Shortfalls of Panel Unit Root Testing

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Abstract

This paper shows that (i) magnitude and variation of contemporaneous correlation are important in panel unit root tests, (ii) demeaning across the panel usually doesn't eliminate these problems, and that (iii) these tests lack power when H_0 and H_A are local to each other.

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Panel unit root procedures such as the Im, Pesaran and Shin (IPS, 1997) have become popular in recent years to analyze issues such as convergence and PPP. IPS procedures address the low power associated with single series ADF tests by averaging the test statistics across the panel (N series) and assuming i.i.d. errors. When this assumption is violated and residuals are contemporaneously correlated, IPS suggests demeaning across N to remedy a size distortion. Our contribution is to demonstrate that the extent of size distortion generated by contemporaneous correlations depends on the magnitude of cross correlation coefficients, their variability and the number of series in the panel. We show that demeaning will not eliminate the size problem caused by the variation of cross correlations. Further, the imposition of a one-for-one restriction common in PPP testing or convergence may be misleading and we illustrate this by constructing a confidence level band.

The IPS test possesses substantially more power than single-equation ADF test by averaging N independent ADF regressions:

$$\Delta y_{it} = \alpha_i + \rho_i y_{i,t-1} + \sum_{j=1}^{p} \theta_{ij} \Delta y_{i,t-j} + v_{it}, \qquad (1)$$

for $i=1,\ldots,N$ series. The procedure allows for heterogeneity in ρ and α. The null hypothesis is that $\rho_i=0$ and the alternative is that certain percentage of the series has a value of ρ significantly less than zero. The limiting distribution is given as:

$$\sqrt{N}\,\frac{(\bar{t}_{ADF} - \mu_{ADF})}{\sqrt{\sigma^2_{ADF}}} \rightarrow N(0, 1) \qquad (2)$$

where the moments μ_{ADF} and σ^2_{ADF} are from Monte Carlo simulations, and $\bar{t}_{ADF}$ is the average estimated ADF *t*-statistics from the sample. The power to reject the null increases by the $\sqrt{N}$. The IPS test is derived assuming that the series are independently generated, and they suggest subtracting cross-sectional means to remove common time specific or aggregate effects. This assumes the error term from Equation (1) consists of two random components, $v_{it}=\theta_t+\zeta_{it}$, where ζ_{it} is the idiosyncratic random component, and θ_t is a stationary time-specific (aggregate) effect that accounts for common correlation in the errors across economies. However, subtracting cross sectional means will only partially reduce the correlation in the data if there is heterogeneity in the cross sectional correlation, and hence a substantial size distortion may still remain.

In Table 1, we report how different levels and variation of cross dependence along with the number of series in the panel affect the size distortion and size adjusted critical values. After generating cross-correlated N series, we ran 5000 Monte Carlo simulations to test the IPS null hypothesis of a unit root process. The variations in cross correlations are produced by adding a random number (distributed uniformly between [-k , k] where k = 0.1, . . , 0.5) to the off-diagonal elements in the correlation matrix. Results clearly show the greater the magnitude and heterogeneity of contemporaneous correlation along with larger the number of series, the higher is the size distortion and more negative are the size adjusted critical values. For variation of 0.5, the size distortion is substantial for N = 25 or higher. Table 2 shows that adjusting the critical values for heterogeneity of the cross correlation also results in lower power as the lack of independence implies that this value does not increase by the square root on N. For N = 50, for instance, the power declines from 0.74 to 0.35 using the size adjusted critical values.

Table 3 applies our simulation studies to three widely used data sets to illustrate that demeaning typically does not remove all of the contemporaneous correlation (see Appendix for data description). To adjust for the size problem, we use the actual covariance matrix in our Monte Carlo simulations to calculate size adjusted critical values and the size distortion. We report these statistics in Table 3 for the demeaned data. For both the OECD and PPP data, demeaned ADF statistics reject the null hypothesis of a unit root process at the 1% level, while critical values adjusting for variation in the cross correlations indicate that we can not reject a unit root process at even the 10% level[1]. The size distortion hence produces incorrect inference and a Type I error.

A second problem with panel unit root procedures is that that the tests only accept or reject the null hypothesis. Confidence intervals for the restriction are typically not reported although they can be particularly useful in supporting or rejecting an economic theory. For instance, stochastic convergence is defined as a one-for-one relationship between country *i* and a benchmark economy, and it is typically tested (Evans 98) by subtracting the mean of the countries. Stochastic convergence occurs if relative per capita GDP, y_{it}, follows a stationary process, where $y_{it} = Y_{it} - \beta_i \overline{y}_t$, and Y_{it} is the log of real per capita GDP for country *i*, $\overline{y}_t = \sum_{i=1}^{N} Y_{it}$ and $\beta_i = 1$. The null hypothesis is that y_{it} follows a nonstationary process indicating no stochastic converge, and the alternative hypothesis is that shocks only temporarily affect the output gap between economies[2]. Researchers such as Evans and Karras (1996) and Fleissig and Strauss (2001) typically interpret rejection of the null as support for the one-for-one restriction. In Table 4, we report different β_i around 1 for two widely used data sets and show that we can reject the null even though β_i is considerably different than one. The first row illustrates the range for β_i using IPS critical values for demeaned data; whereas, the second row displays the range for size adjusted critical values.

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[1] Note that the variation in the three actual datasets ranged between 0.55 and 0.65.

[2] Note that many standard panel unit root tests demean to remove contemporaneous correlations when testing for nonstationarity in a panel. However this process cannot be differentiated from a test for stochastic convergence. Since a precondition for stochastic convergence is that the variables are integrated, we apply IPS tests (with size adjusted critical values) on non-demeaned data. Results confirm that both BLS and Maddison data sets are I(1).

Results cannot reject approximately between .83 (.75) to 1.24 (1.40) for demeaned data for the BLS U.S. States (Maddison). Using size adjusted critical values shrinks the range modestly to .875 (.82) to 1.22 (1.35). Panel unit root methods' lack of local power in testing a restriction implies that the practitioner must be careful in deriving conclusions supporting stochastic convergence[3].

Conclusion

Our paper demonstrates that the greater the extent of cross correlations and their variation along with the size of the panel, the higher is the size distortion and more negative are the size adjusted critical values. We show that demeaning typically does not eliminate the size problem given extensive variation of cross correlations and a large N. A second potential problem with panel unit root procedures is the lack of power when the alternative hypotheses are local to the null hypothesis of one-for-one restriction.

Appendix

The PPP data set is from the IFS CD and includes quarterly data from 1974.1 to 1994.4 for Australia, Austria, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Spain, Sweden, Switzerland and the U.K. We use the U.S. as the benchmark and CPI prices. The Maddison Data includes annual per capita income data from 1870-1994 for Australia, Austria, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, New Zealand, Spain, Sweden, U.K and U.S. The U.S. states includes per capita wage data from the BLS website for 48 states from 1926-1995; two states were dropped due to data unavailability.

[3] An alternative approach is to estimate the confidence interval directly by a panel cointegration technique; however, with this method, appropriate asymptotic distribution for the estimates is unknown in the existence of cross sectional dependence.

Table 1: Critical Values for common and heterogeneous contemporaneous correlation

Correlation	N = 10		N = 25		N = 50		N = 100	
	5% critical value	Size distortion	5% critical value	Size distortion	5% critical value	Size distortion	5% critical value	Size distortion
0	-1.679	0.050	-1.683	0.050	-1.622	0.050	-1.591	0.050
0.25	-2.038	0.084	-2.285	0.116	-2.572	0.161	-3.229	0.235
0.5	-2.742	0.176	-3.791	0.261	-4.947	0.342	-6.564	0.428
0.75	-4.927	0.319	-7.301	0.395	-9.673	0.458	-13.78	0.484
Variation ρ_i								
0.1	-1.688	0.055	-1.688	0.054	-1.744	0.060	-1.721	0.057
0.2	-1.864	0.072	-1.785	0.066	-1.927	0.079	-2.036	0.098
0.3	-1.903	0.077	-1.999	0.093	-2.163	0.110	-2.492	0.142
0.4	-2.055	0.094	-2.235	0.119	-2.577	0.152	-3.007	0.203
0.5	-2.377	0.136	-2.638	0.148	-2.973	0.197	-3.662	0.246

Notes: N represents number of series in the panel. The critical values and size distortion assume identical correlation coefficients (hence no variation) for the top half of the table; whereas, the bottom half has been demeaned (hence an average correlation of 0), but the critical values and size distortion change due to variation in contemporaneous correlation. Number of observations (T) is chosen as 50 since IPS (1997) shows that critical values are going to be independent of T. These values have been obtained with 5000 iterations.

Table 2: Power of panel unit root test with cross correlation.

Variation in ρ_i	N = 25	N = 50	N = 100
0	0.462	0.735	0.958
0.1	0.440	0.721	0.924
0.2	0.410	0.614	0.838
0.3	0.362	0.538	0.699
0.4	0.300	0.454	0.570
0.5	0.251	0.350	0.415

The number of observations is 25 in each series and the autoregressive coefficient used in the simulation studies is .9.

Table 3: Critical Values and Size Distortion on Demeaned Data

	Convergence Maddison	Convergence, BLS Wage	PPP
test statistic	-2.105	-2.267	-2.203
Size Adjusted			
1% critical value	-3.996	-2.797	-3.339
5% critical value	-2.812	-2.036	-2.442
10% critical value	-2.249	-1.620	-1.945
Size distortion	0.181	0.096	0.144

Notes: Critical values and test statistics for real data examples from convergence studies. For Maddison, N = 15 and T = 123, the BLS wage dataset has N = 48 and T = 65 and PPP dataset has N = 17 and T = 96. Critical values are derived from 5000 iterations using the actual (historical) covariance matrix.

Table 4 : Investigating a Confidence Band around a 1:1 Restriction

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β	0.830	0.850	0.860	0.870	0.875	0.880	1.200	1.210	1.220	1.240	1.250
t-stat	-1.632*	-1.789*	-1.870*	-1.953*	-1.995*	-2.037*	-2.296*	-2.148*	-1.996*	-1.680*	-1.515
Adjusted t-stat.	-1.646	-1.812	-1.899	-1.987	-2.031*	-2.076*	-2.351*	-2.194*	-2.033*	-1.696	-1.522

BLS Data

β	0.750	0.754	0.800	0.816	1.300	1.348	1.400	1.402	1.450
t-stat	-1.579	-1.655*	-2.621*	-2.999*	-3.816*	-2.997*	-1.711*	-1.651*	-0.127
Adjusted t-stat.	-1.548	-1.625	-2.608	*-2.993	-3.823*	-2.991*	-1.682	-1.621	-0.072

Maddison Data

Note: The adjusted t-stat. refers to the 5% size adjusted critical value. * indicates significance at 5% confidence level, and the adjusted critical values for BLS and Maddison data are -2.03 and -2.99, respectively.

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