Amin Haghnejad (am.haghnejad@gmail.com)

1. Description

This repository contains the Matlab code for performing the cross-sectional error dependence tests in panel data models, including the Lagrange multiplier (LM) test by Breusch and Pagan (1980), the cross-sectional dependence (CD) and scaled LM (CD_{LM}) tests by Pesaran (2004, 2015), the bias-adjusted LM (LM_{adj}) test by Pesaran, Ullah, and Yamagata (2008), and the bias-corrected scaled LM (LM_{BC}) test by Baltagi, Feng, and Kao (2012).

2. Citation

This code is provided as supplementary material for our paper:

Haghnejad, A., Samadi, S., Nasrollahi, K., Azarbayjani, K., & Kazemi, I. (2020). Market power and efficiency in the Iranian banking industry. *Emerging Markets Finance and Trade*, 56(13), 3217-3234.

Please cite this paper if you are using the code in your research.

3. Cross-sectional dependence tests

The procedure for testing the presence of cross equation error correlations in the panels is based on the following model:

$$y_{it} = \alpha_i + \boldsymbol{\beta}_i'\mathbf{x}_{it} + u_{it}, \quad i = 1, 2, \dots, N, \qquad t = 1, 2, \dots, T, \tag{1}$$

where i is the cross-sectional dimension, t is the time dimension, y_{it} is the dependent variable, $\mathbf{x}_{it}$ is a $p \times 1$ vector of regressors, and α_i and $\boldsymbol{\beta}_i$ are intercept and a $p \times 1$ vector of unknown slope coefficients, respectively, which are allowed to vary across individuals. The null hypothesis of no cross-sectional dependence then becomes

$$H_0: E\left(u_{it}\, u_{jt}\right) = 0, \qquad \forall t \text{ for all } i \neq j$$

against the alternative

$$H_1 : E\left(u_{it}\, u_{jt}\right) \neq 0, \qquad \text{for some } t \text{ and some } i \neq j.$$

Breusch and Pagan (1980) have proposed a Lagrange Multiplier test for cross-sectional dependence based on the ordinary least squares (OLS) residuals. The test statistic is

$$LM = T \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij}^2, \tag{2}$$

where $\hat{\rho}_{ij}$ denote the pair-wise correlations of the residuals derived from the OLS estimation of individual regressions in Equation (1). Under the null hypothesis, the LM statistic has a limiting χ^2 distribution with $N(N-1)/2$ degrees of freedom. However, it is well known that the Breusch and Pagan test is likely to exhibit considerable size distortions when $N \to \infty$. In this case, Pesaran (2004) proposes a scaled version of the LM statistic, defined as

$$CD_{LM} = \sqrt{\frac{1}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \left(T\hat{\rho}_{ij}^2 - 1\right). \tag{3}$$

Under the null hypothesis of cross-sectional independence with $T \to \infty$ first, and then $N \to \infty$, the CD_{LM} statistic has a $N(0,1)$ distribution, and can be used even in cases where both N and T are large. To address the large N bias of the Breusch and Pagan test, Pesaran (2004) proposes another statistic with the reasonable finite sample properties as follows:

$$CD = \sqrt{\frac{2T}{N(N-1)}} \left(\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij} \right). \tag{4}$$

Under the null hypothesis of no cross-sectional dependence, the CD statistic is asymptotically distributed as $N(0,1)$, provided that $N \to \infty$ and T is sufficiently large. Pesaran (2015) establishes that the CD test is best viewed as a test of weak cross sectional dependence, namely the null of weak dependence is more appropriate than the null of independence in the case of large panel data models where only pervasive cross-dependence is of concern.

Pesaran, Ullah, and Yamagata (2008) propose an alternative bias-adjusted version of the LM statistic to test the cross-sectional dependence in the context of a heterogeneous panel data model. This bias-adjusted LM statistic is given by

$$LM_{adj} = \sqrt{\frac{2}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \frac{(T-k)\hat{\rho}_{ij}^2 - \mu_{Tij}}{v_{Tij}}, \tag{5}$$

Where $k = \mathrm{p} + 1$ is the number of parameters in Equation (1), and μ_{Tij} and v_{Tij} denote the exact mean and standard deviation of $(T-k)\hat{\rho}_{ij}^2$, respectively, which are provided by Pesaran, Ullah, and Yamagata (2008) as follows

$$\mu_{Tij} = E\left[(T-k)\hat{\rho}_{ij}^2\right] = \frac{1}{T-k} Tr\left[E(\mathbf{M}_i \mathbf{M}_j)\right],$$

$$v_{Tij}^2 = Var\left[(T-k)\hat{\rho}_{ij}^2\right] = \left\{Tr\left[E(\mathbf{M}_i \mathbf{M}_j)\right]\right\}^2 a_{1T} + 2\left\{Tr\left[E(\mathbf{M}_i \mathbf{M}_j)^2\right]\right\} a_{2T},$$

where

$$a_{1T} = a_{2T} - \left(\frac{1}{T-k}\right)^2, \qquad a_{2T} = 3\left[\frac{(T-k-8)(T-k+2)+24}{(T-k+2)(T-k-2)(T-k-4)}\right]^2,$$

$\mathbf{M}_i = \mathbf{I}_T - \widetilde{\mathbf{X}}_i \left(\widetilde{\mathbf{X}}_i' \widetilde{\mathbf{X}}_i\right)^{-1} \widetilde{\mathbf{X}}_i'$, and $\mathbf{I}_T$ is an identity matrix of order T and $\widetilde{\mathbf{X}}_i$ is a $T \times k$ matrix of observations on $(1, \mathbf{x}_{it}')'$. Under the null hypothesis of cross-sectional independence, with $T \to \infty$ first, and then $N \to \infty$, the LM_{adj} statistic is asymptotically distributed as $N(0,1)$.

Baltagi, Feng, and Kao (2012) correct the asymptotic bias of the CD_{LM} statistic proposed by Pesaran (2004) but applied in the context of a homogeneous panel data model with fixed effects. The bias-corrected LM test statistic is calculated as

$$LM_{BC} = CD_{LM}^{FE} - \frac{N}{2(T-1)} = \sqrt{\frac{1}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} (T\check{\rho}_{ij}^2 - 1) - \frac{N}{2(T-1)}, \quad (6)$$

where $\check{\rho}_{ij}$ denote the pair-wise correlations of the residuals obtained from the fixed effects (within-group) estimation of Equation (1). Under the null hypothesis of cross-sectional independence, $LM_{BC} \rightarrow N(0,1)$.

References

Baltagi, B. H., Feng, Q., & Kao, C. (2012). A Lagrange Multiplier test for cross-sectional dependence in a fixed effects panel data model. *Journal of Econometrics*, 170(1), 164-177.

Breusch, T. S., & Pagan, A. R. (1980). The Lagrange multiplier test and its applications to model specification in econometrics. *The Review of Economic Studies*, 47(1), 239-253.

Haghnejad, A., Samadi, S., Nasrollahi, K., Azarbayjani, K., & Kazemi, I. (2020). Market power and efficiency in the Iranian banking industry. *Emerging Markets Finance and Trade*, 56(13), 3217-3234.

Pesaran, M. H., Ullah, A., & Yamagata, T. (2008). A bias-adjusted LM test of error cross-section independence. *The Econometrics Journal*, 11(1), 105-127.

Pesaran, M. H. (2004). General diagnostic tests for cross section dependence in panels, Cambridge Working Papers in Economics 0435, Faculty of Economics, University of Cambridge.

Pesaran, M. H. (2015). Testing weak cross-sectional dependence in large panels. *Econometric Reviews*, 34(6-10), 1089-1117.