GMM Estimation in Stata

Econometrics I

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Outline

Motivation

Stata and GMM

- Stata can compute the GMM estimators for some linear models:
  1. regression with exogenous instruments using `ivregress` (`ivreg`, `ivreg2` for Stata 9)
     - `demand function using` *2SLS*

       ```
       ivreg 2sls q demand_shiftrs (p=supply_shiftrs), vce(robust)
       ```

     - `demand function using` *GMM*

       ```
       ivreg gmm q demand_shiftrs (p=supply_shiftrs)
       ```

     - with heteroskedasticity, the GMM estimator will be more efficient than the 2SLS estimator
  2. `xtabond` for dynamic panel data
- since Stata 11, it is possible to obtain GMM estimates of non-linear models using the gmm command

Using the gmm command

Using the gmm command

- the command gmm estimates parameters by GMM
- you can specify the moment conditions as substitutable expressions
- a substitutable expression in Stata is like any mathematical expression, except that the parameters of the model are enclosed in braces {}
- alternatively, you may use command program to create a program that you can use as an argument
- we are going to focus on examples using substitutable expressions

The syntax of gmm with instruments

- If $E[ze(b)] = 0$ where z is a $q \times 1$ vector of instrumental variables and $e(b)$ is a scalar function of the data and the parameters beta

```
gmm (e(b)) , instruments(z_list) options
```

- by default, it computes the two-step estimator with identity matrix in the first step
- use `onestep` option to get the one-step estimator and `igmm` to get the iterative estimator
- use `vce(robust)` to get sandwich standard errors
- use `winitial(wmtype)` and `wmatrix(witype)` to change weight-matrix computations
- `gmm` admits `if`, `in`, and `weight` qualifiers

More general moment conditions (1)

- in some applications we cannot write the moment conditions as the product of a residual and a list of instruments
- suppose you have two general moment conditions

$$E\left[h_1\left(b\right)\right] = 0$$
$$E\left[h_2\left(b\right)\right] = 0$$

gmm $(h_1(b))$ $(h_2(b))$, igmm

- computes the iterative GMM estimator imposing in the sample the two moment conditions

More general moment conditions (2)

- instruments may vary with error terms

$$E\left[z_1 e_1\left(b\right)\right] = 0$$
$$E\left[z_2 e_2\left(b\right)\right] = 0$$

gmm ($e_1(b)$) ($e_2(b)$) , instruments(1:z_1) instruments(2:z_2) nolog

- this computes the twostep GMM estimator without adding information on the first step
- you can use this syntax to estimate supply and demand functions simultaneously

Several linear examples

Linear regresssion

- Assume that

$$depvar = \beta_0 + \beta_1 x1 + \beta_2 x2 + v$$

  so that $E[v|x1, x2] = 0$
- Then

$$E\left[\left(depvar - \left(\beta_0 + \beta_1 x1 + \beta_2 x2\right)\right)\right] = 0$$
$$E\left[x1\left(depvar - \left(\beta_0 + \beta_1 x1 + \beta_2 x2\right)\right)\right] = 0$$
$$E\left[x2\left(depvar - \left(\beta_0 + \beta_1 x1 + \beta_2 x2\right)\right)\right] = 0$$

- The gmm command:

```
gmm (depvar-x1*{b1}-x2*{b2}-{b3}), instruments(x1 x2) nolog
```

- equivalently (names of the variables will be displayed in the output) and simpler to write:

```
gmm (depvar-{xb:x1 x2}-{b0}), instruments(x1 x2) nolog
```

Estimating OLS with gmm command

```
. regress mpg gear_ratio turn, r

Linear regression                                      Number of obs =      74
                                                       F(  2,    71) =   47.92
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.5483
                                                       Root MSE      =  3.9429

------------------------------------------------------------------------------
             |               Robust
         mpg |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  gear_ratio |   3.032884   1.533061     1.98   0.052     -.023954    6.089721
        turn |  -.7330502   .1204386    -6.09   0.000    -.9731979   -.4929025
       _cons |   41.21801     8.5723     4.81   0.000     24.12533    58.31069
------------------------------------------------------------------------------
```

```
 gmm (mpg - {b1}*gear_ratio - {b2}*turn - {b0}), instruments(gear_ratio turn) nolog

Final GMM criterion Q(b) =  3.48e-32

GMM estimation

Number of parameters =   3
Number of moments    =   3
Initial weight matrix: Unadjusted                     Number of obs   =      74
GMM weight matrix:     Robust

------------------------------------------------------------------------------
             |               Robust
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         /b1 |   3.032884   1.501664     2.02   0.043     .0896757    5.976092
         /b2 |  -.7330502    .117972    -6.21   0.000    -.9642711                  -.5018293
         /b0 |   41.21801   8.396739     4.91   0.000     24.76071    57.67532
------------------------------------------------------------------------------
Instruments for equation 1: gear_ratio turn _cons
```

2SLS and gmm

```
gmm (depvar-{xb:x1 x2}-{b0}), instruments(z1 z2 z3) onestep
```

```
 ivregress 2sls mpg gear_ratio (turn = weight length headroom)

Instrumental variables (2SLS) regression              Number of obs =      74
                                                       Wald chi2(2)  =   90.94
                                                       Prob > chi2   =  0.0000
                                                       R-squared     =  0.4656
                                                       Root MSE      =  4.2007

------------------------------------------------------------------------------
         mpg |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        turn |  -1.246426   .2012157    -6.19   0.000    -1.640801   -.8520502
  gear_ratio |  -.3146499   1.697806    -0.19   0.853    -3.642288    3.012988
       _cons |   71.66502    12.3775     5.79   0.000     47.40556    95.92447
------------------------------------------------------------------------------
Instrumented:  turn
Instruments:   gear_ratio weight length headroom

. gmm (mpg - {b1}*turn - {b2}*gear_ratio - {b0}), instruments(gear_ratio weight length headroom) onestep

Step 1
Iteration 0:   GMM criterion Q(b) =  475.42283
Iteration 1:   GMM criterion Q(b) =  .16100633
Iteration 2:   GMM criterion Q(b) =  .16100633

GMM estimation

Number of parameters =   3
Number of moments    =   5
Initial weight matrix: Unadjusted                     Number of obs   =      74

------------------------------------------------------------------------------
             |               Robust
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         /b1 |  -1.246426   .1970566    -6.33   0.000    -1.632649   -.8602019
         /b2 |  -.3146499   1.863079    -0.17   0.866    -3.966217    3.336917
         /b0 |   71.66502   12.68722     5.65   0.000     46.79853    96.53151
------------------------------------------------------------------------------
Instruments for equation 1: gear_ratio weight length headroom _cons
```

Linear GMM and gmm

```
gmm (depvar-{xb:x1 x2}-{b0}), instruments(z1 z2 z3) wmatrix(robust)
```

```
. ivregress gmm mpg gear_ratio (turn = weight length headroom)

Instrumental variables (GMM) regression               Number of obs =      74
                                                      Wald chi2(2)  =   97.83
                                                      Prob > chi2   =  0.0000
                                                      R-squared     =  0.4769
GMM weight matrix: Robust                             Root MSE      =  4.1559

------------------------------------------------------------------------------
             |               Robust
         mpg |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        turn |  -1.208549   .1882903    -6.42   0.000    -1.577591   -.8395071
  gear_ratio |    .130328    1.75499     0.07   0.941     -3.30939    3.570046
       _cons |   68.89218   12.05955     5.71   0.000     45.25589    92.52847
------------------------------------------------------------------------------
Instrumented:  turn
Instruments:   gear_ratio weight length headroom

. gmm (mpg - {b1}*turn - {b2}*gear_ratio - {b0}), instruments(gear_ratio weight length headroom) wmatrix(robust) nolog

Final GMM criterion Q(b) =  .0074119

GMM estimation

Number of parameters =   3
Number of moments    =   5
Initial weight matrix: Unadjusted                    Number of obs  =      74
GMM weight matrix:     Robust

------------------------------------------------------------------------------
             |               Robust
             |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         /b1 |  -1.208549   .1882903    -6.42   0.000    -1.577591   -.8395071
         /b2 |    .130328    1.75499     0.07   0.941     -3.30939    3.570046
         /b0 |   68.89218   12.05955     5.71   0.000     45.25589    92.52847
------------------------------------------------------------------------------
Instruments for equation 1: gear_ratio weight length headroom _cons
```

Nonlinear GMM

Exponential regression with exogenous regressors

- exponential regression models are frequently encountered in applied work
- they can be used as alternatives to linear regression models on log-transformed dependent variables
- when the dependent variable represents a discrete count variable, they are also known as Poisson regression models

$$E[y|x] = exp(x\beta + \beta_0)$$

- Moment conditions: $E\left[x\left(y - exp\left(x\beta + \beta_0\right)\right)\right] = 0$
- this is equivalent to $E\left[x\left(y - exp\left(x\beta\right) + \gamma\right)\right] = 0$

```
gmm (depvar-exp({xb:x1 x2})+{b0}), instruments(x1 x2) wmatrix(robust)
```

IV Poisson regression and others

- suppose now $E\left[z\left(y - exp\left(x\beta\right) + \gamma\right)\right] = 0$

```
gmm (depvar-exp({xb:x1 x2})+{b0}), instruments(z1 z2 z3) wmatrix(robust)
```

- the structure of the moment conditions for some models is too complicated for the syntax used thus far
- you should in these cases use the moment-evaluator program syntax (see `help gmm`)

Summary

- Stata can compute the GMM estimators for some linear models:
  1. regression with exogenous instruments using `ivregress` (`ivreg`, `ivreg2` for Stata 9)
  2. `xtabond` for dynamic panel data
- since Stata 11, it is possible to obtain GMM estimates of non-linear models using the gmm command