14 Matrix expressions

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14.1 Overview

Stata has two matrix programming languages, one that might be called Stata’s older matrix language and another that is called Mata. Stata’s Mata is the new one, and there is an uneasy relationship between the two.

Below we discuss Stata’s older language and leave the newer one to another manual—the Mata Reference Manual ([M])—or you can learn about the newer one by typing help mata.

We admit that the newer language is better in almost every way than the older language, but the older one still has a use because it is the one that Stata truly and deeply understands. Even when Mata wants to talk to Stata, matrixwise, it is the older language that Mata must use, so you must learn to use the older language as well as the new.

This is not nearly as difficult, or messy, as you might imagine because Stata’s older language is remarkably easy to use, and really, there is not much to learn. Just remember that for heavy-duty programming, it will be worth your time to learn Mata, too.

14.1.1 Definition of a matrix

Stata’s definition of a matrix includes a few details that go beyond the mathematics. To Stata, a matrix is a named entity containing an \( r \times c \) rectangular array of double-precision numbers (including missing values) that is bordered by a row and a column of names. For the dimensions of a matrix, see [R] Limits.
\[ \text{Here we have a } 3 \times 2 \text{ matrix named } A \text{ containing elements 1, 2, 3, 4, 5, and 6. Row 1, column 2 (written } A_{1,2} \text{ in math and } A[1,2] \text{ in Stata) contains 2. The columns are named c1 and c2 and the rows, r1, r2, and r3. These are the default names Stata comes up with when it cannot do better. The names do not play a role in the mathematics, but they are of great help when it comes to labeling the output.} \]

```
. matrix list A
A[3,2]
   c1  c2
  r1  1  2
  r2  3  4
  r3  5  6
```

```
The names are operated on just as the numbers are. For instance,

. matrix B=A'*A
. matrix list B
   symmetric B[2,2]
   c1  c2
   c1  35
   c2  44  56
```

```
We defined \( B = A' A \). The row and column names of \( B \) are the same. Multiplication is defined for any \( a \times b \) and \( b \times c \) matrices, the result being \( a \times c \). Thus the row and column names of the result are the row names of the first matrix and the column names of the second matrix. We formed \( A' A \), using the transpose of \( A \) for the first matrix—which also interchanged the names—and so obtained the names shown.
```

### 14.2 Row and column names

Matrix rows and columns always have names. Stata is smart about setting these names when the matrix is created, and the matrix commands and operators manipulate these names throughout calculations, so the names typically are set correctly at the conclusion of matrix calculations.

For instance, consider the matrix calculation \( b = (X'X)^{-1}X'y \) performed on real data:

```
. use https://www.stata-press.com/data/r16/auto
   (1978 Automobile Data)
. matrix accum XprimeX = weight foreign
   (obs=74)
. matrix vecaccum yprimeX = mpg weight foreign
. matrix b = syminv(XprimeX)*yprimeX'
. matrix list b
   b[3,1]
   mpg -.00658789
   weight -1.6500291
   foreign 41.679702
```

```
These names were produced without our ever having given a special command to place the names on the result. When we formed matrix XprimeX, Stata produced the result
```

```
. matrix list XprimeX
   symmetric XprimeX[3,3]
   weight foreign _cons
   weight 7.188e+08
   foreign 50950 22
   _cons 223440 22 74
```
matrix accum forms $X'X$ matrices from data and sets the row and column names to the variable names used. The names are correct in the sense that, for instance, the (1,1) element is the sum across the observations of squares of weight and the (2,1) element is the sum of the product of weight and foreign.

Similarly, matrix vecaccum forms $y'X$ matrices, and it sets the row and column names to the variable names used, so matrix vecaccum yprimeX = mpg weight foreign resulted in

```
. matrix list yprimeX
yprimeX[1,3]
    weight foreign _cons
    mpg    4493720    545    1576
```

The final step, matrix $b = \text{invsym}(X'X) * yprimeX'$, manipulated the names, and, if you think carefully, you can derive the rules for yourself. invsym() (inversion) is much like transposition, so row and column names must be swapped. Here, however, the matrix was symmetric, so that amounted to leaving the names as they were. Multiplication amounts to taking the column names of the first matrix and the row names of the second. The final result is

```
. matrix list b
b[3,1]
    mpg    weight -.00658789
    foreign -1.6500291
    _cons  41.679702
```

and the interpretation is $\text{mpg} = -0.00659 \text{ weight} - 1.65 \text{ foreign} + 41.68 + e$.

Researchers realized long ago that using matrix notation simplifies the description of complex calculations. What they may not have realized is that, corresponding to each mathematical definition of a matrix operator, there is a definition of the operator’s effect on the names that can be used to carry the names forward through long and complex matrix calculations.

### 14.2.1 The purpose of row and column names

Mostly, matrices in Stata are used in programming estimators, and Stata uses row and column names to produce pretty output. Say that we wrote code—interactively or in a program—that produced the following coefficient vector $b$ and covariance matrix $V$:

```
. matrix list b
b[1,3]
    weight displacement _cons
    y1    -.00656711    .00528078    40.084522
. matrix list V
symmetric V[3,3]
    weight displacement _cons
    weight    1.360e-06
    displacement    -.0000103    .00009741
    _cons    -.00207455    .01188356    4.0808455
```
We could now produce standard estimation output by coding two more lines:

. ereturn post b V
. ereturn display

| Coef. | Std. Err. | z    | P>|z| | [95% Conf. Interval] |
|-------|-----------|-----|------|----------------------|
| weight| -.0065671 | .0011662 | -5.63 | .000 | -.0088529 | -.0042813 |
| displacement | .0052808 | .0098696 | 0.54 | 0.593 | -.0140632 | .0246248 |
| _cons  | 40.08452 | 2.02011 | 19.84 | .000 | 36.12518 | 44.04387 |

Stata’s ereturn command knew to produce this output because of the row and column names on the coefficient vector and variance matrix. Moreover, we usually do nothing special in our code that produces b and V to set the row and column names because, given how matrix names work, they work themselves out.

Also, sometimes row and column names help us detect programming errors. Assume that we wrote code to produce matrices b and V but made a mistake. Sometimes our mistake will result in the wrong row and column names. Rather than the b vector we previously showed you, we might produce

. matrix list b
b[1,3]
weight c2 _cons
y1 -.0065671 42.23 40.084522

If we posted our estimation results now, Stata would refuse because it can tell by the names that there is a problem:

. ereturn post b V
name conflict
r(507);

Understand, however, that Stata follows the standard rules of matrix algebra; the names are just along for the ride. Matrices are summed by position, meaning that a directive to form \( C = A + B \) results in \( C_{11} = A_{11} + B_{11} \), regardless of the names, and it is not an error to sum matrices with different names:

. matrix list a
symmetric a[3,3]
c1 c2 c3
mpg 14419
weight 1221120 1.219e+08
_cons 545 50950 22
. matrix list b
symmetric b[3,3]
c1 c2 c3
displacement 3211055
mpg 227102 22249
_cons 12153 1041 52
. matrix c = a + b
. matrix list c
symmetric c[3,3]
c1 c2 c3
displacement 3225474
mpg 1448222 1.219e+08
_cons 12698 51991 74

Matrix row and column names are used to label output; they do not affect how matrix algebra is performed.
14.2.2 Two-part names

Row and column names have two parts separated by a colon: equation_name:opvarname.

In the examples shown so far, the equation_name has been blank and the opvarnames have been simple variable names without factor-variable or time-series operators. A blank equation_name is typical. Run any single-equation model (such as regress, probit, or logistic), and if you fetch the resulting matrices, you will find that they have row and column names that use only opvarnames.

Those who work with time-series data will find matrices with row and column names of the form opvarname. For time-series variables, opvarname is the variable name prefixed by a time-series operator such as L., D., or L2D.; see [U] 11.4.4 Time-series varlists. For example,

```
. matrix list example1
symmetric example1[3,3]
    L.     rate   _cons
    rate   3.0952534
    _cons -2.8413483
```

We obtained this matrix by running a linear regression on rate and L.rate and then fetching the covariance matrix. Think of the row and column name L.rate no differently from how you think of rate or, in the previous examples, r1, r2, c1, c2, weight, and foreign.

Those who work with factor variables will also find row and column names of the opvarname form. For factor variables, opvarname is any factor-variable construct that references a single virtual indicator variable. For example, 3.group refers to the virtual variable that is 1 when group = 3 and is 0 otherwise. 1.sex#3.group refers to the virtual variable that is 1 when sex = 1 and group = 3 and is 0 otherwise, and 1.sex#c.age refers to the virtual variable that takes on the values of age when sex = 1 and is 0 otherwise. For example,

```
. matrix list example2
symmetric example2[5,5]
    0b. 1. 0b.sex# 1.sex#
        sex  sex  c.age  c.age  _cons
    0b.sex  0
    1.sex  0  7.7785864
0b.sex#c.age  0  .08350827  .00231307
1.sex#c.age  0  -.09705697  5.606e-17  .00223195
    _cons  0  -3.2868185  -.08350827  -2.131e-15  3.2868185
```

1.sex#c.age is a row name and column name just like rate or L.rate in the prior example. For details on factor variables and valid factor-variable constructs see [U] 11.4.3 Factor variables, [U] 26 Working with categorical data and factor variables, [U] 13.9 Indicator values for levels of factor variables, and [U] 20.12 Accessing estimated coefficients.

Factor-variable operators may be combined with the time-series operators L. and F., leading to opvarnames such as 1L.sex (the first lag of the level 1 indicator of sex) and 3L2.group (the second lag of the level 3 indicator of group).
Equation names are used to label partitioned matrices and, in estimation, occur in the context of multiple equations. Here is a matrix with `equation_names` and simple (unoperated) `opvarnames`.

```
. matrix list example3
symmetric example2[5,5]
                        mpg: mpg: mpg: mpg: mpg: mpg:   foreign  displ  _cons  foreign  _cons
    mpg:foreign  1.6483972
    mpg:displ   .004747 .0003876
    mpg:_cons  -1.4266352 -.0905773  2.4341021
weight:foreign -51.208454 -4.665e-19  15.224135  24997.727
weight:_cons  15.224135  2.077e-17  -15.224135  -7431.7565  7431.7565
```

Here is an example with `equation_names` and operated variable names:

```
. matrix list example4
symmetric example3[5,5]
    val:rate     2.2947268
    val:L rate  .00385216 .0000309
    val:_cons  -1.4533912 -.0072726  2.2583357
weight:foreign -163.86684  7.796e-17  49.384526  25351.696
weight:_cons  49.384526 -1.566e-16  -49.384526  -7640.237  7640.237
```

`val:L rate` is a column name, just as, in the previous section, `c2` and `foreign` were column names.

Say that this last matrix is the variance matrix produced by a program we wrote and that our program also produced a coefficient vector, `b`:

```
. matrix list b
b[1,5]
    rate  rate  _cons  foreign  _cons
y1    4.5366753 -.00316923  20.68421 -1008.7968  3324.7059
```

Here is the result of posting and displaying the results:

```
. ereturn post b example4
. ereturn display
```

|        | Coef. | Std. Err. | z     | P>|z| | [95% Conf. Interval] |
|--------|-------|-----------|-------|------|----------------------|
| **val** |       |           |       |      |                      |
| rate    |  4.536675 |  1.514836 |   2.995 | 0.003 | 1.567652 7.505698   |
| L1      | -0.0031692 |  0.0055591 |  -0.570 | 0.569 |  -0.0140648 0.0077264 |
| _cons   |  20.68421 |  1.502776 |   13.764 | 0.000 |  17.7388223.6296 |
| **weight** |       |           |       |      |                      |
| foreign | -1008.797 |  159.2222 |  -6.336 | 0.000 |  -1320.866 -696.7271 |
| _cons   |  3324.706 |   87.40845 |   38.036 | 0.000 |  3153.388 3496.023 |
We have been using *matrix list* to see the row and column names on our matrices because *matrix list* works on all matrices. There is a better way to see the names when we are working with estimation results because estimation results have the same names on the rows and columns of the variance matrix, and those same names are also the column names for the coefficient vector. That better way is the *coeflegend* display option available on almost every estimation command. For example,

```
. use https://www.stata-press.com/data/r16/fvex
(Artificial factor variables' data)
. generate t = _n
. tsset t
(output omitted)
. sureg (y = sex##group) (distance = d.age il2.sex)
(output omitted)
. sureg, coeflegend
```

Seemingly unrelated regression

<table>
<thead>
<tr>
<th>Equation</th>
<th>Obs</th>
<th>Parms</th>
<th>RMSE</th>
<th>&quot;R-sq&quot;</th>
<th>chi2</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>y</td>
<td>2,998</td>
<td>5</td>
<td>20.03657</td>
<td>0.1343</td>
<td>464.08</td>
<td>0.0000</td>
</tr>
<tr>
<td>distance</td>
<td>2,998</td>
<td>2</td>
<td>181.3797</td>
<td>0.0005</td>
<td>0.92</td>
<td>0.6314</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Coef. Legend</th>
</tr>
</thead>
<tbody>
<tr>
<td>y</td>
</tr>
<tr>
<td>sex</td>
</tr>
<tr>
<td>female</td>
</tr>
<tr>
<td>group</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>sex#group</td>
</tr>
<tr>
<td>female#2</td>
</tr>
<tr>
<td>female#3</td>
</tr>
<tr>
<td>_cons</td>
</tr>
</tbody>
</table>

| distance     |
| age          |
| D1.          | .2230927 _b[distance:D.age] |
| L2. sex      |
| female       | 1.300898 _b[distance:1L2.sex] |
| _cons        | 57.96172 _b[distance:_cons] |

We could have used *matrix list e(V)* or *matrix list e(b)* to see the names, but the limited space available to *matrix list* to write the names would have made the names more difficult to read. With *coeflegend*, the names are neatly arrayed in their own Legend column. One difference between *matrix list* and the *coeflegend* option is that *coeflegend* brackets the names with \_b[]. That is because *coeflegend*’s primary use is to show us how to type coefficients in expressions and postestimation commands; see [U] 13.5 Accessing coefficients and standard errors and [U] 20.12 Accessing estimated coefficients. There the \_b[] is required.
14.2.3 Setting row and column names

You reset row and column names by using the `matrix rownames` and `matrix colnames` commands.

Before resetting the names, use `matrix list` to verify that the names are not set correctly; often, they already are. When you enter a matrix by hand, however, the row names are unimaginatively set to `r1, r2, ...`, and the column names to `c1, c2, ...`.

```
. matrix a = (1,2,3\4,5,6)
. matrix list a
a[2,3]
    c1  c2  c3
  r1  1   2   3
  r2  4   5   6
```

Regardless of the current row and column names, `matrix rownames` and `matrix colnames` reset them:

```
. matrix colnames a = foreign alpha _cons
. matrix rownames a = one two
. matrix list a
a[2,3]    
    foreign   alpha   _cons
  one      1       2       3
  two      4       5       6
```

You may set the `operator` as part of the `opvarname`,

```
. matrix colnames a = foreign l.rate _cons
. matrix list a
a[2,3]    
    L. foreign  rate   _cons
  one      1       2       3
  two      4       5       6
```

The names you specify may be any virtual factor-variable indicators, and those names may include the base (b.) and omitted (o.) operators,

```
. matrix colnames b = 0b.sex 2o.arm 1.sex#c.age 1.sex#3.group#2.arm
. matrix list b
b[2,4]  
    1.sex#  0b.  2o.  1.sex#  3/group#   
sex      arm     c.age   2.arm
  one      1       2       3       3
  two      5       6       7       8
```

See [U] 11.4.3 Factor variables for more about factor-variable operators.

You may set equation names:

```
. matrix colnames a = this:foreign this:l.rate that:_cons
. matrix list a
a[2,3]  
    this: this:     that:
    L. foreign     rate   _cons
  one      1       2       3
  two      4       5       6
```

See [P] matrix rownames for more information.
14.2.4 Obtaining row and column names

`matrix list` displays the matrix with its row and column names. In a programming context, you can fetch the row and column names into a macro using

```
local ... : rowfullnames matname
local ... : colfullnames matname
local ... : rownames matname
local ... : colnames matname
local ... : roweq matname
local ... : coleq matname
```

`rowfullnames` and `colfullnames` return the full names (`equation_name:opvarnames`) listed one after the other.

`rownames` and `colnames` omit the equations and return `opvarnames`, listed one after the other.

`roweq` and `coleq` return the equation names, listed one after the other.

See [P] `macro` and [P] `matrix define` for more information.

14.3 Vectors and scalars

Stata does not have vectors as such—they are considered special cases of matrices and are handled by the `matrix` command.

Stata does have scalars, although they are not strictly necessary because they, too, could be handled as special cases. See [P] `scalar` for a description of scalars.

14.4 Inputting matrices by hand

You input matrices using

```
matrix input matname = (...) 
```
or

```
matrix matname = (...) 
```

In either case, you enter the matrices by row. You separate one element from the next by using commas (,) and one row from the next by using backslashes (\). If you omit the word `input`, you are using the expression parser to input the matrix:

```
. matrix a = (1,2\3,4)
. matrix list a
```

```
  a[2,2]      
  c1 c2      
 r1  1  2     
 r2  3  4     
```

This has the advantage that you can use expressions for any of the elements:

```
. matrix b = (1, 2+3/2 \ cos(_pi), _pi)
. matrix list b
```

```
  b[2,2]      c1 c2      
 r1  1  3.5    
 r2 -1  3.1415927 
```

The disadvantage is that the matrix must be small, say, no more than 50 elements.
matrix input has no such restriction, but you may not use subexpressions for the elements:

```
. matrix input c = (1,2\3,4)
. matrix input d = (1, 2+3/2 \ cos(_pi), _pi)
```

invalid syntax
r(198);

Either way, after inputting the matrix, you will probably want to set the row and column names; see [U] 14.2.3 Setting row and column names above.

For small matrices, you may prefer entering them in a dialog box. Launch the dialog box from the menu Data > Matrices, ado language > Input matrix by hand, or by typing db matrix_input. The dialog box is particularly convenient for small symmetric matrices.

### 14.5 Accessing matrices created by Stata commands

Some Stata commands—including all estimation commands—leave behind matrices that you can subsequently use. After executing an estimation command, type `ereturn list` to see what is available:

```
. use https://www.stata-press.com/data/r16/auto
(1978 Automobile Data)
. probit foreign mpg weight
(output omitted)
. ereturn list
```

**Scalars:**

<table>
<thead>
<tr>
<th>Scalar</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>e(rank)</code></td>
<td>3</td>
</tr>
<tr>
<td><code>e(N)</code></td>
<td>74</td>
</tr>
<tr>
<td><code>e(ic)</code></td>
<td>5</td>
</tr>
<tr>
<td><code>e(k)</code></td>
<td>3</td>
</tr>
<tr>
<td><code>e(k_eq)</code></td>
<td>1</td>
</tr>
<tr>
<td><code>e(k_dv)</code></td>
<td>1</td>
</tr>
<tr>
<td><code>e(converged)</code></td>
<td>1</td>
</tr>
<tr>
<td><code>e(rc)</code></td>
<td>0</td>
</tr>
<tr>
<td><code>e(ll)</code></td>
<td>-26.8418900579869</td>
</tr>
<tr>
<td><code>e(ll_0)</code></td>
<td>-45.03320956699139</td>
</tr>
<tr>
<td><code>e(df_m)</code></td>
<td>2</td>
</tr>
<tr>
<td><code>e(chi2)</code></td>
<td>36.3780411023854</td>
</tr>
<tr>
<td><code>e(p)</code></td>
<td>1.26069126402e-08</td>
</tr>
<tr>
<td><code>e(N_cdf)</code></td>
<td>0</td>
</tr>
<tr>
<td><code>e(N_cds)</code></td>
<td>0</td>
</tr>
<tr>
<td><code>e(r2_p)</code></td>
<td>0.4039023807124771</td>
</tr>
</tbody>
</table>

**Macros:**

<table>
<thead>
<tr>
<th>Macro</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>e(cmdline)</code></td>
<td>&quot;probit foreign mpg weight&quot;</td>
</tr>
<tr>
<td><code>e(cmd)</code></td>
<td>&quot;probit&quot;</td>
</tr>
<tr>
<td><code>e(estat_cmd)</code></td>
<td>&quot;probit_estat&quot;</td>
</tr>
<tr>
<td><code>e(predict)</code></td>
<td>&quot;probit_p&quot;</td>
</tr>
<tr>
<td><code>e(marginsok)</code></td>
<td>&quot;default Pr&quot;</td>
</tr>
<tr>
<td><code>e(marginsnotok)</code></td>
<td>&quot;stdp DEviance SCore&quot;</td>
</tr>
<tr>
<td><code>e(title)</code></td>
<td>&quot;Probit regression&quot;</td>
</tr>
<tr>
<td><code>e(chi2type)</code></td>
<td>&quot;LR&quot;</td>
</tr>
<tr>
<td><code>e(opt)</code></td>
<td>&quot;moptimize&quot;</td>
</tr>
<tr>
<td><code>e(vce)</code></td>
<td>&quot;oim&quot;</td>
</tr>
<tr>
<td><code>e(user)</code></td>
<td>&quot;mopt__probit_d2()&quot;</td>
</tr>
<tr>
<td><code>e(ml_method)</code></td>
<td>&quot;d2&quot;</td>
</tr>
<tr>
<td><code>e(technique)</code></td>
<td>&quot;nr&quot;</td>
</tr>
<tr>
<td><code>e(which)</code></td>
<td>&quot;max&quot;</td>
</tr>
<tr>
<td><code>e(properties)</code></td>
<td>&quot;b V&quot;</td>
</tr>
</tbody>
</table>
14 Matrix expressions

matrices:
- \( e(b) \): 1 x 3
- \( e(V) \): 3 x 3
- \( e(mns) \): 1 x 3
- \( e(rules) \): 1 x 4
- \( e(ilog) \): 1 x 20
- \( e(gradient) \): 1 x 3

functions:
- \( e(sample) \)

Most estimation commands leave behind \( e(b) \) (the coefficient vector) and \( e(V) \) (the variance–covariance matrix of the estimator):

```
. matrix list e(b)
e(b)[1,3]
foreign: foreign: foreign:
mpg  weight   _cons
y1  -.10395033 -.00233554  8.275464
```

You can refer to \( e(b) \) and \( e(V) \) in any matrix expression:

```
. matrix myb = e(b)
. matrix list myb
myb[1,3]
foreign: foreign: foreign:
mpg  weight   _cons
y1  -.10395033 -.00233554  8.275464
. matrix c = e(b)*invsym(e(V))*e(b)'
. matrix list c
symmetric c[1,1]
y1   y1  22.440542
```

14.6 Creating matrices by accumulating data

In programming estimators, matrices of the form \( X'X \), \( X'Z \), \( X'WX \), and \( X'WZ \) often occur, where \( X \) and \( Z \) are data matrices. `matrix accum`, `matrix glsaccum`, `matrix vecaccum`, and `matrix opaccum` produce such matrices; see `matrix accum`.

We recommend that you not load the data into a matrix and use the expression parser directly to form such matrices, although see `matrix mkmat` if that is your interest. If that is your interest, be sure to read the technical note at the end of `matrix mkmat`. There is much to recommend learning how to use the `matrix accum` commands.

14.7 Matrix operators

You can create new matrices or replace existing matrices by typing

```
matrix matname = matrix_expression
```

For instance,

```
. matrix A = invsym(R*V*R')
. matrix IAR = I(rowsof(A)) - A*R
. matrix beta = b*IAR' + r*A'
. matrix C = -C'
. matrix D = (A, B \ B', A)
. matrix E = (A+B)*C'
. matrix S = (S+S')/2
```
The following operators are provided:

<table>
<thead>
<tr>
<th>Operator</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unary operators</td>
<td></td>
</tr>
<tr>
<td>negation</td>
<td>-</td>
</tr>
<tr>
<td>transposition</td>
<td>'</td>
</tr>
<tr>
<td>Binary operators</td>
<td></td>
</tr>
<tr>
<td>(lowest precedence)</td>
<td></td>
</tr>
<tr>
<td>row join</td>
<td>\</td>
</tr>
<tr>
<td>column join</td>
<td>,</td>
</tr>
<tr>
<td>addition</td>
<td>+</td>
</tr>
<tr>
<td>subtraction</td>
<td>-</td>
</tr>
<tr>
<td>multiplication</td>
<td>*</td>
</tr>
<tr>
<td>division by scalar</td>
<td>/</td>
</tr>
<tr>
<td>Kronecker product</td>
<td>#</td>
</tr>
<tr>
<td>(highest precedence)</td>
<td></td>
</tr>
</tbody>
</table>

Parentheses may be used to change the order of evaluation.

Note in particular that, and \ are operators; \( (1,2) \) creates a \( 1 \times 2 \) matrix (vector), and \( (A,B) \) creates a \( \text{rows}(A) \times \text{cols}(A) + \text{cols}(B) \) matrix, where \( \text{rows}(A) = \text{rows}(B) \). \( (1\backslash 2) \) creates a \( 2 \times 1 \) matrix (vector), and \( (A\backslash B) \) creates a \( \text{rows}(A) + \text{rows}(B) \times \text{cols}(A) \) matrix, where \( \text{cols}(A) = \text{cols}(B) \). Thus expressions of the form

\[
\text{matrix } R = (A,B) \ast \text{Vinv} \ast (A,B)'
\]

are allowed.

### 14.8 Matrix functions

In addition to the functions listed below, see [P] matrix svd for singular value decomposition, [P] matrix symeigen for eigenvalues and eigenvectors of symmetric matrices, and see [P] matrix eigenvalues for eigenvalues of nonsymmetric matrices. For a full description of the matrix functions, see [FN] Matrix functions.

**Matrix functions returning matrices:**

- `cholesky(M)`
- `corr(M)`
- `diag(v)`
- `get(systemname)`
- `hadamard(M,N)`
- `I(n)`
- `inv(M)`
- `invsym(M)`
- `J(r,c,z)`
- `nullmat(matname)`
- `sweep(M,i)`
- `vec(M)`
- `vecdiag(M)`
- `matuniform(r,c)`

**Matrix functions returning scalars:**

- `coleqnumb(M,s)`
- `colnfreeparms(M)`
- `colnumb(M,s)`
- `colorf(M)`
- `det(M)`
- `diag0cnt(M)`
- `el(M,i,j)`
- `issymmetric(M)`
- `matmissing(M)`
- `mreldif(X,Y)`
- `roweqnumb(M,s)`
- `równfreeparms(M)`
- `rownumb(M,s)`
- `rowsf(M)`
- `trace(M)`
14.9 Subscripting

1. In matrix and scalar expressions, you may refer to $matname[r,c]$, where $r$ and $c$ are scalar expressions, to obtain one element of $matname$ as a scalar.

   Examples:
   
   matrix A = A / A[1,1]  
   generate newvar = oldvar / A[2,2]

2. In matrix expressions, you may refer to $matname[s_r,s_c]$, where $s_r$ and $s_c$ are string expressions, to obtain a submatrix with one element. The element returned is based on searching the row and column names.

   Examples:
   
   matrix B = V["price","price"]  
   generate sdif = dif / sqrt(V["price","price"])

3. In matrix expressions, you may mix these two syntaxes and refer to $matname[r,s_c]$ or to $matname[s_r,c]$.

   Example:
   
   matrix b = b * R[1,"price"]

4. In matrix expressions, you may use $matname[r_1\ldots r_2,c_1\ldots c_2]$ to refer to submatrices; $r_1$, $r_2$, $c_1$, and $c_2$ may be scalar expressions. If $r_2$ evaluates to missing, it is taken as referring to the last row of $matname$; if $c_2$ evaluates to missing, it is taken as referring to the last column of $matname$. Thus $matname[r_1\ldots,c_1\ldots]$ is allowed.

   Examples:
   
   matrix S = Z[1..4, 1..4]  
   matrix R = Z[5..., 5...]

5. In matrix expressions, you may refer to $matname[s_{r_1}\ldots s_{r_2},s_{c_1}\ldots s_{c_2}]$ to refer to submatrices where $s_{r_1}$, $s_{r_2}$, $s_{c_1}$, and $s_{c_2}$, are string expressions. The matrix returned is based on looking up the row and column names.

   If the string evaluates to an equation name only, all the rows or columns for the equation are returned.

   Examples:
   
   matrix S = Z["price".."weight", "price".."weight"]  
   matrix L = D["mpg:price".."mpg:weight", "mpg:price".."mpg:weight"]  
   matrix T1 = C["mpg:", "mpg:"]  
   matrix T2 = C["mpg:", "price:"]

6. In matrix expressions, any of the above syntaxes may be combined.

   Examples:
   
   matrix T1 = C["mpg:", "price:weight".."price:displ"]  
   matrix T2 = C["mpg:", "price:weight"...]  
   matrix T3 = C["mpg:price", 2..5]  
   matrix T4 = C["mpg:price", 2]
7. When defining an element of a matrix, use

\[
\text{matrix matname} [i,j] = \text{expression}
\]

where \( i \) and \( j \) are scalar expressions. The matrix \( \text{matname} \) must already exist.

Example:
\[
\text{matrix A} = J(2,2,0)
\text{matrix A}[1,2] = \text{sqrt}(2)
\]

8. To replace a submatrix within a matrix, use the same syntax. If the expression on the right evaluates to a scalar or \( 1 \times 1 \) matrix, the element is replaced. If it evaluates to a matrix, the submatrix with top-left element at \( (i, j) \) is replaced. The matrix \( \text{matname} \) must already exist.

Example:
\[
\text{matrix A} = J(4,4,0)
\text{matrix A}[2,2] = \text{C}'*\text{C}
\]

14.10 Using matrices in scalar expressions

Scalar expressions are documented as \( \text{exp} \) in the Stata manuals:

\begin{verbatim}
generate newvar = \text{exp} if \text{exp} . . .
replace newvar = \text{exp} if \text{exp} . . .
regress . . . if \text{exp} . . .
if \text{exp} {...}
while \text{exp} {...}
\end{verbatim}

Most importantly, scalar expressions occur in \text{generate} and \text{replace}, in the \text{if exp} qualifier allowed on the end of many commands, and in the \text{if} and \text{while} commands for program control.

You will rarely need to refer to a matrix in any of these situations except when using the \text{if} qualifier and the \text{while} command.

In any case, you may refer to matrices in any of these situations, but the expression cannot require evaluation of matrix expressions returning matrices. Thus you could refer to \text{trace(A)} but not to \text{trace(A+B)}.

It can be difficult to predict when an evaluation of an expression requires evaluating a matrix; even experienced users can be surprised. If you get the error message “matrix operators that return matrices not allowed in this context”, \text{r(509)}, you have encountered such a situation.

The solution is to split the line in two. For instance, you would change

\[
\text{if trace(A+B)}==0 \{
\text{. . .}
\}
\]

to

\[
\text{matrix AplusB} = \text{A+B}
\text{if trace(AplusB)}==0 \{
\text{. . .}
\}
\]

or even to

\[
\text{matrix Trace} = \text{trace(A+B)}
\text{if Trace}[1,1]==0 \{
\text{. . .}
\}
\]
14.11 Reference