi mynewset`). When the user types `mi mynewset`, `mi` will 1) give `mynewset` a clean, $m = 0$ dataset on which it can run and 2) duplicate whatever `mynewset` does to $m = 0$ on $m = 1$, $m = 2$, …, $m = M$.

To achieve this, modify your code to look like this:

```
program mynewset
    ...
    syntax ... [, ... MI]                                          (1)
    if ("‘mi’"=="") {                                              (2)
            u_mi_not_mi_set "mynewset"
            local checkvars "*"                                    (3)
    }
    else {
            local checkvars "u_mi_check_setvars settime"           (3)
    }
    ...
    ‘checkvars’ ‘varlist’                                          (4)
    ...
end
```

That is,

1. Add the mi option to any options you already have.
2. If the mi option is not specified, execute u_mi_not_mi_set, passing to it the name of your set command. If the data are not mi, then u_mi_not_mi_set will do nothing. If the data are mi, then u_mi_not_mi_set will issue an error telling the user to run mi mynewset.
3. Set new local macro checkvars to * if the mi option is not specified, and otherwise to u_mi_check_setvars. We should mention that the mi option will be specified when mi mynewset calls mynewset.
4. Run ‘checkvars’ on any input variables mynewset uses that must not vary across m. mi does not care about other variables or even about new variables mynewset might create; it cares only about existing variables that should not vary across m.

   Let's understand what "‘checkvars’ *varlist*" does. If the mi option was not specified, the line expands to "* *varlist*", which is a comment, and does nothing. If the mi option was specified, the line expands to "u_mi_check_setvars settime *varlist*". We are calling mi routine u_mi_check_setvars, telling it that we are calling at set time, and passing along *varlist*. u_mi_check_setvars will verify that *varlist* does not contain mi system variables or variables that vary across m. Within mynewset, you may call ‘checkvars’ repeatedly if that is convenient.

You have completed the changes to mynewset. You finally need to write one short program that reads

```
program mi_cmd_mynewset
        version 19.5      // (or version 19 if you do not have StataNow)
        mi_cmd_genericset ‘"mynewset ‘0’"’ "_mynewset_x _mynewset_y"
end
```

In the above, we assume that mynewset might add one or two variables to the data named _mynewset_x and _mynewset_y. List in the second argument all variables mynewset might create. If mynewset never creates new variables, then the program should read

```
program mi_cmd_mynewset
        version 19.5      // (or version 19 if you do not have StataNow)
        mi_cmd_genericset ‘"mynewset ‘0’"’
end
```

You are done.

Also see

[MI] **Intro** — Introduction to mi

Description Remarks and examples Also see

Description

Provided below are suggested workflows for working with original data and for working with data that already have imputations.

Remarks and examples

Remarks are presented under the following headings:

Suggested workflow for original data
Suggested workflow for data that already have imputations
Example

Suggested workflow for original data

By original data, we mean data with missing values for which you do not already have imputations. Your task is to identify the missing values, impute values for them, and perform estimation.

`mi` does not have a fixed order in which you must perform tasks except that you must `mi set` the data first.

1. `mi set` your data; see [MI] **mi set**.

   Set the data to be wide, mlong, flong, or flongsep. Choose flongsep only if your data are bumping up against the constraints of memory. Choose flong or flongsep if you will need super-varying variables.

   Memory is not usually a problem, and super-varying variables are seldom necessary, so we generally start with the data as wide:

   ```
   . use originaldata
   . mi set wide
   ```

   If you need to use flongsep, you also need to specify a name for the flongsep dataset collection. Choose a name different from the current name of the dataset:

   ```
   . use originaldata
   . mi set flongsep newname
   ```

   If the original dataset is `chd.dta`, you might choose `chdm` for *newname*. *newname* does not include the `.dta` suffix. If you choose `chdm`, the data will then be stored in `chdm.dta`, `_1_chdm.dta`, and so on. It is important that you choose a name different from *originaldata* because you do not want your `mi` data to overwrite the original. Stata users are used to working with a copy of the data in memory, meaning that the changes made to the data are not reflected in the `.dta` dataset until the user saves them. With flongsep data, however, changes are made to the `mi .dta` dataset collection as you work. See *Advice for using flongsep* in [MI] **Styles**.

2. Use `mi describe` often; see [MI] **mi describe**.

   `mi describe` will not tell you anything useful yet, but as you set more about the data, `mi describe` will be more informative.

   ```
   . mi describe
   ```

3. Use `mi misstable` to identify missing values; see [MI] **mi misstable**.

   `mi misstable` is the standard `misstable` (see [R] **misstable**) but tailored for `mi` data. Several Stata commands have `mi` variants—become familiar with them. If there is no `mi` variant, then it is generally safe to use the standard command directly, although it may not be appropriate. For instance, typing `misstable` rather than `mi misstable` would produce appropriate results right now, but it would not produce appropriate results later. If `mi` datasets $m = 0$, $m = 1$, …, $m = M$ exist and you run `misstable`, you might end up running the command on a strange combination of the m's. We recommend the wide style because general Stata commands will do what you expect. The same is true for the flongsep style. It is your responsibility to get this right.

   So what is the difference between `mi misstable` and `misstable`? `mi misstable` amounts to `mi xeq 0: misstable, exok`, which is to say it runs on $m = 0$ and specifies the `exok` option so that extended missing values are treated as hard missings.

   In general, you need to become familiar with all the `mi` commands, use the `mi` variant of regular Stata commands whenever one exists, and think twice before using a command without an `mi` prefix. Doing the right thing will become automatic once you gain familiarity with the styles; see [MI] **Styles**.

   To learn about the missing values in your data, type

   ```
   . mi misstable summarize
   ```

4. Use `mi register imputed` to register the variables you wish to impute; see [MI] **mi set**.

   The only variables that `mi` will impute are those registered as `imputed`. You can register variables one at a time or all at once. If you register a variable mistakenly, use `mi unregister` to unregister it.

   ```
   . mi register imputed varname [varname ...]
   ```

5. Use `mi impute` to impute (fill in) the missing values; see [MI] **mi impute**.

   There is a lot to be said here. For instance, in a dataset where variables `age` and `bmi` contain missing, you might type

   ```
   . mi register imputed age bmi
   . mi impute mvn age bmi = attack smokes hsgrad, add(10)
   ```

   `mi impute`'s `add(#)` option specifies the number of imputations to be added. We currently have 0 imputations, so after imputation, we will have 10. We usually start with a small number of imputations and add more later.

6. Use `mi describe` to verify that all missing values are filled in; see [MI] **mi describe**.

   ```
   . mi describe
   ```

   You might also want to use `mi xeq` (see [MI] **mi xeq**) to look at summary statistics in each of the imputation datasets:

   ```
   . mi xeq: summarize
   ```

7. Generate passive variables; see [MI] **mi passive**.

   Passive variables are variables that are functions of imputed variables, such as `lnage` when some values of `age` are imputed. The values of passive variables differ across m just as the values of imputed variables do. The official way to generate imputed values is by using `mi passive`:

   ```
   . mi passive: generate lnage = ln(age)
   ```

   Rather than use the official way, however, we often switch our data to mlong and just generate the passive variables directly:

   ```
   . mi convert mlong
   . generate lnage = ln(age)
   . mi register passive lnage
   ```

   If you work as we do, remember to register any passive variables you create. When you are done, you may `mi convert` your data back to wide, but there is no reason to do that.

8. Use `mi estimate` (see [MI] **mi estimate**) to fit models:

   ```
   . mi estimate: logistic attack smokes age bmi hsgrad
   ```

   You fit your model just as you would ordinarily except that you add `mi estimate:` in front of the command.

To see an example of the advice applied to a simple dataset, see *Example* below.

In theory, you should get your data cleaning and data management out of the way before `mi set`ting your data. In practice that will not happen, so you will want to become familiar with the other `mi` commands. Among the data management commands available are `mi append` (see [MI] **mi append**), `mi merge` (see [MI] **mi merge**), `mi expand` (see [MI] **mi expand**), and `mi reshape` (see [MI] **mi reshape**). If you are working with survival-time data, also see [MI] **mi stsplit**. To `stset` your data, or `svyset`, or `xtset`, see [MI] **mi set** and [MI] **mi XXXset**.

Suggested workflow for data that already have imputations

Data sometimes come with imputations included. The data might be made by another researcher for you or the data might come from an official source. Either way, we will assume that the data are not in Stata format, because if they were, you would just use the data and would type `mi describe`.

`mi` can import officially produced datasets created by the National Health and Nutrition Examination Survey (NHANES) with the `mi import nhanes1` command, and `mi` can import more informally created datasets that are wide-, flong-, or flongsep-like with `mi import wide`, `mi import flong`, or `mi import flongsep`; see [MI] **mi import**.

The required workflow is hardly different from *Suggested workflow for original data*, presented above. The differences are that you will use `mi import` rather than `mi set` and you will skip using `mi impute` to generate the imputations. In this sense, your job is easier.

On the other hand, you need to verify that you have imported your data correctly, and we have a lot to say about that. Basically, after importing, you need to be careful about which `mi` commands you use until you have verified that you have the variables registered correctly. That is discussed in [MI] **mi import**.

Example

We are going to repeat *A simple example* from [MI] **Intro**, but this time we are going to follow the advice given above in *Suggested workflow for original data*.

We have fictional data on 154 patients and want to examine the relationship between binary outcome `attack`, recording heart attacks, and variables `smokes`, `age`, `bmi`, `hsgrad`, and `female`. We will use logistic regression. Below we load our original data and show you a little about it using the standard commands `describe` and `summarize`. We emphasize that `mheart5.dta` is just a standard Stata dataset; it has not been `mi set`.

```
. use https://www.stata-press.com/data/r19/mheart5
(Fictional heart attack data)

. describe
Contains data from https://www.stata-press.com/data/r19/mheart5.dta
 Observations:           154                  Fictional heart attack data
    Variables:             6                  19 Jun 2024 10:50
-------------------------------------------------------------------------------
Variable      Storage   Display    Value
    name         type    format    label      Variable label
-------------------------------------------------------------------------------
attack          byte    %9.0g                 Outcome (heart attack)
smokes          byte    %9.0g                 Current smoker
age             float   %9.0g                 Age, in years
bmi             float   %9.0g                 Body mass index, kg/m^2
female          byte    %9.0g                 Gender
hsgrad          byte    %9.0g                 High school graduate
-------------------------------------------------------------------------------
Sorted by:

. summarize
    Variable |        Obs        Mean    Std. dev.       Min        Max
-------------+---------------------------------------------------------
      attack |        154    .4480519    .4989166         0          1
      smokes |        154    .4155844    .4944304         0          1
         age |        142    56.43324    11.59131   20.73613   83.78423
         bmi |        126    25.23523    4.029325   17.22643   38.24214
      female |        154    .2467532    .4325285         0          1
-------------+---------------------------------------------------------
      hsgrad |        154    .7532468    .4325285         0          1
```

The first guideline is

1. `mi set` your data; see [MI] **mi set**.

We will set the data to be flong even though in *A simple example* we set the data to be mlong. `mi` provides four styles—flong, mlong, wide, and flongsep—and at this point it does not matter which we choose. `mi` commands work the same way regardless of style. Four styles are provided because, should we decide to step outside of `mi` and attack the data with standard Stata commands, we will find different styles more convenient depending on what we want to do. It is easy to switch styles.

Below we type `mi set flong` and then, to show you what that command did to the data, we show you the output from a standard `describe`:

```
. mi set flong
. describe
Contains data from https://www.stata-press.com/data/r19/mheart5.dta
 Observations:           154                  Fictional heart attack data
    Variables:             9                  19 Jun 2024 10:50
-------------------------------------------------------------------------------
Variable      Storage   Display    Value
    name         type    format    label      Variable label
-------------------------------------------------------------------------------
attack          byte    %9.0g                 Outcome (heart attack)
smokes          byte    %9.0g                 Current smoker
age             float   %9.0g                 Age, in years
bmi             float   %9.0g                 Body mass index, kg/m^2
female          byte    %9.0g                 Gender
hsgrad          byte    %9.0g                 High school graduate
_mi_miss        byte    %8.0g                 Incomplete observation
_mi_m           int     %8.0g                 Imputation number
_mi_id          int     %8.0g                 Observation ID
-------------------------------------------------------------------------------
Sorted by:
```

Typing `mi set flong` added three variables to our data: `_mi_miss`, `_mi_m`, and `_mi_id`. Those variables belong to `mi`. If you are curious about them, see [MI] **Styles**. Advanced users can even use them. No matter how advanced you are, however, you must never change their contents.

Except for the three added variables, the data are unchanged, and we would see that if we typed `summarize`. The three added variables are due to the style we chose. When you `mi set` your data, different styles will change the data differently, but the changes will be just around the edges.

The second guideline is

2. Use `mi describe` often; see [MI] **mi describe**.

The guideline is to use `mi describe`, not `describe` as we just did. Here is the result:

```
. mi describe
Style: flong
       last mi update 04mar2025 08:52:52, 0 seconds ago
Observations:
   Complete          154
   Incomplete          0  (M = 0 imputations)
   ------------------------
   Total             154
Variables:
   Imputed: 0
   Passive: 0
   Regular: 0
   System:  3; _mi_m _mi_id _mi_miss
   (there are 6 unregistered variables)
```

As the guideline warned us, "`mi describe` will not tell you anything useful yet."

The third guideline is

3. Use `mi misstable` to identify missing values; see [MI] **mi misstable**.

Below we type `mi misstable summarize` and `mi misstable nested`:

```
. mi misstable summarize
```

				Obs<.		
Variable	Obs=.	Obs>.	Obs<.	Unique values	Min	Max
age	12		142	142	20.73613	83.78423
bmi	28		126	126	17.22643	38.24214

```
. mi misstable nested
    1.  age(12) -> bmi(28)
```

`mi misstable summarize` reports the variables containing missing values. Those variables in our data are `age` and `bmi`. Notice that `mi misstable summarize` draws a distinction between, as it puts it, "Obs=." and "Obs>.", which is to say between standard missing (`.`) and extended missing (`.a`, `.b`, ..., `.z`). That is because `mi` has a concept of soft and hard missing, and it associates soft missing with system missing and hard missing with extended missing. Hard missing values—extended missings—are taken to mean missing values that are not to be imputed. Our data have no missing values like that.

After typing `mi misstable summarize`, we typed `mi misstable nested` because we were curious whether the missing values were nested or, to use the jargon, monotone. We discovered that they were. That is, `age` has 12 missing values in the data, and in every observation in which `age` is missing, so is `bmi`, although `bmi` has another 16 missing values scattered around the data. That means we can use a monotone imputation method, and that is good news because monotone methods are more flexible and faster. We will discuss the implications of that shortly. There is a mechanical detail we must handle first.

The fourth guideline is

4. Use `mi register imputed` to register the variables you wish to impute; see [MI] **mi set**.

We know that `age` and `bmi` have missing values, and before we can impute replacements for those missing values, we must register the variables as to-be-imputed, which we do by typing

```
. mi register imputed age bmi
(28 m=0 obs now marked as incomplete)
```

Guideline 2 suggested that we type `mi describe` often. Perhaps now would be a good time:

```
. mi describe
Style: flong
       last mi update 04mar2025 08:52:52, 0 seconds ago
Observations:
   Complete          126
   Incomplete         28  (M = 0 imputations)
   ------------------------
   Total             154
Variables:
   Imputed: 2; age(12) bmi(28)
   Passive: 0
   Regular: 0
   System:  3; _mi_m _mi_id _mi_miss
   (there are 4 unregistered variables; attack smokes female hsgrad)
```

The output has indeed changed. mi knows just as it did before that we have 154 observations, and it now knows that 126 of them are complete and 28 of them are incomplete. It also knows that age and bmi are to be imputed. The numbers in parentheses are the number of missing values.

The fifth guideline is

5. Use mi impute to impute (fill in) the missing values; see [MI] **mi impute**.

In *A simple example* from [MI] **Intro**, we imputed values for age and bmi by typing

```
. mi impute mvn age bmi = attack smokes hsgrad female, add(10)
```

This time, we will impute values by typing

```
. mi impute monotone (regress) age bmi = attack smokes hsgrad female, add(20)
```

We changed add(10) to add(20) for no other reason than to show that we could, although we admit to a preference for more imputations whenever possible. add() specifies the number of imputations to be added to the data. For every missing value, we will impute 20 nonmissing replacements.

We switched from mi impute mvn to mi impute monotone because our data are monotone. Here mi impute monotone will be faster than mi impute mvn but will offer no statistical advantage. In other cases, there might be statistical advantages. All of which is to say that when you get to the imputation step, you have important decisions to make and you need to become knowledgeable about the subject. You can start by reading [MI] **mi impute**.

```
. set seed 20039
. mi impute monotone (regress) age bmi = attack smokes hsgrad female, add(20)
Conditional models:
               age: regress age attack smokes hsgrad female
               bmi: regress bmi age attack smokes hsgrad female

Multivariate imputation                     Imputations =       20
Monotone method                                    added =       20
Imputed: m=1 through m=20                        updated =        0
               age: linear regression
               bmi: linear regression
```

	Observations per *m*			
Variable	Complete	Incomplete	Imputed	Total
age	142	12	12	154
bmi	126	28	28	154

```
(Complete + Incomplete = Total; Imputed is the minimum across m
 of the number of filled-in observations.)
```

Note that we typed set seed 20039 before issuing the mi impute command. Doing that made our results reproducible. We could have specified mi impute's rseed(20039) option instead. Or we could have skipped setting the random-number seed altogether, and then we would not be able to reproduce our results.

The sixth guideline is

6. Use mi describe to verify that all missing values are filled in; see [MI] **mi describe**.

```
. mi describe, detail
Style: flong
       last mi update 04mar2025 08:52:53, 0 seconds ago
Observations:
   Complete           126
   Incomplete          28  (M = 20 imputations)
   ----------------------
   Total              154
Variables:
   Imputed: 2; age(12; 20*0) bmi(28; 20*0)
   Passive: 0
   Regular: 0
   System:  3; _mi_m _mi_id _mi_miss
   (there are 4 unregistered variables; attack smokes female hsgrad)
```

This time, we specified `mi describe`'s `detail` option, although you have to look closely at the output to see the effect. When you do not specify `detail`, `mi describe` reports results for the original, unimputed data only, what we call $m = 0$ throughout this documentation. When you specify `detail`, `mi describe` also includes information about the imputation data, what we call $m > 0$ and is $m = 1$, $m = 2, \ldots, m = 20$ here. Previously, `mi describe` reported "age(12)", meaning that `age` in $m = 0$ has 12 missing values. This time, it reports "age(12; 20*0)", meaning that `age` still has 12 missing values in $m = 0$, and it has 0 missing values in the 20 imputations. `bmi` also has 0 missing values in the imputations. Success!

Let's take a detour to see how our data really look. Let's type Stata's standard `describe` command. The last time we looked, our data had three extra variables.

```
. describe
Contains data from https://www.stata-press.com/data/r19/mheart5.dta
 Observations:         3,234                  Fictional heart attack data
    Variables:             9                  4 Mar 2025 08:52
-------------------------------------------------------------------------------
Variable      Storage   Display    Value
    name         type    format    label      Variable label
-------------------------------------------------------------------------------
attack          byte    %9.0g                 Outcome (heart attack)
smokes          byte    %9.0g                 Current smoker
age             float   %9.0g                 Age, in years
bmi             float   %9.0g                 Body mass index, kg/m^2
female          byte    %9.0g                 Gender
hsgrad          byte    %9.0g                 High school graduate
_mi_id          int     %8.0g                 Observation ID
_mi_miss        byte    %8.0g
_mi_m           int     %8.0g
-------------------------------------------------------------------------------
Sorted by: _mi_m  _mi_id
     Note: Dataset has changed since last saved.
```

Nothing has changed as far as variables are concerned, but notice the number of observations. Previously, we had 154 observations. Now we have 3,234! That works out to 21*154. Stored is our original data plus 20 imputations. The flong style makes extra copies of the data.

We chose style flong only because it is so easy to explain. In *A simple example* from [MI] **Intro** using this same data, we choose style mlong. It is not too late:

```
. mi convert mlong
```

All that is required to change styles is typing `mi convert`. The style of the data changes, but not the contents. Let's see what `describe` has to report:

```
. describe
Contains data from https://www.stata-press.com/data/r19/mheart5.dta
 Observations:           714                  Fictional heart attack data
    Variables:             9                  4 Mar 2025 08:52
-------------------------------------------------------------------------------
Variable      Storage   Display    Value
    name         type    format    label      Variable label
-------------------------------------------------------------------------------
attack          byte    %9.0g                 Outcome (heart attack)
smokes          byte    %9.0g                 Current smoker
age             float   %9.0g                 Age, in years
bmi             float   %9.0g                 Body mass index, kg/m^2
female          byte    %9.0g                 Gender
hsgrad          byte    %9.0g                 High school graduate
_mi_id          int     %8.0g                 Observation ID
_mi_miss        byte    %8.0g
_mi_m           int     %8.0g
-------------------------------------------------------------------------------
Sorted by: _mi_m  _mi_id
     Note: Dataset has changed since last saved.
```

The data look much like they did when they were flong, except that the number of observations has fallen from 3,234 to 714! Style mlong is an efficient style in that rather than storing the full data for every imputation, it stores only the changes. Back when the data were flong, `mi describe` reported that we had 28 incomplete observations. We get 714 from the 154 original observations plus 20×28 replacement observations for the incomplete observations.

We recommend style mlong. Style wide is also recommended. Below we type `mi convert` to convert our mlong data to wide, and then we run the standard `describe` command:

```
. mi convert wide, clear
. describe
Contains data from https://www.stata-press.com/data/r19/mheart5.dta
 Observations:           154                  Fictional heart attack data
    Variables:            47                  4 Mar 2025 08:52
-------------------------------------------------------------------------------
Variable      Storage   Display    Value
    name         type    format    label      Variable label
-------------------------------------------------------------------------------
attack          byte    %9.0g                 Outcome (heart attack)
smokes          byte    %9.0g                 Current smoker
age             float   %9.0g                 Age, in years
bmi             float   %9.0g                 Body mass index, kg/m^2
female          byte    %9.0g                 Gender
hsgrad          byte    %9.0g                 High school graduate
_mi_miss        byte    %8.0g
_1_age          float   %9.0g                 Age, in years
_1_bmi          float   %9.0g                 Body mass index, kg/m^2
_2_age          float   %9.0g                 Age, in years
_2_bmi          float   %9.0g                 Body mass index, kg/m^2
  (output omitted)
_20_age         float   %9.0g                 Age, in years
_20_bmi         float   %9.0g                 Body mass index, kg/m^2
-------------------------------------------------------------------------------
Sorted by:
     Note: Dataset has changed since last saved.
```

In the wide style, our data are back to having 154 observations, but now we have 47 variables! Variable _1_age contains age for $m = 1$, _1_bmi contains bmi for $m = 1$, _2_age contains age for $m = 2$, and so on.

Guideline 7 is

7. Generate passive variables.

Passive variables are variables derived from imputed variables. For instance, if we needed lnage $=$ ln(age), variable lnage would be passive. Passive variables are easy to create; see [MI] **mi passive**. We are not going to need any passive variables in this example.

Guideline 8 is

8. Use mi estimate to fit models; see [MI] **mi estimate**.

Our data are wide right now, but that does not matter. We fit our model:

```
. mi estimate: logistic attack smokes age bmi hsgrad female
Multiple-imputation estimates                   Imputations       =         20
Logistic regression                             Number of obs     =        154
                                                Average RVI       =     0.1104
                                                Largest FMI       =     0.3267
DF adjustment:   Large sample                   DF:     min       =     186.13
                                                        avg       =  67,625.01
                                                        max       = 220,747.20
Model F test:       Equal FMI                   F(   5, 6512.5)   =       3.08
Within VCE type:          OIM                   Prob > F          =     0.0089
```

attack	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
smokes	1.171797	.3573997	3.28	0.001	.4712929	1.8723
age	.028737	.0165865	1.73	0.083	-.0038133	.0612873
bmi	.1017045	.0535639	1.90	0.059	-.003966	.2073749
hsgrad	.1501389	.4038092	0.37	0.710	-.6413206	.9415985
female	-.1022359	.4138162	-0.25	0.805	-.9133052	.7088334
_cons	-4.979444	1.829307	-2.72	0.007	-8.580825	-1.378062

Those familiar with the logistic command will be surprised that mi estimate: logistic reported coefficients rather than odds ratios. That is because the estimation command is not logistic using mi estimate, it is mi estimate using logistic. If we wanted to see odds ratios at estimation time, we could have typed

```
. mi estimate, or: logistic ...
```

By the same token, if we wanted to replay results, we would not type logistic, we would type mi estimate:

```
. mi estimate
```

If we wanted to replay results with odds ratios, we would type

```
. mi estimate, or
```

And that concludes the guidelines.

Also see

[MI] **Intro** — Introduction to mi

[MI] **Glossary**

Glossary

arbitrary missing pattern. Any missing-value pattern. Some imputation methods are suitable only when the pattern of missing values is special, such as a monotone-missing pattern. An imputation method suitable for use with an arbitrary missing pattern may be used regardless of the pattern.

augmented regression. Regression performed on the augmented data, the data with a few extra observations with small weights. The data are augmented in a way that prevents perfect prediction, which may arise during estimation of categorical data. See *The issue of perfect prediction during imputation of categorical data* under *Remarks and examples* of [MI] **mi impute**.

burn-between period. The number of iterations between two draws of an MCMC sequence such that these draws may be regarded as independent.

burn-in period. The number of iterations it takes for an MCMC sequence to reach stationarity.

casewise deletion. See *listwise deletion*.

chained equations. See *fully conditional specification*.

complete and incomplete observations. An observation in the $m = 0$ data is said to be complete if no imputed variable in the observation contains soft missing (.). Observations that are not complete are said to be incomplete.

complete data. Data that do not contain any missing values.

complete degrees of freedom. The degrees of freedom that would have been used for inference if the data were complete.

complete DF. See *complete degrees of freedom*.

complete-cases analysis. See *listwise deletion*.

complete-data analysis. The analysis or estimation performed on the complete data, the data for which all values are observed. This term does not refer to analysis or estimation performed on the subset of complete observations. Do not confuse this with completed-data analysis.

completed data. See *imputed data*.

completed-data analysis. The analysis or estimation performed on the made-to-be completed (imputed) data. This term does not refer to analysis or estimation performed on the subset of complete observations.

conditional imputation. Imputation performed using a conditional sample, a restricted part of the sample. Missing values outside the conditional sample are replaced with a conditional constant, the constant value of the imputed variable in the nonmissing observations outside the conditional sample. See *Conditional imputation* under *Remarks and examples* of [MI] **mi impute**.

DA. See *data augmentation*.

data augmentation. An MCMC method used for the imputation of missing data.

EM. See *expectation-maximization algorithm*.

expectation-maximization algorithm. In the context of MI, an iterative procedure for obtaining maximum likelihood or posterior-mode estimates in the presence of missing data.

FCS. See *fully conditional specification*.

flong data. See *style*.

flongsep data. See *style*.

FMI. See *fraction of missing information*.

fraction of missing information. The ratio of information lost due to the missing data to the total information that would be present if there were no missing data.

An equal FMI test is a test under the assumption that FMIs are equal across parameters.

An unrestricted FMI test is a test without the equal FMI assumption.

fully conditional specification. Consider imputation variables $X_1, X_2, \ldots, X_p$. Fully conditional specification of the prediction equation for X_j includes all variables except X_j; that is, variables $\mathbf{X}_{-j} = (X_1, X_2, \ldots, X_{j-1}, X_{j+1}, \ldots, X_p)$.

hard missing and soft missing. A hard missing value is a value of `.a`, `.b`, ..., `.z` in $m = 0$ in an imputed variable. Hard missing values are not replaced in $m > 0$.

A soft missing value is a value of `.` in $m = 0$ in an imputed variable. If an imputed variable contains soft missing, then that value is eligible to be imputed, and perhaps is imputed, in $m > 0$.

Although you can use the terms hard missing and soft missing for passive, regular, and unregistered variables, it has no special significance in terms of how the missing values are treated.

ignorable missing-data mechanism. The missing-data mechanism is said to be ignorable if missing data are missing at random and the parameters of the data model and the parameters of the missing-data mechanism are distinct; that is, the joint distribution of the model and the missing-data parameters can be factorized into two independent marginal distributions of model parameters and of missing-data parameters.

imputed, passive, and regular variables. An imputed variable is a variable that has missing values and for which you have or will have imputations.

A passive variable is a varying variable that is a function of imputed variables or of other passive variables. A passive variable will have missing values in $m = 0$ and varying values for observations in $m > 0$.

A regular variable is a variable that is neither imputed nor passive and that has the same values, whether missing or not, in all m.

Imputed, passive, and regular variables can be registered using the `mi register` command; see [MI] **mi set**. You are required to register imputed variables, and we recommend that you register passive variables. Regular variables can also be registered. See *registered and unregistered variables*.

The names of imputation and passive variables may not exceed 29 characters. In the wide style, the names of these variables may be restricted to less than 29 characters depending on the number of imputations. In the flongsep style, the names of regular variables in addition to the names of imputation and passive variables also may not exceed 29 characters.

imputed data. Data in which all missing values are imputed.

incomplete observations. See *complete and incomplete observations*.

ineligible missing value. An ineligible missing value is a missing value in a to-be-imputed variable that is due to inability to calculate a result rather than an underlying value being unobserved. For instance, assume that variable `income` had some missing values and so you wish to impute it. Because `income` is skewed, you decide to impute the log of income, and you begin by typing

```
. generate lnincome = log(income)
```

If `income` contained any zero values, the corresponding missing values in `lnincome` would be ineligible missing values. To ensure that values are subsequently imputed correctly, it is of vital importance that any ineligible missing values be recorded as hard missing. You would do that by typing

```
. replace lnincome = .a if lnincome==. & income!=.
```

As an aside, if after imputing `lnincome` using `mi impute` (see [MI] **mi impute**), you wanted to fill in `income`, `income` surprisingly would be a passive variable because `lnincome` is the imputed variable and `income` would be derived from it. You would type

```
. mi register passive income
    . mi passive: replace income = cond(lnincome==.a, 0, exp(lnincome))
```

In general, you should avoid using transformations that produce ineligible missing values to avoid the loss of information contained in other variables in the corresponding observations. For example, in the above, for zero values of `income` we could have assigned the log of income, `lnincome`, to be the smallest value that can be stored as `double`, because the logarithm of zero is negative infinity:

```
. generate lnincome = cond(income==0, mindouble(), log(income))
```

This way, all observations for which `income==0` will be used in the imputation model for `lnincome`.

jackknifed standard error. See *Monte Carlo error*.

listwise deletion, **casewise deletion**. Omitting from analysis observations containing missing values.

M, **m**. M is the number of imputations. m refers to a particular imputation, $m = 1, 2, \ldots, M$. In `mi`, $m = 0$ is used to refer to the original data, the data containing the missing values. Thus `mi` data in effect contain $M + 1$ datasets, corresponding to $m = 0$, $m = 1$, …, and $m = M$.

MAR. See *missing at random*.

Markov chain Monte Carlo. A class of methods for simulating random draws from otherwise intractable multivariate distributions. The Markov chain has the desired distribution as its equilibrium distribution.

MCAR. See *missing completely at random*.

MCE. See *Monte Carlo error*.

MCMC. See *Markov chain Monte Carlo*.

mi data. Any data that have been `mi set` (see [MI] **mi set**), whether directly by `mi set` or indirectly by `mi import` (see [MI] **mi import**). The `mi` data might have no imputations (have $M = 0$) and no imputed variables, at least yet, or they might have $M > 0$ and no imputed variables, or vice versa. An `mi` dataset might have $M > 0$ and imputed variables, but the missing values have not yet been replaced with imputed values. Or `mi` data might have $M > 0$ and imputed variables and the missing values of the imputed variables filled in with imputed values.

missing at random. Missing data are said to be missing at random (MAR) if the probability that data are missing does not depend on unobserved data but may depend on observed data. Under MAR, the missing-data values do not contain any additional information given observed data about the missing-data mechanism. Thus the process that causes missing data can be ignored.

missing completely at random. Missing data are said to be missing completely at random (MCAR) if the probability that data are missing does not depend on observed or unobserved data. Under MCAR, the missing data values are a simple random sample of all data values, so any analysis that discards the missing values remains consistent, albeit perhaps inefficient.

missing not at random. Missing data are missing not at random (MNAR) if the probability that data are missing depends on unobserved data. Under MNAR, a missing-data mechanism (the process that causes missing data) must be modeled to obtain valid results.

mlong data. See *style*.

MNAR. See *missing not at random*.

monotone-missing pattern, **monotone missingness**. A special pattern of missing values in which if the variables are ordered from least to most missing, then all observations of a variable contain missing in the observations in which the prior variable contains missing.

Monte Carlo error. Within the multiple-imputation context, a Monte Carlo error is defined as the standard deviation of the multiple-imputation results across repeated runs of the same imputation procedure using the same data. The Monte Carlo error is useful for evaluating the statistical reproducibility of multiple-imputation results. See *Example 6: Monte Carlo error estimates* under *Remarks and examples* of [MI] **mi estimate**.

original data. Original data are the data as originally collected, with missing values in place. In `mi` data, the original data are stored in $m = 0$. The original data can be extracted from `mi` data by using `mi extract`; see [MI] **mi extract**.

passive variable. See *imputed, passive, and regular variables*.

registered and unregistered variables. Variables in `mi` data can be registered as imputed, passive, or regular by using the `mi register` command; see [MI] **mi set**.

You are required to register imputed variables.

You should register passive variables; if your data are style wide, you are required to register them. The `mi passive` command (see [MI] **mi passive**) makes creating passive variables easy, and it automatically registers them for you.

Whether you register regular variables is up to you. Registering them is safer in all styles except wide, where it does not matter. By definition, regular variables should be the same across m. In the long styles, you can unintentionally create variables that vary. If the variable is registered, `mi` will detect and fix your mistakes.

Super-varying variables, which rarely occur and can be stored only in flong and flongsep data, should never be registered.

The registration status of variables is listed by the `mi describe` command; see [MI] **mi describe**.

regular variable. See *imputed, passive, and regular variables*.

relative efficiency. Ratio of variance of a parameter given estimation with finite M to the variance if M were infinite.

relative variance increase. The increase in variance of a parameter estimate due to nonresponse.

RVI. See *relative variance increase*.

style. Style refers to the format in which the `mi` data are stored. There are four styles: flongsep, flong, mlong, and wide. You can ignore styles, except for making an original selection, because all `mi` commands work regardless of style. You will be able to work more efficiently, however, if you understand the details of the style you are using; see [MI] **Styles**. Some tasks are easier in one style than another. You can switch between styles by using the `mi convert` command; see [MI] **mi convert**.

The flongsep style is best avoided unless your data are too big to fit into one of the other styles. In flongsep style, a separate `.dta` set is created for $m = 0$, for $m = 1, \ldots$, and for $m = M$. Flongsep is best avoided because `mi` commands work more slowly with it.

In all the other styles, the $M + 1$ datasets are stored in one `.dta` file. The other styles are both more convenient and more efficient.

The most easily described of these `.dta` styles is flong; however, flong is also best avoided because mlong style is every bit as convenient as flong, and mlong is memorywise more efficient. In flong, each observation in the original data is repeated M times in the `.dta` dataset, once for $m = 1$, again for $m = 2$, and so on. Variable `_mi_m` records m and takes on values 0, 1, 2, …, M. Within each value of m, variable `_mi_id` takes on values 1, 2, …, N and thus connects imputed with original observations.

The mlong style is recommended. It is efficient and easy to use. Mlong is much like flong except that complete observations are not repeated.

Equally recommended is the wide style. In wide, each imputed and passive variable has an additional M variables associated with it, one for the variable's value in $m = 1$, another for its value in $m = 2$, and so on. If an imputed or passive variable is named *vn*, then the values of *vn* in $m = 1$ are stored in variable `_1_`*vn*; the values for $m = 2$, in `_2_`*vn*; and so on.

What makes mlong and wide so convenient? In mlong, there is a one-to-one correspondence of your idea of a variable and Stata's idea of a variable—variable *vn* refers to *vn* for all values of m. In wide, there is a one-to-one correspondence of your idea of an observation and Stata's idea—physical observation 5 is observation 5 in all datasets.

Choose the style that matches the problem at hand. If you want to create new variables or modify existing ones, choose mlong. If you want to drop observations or create new ones, choose wide. You can switch styles with the `mi convert` command; see [MI] **mi convert**.

For instance, if you want to create new variable `ageXexp` equal to `age*exp` and your data are mlong, you can just type `generate ageXexp = age*exp`, and that will work even if `age` and `exp` are imputed, passive, or a mix. Theoretically, the right way to do that is to type `mi passive: generate ageXexp = age*exp`, but concerning variables, if your data are mlong, you can work the usual Stata way.

If you want to drop observation 20 or drop `if sex==2`, if your data are wide, you can just type `drop in 20` or `drop if sex==2`. Here the "right" way to do the problem is to type the `drop` command and then remember to type `mi update` so that `mi` can perform whatever machinations are required to carry out the change throughout $m > 0$; however, in the wide form, there are no machinations required.

super-varying variables. See *varying and super-varying variables*.

unregistered variables. See *registered and unregistered variables*.

varying and super-varying variables. A variable is said to be varying if its values in the incomplete observations differ across m. Imputed and passive variables are varying. Regular variables are nonvarying. Unregistered variables can be either.

Imputed variables are supposed to vary because their incomplete values are filled in with different imputed values, although an imputed variable can be temporarily nonvarying if you have not imputed its values yet. Similarly, passive variables should vary because they are or will be filled in based on values of varying imputed variables.

A variable is said to be super varying if its values in the complete observations differ across m. The existence of super-varying variables is usually an indication of error. It makes no sense for a variable to have different values in, say, $m = 0$ and $m = 2$ in the complete observations—in observations that contain no missing values. That is, it makes no sense unless the values of the variable is a function of the values of other variables across multiple observations. If variable `sumx` is the sum of `x` across observations, and if `x` is imputed, then `sumx` will differ across m in all observations after the first observation in which `x` is imputed.

The `mi varying` command will identify varying and super-varying variables, as well as nonvarying imputed and passive variables. [MI] **mi varying** explains how to fix problems when they are due to error.

Some problems that theoretically could arise cannot arise because `mi` will not let them. For instance, an imputed variable could be super varying and that would obviously be a serious error. Or a regular variable could be varying and that, too, would be a serious error. When you register a variable, `mi` fixes any such problems and, from that point on, watches for problems and fixes them as they arise.

Use `mi register` to register variables; see [MI] **mi set**. You can perform the checks and fixes at any time by running `mi update`; see [MI] **mi update**. Among other things, `mi update` replaces values of regular variables in $m > 0$ with their values from $m = 0$; it replaces values of imputed variables in $m > 0$ with their nonmissing values from $m = 0$; and it replaces values of passive variables in incomplete observations of $m > 0$ with their $m = 0$ values. `mi update` follows a hands-off policy with respect to unregistered variables.

If you need super-varying variables, use flong or flongsep style and do not register the variable. You must use one of the flong styles because in the wide and mlong styles, there is simply no place to store super-varying values.

wide data. See *style*.

WLF. See *worst linear function*.

worst linear function. A linear combination of all parameters being estimated by an iterative procedure that is thought to converge slowly.

Also see

[MI] **Intro** — Introduction to mi

Subject and author index

See the combined subject index and the combined author index in the *Stata Index*.