# Longitudinal/Panel Data Analysis: Lecture 1

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# Week 2 Topics

- Fixed Effects
- Random Effects
- Dynamic Models

# Readings week 2

- Stata 11.0 Manual Longitudinal/Panel Data, xtabond, xtabond postestimation, xtdpdsys, xtivreg
- Wawro, Gregory. 2002. "Estimating Dynamic Panel Data Models in Political Science" Political Analysis 10: 25-48.
- Halaby, Charles N. 2004. "Panel Models in Sociological Research: Theory into Practice." Annual Review of Sociology. 30:507-44.
- Hsiao, Cheng. 2003. "Analysis of Panel Data: Second Edition." Chapter 4.

# Fixed Effects Estimator

Deviations from within-unit means:

$$\bar{y}_{i.} = (\delta_1 + \delta_0)/2 + \gamma \bar{d}_{i.} + \theta_i \hat{\epsilon}_i \quad (1)$$

Consistent fixed effects estimator:

$$(y_{it} - \bar{y}_i) = (\delta_0 - \delta_1)/2 + (\delta_1 - \delta_0) p_1 + \gamma (d_{it} - \bar{d}_i) + (\epsilon_{it} - \bar{\epsilon}_i) \quad (2)$$

# Regression Labour Evaluations, Economy and Income

```
.      regr labour_therm retnat_ttl income_ttl

      Source |       SS       df       MS              Number of obs =   18653
-------------+------------------------------           F(  2, 18650) = 1108.95
       Model |  17549.7573     2  8774.87865           Prob > F      =  0.0000
    Residual |   147573.07 18650  7.91276515           R-squared     =  0.1063
-------------+------------------------------           Adj R-squared =  0.1062
       Total |  165122.827 18652  8.85282154           Root MSE      =   2.813

------------------------------------------------------------------------------
labour_therm |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  retnat_ttl |  -1.015335   .0215739   -47.06   0.000    -1.057622   -.973048
  income_ttl |   .0043702   .0058558     0.75   0.455    -.0071077   .0158482
       _cons |   7.861831   .1025247    76.68   0.000     7.660873   8.062789
------------------------------------------------------------------------------
```

# Fixed Effects with Income

```
.
. xtreg  labour_therm retnat_ttl income_ttl, fe

Fixed-effects (within) regression               Number of obs      =     18653
Group variable: id                              Number of groups   =      8215

R-sq:  within  = 0.0045                         Obs per group: min =         1
       between = 0.0568                                        avg =       2.3
       overall = 0.0557                                        max =         5

                                                F(2,10436)         =     23.76
corr(u_i, Xb)  = 0.2075                         Prob > F           =    0.0000

------------------------------------------------------------------------------
labour_therm |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  retnat_ttl |  -.0903765    .013828    -6.54   0.000    -.1174819    -.063271
  income_ttl |   .0246439    .011645     2.12   0.034     .0018175    .0474702
       _cons |   3.831079   .1016761    37.68   0.000     3.631775    4.030384
-------------+----------------------------------------------------------------
     sigma_u |  2.7985428
     sigma_e |   1.282659
         rho |   .8264003   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(8214, 10436) =     9.65         Prob > F = 0.0000
```

# Fixed Effects with Gender

```
.
.     xtreg  labour_therm retnat_ttl female, fe
note: female omitted because of collinearity

Fixed-effects (within) regression               Number of obs      =     22890
Group variable: id                              Number of groups   =      9538

R-sq:  within  = 0.0035                         Obs per group: min =         1
       between = 0.1729                                        avg =       2.4
       overall = 0.1101                                        max =         5

                                                F(1,13351)         =     46.90
corr(u_i, Xb)  = 0.3258                         Prob > F           =    0.0000

------------------------------------------------------------------------------
labour_therm |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
  retnat_ttl |   -.084394   .0123232    -6.85   0.000    -.1085491   -.0602388
      female |  (omitted)
       _cons |   3.897776   .0526257    74.07   0.000     3.794622     4.00093
-------------+----------------------------------------------------------------
     sigma_u |  2.7990027
     sigma_e |  1.2753294
         rho |  .82808525   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(9537, 13351) =    10.28         Prob > F = 0.0000
```

# Features of Dynamic Panel Models

1. include in their specification 1) lagged dependent variables and 2) unobserved individual-specific effects
2. models are powerful because allow for 1) empirical modeling of dynamics while 2) accounting for individual-specific dynamics
3. parse out: 1) does past behaviour directly affect current behaviour (dynamic effect) versus 2) individuals have predilection to behave in particular way (individual-specific)

# Regression model for dynamic panel data

$$y_{i,t} = \gamma y_{i,t-1} + x_{i,t}\beta + \alpha_i + u_{i,t} \tag{3}$$

$$E\left[u_{i,t} | y_{i,t-1}, \dots, y_{i,1}, x_{i,t}, x_{i,t-1}, \dots, x_{i,1}\right] = 0 \tag{4}$$

$$y_{i,t} = \gamma y_{i,t-1} + x_{i,t}\beta + u^*_{i,t} \tag{5}$$

where $u^*_{i,t} = \alpha_i + u_{i,t}$

# Dynamic specification issues

$$y_{i,t} = \gamma y_{i,t-1} + x_{i,t}\beta + \alpha_i + u_{i,t} \quad (6)$$

- all explanatory variables are strictly exogenous
- $u_{i,t}$ is mean zero, constant variance, and independently distributed
- least squares estimator is badly biased because of the correlation between the lagged endogenous variable $y_{i,t-1}$ and the unit effects – because $u_{i,t}$ affects $y_{i,t}$ it also affects $y_{i,t-1}$

# Lagging illustrates the problem

$$y_{i,t-1} = \gamma y_{i,t-2} + x_{i,t-1}\beta + \alpha_i + u_{i,t-1} \quad (7)$$

# Anderson-Hsiao Estimator

$$y_{i,t} - y_{i,t-1} = \gamma \left(y_{i,t-1} - y_{i,t-2}\right) + \left(x_{i,t} - x_{i,t-1}\right) \beta + u_{i,t} - u_{i,t-1} \quad (8)$$

$$\Delta y_{i,t} = \gamma \Delta y_{i,t-1} + \Delta x_{i,t} \beta + \Delta u_{i,t} \quad (9)$$

- eliminate unit effect by first differencing the variables
- apply instrumental variables estimation for the parameters of the lagged endogenous variable ($\gamma$)
- $y_{i,t-2} - y_{i,t-3}$ and $y_{i,t-2}$ are correlated with $y_{i,t-1} - y_{i,t-2}$ but not $u_{i,t} - u_{i,t-1}$
- the same is true for $x_{i,t} - x_{i,t-1}$
- Anderson-Hsiao propose two instruments: $\Delta y_{i,t-2}$ and $y_{i,t-2}$

# Stata Instrumental Variable Estimation (xtivreg)

```
. xtivreg n l2.n l(0/1).w l(0/2).(k ys) yr1981-yr1984 (l.n=l3.n), fd

First-differenced IV regression

Group variable:    id                         Number of obs      =       471
Time variable (t): year                       Number of groups   =       140
R-sq:  within  = 0.0141                       Obs per group: min =         3
       between = 0.9165                                      avg =       3.4
       overall = 0.9892                                      max =         5
                                              Wald chi2(14)      =    122.53
corr(u_i, Xb)  = 0.9239                       Prob > chi2        =    0.0000
```

# Stata IV Estimation (xtivreg) from Arellano and Bond

```
------------------------------------------------------------------------------
         D.n |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           n |
         LD. |   1.422765   1.583053     0.90   0.369    -1.679962    4.525493
        L2D. |  -.1645517   .1647179    -1.00   0.318    -.4873928    .1582894
           w |
         D1. |  -.7524675   .1765733    -4.26   0.000    -1.098545   -.4063902
         LD. |   .9627611   1.086506     0.89   0.376    -1.166752    3.092275
           k |
         D1. |   .3221686   .1466086     2.20   0.028     .0348211    .6095161
         LD. |  -.3248778   .5800599    -0.56   0.575    -1.461774    .8120187
        L2D. |  -.0953947   .1960883    -0.49   0.627    -.4797207    .2889314
          ys |
         D1. |   .7660906    .369694     2.07   0.038     .0415037    1.490678
         LD. |  -1.361881   1.156835    -1.18   0.239    -3.629237    .9054744
        L2D. |   .3212993   .5440403     0.59   0.555        -.745    1.387599
      yr1981 |
         D1. |  -.0574197   .0430158    -1.33   0.182    -.1417291    .0268896
      yr1982 |
         D1. |  -.0882952   .0706214    -1.25   0.211    -.2267106    .0501203
      yr1983 |
         D1. |  -.1063153     .10861    -0.98   0.328     -.319187    .1065563
      yr1984 |
         D1. |  -.1172108     .15196    -0.77   0.441    -.4150468    .1806253
       _cons |   .0161204   .0336264     0.48   0.632    -.0497861     .082027
-------------+----------------------------------------------------------------
     sigma_u |  .29069213
     sigma_e |  .18855982
         rho |  .70384993   (fraction of variance due to u_i)
------------------------------------------------------------------------------
Instrumented:   L.n
Instruments:    L2.n w L.w k L.k L2.k ys L.ys L2.ys yr1981 yr1982 yr1983 yr1984 L3.n
------------------------------------------------------------------------------
```

# Stata IV Estimation(xtivreg) BCCAP Data

```
. xtivreg labour_therm retnat_ttl income_ttl (l.labour_therm=l2.labour_therm), fd
First-differenced IV regression
Group variable:    id                           Number of obs      =      1781
Time variable:     wave_id                      Number of groups   =      1012

R-sq:  within  = 0.0660                         Obs per group: min =         1
       between = 0.7964                                        avg =       1.8
       overall = 0.7441                                        max =         2
                                                Wald chi2(3)       =     15.93
corr(u_i, Xb)  = 0.8611                         Prob > chi2        =    0.0012
------------------------------------------------------------------------------
D.           |
labour_therm |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
labour_therm |
         LD. |   .2078332   .0653546     3.18   0.001     .0797404    .3359259
             |
  retnat_ttl |
         D1. |  -.1002493   .0426182    -2.35   0.019    -.1837796   -.0167191
             |
  income_ttl |
         D1. |   -.039653   .0371654    -1.07   0.286     -.112496    .0331899
             |
       _cons |   .1600316   .0434016     3.69   0.000      .074966    .2450973
-------------+----------------------------------------------------------------
     sigma_u |  2.3998146
     sigma_e |  1.6578996
         rho |  .67692586   (fraction of variance due to u_i)
------------------------------------------------------------------------------
Instrumented:   L.labour_therm
Instruments:    retnat_ttl income_ttl L2.labour_therm
------------------------------------------------------------------------------
```

# GMM Estimation

$$y_i = x_i \beta + u_i \tag{10}$$

$$E\left[x_i' u_i\right] = 0 \tag{11}$$

$$E\left[x_i' \left(y_i - x_i \beta\right)\right] = 0 \tag{12}$$

$$\frac{1}{N} \sum_{i=1}^{N} x_i' \left(y_i - x_i \hat{\beta}\right) = 0 \tag{13}$$

$$\hat{\beta} = \left( \sum_{i=1}^{N} x_i' x_i \right)^{-1} \left( \sum_{i=1}^{N} x_i' y_i \right) \tag{14}$$

$$E\left[ z_i' u_i \right] = 0 \tag{15}$$

$$E\left[ z_i' \left( y_i - x_i \beta \right) \right] = 0 \tag{16}$$

$$\frac{1}{N} \sum_{i=1}^{N} z_i' \left( y_i - x_i \hat{\beta} \right) = 0 \tag{17}$$

$$\left( \sum_{i=1}^{N} z_i' \left( y_i - x_i \hat{\beta} \right) \right)' W \left( \sum_{i=1}^{N} z_i' \left( y_i - x_i \hat{\beta} \right) \right) \tag{18}$$

$$\hat{\beta} = \left( X' Z W Z' X \right)^{-1} \left( X' Z W Z' y \right) \tag{19}$$

$$\Omega = \left(E\left[X_i' Z_i\right] WE\left[Z_i' X_i\right]\right)^{-1} E\left[X_i' Z_i\right] WVWE\left[Z_i' X_i\right] \left(E\left[X_i' Z_i\right] WE\left[Z_i' X_i\right]\right)^{-1} \tag{20}$$

where:

$$V = Var\left[Z_i' u_i\right] = E\left[Z_i' u_i u_i' Z_i\right]$$

$$\Omega = \left(X_i' Z_i V^{-1} Z_i' X_i\right)^{-1} \tag{21}$$

$$\hat{W} = \hat{V}^{-1} = \left\{\frac{1}{N} \sum_{i=1}^{N} Z_i' \hat{u}_i \hat{u}_i' Z_i\right\}^{-1} \tag{22}$$

$$E\left[z_{i,t}' \Delta u_{i,t}\right] = 0 \quad t = 2, \ldots, T \tag{23}$$

$$y_i = X_i\theta + u_i \tag{24}$$

where

$$y_i = \begin{bmatrix} \Delta y_{i,3} \\ \Delta y_{i,4} \\ \vdots \\ \Delta y_{i,T} \end{bmatrix}, \quad X_i = \begin{bmatrix} \Delta y_{i,2} & \Delta X_{i,3} \\ \Delta y_{i,3} & \Delta X_{i,4} \\ \vdots & \\ \Delta y_{i,T-1} & \Delta X_{i,T} \end{bmatrix}, \quad \text{and} \quad u_i = \begin{bmatrix} \Delta u_{i,3} \\ \Delta u_{i,4} \\ \vdots \\ \Delta u_{i,T} \end{bmatrix}$$

$$Z_i = \begin{bmatrix} Z_{i,3} & & & 0 \\ & Z_{i,4} & & \\ & & \ddots & \\ 0 & & & Z_{i,T} \end{bmatrix}$$

# Instrumental Variable Estimation: Arellano-Bond

$$(y_{it} - y_{jt-1}) = \gamma(y_{it-1} - y_{it-2}) + \sum_k \beta_k(x_{kit} - x_{kit-1}) + \sum_s \phi_s(w_{sit} - w_{sit-1}) + (\epsilon_{it} - \epsilon_{it-1}) \quad (25)$$

- $x_{kit}$ are strictly exogenous covariates
- $w_{sit}$ are predetermined and endogenous covaraites
- eliminate unit effect by first differencing the variables
- apply instrumental variables estimation for the parameters of the lagged endogenous variable ($\gamma$)

# The Instrumental Variables in Arellano-Bond GMM Estimation

General form of GMM estimator of $\hat{\beta}$

$$\hat{\beta} = (\mathbf{X}'\mathbf{Z}\hat{\mathbf{W}}\mathbf{Z}'\mathbf{X})^{-1}(\mathbf{X}'\mathbf{Z}\hat{\mathbf{W}}\mathbf{Z}'\mathbf{Y}) \qquad (26)$$

- $\mathbf{Z}$ consists of the valid instruments in the differenced equation
- the GMM-type instruments are lagged values of $w_{sit}$ – predetermined and endogenous covaraites
- the standard instruments are the first differences of $x_{kit}$ – the exogenous variables

# Example from Arellano and Bond

$$n_{it} = \alpha_1 y_{it-1} + \alpha_2 y_{it-2} + \gamma_1 w_{it} + \gamma_2 k_{it} + \gamma_3 ys_{it} + \eta_i + \lambda_t + \epsilon_{it} \tag{27}$$

- $n_{it}$ is log employment in company $i$ at end of year $t$
- $k$ is log of gross capital; $w$ is log of real product wage; $ys$ is log of industry output
- $\lambda_t$ captures a time effect common to all firms
- sample consists of 140 firms over period 1976-1984 – note three cross sections lost in constructing lags

# Basic Instrument Set

$$\mathbf{Z}_i = \begin{bmatrix} n_{i,1} & n_{i,2} & 0 & 0 & 0 & \cdots & 0 & \cdots & 0 & \vdots & \Delta x_{i,4} \\ 0 & 0 & n_{i,1} & n_{i,2} & n_{i,3} & \cdots & 0 & \cdots & 0 & \vdots & \Delta x_{i,5} \\ \vdots & & & & & \ddots & & & & & \\ 0 & 0 & 0 & 0 & 0 & \cdots & n_{i,1} & \cdots & n_{i,7} & \vdots & \Delta x_{i,9} \end{bmatrix}$$

For example, the equation for 1979 in first differences can be written as

$$\Delta n_{i,4} = \gamma_1 \Delta n_{i,3} + \gamma_2 \Delta n_{i,2} + \Delta x_{i,4} \beta + \Delta \epsilon_{i,4}$$

# Stata Instrumental Variable Estimation (xtabond)

```
. xtabond n l(0/1).w l(0/2).(k ys) yr1980-yr1984 year, lags(2) vce(robust) noconstant

Arellano-Bond dynamic panel-data estimation  Number of obs         =       611
Group variable: id                           Number of groups      =       140
Time variable: year
                                             Obs per group:    min =         4
                                                               avg =  4.364286
                                                               max =         6

Number of instruments =     41               Wald chi2(16)         =   1727.45
                                             Prob > chi2           =    0.0000
```

# Stata Instrumental Variable Estimation(xtabond)

```
One-step results
------------------------------------------------------------------------------
             |               Robust
           n |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           n |
         L1. |   .6862261   .1445943     4.75   0.000     .4028266    .9696257
         L2. |  -.0853582   .0560155    -1.52   0.128    -.1951467    .0244302
           w |
         --. |  -.6078208   .1782055    -3.41   0.001    -.9570972   -.2585445
         L1. |   .3926237   .1679931     2.34   0.019     .0633632    .7218842
           k |
         --. |   .3568456   .0590203     6.05   0.000      .241168    .4725233
         L1. |  -.0580012   .0731797    -0.79   0.428    -.2014308    .0854284
         L2. |  -.0199475   .0327126    -0.61   0.542    -.0840631    .0441681
          ys |
         --. |   .6085073   .1725313     3.53   0.000     .2703522    .9466624
         L1. |  -.7111651   .2317163    -3.07   0.002    -1.165321   -.2570095
         L2. |   .1057969   .1412021     0.75   0.454    -.1709542     .382548
      yr1980 |   .0029062   .0158028     0.18   0.854    -.0280667    .0338791
      yr1981 |  -.0404378   .0280582    -1.44   0.150    -.0954307    .0145552
      yr1982 |  -.0652767   .0365451    -1.79   0.074    -.1369038    .0063503
      yr1983 |  -.0690928    .047413    -1.46   0.145    -.1620205    .0238348
      yr1984 |  -.0650302   .0576305    -1.13   0.259    -.1779839    .0479235
        year |   .0095545   .0102896     0.93   0.353    -.0106127    .0297217
------------------------------------------------------------------------------
Instruments for differenced equation
        GMM-type: L(2/.).n
        Standard: D.w LD.w D.k LD.k L2D.k D.ys LD.ys L2D.ys D.yr1980 D.yr1981 D.yr1982 D.yr1983 D.yr1984
```

# Sargan test

Test of overidentifying restrictions is the Sargan test:

$$s = \hat{\epsilon}' \mathbf{Z} (\frac{1}{N} \sum_{i=1}^{N} \mathbf{Z}_i' \hat{\epsilon}_i \hat{\epsilon}_i' \mathbf{Z}_i)^{-1} \mathbf{Z}_i' \hat{\epsilon} \tag{28}$$

# Implementing the Sargan test

1. Estimating the equation by IV and obtain the residuals $\hat{\epsilon_{jt}}$
2. Regress the IV $\hat{\epsilon_{jt}}$ on all exogenous variables (instrument + controls)
3. Obtain the $R^2$
4. The test statistic is $S = nR^2$
5. Where n is the number of observations
6. Under the null hypothesis that all instruments are exogenous $S$ is distributed as $\chi^2_{m-r}$, where $m - r$ is the number of instruments minus the number of endogenous variables

# Stata Instrumental Variable Estimation(xtabond)

```
. xtabond n l(0/1).w l(0/2).(k ys) yr1980-yr1984 year, lags(2) noconstant
Arellano-Bond dynamic panel-data estimation  Number of obs         =       611
Group variable: id                           Number of groups      =       140
Time variable: year
                                             Obs per group:    min =         4
                                                               avg =  4.364286
                                                               max =         6
Number of instruments =     41               Wald chi2(16)         =   1757.07
                                             Prob > chi2           =    0.0000
One-step results
------------------------------------------------------------------------------
           n |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
           n |
         L1. |   .6862261   .1486163     4.62   0.000     .3949435    .9775088
         L2. |  -.0853582   .0444365    -1.92   0.055    -.1724523    .0017358
           w |
         --. |  -.6078208   .0657694    -9.24   0.000    -.7367265   -.4789151
         L1. |   .3926237   .1092374     3.59   0.000     .1785222    .6067251
           k |
         --. |   .3568456   .0370314     9.64   0.000     .2842653    .4294259
         L1. |  -.0580012   .0583051    -0.99   0.320     -.172277    .0562747
         L2. |  -.0199475   .0416274    -0.48   0.632    -.1015357    .0616408
          ys |
         --. |   .6085073   .1345412     4.52   0.000     .3448115    .8722031
         L1. |  -.7111651   .1844599    -3.86   0.000      -1.0727   -.3496304
         L2. |   .1057969   .1428568     0.74   0.459    -.1741974    .3857912
      yr1980 |   .0029062   .0212705     0.14   0.891    -.0387832    .0445957
      yr1981 |  -.0404378   .0354707    -1.14   0.254    -.1099591    .0290836
      yr1982 |  -.0652767    .048209    -1.35   0.176    -.1597646    .0292111
      yr1983 |  -.0690928   .0627354    -1.10   0.271    -.1920521    .0538664
      yr1984 |  -.0650302   .0781322    -0.83   0.405    -.2181665    .0881061
        year |   .0095545   .0142073     0.67   0.501    -.0182912    .0374002
```

# Stata Instrumental Variable Estimation: A-B Test for Serial Correlation and Sargan Test

```
. estat abond

Arellano-Bond test for zero autocorrelation in first-differenced errors
  +-----------------------+
  |Order |  z     Prob > z|
  |------+----------------|
  |   1  |-3.9394  0.0001 |
  |   2  |-.54239  0.5876 |
  +-----------------------+
   H0: no autocorrelation

. estat sargan
Sargan test of overidentifying restrictions
        H0: overidentifying restrictions are valid

        chi2(25)     =  65.81806
        Prob > chi2  =    0.0000

.
end of do-file
```

# Stata Instrumental Variable Estimation not assuming strict exogeneity (xtabond)

Recall

$$E[x_{jt}\epsilon_{js}] = 0 \tag{29}$$

for all t, s

Predetermined variables

$$E[x_{jt}\epsilon_{js}] \neq 0 \tag{30}$$

for $s < t$

# Stata Instrumental Variable Estimation not assuming strict exogeneity (xtabond)

```
. xtabond n l(0/1).ys yr1980-yr1984 year, lags(2) twostep pre(w,lag(1,.)) ///
>    pre(k, lag(2,.)) vce(robust) noconstant
Arellano-Bond dynamic panel-data estimation  Number of obs         =       611
Group variable: id                           Number of groups      =       140
Time variable: year
                                             Obs per group:    min =         4
                                                               avg =  4.364286
                                                               max =         6
Number of instruments =     83               Wald chi2(15)         =    958.30
                                             Prob > chi2           =    0.0000
```

# Stata Instrumental Variable Estimation not assuming strict exogeneity (xtabond)

Two-step results

| n | Coef. | WC-Robust Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| n | | | | | | |
| L1. | .8580958 | .1265515 | 6.78 | 0.000 | .6100594 | 1.106132 |
| L2. | -.081207 | .0760703 | -1.07 | 0.286 | -.2303022 | .0678881 |
| w | | | | | | |
| --. | -.6910855 | .1387684 | -4.98 | 0.000 | -.9630666 | -.4191044 |
| L1. | .5961712 | .1497338 | 3.98 | 0.000 | .3026982 | .8896441 |
| k | | | | | | |
| --. | .4140654 | .1382788 | 2.99 | 0.003 | .1430439 | .6850868 |
| L1. | -.1537048 | .1220244 | -1.26 | 0.208 | -.3928681 | .0854586 |
| L2. | -.1025833 | .0710886 | -1.44 | 0.149 | -.2419143 | .0367477 |
| ys | | | | | | |
| --. | .6936392 | .1728623 | 4.01 | 0.000 | .3548354 | 1.032443 |
| L1. | -.8773678 | .2183085 | -4.02 | 0.000 | -1.305245 | -.449491 |
| yr1980 | -.0072451 | .017163 | -0.42 | 0.673 | -.0408839 | .0263938 |
| yr1981 | -.0609608 | .030207 | -2.02 | 0.044 | -.1201655 | -.0017561 |
| yr1982 | -.1130369 | .0454826 | -2.49 | 0.013 | -.2021812 | -.0238926 |
| yr1983 | -.1335249 | .0600213 | -2.22 | 0.026 | -.2511645 | -.0158853 |
| yr1984 | -.1623177 | .0725434 | -2.24 | 0.025 | -.3045001 | -.0201352 |
| year | .0264501 | .0119329 | 2.22 | 0.027 | .003062 | .0498381 |

```
Instruments for differenced equation
        GMM-type: L(2/.).n L(1/.).L.w L(1/.).L2.k
        Standard: D.ys LD.ys D.yr1980 D.yr1981 D.yr1982 D.yr1983 D.yr1984 D.year
```

# BCCAP Data: Stata IV Estimation (xtabond)

```
. xtabond labour_therm retnat_ttl income_ttl,lags(2) vce(robust)

Arellano-Bond dynamic panel-data estimation  Number of obs         =      1781
Group variable: id                           Number of groups      =       991
Time variable: wave_id
                                             Obs per group:    min =         1
                                                               avg =  1.797175
                                                               max =         2

Number of instruments =      8               Wald chi2(4)          =     40.60
                                             Prob > chi2           =    0.0000
One-step results
                                     (Std. Err. adjusted for clustering on id)
------------------------------------------------------------------------------
             |               Robust
labour_therm |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
labour_therm |
         L1. |   .0840334   .1165902     0.72   0.471    -.1444792     .312546
         L2. |  -.0780486   .0559124    -1.40   0.163    -.1876348    .0315377
             |
  retnat_ttl |   -.195831   .0417068    -4.70   0.000    -.2775748   -.1140871
  income_ttl |  -.0276891   .0361906    -0.77   0.444    -.0986214    .0432432
       _cons |   4.580348   .6670734     6.87   0.000     3.272908    5.887788
------------------------------------------------------------------------------
Instruments for differenced equation
        GMM-type: L(2/.).labour_therm
        Standard: D.retnat_ttl D.income_ttl
Instruments for level equation
        Standard: _cons
```