

## Panel Data Regression Models

### 1. Panel Least Squares

The model can be stated as:

$$GPP_{it} = \beta_0 + \beta_1 G_{it} + \beta_2 LOAN_{it} + \beta_3 AGRI_{it} + u_{it} \quad (1)$$

where:

$GPP_{it}$  = Gross of provincial product of province  $i$  at time  $t$ .

$G_{it}$  = Government spending on province  $i$  at time  $t$ .

$LOAN_{it}$  = Loan outstanding of province  $i$  at time  $t$ .

$AGRI_{it}$  = Agricultural production of province  $i$  at time  $t$ .

$u_{it}$  = Disturbance term of province  $i$  at time  $t$ .

To estimate the model using STATA, we begin by setting the data set to be panel data setting.

```
. xtset id year
      panel variable:  id (strongly balanced)
      time variable:  year, 0 to 9
      delta:         1 year
```

#### The model without any problems

```
. xtgls gpp g loan agri
```

Cross-sectional time-series FGLS regression

Coefficients: generalized least squares

Panel s: homoskedastic

Correlation: no autocorrelation

Estimated covariances	=	1	Number of obs	=	80
Estimated autocorrelations	=	0	Number of groups	=	8
Estimated coefficients	=	4	Time periods	=	10
Log likelihood	=	-779.4455	Wald chi2(3)	=	748.54
			Prob > chi2	=	0.0000

gpp	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]
g	1.920918	.8032843	2.39	0.017	.3465095 3.495326
loan	.5097789	.046617	10.94	0.000	.4184112 .6011465
agri	-53.35561	14.93147	-3.57	0.000	-82.62075 -24.09048
_cons	11683.41	1378.756	8.47	0.000	8981.096 14385.72

**The model with Heteroskedasticity**

```
. xtgls gpp g loan agri, igls panels(heteroskedastic)
```

```
Iteration 1: tolerance = .41982167
```

```
Iteration 22: tolerance = 6.777e-08
```

```
Cross-sectional time-series FGLS regression
```

```
Coefficients: generalized least squares
```

```
Panel s: heteroskedastic
```

```
Correlation: no autocorrelation
```

```
Estimated covariances = 8          Number of obs = 80
Estimated autocorrelations = 0      Number of groups = 8
Estimated coefficients = 4          Time periods = 10
Log likelihood = -721.8528          Wald chi2(3) = 1140.96
                                   Prob > chi2 = 0.0000
```

gpp	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]
g	-.1485432	.2537412	-0.59	0.558	-.6458667 .3487803
loan	.6368605	.0246414	25.85	0.000	.5885644 .6851567
agri	-12.99571	2.658269	-4.89	0.000	-18.20582 -7.785598
_cons	6153.178	344.0983	17.88	0.000	5478.757 6827.598

**Compute LR-Test for Heteroskedasticity**

Firstly, keep estimated result of the model with Heteroskedaticity.

```
. estimates store hetero
```

Second, estimate model without Heteroskedaticity.

```
. xtgls gpp g loan agri
```

```
Cross-sectional time-series FGLS regression
```

```
Coefficients: generalized least squares
```

```
Panel s: homoskedastic
```

```
Correlation: no autocorrelation
```

```
Estimated covariances = 1          Number of obs = 80
Estimated autocorrelations = 0      Number of groups = 8
Estimated coefficients = 4          Time periods = 10
Log likelihood = -779.4455          Wald chi2(3) = 748.54
                                   Prob > chi2 = 0.0000
```

gpp	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]
g	1.920918	.8032843	2.39	0.017	.3465095 3.495326
loan	.5097789	.046617	10.94	0.000	.4184112 .6011465
agri	-53.35561	14.93147	-3.57	0.000	-82.62075 -24.09048
_cons	11683.41	1378.756	8.47	0.000	8981.096 14385.72

Third, specify degree of freedom of the test.

```
. local df=e(N_g)-1
```

Finally, compute the LR-test =  $2(\log L_{UR} - \log L_R)$ .

```
. lrtest hetero, df(`df')
```

(log-likelihoods of null models cannot be compared)

Likelihood-ratio test (Assumption: . nested in hetero) LR chi2(7) = 115.19  
 Prob > chi2 = 0.0000

### **Model with Heteroskedasticity and Cross-sectional Correlation**

. xtgls gpp g loan agri, panels(correlated)

Cross-sectional time-series FGLS regression

Coefficients: generalized least squares  
 Panels: heteroskedastic with cross-sectional correlation  
 Correlation: no autocorrelation

Estimated covariances	=	36	Number of obs	=	80
Estimated autocorrelations	=	0	Number of groups	=	8
Estimated coefficients	=	4	Time periods	=	10
Log likelihood	=	-669.5133	Wald chi2(3)	=	2262.05
			Prob > chi2	=	0.0000

gpp	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]
g	1.50661	.3003486	5.02	0.000	.9179374 2.095282
loan	.508701	.0178062	28.57	0.000	.4738015 .5436004
agri	-42.39837	3.959852	-10.71	0.000	-50.15954 -34.6372
_cons	10721.04	388.408	27.60	0.000	9959.776 11482.31

### **Wooldridge Test for Autocorrelation**

. xtserial gpp g loan agri

Wooldridge test for autocorrelation in panel data

H0: no first order autocorrelation  
 F( 1, 7) = 105.860  
 Prob > F = 0.0000

### **Model with Heteroskedasticity, Cross-sectional Correlation, and Autocorrelation**

. xtgls gpp g loan agri, panels(correlated) corr(ar1)

Cross-sectional time-series FGLS regression

Coefficients: generalized least squares  
 Panels: heteroskedastic with cross-sectional correlation  
 Correlation: common AR(1) coefficient for all panels (0.8532)

Estimated covariances	=	36	Number of obs	=	80
Estimated autocorrelations	=	1	Number of groups	=	8
Estimated coefficients	=	4	Time periods	=	10
Log likelihood	=	-610.0246	Wald chi2(3)	=	265.49
			Prob > chi2	=	0.0000

gpp	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]
g	-.2611345	.3368487	-0.78	0.438	-.9213458 .3990767
loan	.518529	.0439935	11.79	0.000	.4323034 .6047546
agri	.4994303	1.297904	0.38	0.700	-2.044414 3.043275
_cons	8643.839	311.1028	27.78	0.000	8034.088 9253.589

**LR-Test for the Problems<sup>1</sup>**

```
. estimates store hauto
```

```
. xtgls gpp g loan agri
```

Cross-sectional time-series FGLS regression

Coefficients: generalized least squares

Panel s: homoskedastic

Correlation: no autocorrelation

```
Estimated covariances = 1          Number of obs = 80
Estimated autocorrelations = 0      Number of groups = 8
Estimated coefficients = 4          Time periods = 10
Log likelihood = -779.4455          Wald chi2(3) = 748.54
                                   Prob > chi2 = 0.0000
```

gpp	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]
g	1.920918	.8032843	2.39	0.017	.3465095 3.495326
loan	.5097789	.046617	10.94	0.000	.4184112 .6011465
agri	-53.35561	14.93147	-3.57	0.000	-82.62075 -24.09048
_cons	11683.41	1378.756	8.47	0.000	8981.096 14385.72

```
. local df2=e(N_g)-1
```

```
. lrtest hauto, df(`df')
```

(log-likelihoods of null models cannot be compared)

Likelihood-ratio test

(Assumption: . nested in hauto)

LR chi2(7) = 338.84

Prob > chi2 = 0.0000

```
. predict gpp_gls, xb
```

<sup>1</sup> In order to obtain an appropriated LR-test, the estimated likelihood-value should be computed from MLE process or MLE equivalent. In this case, GLS does not produce MLE equivalent estimated result. Thus, the LR-test computed from these estimated resulted might not be appropriated.

## 2. Fixed Effect Model

The model can also be applied as fixed effect model:

$$GPP_{it} = \beta_{10} + \beta_1 G_{it} + \beta_2 LOAN_{it} + \beta_3 AGRI_{it} + u_{it} \quad (2)$$

```
. xtreg gpp g loan agri , fe
```

```
Fixed-effects (within) regression          Number of obs   =          80
Group variable (i): id                    Number of groups =           8

R-sq:  within = 0.7585                    Obs per group:  min =          10
        between = 0.8963                  avg   =         10.0
        overall  = 0.8346                  max   =          10

corr(u_i, Xb) = 0.8353                    F(3, 69)        =         72.25
                                                Prob > F         =         0.0000
```

	gpp	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
	g	1.442314	.2248462	6.41	0.000	.993758 1.89087
	loan	.1171806	.0358101	3.27	0.002	.0457415 .1886197
	agri	11.94431	5.654815	2.11	0.038	.6632614 23.22536
	_cons	12472.26	667.2543	18.69	0.000	11141.12 13803.4
	sigma_u	10363.779				
	sigma_e	906.01137				
	rho	.99241554	(fraction of variance due to u_i)			

```
F test that all u_i=0:          F(7, 69) = 226.72          Prob > F = 0.0000
```

```
. estimates store fixed
```

To compute fixed effect, use the following command:

```
. predict ai, u
. table id, c(mean ai)
```

ID	mean(ai)
1	21100.33
2	2711.693
3	5643.245
4	-10611.55
5	2260.344
6	-6132.393
7	-7620.03
8	-7351.638

### 3. Random Effect Model

The model can also be specified as random effect model:

$$GPP_{it} = \beta_0 + \beta_1 G_{it} + \beta_2 LOAN_{it} + \beta_3 AGRI_{it} + u_{it} \quad (3)$$

and  $u_{it} = v_i + w_t + \varepsilon_{it}$

where:  $v_i$  = cross-section random effect

$w_t$  = time random effect

$\varepsilon_{it}$  = residual term

```
. xtreg gpp g loan agri, re
```

```
Random-effects GLS regression              Number of obs   =       80
Group variable (i): id                    Number of groups =        8

R-sq:  within = 0.6104                    Obs per group:  min =       10
        between = 0.9007                  avg =      10.0
        overall = 0.8840                  max =       10

Random effects u_i ~ Gaussian             Wald chi2(3)    =    246.85
corr(u_i, X) = 0 (assumed)                Prob > chi2    =     0.0000
```

	gpp	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]
	g	.4391357	.4329641	1.01	0.310	-.4094584 1.28773
	loan	.4686367	.045272	10.35	0.000	.3799053 .5573682
	agri	4.008584	11.51057	0.35	0.728	-18.55171 26.56888
	_cons	8736.887	1368.123	6.39	0.000	6055.414 11418.36
	sigma_u	1009.6082				
	sigma_e	906.01137				
	rho	.55392236	(fraction of variance due to u_i)			

```
. estimates store random
```

To compute random effect, use the following command:

```
. predict ri, u
. table id, c(mean ri)
```

ID	mean(ri)
1	5131.64
2	4695.539
3	6389.667
4	-6270.812
5	624.1134
6	-3240.626
7	-3939.543
8	-3389.978

To compute perform Hausman test, use the following command:

```
. hausman random fixed
```

```
----- Coefficients -----
| (b) (B) (b-B) sqrt(diag(V_b-V_B))
```

	random	fixed	Difference	S. E.
g	.4391357	1.442314	-1.003178	.3700028
loan	.4686367	.1171806	.3514562	.0276982
agri	4.008584	11.94431	-7.935725	10.02578

b = consistent under  $H_0$  and  $H_a$ ; obtained from xtreg  
 B = inconsistent under  $H_a$ , efficient under  $H_0$ ; obtained from xtreg

Test:  $H_0$ : difference in coefficients not systematic

$$\begin{aligned} \chi^2(3) &= (b-B)' [(V_b-V_B)^{-1}] (b-B) \\ &= 285.14 \\ \text{Prob}>\chi^2 &= 0.0000 \end{aligned}$$