ECO310 - Tutorial 3

Estimating Production Functions

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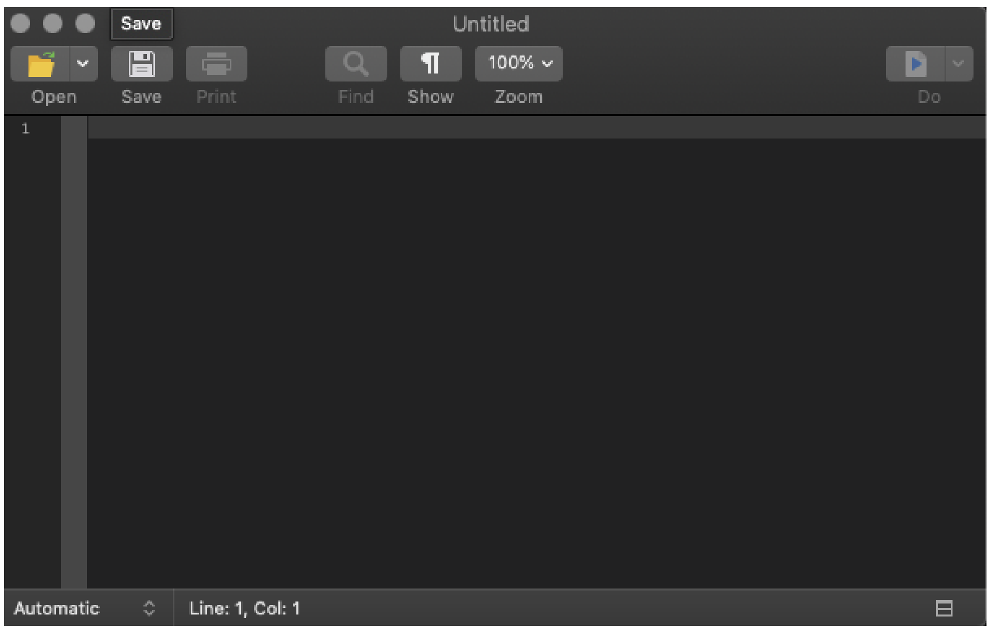
In this tutorial, we will consider the Blundell-Bond (2000) panel dataset, which is available on Quercus under **blundell_bond_2000_production_function.dta**. At any point, if we are unsure about how to use a certain command, we simply type *help command_name* in the Command Window of Stata.

1 Creating a Do-File

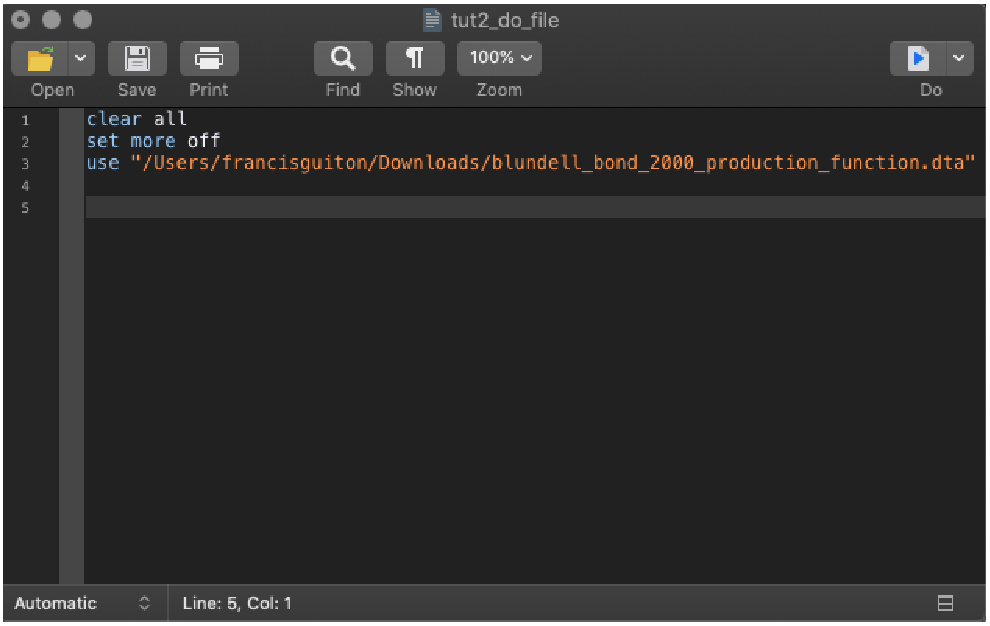
In last week's tutorial, we typed all of our commands in Stata's "Command Window" in succession. This week, we will create a Do-File in which we will write all of the commands we want Stata to execute, and we will save the file to our computer for future reference.

In order to create a Do-File, in Stata we navigate to $File \rightarrow New \rightarrow Do - file$.



In our Do-File window, every line of code that we type will be a command that is executed by Stata. In order to execute a specific line, we highlight our line of code and click on the top right icon *Do*. Alternatively, we can run our whole Do-file by clicking on *Do* without highlighting any lines.

We begin our Do-File by clearing Stata's memory of data with the command *clear all*. In the next line, we can type *set more off* to disable any requests for user interaction when we run the whole Do-File. Next, we will want to load our dataset with the command *use*.



With our Do-File created and our dataset loaded, we will now estimate the production function using various commands that we will input into our Do-File. Note that the dataset we are using is in panel format, with the data being index by *id* and *year*. Therefore, we must tell Stata that our dataset is a panel using the command *xtset*.

```
. xtset id year
       panel variable:  id (strongly balanced)
        time variable:  year, 1982 to 1989
                delta:  1 unit
```

2 Ordinary Least Squares

First, similarly to last week's tutorial, we will begin by creating the logarithms of *sales*, *capital*, and *labor*. The logarithm of sales will be our (dependent) variable of interest in our analysis, while the logarithms of capital and labor will be the main explanatory variables.

Pooled OLS

In order to investigate the relationship between these variables, we run a simple OLS regression of (log) sales against (log) labor and (log) capital.

```
. reg ln_sales ln_labor ln_capital

      Source |       SS           df       MS      Number of obs   =     4,072
-------------+----------------------------------   F(2, 4069)      =  63804.90
       Model |  15942.9273         2  7971.46365   Prob > F        =    0.0000
    Residual |  508.360451     4,069  .124934984   R-squared       =    0.9691
-------------+----------------------------------   Adj R-squared   =    0.9691
       Total |  16451.2878     4,071  4.04109255   Root MSE        =    .35346

------------------------------------------------------------------------------
    ln_sales |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    ln_labor |    .560581   .0096412    58.14   0.000      .541679    .5794829
  ln_capital |   .4298586   .0079525    54.05   0.000     .4142675    .4454498
       _cons |   3.005052   .0293099   102.53   0.000     2.947588    3.062515
------------------------------------------------------------------------------
```

As expected, we obtain positive (and statistically significant) parameter estimates for both labor and capital.

Time Fixed Effects

In order to control for any time effect in our dataset, we will include year fixed effects in our previous regression using *i.year*. This effectively creates year dummy variables that will control for any time trend in our data. Importantly, year 1982 in the regression output below is omitted. This is because Stata by default uses 1982 as the "reference" or "base" year, against which each dummy variable is compared. Therefore, the parameter estimate for each year dummy is to be interpreted as a relative estimate with respect to year 1982.

```
. reg ln_sales ln_labor ln_capital i.year
```

Source	SS	df	MS			
				Number of obs	=	4,072
				F(9, 4062)	=	14254.66
Model	15946.3907	9	1771.82119	Prob > F	=	0.0000
Residual	504.897075	4,062	.124297655	R-squared	=	0.9693
				Adj R-squared	=	0.9692
Total	16451.2878	4,071	4.04109255	Root MSE	=	.35256

ln_sales	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
ln_labor	.5578836	.0098286	56.76	0.000	.5386142	.577153
ln_capital	.4322828	.0081396	53.11	0.000	.4163247	.4482409
year						
1983	-.0568626	.022107	-2.57	0.010	-.1002045	-.0135206
1984	-.050041	.0221342	-2.26	0.024	-.0934362	-.0066458
1985	-.0875714	.0221985	-3.94	0.000	-.1310926	-.0440503
1986	-.092866	.0222691	-4.17	0.000	-.1365256	-.0492063
1987	-.0580931	.0223043	-2.60	0.009	-.1018218	-.0143644
1988	-.0211632	.0223277	-0.95	0.343	-.0649378	.0226114
1989	-.0382923	.0224365	-1.71	0.088	-.0822802	.0056957
_cons	3.046843	.0315266	96.64	0.000	2.985033	3.108652

Clustered Standard Errors

We notice that our data indexes observations by the variable *id*. This leads us to believe that observations within an *id* group are related, and this correlation should therefore be controlled for. We allow for clusters at the *id* level by adding the option *vce(cluster id)* to our previous regression.

```
. reg ln_sales ln_labor ln_capital i.year, vce(cluster id)

Linear regression                               Number of obs     =      4,072
                                                F(9, 508)         =    2507.63
                                                Prob > F          =     0.0000
                                                R-squared         =     0.9693
                                                Root MSE          =     .35256

                                 (Std. Err. adjusted for 509 clusters in id)
------------------------------------------------------------------------------
             |               Robust
    ln_sales |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    ln_labor |   .5578836   .0308763    18.07   0.000     .4972227    .6185445
  ln_capital |   .4322828   .0274846    15.73   0.000     .3782853    .4862803
             |
        year |
       1983  |  -.0568626   .0083657    -6.80   0.000    -.0732982   -.0404269
       1984  |   -.050041   .0110933    -4.51   0.000    -.0718355   -.0282465
       1985  |  -.0875714   .0135255    -6.47   0.000    -.1141442   -.0609987
       1986  |   -.092866    .016461    -5.64   0.000     -.125206   -.0605259
       1987  |  -.0580931   .0174944    -3.32   0.001    -.0924634   -.0237228
       1988  |  -.0211632   .0185846    -1.14   0.255    -.0576754     .015349
       1989  |  -.0382923    .020265    -1.89   0.059    -.0781058    .0015213
             |
       _cons |   3.046843   .0915369    33.29   0.000     2.867005     3.22668
------------------------------------------------------------------------------
```

Lagged Explanatory Variables

We hypothesize that our dependent variable *ln_sales* may depend on past values of the labor and capital inputs. That is, the effects of increasing labor and capital on output may occur with a delay. Therefore, we include lagged values of *ln_labor* and *ln_capital* as explanatory variables, as well as the lagged value of the dependent variable *ln_sales*.

```
. reg ln_sales ln_labor ln_capital L.ln_sales L.ln_labor L.ln_capital i.year, vce(cluster id)

Linear regression                               Number of obs     =      3,563
                                                F(11, 508)        =   75113.93
                                                Prob > F          =     0.0000
                                                R-squared         =     0.9949
                                                Root MSE          =      .1426

                                  (Std. Err. adjusted for 509 clusters in id)
------------------------------------------------------------------------------
             |               Robust
    ln_sales |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    ln_labor |   .4789653   .0288963    16.58   0.000     .4221944    .5357362
  ln_capital |   .2348098   .0352859     6.65   0.000     .1654854    .3041341
             |
    ln_sales |
         L1. |   .9216418   .0105283    87.54   0.000     .9009575    .9423261
             |
    ln_labor |
         L1. |  -.4233997   .0305806   -13.85   0.000    -.4834797   -.3633198
             |
  ln_capital |
         L1. |  -.2120621   .0347141    -6.11   0.000     -.280263   -.1438613
             |
        year |
        1984 |   .0661134   .0096619     6.84   0.000     .0471313    .0850956
        1985 |   .0127151   .0101712     1.25   0.212    -.0072678     .032698
        1986 |    .034839   .0102827     3.39   0.001     .0146373    .0550408
        1987 |   .0767564   .0086928     8.83   0.000     .0596782    .0938346
        1988 |   .0779253   .0094209     8.27   0.000     .0594167     .096434
        1989 |   .0356445   .0097659     3.65   0.000     .0164579    .0548311
             |
       _cons |    .246604   .0322971     7.64   0.000     .1831516    .3100564
------------------------------------------------------------------------------
```

3 Panel Regression

As we are considering a panel dataset (and we have already declared to Stata that our data is a panel), we will now perform various panel regressions to investigate the relationship between ln_sales and the two inputs ln_labor and $ln\_capital$.

Fixed Effects (Within-Group Estimator)

We begin by performing a fixed effects panel regression using the command *xtreg*, with option *fe*. That is, we believe that there is group-specific unobserved heterogeneity in the error term of our model, and we therefore want to control for this (fixed) effect.

```
. xtreg ln_sales ln_labor ln_capital L.ln_sales L.ln_labor L.ln_capital i.year, fe vce(cluster id)

Fixed-effects (within) regression               Number of obs     =      3,563
Group variable: id                              Number of groups  =        509

R-sq:                                           Obs per group:
     within  = 0.7825                                         min =          7
     between = 0.9879                                         avg =        7.0
     overall = 0.9847                                         max =          7

                                                F(11,508)         =     345.86
corr(u_i, Xb)  = 0.7191                         Prob > F          =     0.0000

                                  (Std. Err. adjusted for 509 clusters in id)
------------------------------------------------------------------------------
             |               Robust
    ln_sales |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    ln_labor |   .4880013   .0299207    16.31   0.000     .4292178    .5467848
  ln_capital |   .1765454   .0340853     5.18   0.000     .1095799    .2435109
             |
    ln_sales |
         L1. |   .4039344   .0293221    13.78   0.000     .3463269    .4615418
             |
    ln_labor |
         L1. |  -.0231194     .03455    -0.67   0.504    -.0909977     .044759
             |
  ln_capital |
         L1. |  -.1305487   .0252882    -5.16   0.000    -.1802311   -.0808663
             |
        year |
        1984 |   .0564054   .0074048     7.62   0.000     .0418576    .0709533
        1985 |   .0271379   .0092935     2.92   0.004     .0088795    .0453963
        1986 |   .0494812   .0116301     4.25   0.000     .0266322    .0723302
        1987 |   .1033078   .0116548     8.86   0.000     .0804104    .1262053
        1988 |   .1310847     .01305    10.04   0.000     .1054461    .1567234
        1989 |   .1174383   .0150838     7.79   0.000      .087804    .1470726
             |
       _cons |   2.625541   .1591593    16.50   0.000      2.31285    2.938233
-------------+----------------------------------------------------------------
     sigma_u |  .31731619
     sigma_e |  .12076713
         rho |  .87347826   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

Difference GMM

We suspect that there is endogeneity in our model. That is, we believe that the explanatory variables are correlated with the error term. We will therefore use an instrumental variable approach to deal with this endogeneity problem.

First, we install the *xtabond2* command - the user-created Stata command for the Arellano–Bond dyanmic panel data estimators. We type *ssc install xtabond2* in the Command Window of Stata.

```
. ssc install xtabond2
checking xtabond2 consistency and verifying not already installed...
installing into /Users/francisguiton/Library/Application Support/Stata/ado/plus/...
installation complete.
```

We will now run the Difference GMM estimation, which effectively considers the regression equation in first differences, and instruments the endogenous variables with their higher lagged values (in this case, higher than the first lag). We type *xtabond2* followed by our usual dependent and independent variables, and add the option *gmm()*. We include in the parentheses the set of endegenous variables in our model, and the lowest lag of these variables that is not correlated with the error term. We add the option *iv()* in which we list the strictly exogenous variables, and *robust* which tells Stata that we wish to have robust standard errors. Finally, we include *noleveleq* to specify that we wish to implement the Difference GMM estimator (and not the System GMM estimator which we will explore in the next section):

xtabond2 ln_sales ln_labor ln_capital L.ln_sales L.ln_labor L.ln_capital i.year, gmm(ln_sales ln_capital ln_labor, lag(2 .)) iv(i.year) robust noleveleq

```
Dynamic panel-data estimation, one-step difference GMM
------------------------------------------------------------------------------
Group variable: id                              Number of obs      =      3054
Time variable : year                            Number of groups   =       509
Number of instruments = 69                      Obs per group: min =         6
Wald chi2(0)  =         .                                      avg =      6.00
Prob > chi2   =         .                                      max =         6
------------------------------------------------------------------------------
             |              Robust
    ln_sales |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    ln_labor |   .5128697   .0892432     5.75   0.000     .3379563    .6877831
  ln_capital |   .1318291   .1179029     1.12   0.264    -.0992562    .3629145
             |
    ln_sales |
         L1. |   .3264209   .0521606     6.26   0.000     .2241881    .4286538
             |
    ln_labor |
         L1. |   .0726061   .0927269     0.78   0.434    -.1091353    .2543475
             |
  ln_capital |
         L1. |  -.2066298   .0949589    -2.18   0.030    -.3927458   -.0205137
             |
        year |
       1983  |  -.1552384   .0224468    -6.92   0.000    -.1992334   -.1112435
       1984  |  -.0876288   .0172895    -5.07   0.000    -.1215155   -.0537421
       1985  |  -.0987342   .0126165    -7.83   0.000    -.1234621   -.0740063
       1986  |  -.0639394     .00849    -7.53   0.000    -.0805794   -.0472994
       1988  |   .0376223     .00671     5.61   0.000      .024471    .0507736
       1989  |   .0347582   .0108629     3.20   0.001     .0134673    .0560491
------------------------------------------------------------------------------
Instruments for first differences equation
  Standard
    D.(1982b.year 1983.year 1984.year 1985.year 1986.year 1987.year 1988.year
    1989.year)
  GMM-type (missing=0, separate instruments for each period unless collapsed)
    L(2/7).(ln_sales ln_capital ln_labor)
------------------------------------------------------------------------------
Arellano-Bond test for AR(1) in first differences: z =  -6.21  Pr > z =  0.000
Arellano-Bond test for AR(2) in first differences: z =  -1.36  Pr > z =  0.173
------------------------------------------------------------------------------
Sargan test of overid. restrictions: chi2(58)   = 213.56  Prob > chi2 =  0.000
  (Not robust, but not weakened by many instruments.)
Hansen test of overid. restrictions: chi2(58)   =  98.39  Prob > chi2 =  0.001
  (Robust, but weakened by many instruments.)

Difference-in-Hansen tests of exogeneity of instrument subsets:
  iv(1982b.year 1983.year 1984.year 1985.year 1986.year 1987.year 1988.year 1989.year)
    Hansen test excluding group:     chi2(52)   =  78.58  Prob > chi2 =  0.010
    Difference (null H = exogenous): chi2(6)    =  19.81  Prob > chi2 =  0.003
```

The Sargan test of overidentifying restrictions presents the null hypothesis that the instruments are exogenous as a group. According to the above output, we reject this null hypothesis, which therefore entails that we may have a poor set of instruments.

System GMM

With the same command *xtabond2*, we can implement the System GMM estimator. This estimator is the augmented version of the previous Difference GMM estimator. Broadly speaking, the System GMM estimator considers both the first-differenced regression equation and the regression equation in levels, and therefore produces two sets of instruments for the endogenous variables. In this case, we exclude the option *noleveleq* to tell Stata we wish to implement System GMM, and we add the option *h(1)* to specify the one-step estimator to be used - here we consider 2SLS. Finally, we will consider the third lags of the endogenous variables (and earlier) as instruments for the equation in first differences, and therefore include *lag(3 .)*.

xtabond2 ln_sales ln_labor ln_capital L.ln_sales L.ln_labor L.ln_capital i.year, gmm(ln_sales ln_capital ln_labor, lag(3 .)) iv(i.year) robust h(1)

```
Dynamic panel-data estimation, one-step system GMM
------------------------------------------------------------------------------
Group variable: id                              Number of obs      =      3563
Time variable : year                            Number of groups   =       509
Number of instruments = 67                      Obs per group: min =         7
Wald chi2(11) =  1.08e+06                                      avg =      7.00
Prob > chi2   =     0.000                                      max =         7
------------------------------------------------------------------------------
             |               Robust
    ln_sales |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    ln_labor |   .4650059   .1128788     4.12   0.000     .2437675    .6862443
  ln_capital |   .4070006   .1522005     2.67   0.007     .1086931    .7053082
             |
    ln_sales |
         L1. |   .6087156   .0997699     6.10   0.000     .4131701    .8042611
             |
    ln_labor |
         L1. |  -.2814321   .1208803    -2.33   0.020    -.5183532    -.044511
             |
  ln_capital |
         L1. |  -.2168042   .1194903    -1.81   0.070    -.4510008    .0173925
             |
        year |
        1983 |  -.0609928   .0158425    -3.85   0.000    -.0920436   -.0299421
        1984 |  -.0187287   .0169831    -1.10   0.270    -.0520149    .0145574
        1985 |  -.0671562   .0129478    -5.19   0.000    -.0925333    -.041779
        1986 |  -.0537623   .0122459    -4.39   0.000    -.0777637   -.0297608
        1987 |  -.0144227   .0094953    -1.52   0.129    -.0330332    .0041878
        1989 |  -.0398253   .0095249    -4.18   0.000    -.0584936   -.0211569
             |
       _cons |   1.144956   .3606024     3.18   0.001     .4381879    1.851723
------------------------------------------------------------------------------
Instruments for first differences equation
  Standard
    D.(1982b.year 1983.year 1984.year 1985.year 1986.year 1987.year 1988.year
    1989.year)
  GMM-type (missing=0, separate instruments for each period unless collapsed)
    L(3/7).(ln_sales ln_capital ln_labor)
Instruments for levels equation
  Standard
    1982b.year 1983.year 1984.year 1985.year 1986.year 1987.year 1988.year
    1989.year
    _cons
  GMM-type (missing=0, separate instruments for each period unless collapsed)
    DL2.(ln_sales ln_capital ln_labor)
```

```
------------------------------------------------------------------------------
Arellano-Bond test for AR(1) in first differences: z =  -6.69  Pr > z =  0.000
Arellano-Bond test for AR(2) in first differences: z =  -0.45  Pr > z =  0.654
------------------------------------------------------------------------------
Sargan test of overid. restrictions: chi2(55)   =  58.04  Prob > chi2 =  0.364
  (Not robust, but not weakened by many instruments.)
Hansen test of overid. restrictions: chi2(55)   =  75.48  Prob > chi2 =  0.035
  (Robust, but weakened by many instruments.)

Difference-in-Hansen tests of exogeneity of instrument subsets:
  GMM instruments for levels
    Hansen test excluding group:     chi2(40)   =  46.20  Prob > chi2 =  0.232
    Difference (null H = exogenous): chi2(15)   =  29.28  Prob > chi2 =  0.015
  iv(1982b.year 1983.year 1984.year 1985.year 1986.year 1987.year 1988.year 1989.year)
    Hansen test excluding group:     chi2(49)   =  64.06  Prob > chi2 =  0.073
    Difference (null H = exogenous): chi2(6)    =  11.42  Prob > chi2 =  0.076
```