Title

> **canon postestimation —** Postestimation tools for canon

Postestimation commands

The following postestimation commands are of special interest after `canon`:

Command	Description
estat correlations	show correlation matrices
estat loadings	show loading matrices
estat rotate	rotate raw coefficients, standard coefficients, or loading matrices
estat rotatecompare	compare rotated and unrotated coefficients or loadings
screeplot	plot canonical correlations

The following standard postestimation commands are also available:

Command	Description
estat summarize	summary statistics for the estimation sample
estat vce	variance–covariance matrix of the estimators (VCE)
estimates	cataloging estimation results
etable	table of estimation results
lincom	point estimates, standard errors, testing, and inference for linear combinations of coefficients
nlcom	point estimates, standard errors, testing, and inference for nonlinear combinations of coefficients
predict	linear combinations and their SEs
predictnl	point estimates, standard errors, testing, and inference for generalized predictions
test	Wald tests of simple and composite linear hypotheses
testnl	Wald tests of nonlinear hypotheses

predict

Description for predict

predict creates a new variable containing predictions such as linear combinations and their standard errors.

Menu for predict

Statistics > Postestimation

Syntax for predict

> predict $[$ *type* $]$ *newvar* $[$ *if* $]$ $[$ *in* $]$, *statistic** $[$ correlation(*#*) $]$

*statistic**	Description
Main	
u	calculate linear combination of *varlist*$_1$
v	calculate linear combination of *varlist*$_2$
stdu	calculate standard error of the linear combination of *varlist*$_1$
stdv	calculate standard error of the linear combination of *varlist*$_2$

* There is no default statistic; you must specify one *statistic* from the list.

These statistics are available both in and out of sample; type predict ... if e(sample) ... if wanted only for the estimation sample.

Options for predict

> **Main**

u and v calculate the linear combinations of *varlist*$_1$ and *varlist*$_2$, respectively. For the first canonical correlation, u and v are the linear combinations having maximal correlation. For the second canonical correlation, specified in predict with the correlation(2) option, u and v have maximal correlation subject to the constraints that u is orthogonal to the u from the first canonical correlation, and v is orthogonal to the v from the first canonical correlation. The third and higher correlations are defined similarly. Canonical correlations may be chosen either with the lc() option to canon or by specifying the correlation() option to predict.

stdu and stdv calculate the standard errors of the respective linear combinations.

correlation(*#*) specifies the canonical correlation for which the requested statistic is to be computed. The default is correlation(1). If the lc() option to canon was used to calculate a particular canonical correlation, then only this canonical correlation is in the estimation results. You can obtain estimates for it either by specifying correlation(1) or by omitting the correlation() option.

estat

Description for estat

estat correlations displays the correlation matrices calculated by canon for *varlist*$_1$ and *varlist*$_2$ and between the two lists.

estat loadings displays the canonical loadings computed by canon.

estat rotate performs orthogonal varimax rotation of the raw coefficients, standard coefficients, or canonical loadings. Rotation is calculated on the canonical loadings regardless of which coefficients or loadings are actually rotated.

estat rotatecompare displays the rotated and unrotated coefficients or loadings and the most recently rotated coefficients or loadings. This command may be used only if estat rotate has been performed first.

Menu for estat

Statistics > Postestimation

Syntax for estat

Display the correlation matrices

> estat <u>corr</u>elations [, <u>f</u>ormat(%*fmt*)]

Display the canonical loadings

> estat <u>loa</u>dings [, <u>f</u>ormat(%*fmt*)]

Perform orthogonal varimax rotation

> estat <u>rot</u>ate [, <u>raw</u>coefs <u>std</u>coefs <u>l</u>oadings <u>f</u>ormat(%*fmt*)]

Display the rotated and unrotated coefficients or loadings

> estat <u>rotate</u>compare [, <u>f</u>ormat(%*fmt*)]

collect is allowed with estat correlations, estat loadings, and estat rotate; see [U] **11.1.10 Prefix commands**.

Option for estat

format(%*fmt*) specifies the display format for numbers in matrices; see [D] **format**. format(%8.4f) is the default.

rawcoefs, an option for estat rotate, requests the rotation of raw coefficients. It is the default.

stdcoefs, an option for estat rotate, requests the rotation of standardized coefficients.

loadings, an option for estat rotate, requests the rotation of the canonical loadings.

Remarks and examples   stata.com

In addition to the coefficients presented by `canon` in computing canonical correlations, several
other matrices may be of interest.

▷ Example 1: Predictions

Recall from canon the example of two scientists trying to describe how "big" a car is. One took
physical measurements—the length, weight, headroom, and trunk space—whereas the second took
mechanical measurements—engine displacement, mileage rating, gear ratio, and turning radius. We
discovered that these two views are closely related, with the best linear combination of the two types
of measurements, the largest canonical correlation, at 0.9476. We can prove that the first canonical
correlation is correct by calculating the two linear combinations and then calculating the ordinary
correlation.

```
. use https://www.stata-press.com/data/r18/auto
(1978 automobile data)

. quietly canon (length weight headroom trunk) (displ mpg gear_ratio turn)

. predict physical, u corr(1)

. predict mechanical, v corr(1)

. correlate mechanical physical
(obs=74)

             | mechan~l physical

  mechanical |  1.0000
    physical |  0.9476   1.0000

. drop mechanical physical
```

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▷ Example 2: Canonical loadings

Researchers are often interested in the canonical loadings, the correlations between the original
variable lists and their canonical variates. The canonical loadings are used to interpret the canonical
variates. However, as shown in the technical note later in this entry, Rencher (1988; 1992; 1998,
sec. 8.6.3) and Rencher and Christensen (2012, 397) have shown that there is no information in these
correlations about how one variable list contributes jointly to canonical correlation with the other.
Loadings are still often discussed, and `estat loadings` reports these as well as the cross-loadings
or correlations between *varlist*$_1$ and the canonical variates for *varlist*$_2$ and the correlations between
varlist$_2$ and the canonical variates for *varlist*$_1$. The loadings and cross-loadings are all computed by
`canon`.

```
. estat loadings
```

Canonical loadings for variable list 1

	1	2	3	4
length	0.9664	0.2481	0.0361	-0.0566
weight	0.9972	-0.0606	-0.0367	0.0235
headroom	0.5140	-0.1295	0.7134	-0.4583
trunk	0.6941	0.0644	-0.0209	-0.7167

Canonical loadings for variable list 2

	1	2	3	4
displacement	0.9404	-0.3091	0.1050	0.0947
mpg	-0.8569	-0.1213	0.1741	0.4697
gear_ratio	-0.7945	0.3511	0.4474	-0.2129
turn	0.9142	0.3286	-0.0345	0.2345

Correlation between variable list 1 and canonical variates from list 2

	1	2	3	4
length	0.9158	0.0844	0.0023	-0.0025
weight	0.9449	-0.0206	-0.0023	0.0011
headroom	0.4871	-0.0440	0.0452	-0.0205
trunk	0.6577	0.0219	-0.0013	-0.0320

Correlation between variable list 2 and canonical variates from list 1

	1	2	3	4
displacement	0.8912	-0.1051	0.0067	0.0042
mpg	-0.8120	-0.0413	0.0110	0.0210
gear_ratio	-0.7529	0.1194	0.0284	-0.0095
turn	0.8663	0.1117	-0.0022	0.0105

```
. matrix load2 = r(canload22)
```

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▷ Example 3: Predictions and correlation matrices

In example 2, we saved the loading matrix for *varlist₂*, containing the mechanical variables, and we wish to verify that it is correct. We predict the canonical variates for *varlist₂* and then find the canonical correlations between the canonical variates and the original mechanical variables as a means of getting the correlation matrices, which we then display using `estat correlations`. The mixed correlation matrix is the same as the loading matrix that we saved.

```
. predict mechanical1, v corr(1)
. predict mechanical2, v corr(2)
. predict mechanical3, v corr(3)
. predict mechanical4, v corr(4)
. quietly canon (mechanical1-mechanical4) (displ mpg gear_ratio turn)
. estat correlation
```

Correlations for variable list 1

	mechan~1	mechan~2	mechan~3	mechan~4
mechanical1	1.0000			
mechanical2	-0.0000	1.0000		
mechanical3	-0.0000	0.0000	1.0000	
mechanical4	-0.0000	-0.0000	-0.0000	1.0000

Correlations for variable list 2

	displa~t	mpg	gear_r~o	turn
displacement	1.0000			
mpg	-0.7056	1.0000		
gear_ratio	-0.8289	0.6162	1.0000	
turn	0.7768	-0.7192	-0.6763	1.0000

Correlations between variable lists 1 and 2

	mechan~1	mechan~2	mechan~3	mechan~4
displacement	0.9404	-0.3091	0.1050	0.0947
mpg	-0.8569	-0.1213	0.1741	0.4697
gear_ratio	-0.7945	0.3511	0.4474	-0.2129
turn	0.9142	0.3286	-0.0345	0.2345

```
. matlist load2, format(%8.4f) border(bottom)
```

	1	2	3	4
displacement	0.9404	-0.3091	0.1050	0.0947
mpg	-0.8569	-0.1213	0.1741	0.4697
gear_ratio	-0.7945	0.3511	0.4474	-0.2129
turn	0.9142	0.3286	-0.0345	0.2345

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▷ Example 4: Rotated canonical loadings

Here we observe the results of rotation of the canonical loadings, via the Kaiser varimax method outlined in Cliff and Krus (1976). This observation is often done for interpretation of the results; however, rotation destroys several fundamental properties of canonical correlation.

```
. quietly canon (length weight headroom trunk) (displ mpg gear_ratio turn)
. estat rotate, loadings
```

```
    Criterion          varimax
    Rotation class     orthogonal
    Normalization      none
```

Rotated canonical loadings

	1	2	3	4
length	0.3796	0.7603	0.4579	0.2613
weight	0.6540	0.5991	0.3764	0.2677
headroom	0.0390	0.1442	0.3225	0.9347
trunk	0.1787	0.2052	0.8918	0.3614
displacement	0.7638	0.4424	0.2049	0.4230
mpg	-0.3543	-0.4244	-0.8109	-0.1918
gear_ratio	-0.9156	-0.3060	-0.2292	0.1248
turn	0.3966	0.8846	0.2310	0.0832

Rotation matrix

	1	2	3	4
1	0.5960	0.6359	0.3948	0.2908
2	-0.6821	0.6593	0.1663	-0.2692
3	-0.3213	0.1113	-0.3400	0.8768
4	0.2761	0.3856	-0.8372	-0.2724

```
. estat rotatecompare
```

Rotated canonical loadings —— orthogonal varimax

	1	2	3	4
length	0.3796	0.7603	0.4579	0.2613
weight	0.6540	0.5991	0.3764	0.2677
headroom	0.0390	0.1442	0.3225	0.9347
trunk	0.1787	0.2052	0.8918	0.3614
displacement	0.7638	0.4424	0.2049	0.4230
mpg	-0.3543	-0.4244	-0.8109	-0.1918
gear_ratio	-0.9156	-0.3060	-0.2292	0.1248
turn	0.3966	0.8846	0.2310	0.0832

Unrotated canonical loadings

	1	2	3	4
length	0.9664	0.2481	0.0361	-0.0566
weight	0.9972	-0.0606	-0.0367	0.0235
headroom	0.5140	-0.1295	0.7134	-0.4583
trunk	0.6941	0.0644	-0.0209	-0.7167
displacement	0.9404	-0.3091	0.1050	0.0947
mpg	-0.8569	-0.1213	0.1741	0.4697
gear_ratio	-0.7945	0.3511	0.4474	-0.2129
turn	0.9142	0.3286	-0.0345	0.2345

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❑ Technical note

estat loadings reports the canonical loadings or correlations between a *varlist* and its corresponding canonical variates. It is widely claimed that the loadings provide a more valid interpretation of the canonical variates. Rencher (1988; 1992; 1998, sec. 8.6.3) and Rencher and Christensen (2012, 397) has shown that a weighted sum of the correlations between an $x_j \in varlist_1$ and the canonical variates from $varlist_1$ is equal to the squared multiple correlation between x_j and the variables in $varlist_2$. The correlations do not give new information on the importance of a given variable in the context of the others. Rencher and Christensen (2012, 397) notes, "The researcher who uses these correlations for interpretation is unknowingly reducing the multivariate setting to a univariate one."

❑

Stored results

estat correlations stores the following in r():

Matrices
    r(corr_var1)   correlations for $varlist_1$
    r(corr_var2)   correlations for $varlist_2$
    r(corr_mixed)   correlations between $varlist_1$ and $varlist_2$

estat loadings stores the following in r():

Matrices
    r(canload11)   canonical loadings for $varlist_1$
    r(canload22)   canonical loadings for $varlist_2$
    r(canload21)   correlations between $varlist_2$ and the canonical variates for $varlist_1$
    r(canload12)   correlations between $varlist_1$ and the canonical variates for $varlist_2$

estat rotate stores the following in r():

Macros
    r(coefficients)   coefficients rotated
    r(class)   rotation classification
    r(criterion)   rotation criterion
Matrices
    r(AT)   rotated coefficient matrix
    r(T)   rotation matrix

Methods and formulas

Cliff and Krus (1976) state that they use the Kaiser varimax method with normalization for rotation. The loading matrix, the correlation matrix between the original variables and their canonical variates, is already normalized. Consequently, normalization is not required, nor is it offered as an option.

Rotation after canonical correlation is a subject fraught with controversy. Although some researchers wish to rotate coefficients and loadings for greater interpretability, and Cliff and Krus (1976) have shown that some properties of canonical correlations are preserved by orthogonal rotation, rotation does destroy some of the fundamental properties of canonical correlation. Rencher (1992), Rencher and Christensen (2012), and Thompson (1984) contribute on the topic. Rencher speaks starkly against rotation. Thompson explains why rotation is desired as well as why it is at odds with the principles of canonical correlation analysis.

The researcher is encouraged to consider carefully his or her goals in canonical correlation analysis and these references when evaluating whether rotation is an appropriate tool to use.

Harris (2001) gives an amusing critique on the misuse of canonical loadings in the interpretation of canonical correlation analysis results. As mentioned, Rencher (1988; 1992; 1998, sec. 8.6.3) and Rencher and Christensen (2012, 397) critique the use of canonical loadings.

References

Cliff, N., and D. J. Krus. 1976. Interpretation of canonical analysis: Rotated vs. unrotated solutions. *Psychometrika* 41: 35–42. https://doi.org/10.1007/BF02291696.

Harris, R. J. 2001. *A Primer of Multivariate Statistics*. 3rd ed. Mahwah, NJ: Lawrence Erlbaum.

Rencher, A. C. 1988. On the use of correlations to interpret canonical functions. *Biometrika* 75: 363–365. https://doi.org/10.2307/2336185.

———. 1992. Interpretation of canonical discriminant functions, canonical variates, and principal components. *American Statistician* 46: 217–225. https://doi.org/10.2307/2685219.

———. 1998. *Multivariate Statistical Inference and Applications*. New York: Wiley.

Rencher, A. C., and W. F. Christensen. 2012. *Methods of Multivariate Analysis*. 3rd ed. Hoboken, NJ: Wiley.

Thompson, B. 1984. *Canonical Correlation Analysis: Uses and Interpretation*. Thousand Oaks, CA: Sage.

Also see

[MV] **canon** — Canonical correlations

[MV] **rotatemat** — Orthogonal and oblique rotations of a Stata matrix

[MV] **screeplot** — Scree plot of eigenvalues

[U] **20 Estimation and postestimation commands**