Specification Tests for Linear Panel Data Models

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February 19, 2001

Abstract

`xttest1` computes seven specification tests for balanced error component models. It is an extension of `xttest0` and it is used exactly in the same way except that panels must be balanced.

`xttest1` is used after estimating a random effects model with `xtreg, re`, and presents specification tests for balanced error component models, all of them based solely on OLS residuals. It includes the Breusch and Pagan (1980) Lagrange Multiplier test for random effects, the Baltagi and Li (1995) test for first order serial correlation, the Baltagi and Li (1991) joint test for serial correlation and random effects, and the family of adjusted tests in Bera, Sosa-Escudero and Yoon (2001).

Description

Consider a simple one-way error component model which allows for possible random individual effects and first order autocorrelation in the disturbance term:

$$
\begin{aligned}
y_{it} &= x_{it}'\beta + u_{it}, \quad i = 1, 2, \ldots, N, \; t = 1, 2, \ldots, T, \\
u_{it} &= \mu_i + \nu_{it}, \\
\nu_{it} &= \rho \nu_{i,t-1} + \epsilon_{it}, \quad |\rho| < 1,
\end{aligned}
$$

where β is a $(k \times 1)$ vector of parameters including the intercept, $\mu_i \sim IIDN(0, \sigma_\mu^2)$ is a random individual component, and $\epsilon_{it} \sim IIDN(0, \sigma_\epsilon^2)$. The μ_i and ν_{it} are assumed to be independent of each other with $\nu_{i,0} \sim N(0, \sigma_\epsilon^2/(1-\rho^2))$. N and T denote the number of individual units and the number of time periods, respectively.

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Researchers are typically interested in testing the nulls of no random effects ($H_0 : \sigma_\epsilon^2 = 0$) and/or no first order serial correlation ($H_0 : \rho = 0$). The standard Breusch and Pagan (1980) statistic is used to test the null of no random effects, assuming that there is no serial correlation. Similarly, the statistic derived by Baltagi and Li (1995) tests the null of no serial correlation, assumming no random effects.

Recently, Bera, Sosa-Escudero and Yoon (2001, BSY hereafter) showed that the presence of first order serial correlation makes the Breusch and Pagan (1980) test reject the null of no random effects even when it is correct. They propose an adjusted version which is not affected by the presence of serial correlation. A similar adjusted version is derived by BSY for the Baltagi and Li (1995) test for serial correlation, which is invalid under the presence of random effects.

Baltagi and Li (1991) propose a simple test for the joint null of no serial correlation and random effects. Recognizing the one-sided nature of the problem of testing for random effects, Honda (1985) proposes a one-sided version of the Breusch-Pagan test which is also invalid in the presence of first order serial correlation. BSY propose a corrected verison of this one-sided test.

Expressions of the test statistics

Let I_N be an identity matrix of dimension N, e_T a vector of ones of dimension T, let

$$u' = (u_{11}, \ldots, u_{1T}, \ldots, u_{N1}, \ldots, u_{NT})$$

and u_{-1} an $(NT \times 1)$ vector containing $u_{i,t-1}$. Define A and B as in Baltagi and Li (1991):

$$A = 1 - \frac{\widetilde{u}'(I_N \quad e_T e_T')\widetilde{u}}{\widetilde{u}'\widetilde{u}},$$

and

$$B = \frac{\widetilde{u}'\widetilde{u}_{-1}}{\widetilde{u}'\widetilde{u}}.$$

where $\widetilde{u}$ are the OLS residuals from the standard linear model $y_{it} = x_{it}'\beta + u_{it}$ without the random effects and serial correlation.

The LM test (or Rao's (1948) score test) for random effects is given in Breusch and Pagan (1980):

$$\texttt{LM(Var(u)=0)} = \frac{NTA^2}{2(T-1)},$$

and the adjusted version in BSY (2001) is:

$$\texttt{ALM(Var(u)=0)} = \frac{NT(A+2B)^2}{2(T-1)(1-\frac{2}{T})}$$

The one-sided versions of the previous tests are given by:

$$\texttt{LMO(Var(u)=0)} = -\sqrt{\frac{NT}{2(T-1)}}A$$

and

$$\texttt{ALMO(Var(u)=0)} = -\sqrt{\frac{NT}{2(T-1)(1-\frac{2}{T})}}(A-2B)$$

The LM statistic to test the null of no serial correlation assuming no random effects is given in Baltagi and Li (1991):

$$\texttt{LM(rho=0)} = \frac{NT^2B^2}{T-1}$$

and the adjusted version by BYS (2000), valid under random effects, is:

$$\texttt{ALM(rho=0)} = \frac{NT^2(B+\frac{A}{T})^2}{(T-1)(1-\frac{2}{T})}.$$

Baltagi and Li (1991, 1995) derived a joint LM test for serial correlation and random individual effects which is given by

$$\texttt{LM(Var(u)=0,rho=0)} = \frac{NT^2}{2(T-1)(T-2)}[A^2+4AB+2TB^2]$$

It is interesting to note that this joint test statistic is related to the one-directional adjusted and unadjusted tests as follows:

```
LM(Var(u)=0,rho=0) = ALM(Var(u)=0) + LM(rho=0) = LM(Var(u)=0) + ALM(rho=0)
```

which implies that the adjusted tests could be computed as,

```
ALM(Var(u)=0) = LM(Var(u)=0, rho=0) - LM(rho=0)
ALM(rho=0) = LM(Var(u)=0, rho=0) - LM(Var(u)=0)
```

Example

This example illustrates the use `xttest1` and the interpretation of the statistics computed, and it is taken from BSY(2001). It is based on the well-known Grunfeld (1958) investment data set for five US manufacturing firms measured over 20 years which is frequently used to illustrate panel issues. It has been used in the illustration of misspecification tests in the error-component model in Baltagi et al. (1992), and in recent books such as those by Baltagi (1995, p.20) and Greene (2000, p.592). The equation to be estimated is a panel model of firm investment using the real value of the firm and the real value of capital stock as explanatory variables:

$$I_{it} = \beta_0 + \beta_1 F_{it} + \beta_2 C_{it} + u_{it},$$

where I_{it} denotes real gross investment for firm i in period t, F_{it} is the real value of the firm and C_{it} is the real value of the capital stock, $i = 1, 2, \ldots, 5$, and $t = 1, 2, \ldots, 20$.

First we estimate the parameters of a one-way error component model with random effects using `xtreg`:

```
. xtreg i f c, i(firm)

Random-effects GLS regression                   Number of obs      =       100
Group variable (i) : firm                       Number of groups   =         5

R-sq:  within  = 0.8003                         Obs per group: min =        20
       between = 0.7696                                        avg =      20.0
       overall = 0.7781                                        max =        20
```

```
Random effects u_i ~ Gaussian                    Wald chi2(2)       =    384.93
corr(u_i, X)       = 0 (assumed)                 Prob > chi2        =    0.0000

------------------------------------------------------------------------------
       i |      Coef.   Std. Err.       z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
       f |   .1048856   .0147972      7.088   0.000       .0758835    .1338876
       c |   .3460156   .0242535     14.267   0.000       .2984796    .3935517
   _cons |  -60.29048   54.48389     -1.107   0.268      -167.0769    46.49599
---------+--------------------------------------------------------------------
 sigma_u |   104.6527
 sigma_e |  69.117979
     rho |  .69628405   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

Then the `xttest1` command computes the seven tests described before: the Breusch and Pagan test for random effects (`LM(Var(u)=0)`), the BSY adjusted version (`ALM(Var(u)=0)`), the corresponding one sided versions (`LMO(Var(u)=0)` and `ALMO(Var(u)=0)`), the Baltagi and Li serial correlation test (`LM(rho=0)`), the corresponding adjusted version (`ALM(rho=0)`), the Baltagi and Li joint test for serial correlation and random effects (`LM(Var(u)=0,rho=0)`), the Honda one-sided test for random effects (`LMO(Var(u)=0)`) and the adjusted version (`ALMO(Var(u)=0)`). The output of `xttest1` is as follows:

```
.xttest1
Tests for the error component model:

        i[firm,t] = Xb + u[firm] + v[firm,t]
           v[firm,t] = rho v[firm,(t-1)] + e[firm,t]

        Estimated results:
                                 Var     sd = sqrt(Var)
                ---------+-----------------------------
                       i |    71751.9       267.8654
                       e |   4777.295      69.117979
                       u |   10952.19      104.6527

        Tests:
           Random Effects, Two Sided:
           LM(Var(u)=0)        =  453.82   Pr>chi2(1) =  0.0000
           ALM(Var(u)=0)       =  384.18   Pr>chi2(1) =  0.0000

           Random Effects, One Sided:
           LMO(Var(u)=0)       =   21.30   Pr>N(0,1)  =  0.0000
           ALMO(Var(u)=0)      =   19.60   Pr>N(0,1)  =  0.0000

           Serial Correlation:
           LM(rho=0)           =   73.35   Pr>chi2(1) =  0.0000
           ALM(rho=0)          =    3.71   Pr>chi2(1) =  0.0540

           Joint Test:
           LM(Var(u)=0,rho=0)  =  457.53   Pr>chi2(2) =  0.0000
```

The unadjusted tests for serial correlation (`LM(rho=0)`) and for random effects (`LM(Var(u)=0)` and `LMO(Var(u)=0)`) reject the respective null hypothesis of no serial correlation and no random effects, and the omnibus test (`LM(Var(u)=0,rho=0)`) rejects the joint null. But the adjusted tests suggest that in this example the problem seems to be the presence of random effects rather serial correlation. The adjusted versions of the random effect tests (`ALM(Var(u)=0)` and `ALMO(Var(u)=0)`) also reject the null but the adjusted serial correlation test (`ALM(rho=0)`) barely rejects the null at the 5% significance level. It is interesting to note the substantial reduction of the autocorrelation test statistic, from 73.351 to 3.712. So in this example the misspecification can be thought to come from the presence of random effects rather than serial correlation.

In spite of the small sample size of the data sets, this example seems to illustrate clearly the usefulness of BSY tests: the adjusted versions are more informative than a test for serial correlation or random effect that ignores the presence of the other effect. In this case, the presence of a random effect seems to spuriously induce rejection of the no-serial correlation hypothesis. The joint test (`LM(Var(u)=0,rho=0)`) rejects the joint null but is not informative about the direction of the misspecification.

Saved results

`xttest1` saves in variables $S_1, S_2, \ldots, S_7$ the test statistics in the following order: `LM(Var(u)=0)`, `ALM(Var(u)=0)` ,`LMO(Var(u)=0)`, `ALMO(Var(u)=0)`, `LM(rho=0)`, `ALM(rho=0)` and `LM(Var(u)=0,rho=0)`.

References

Baltagi, B., 1995, *Econometric Analysis of Panel Data*, New York: Wiley & Sons.

Baltagi, B., Y. Chang and Q. Li, 1992, Monte Carlo results on several new and existing tests for the error component model, *Journal of Econometrics*, 54, 95-120.

Baltagi, B. and Q. Li, 1991, A joint test for serial correlation and random individual effects, *Statistics & Probability Letters*, 11, 277–280.

Baltagi, B. and Q. Li, 1995, Testing AR(1) against MA(1) disturbances in an error component model, *Journal of Econometrics*, 68, 133-151.

Bera, A., Sosa-Escudero, W. and Yoon, M., 2001, Tests for the error component model in the presence of local misspecification, *Journal of Econometrics*, 101, 1-23.

Breusch, T.S. and A.R. Pagan, 1980, The Lagrange multiplier test and its applications to model specification in econometrics, *Review of Economic Studies*, 47, 239–253.

Greene, W., 2000, *Econometric Analysis*, 4th Edition, New Jersey: Prentice Hall.

Grunfeld, Y., 1958, The Determinants of Corporate Investment, Unpublished Ph.D thesis, Department of Economics, University of Chicago.

Honda, Y., 1985, Testing the error component model with non-normal disturbances, *Review of Economic Studies*, 52, 681-690.

Rao, C.R., 1948, Large sample tests of statistical hypothesis concerning several parameters with applications to problems of estimation, *Proceedings of the Cambridge Philosophical Society*, 44, 50-57.