

Annual Methodological Archive Research Review

<http://amresearchreview.com/index.php/Journal/about>

Volume 3, Issue 7 (2025)

Empirical Decision in Panel Unit Root Testing: Comparing Simulated and Asymptotic Critical Values

¹Shahid Akbar, ²Mehvish Raja, ³Farzana Munir

Article Details

ABSTRACT

Key Words: Asymptotic Critical Value, Oversized, Undersized, Simulated Critical Value, Size Distortion.

Shahid Akbar Corresponding Author
Department of Economics, The University of Lahore, Lahore Pakistan.
Email: shahid.akbar@econ.uol.edu.pk

Mehvish Raja
Skans School of Accountancy
Rawalpindi Campus
Email: mehvish.raja2080@gmail.com

Farzana Munir
School of Economics, Bahauddin Zakariya University, Multan, Pakistan.
Email: farzanamunir@bzu.edu.pk

A comparison of asymptotic and simulated critical values for panel unit root tests is made to address the problem of size distortions under asymptotic critical values and how to achieve the stabilized size under the simulated critical values. Our results suggest that the simulated critical values are more appropriate to avoid size distortion, especially in finite panel dimensions, and to get the stabilized size around nominal size of 5%. This finding holds whether panel dimensions are small, medium or large.

INTRODUCTION

It is seen in the literature that whenever researchers develop a statistical test for time series or panel data, they also calculate asymptotic critical value (ACV) for a proposed test-statistic from the derived asymptotic distribution in order to make statistical inference. However, ASVs cause size distortion, especially in finite samples, providing misleading results for the data under investigation. Also, one of the main tedious work under ASCs is the derivation of asymptotic probability distribution for a given test statistic using sequential or joint limit theory. This size distortion is considered to be more serious in two dimension data as related to time series data. This is because panel test statistics are considered to be more powerful tests under two-dimensional data.

In panel data literature, under the panel unit root (PUR) tests, almost all PUR tests comparative studies have used ASCs to evaluate the size behavior of tests. This causes size distortion for bulk of the PUR tests, especially in finite panel dimension, which produces misleading pattern of power evaluation for the tests under investigation. This as a result also miscalculates a true pattern of data under observation. (Maddala and Wu 1999) carried out simulation study by comparing their developed PUR test (base on (Fisher 1934) method) with tests developed in (Levin et al. 2002); and (Im et al. 2003) to examine the size behavior by taking Augmented Dickey-Fuller (ADF) regressions. They showed that all these three tests are under sized if the ADF regression is of order zero. However, at ADF(1) the size of Fisher type test is approximately equal to nominal size of 5% while (Levin et al. 2002); and (Im et al. 2003) tests are identified as oversized. Similarly, (Hlouskova and Wagner 2006) compared four PUR tests developed in (Im et al. 2003); (Levin et al. 2002); Breitung (1999); and (Maddala and Wu 1999), and concluded that all these tests face serious size distortion if cross section (N) units are more as compared to time series (T) units. However, overall size distortion of (Breitung 1999); and (Levin et al. 2002) tests is identified as less as compared to other tests. Further, (Gutierrez 2006) also carried out Monte Carlo simulation study by comparing size behavior of PUR tests settled in (Choi 2001), (Moon and Perron 2004), (Bai and Ng 2004), and (Phillips and Sul 2003) and showed size distortion of these tests in different situations. All these comparative studies have used ACVs which have caused serious size distortion to assess the performances of PUR tests. Also, in the applied research, ACVs cause serious size distortion as different PUR tests produce different ACVs, showing different conclusion for the same data under investigation.

To tackle size distortion under ACVs, this study uses simulated critical values (SCVs) to achieve

stable size of PUR tests approximate to insignificant size of 5%. Also, a large number (eighteen) of PUR tests are taken to provide a clear view of size instability under ACVs and investigates a stabilized size under SCVs. In this study, we are investigating size pattern of eighteen PUR tests developed in (Breitung 1999); (Maddala and Wu 1999); (Choi 2001); (Levin et al. 2002); (Chang 2002); (Im et al. 2003); (Phillips and Sul 2003); (Bai and Ng 2004); (Oh and So 2004); (Moon and Perron 2004); (Pesaran 2007); (De Wachter et al. 2007); (Sul 2009); (Lee and Wu 2012); (Demetrescu and Hanck 2012); (Westerlund and Larsson 2012); and (Westerlund 2014); all these tests hereafter abbreviated as MW, BU, CHO, LLC, CH, IPS, PS, MP, BN, OS, CIPS and CIPS_star¹, DWH, RMA, LW, DH, WL and WT respectively. This study is carried out in four sections. In Section 2, the methodology of the paper is explained for SCVs. Section 3 shows size distortion and size stability results under the mentioned methodology. Lastly, Section 4 provides some conclusions.

METHODOLOGY

Let y_{it} denotes the panel data series, where $t \in T$ and $i \in N$, panel data series are generated using the mathematical model,

$$y_{it} = \gamma_i + \lambda_i t + \rho y_{i,t-1} + \varepsilon_{it}$$

where $\gamma_i \sim N(0,1)$, $\lambda_i \sim N(0,1)$, $\varepsilon_{it} \sim N(0, \delta_{\varepsilon_i})$ and $\delta_{\varepsilon_i} \sim U[0.5, 1.5]$ to generate a complete

heterogeneous model. Here, $\rho = 1$ under H_0 of unit root and $0 \leq \rho < 1$ under H_A of stationarity. We take $\rho = 1$ since our interest is in size of the test. A detail methodological discussion of times series and PUR tests can be found in (Akbar et al., 2024a; Akbar et al., 2024b; Khan et al., 2023; Waheed et al., 2023; Waheed et al., 2021; Raza et al., 2021a; Raza et al., 2021b; Hussan et al., 2019; Akbar et al., 2019).

SIMULATED CRITICAL VALUE (SCV) OF A TEST

The following simulation procedure to calculate the SCVs for the tests under consideration.

- Data are generated under H_0 of PUR according to given DGP.
- Each test statistic is calculated for the given DGP (i.e. DGP under H_0).
- Step-1 and Step-2 (given above) are repeated 10000 times which is called Monte Carlo Sample Size (MCSS) and test statistic is sorted and saved in a column matrix.

¹Both tests are developed in Pesaran (2007)

- SCVs are calculated depending upon nature (i.e. left, right or two tail test) of the test statistic. For the right and left tail tests 95th and 5th percentiles of the matrix are the desired SCVs respectively. SCV. While for a two tail test, 97.5th and 2.5th percentiles are the right SCVs in the column matrix.

FINDING SIZE OF THE TEST

Test size is calculated using the following procedure;

- Data are generated a fixed number of panel dimensions under H_0 . The panel dimensions considered in this study are T=10, 25, 50, 100 and N=4, 8, 16, 32, respectively.
- Test statistic is calculated corresponding to given panel dimensions and the number of significant value is counted if test statistic value is greater than either ACV or SCV.
- A repetition of this process is carried for MCSS=10000 and test size is obtained as

$$Size\ of\ Test = \frac{significant\ count}{MCSS} \times 100$$

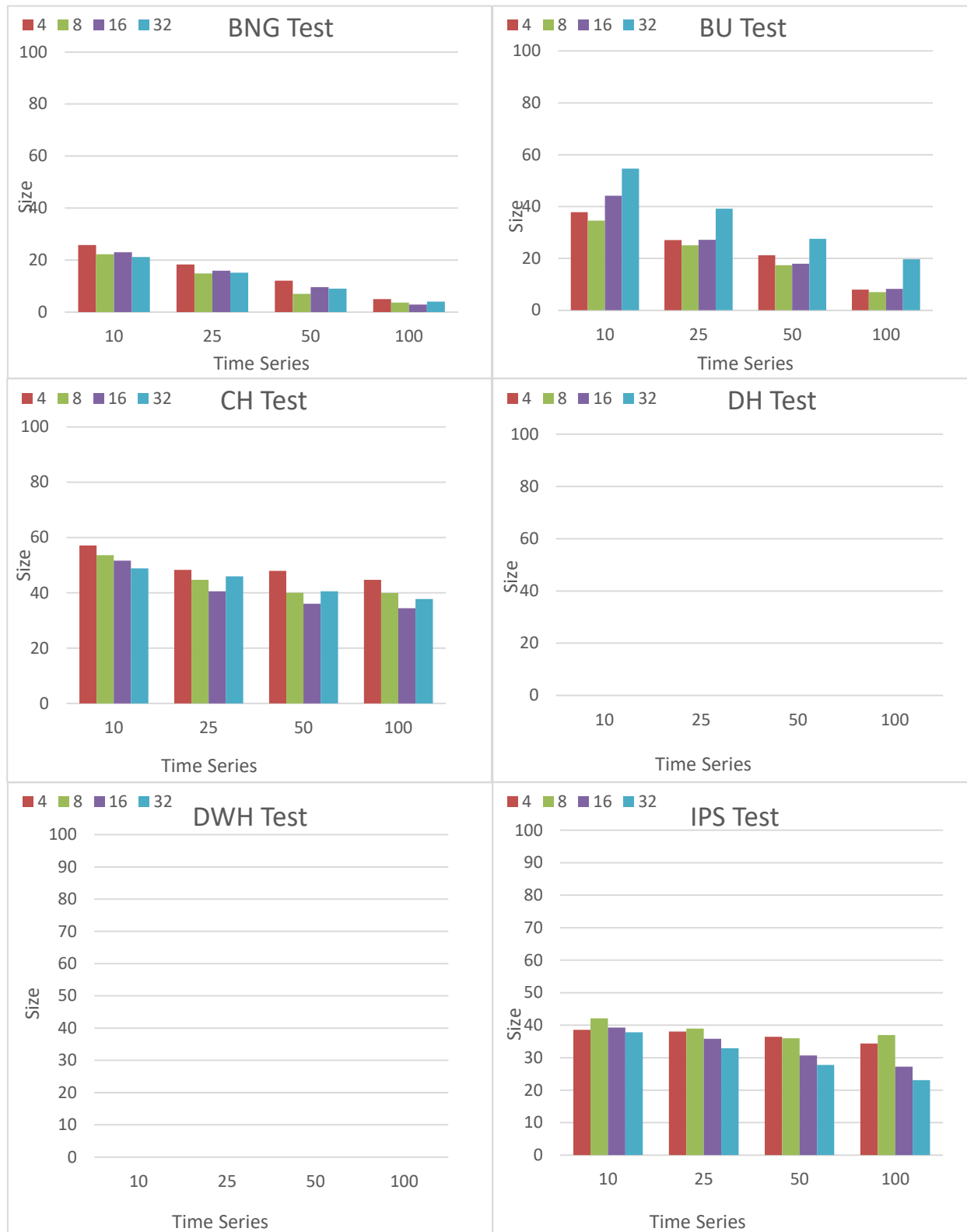
RESULTS AND DISCUSSIONS

This section explains results obtained. First subsection investigates the size distortion issue under ACVs developed for PUR tests. In the second subsection SCVs are calculated and used to stabilize the size.

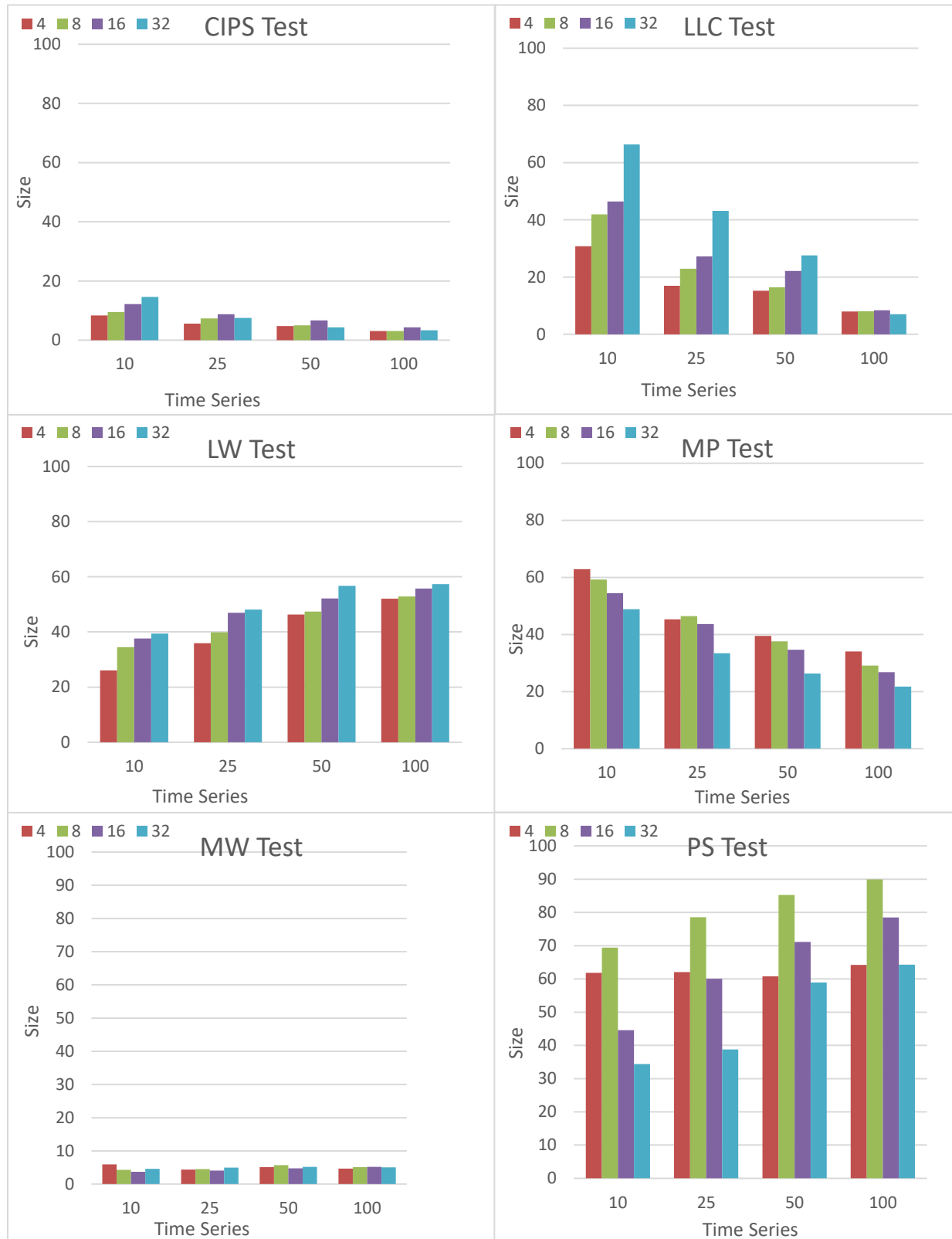
EMPIRICAL SIZE EVALUATION UNDER ACV

ACVs have been used for different combination of T and N dimensions to inspect the size of eighteen tests having H_0 of PUR. Figure 1 represents the results of empirical size evaluation of these PUR tests when data are generated with intercept term only.

FIGURE 1: Empirical Size of Panel Unit Root Tests under Asymptotic Critical Values



Continue.....



Continue.....



Sixteen out of eighteen PUR tests shows a serious upward or downward size distortion from the nominal size of 5% for different panel dimensions (see Figure 1). A serious size distortion with divergence behavior from nominal size of 5% is observed for LW, WL and OS tests as N and T units increase under the considered DGP. A minimum of 26.1%, 35.78%, 4.04% and maximum of 57.31%, 100%, 93.96% size has observed corresponding to LW, WL and OS tests respectively. However, majority of the other tests have also size distortion but their pattern, i.e. convergence or remain stable towards nominal size of 5%, is opposite to the pattern of LW, WL and OS tests as panel dimension gets larger. PS test has gained a divergence pattern for small panel dimension, however it becomes convergent as panel dimension increases.

Moreover, majority of the tests have a maximum size distortion from nominal size of 5% at small panel dimension but as both dimensions gets larger the difference between empirical and nominal size becomes smaller, thus having convergence behavior, and at very large panel dimension empirical size approximately become equal to the size of 5%. Among these convergent size based tests, CH, IPS and MP tests have a maximum and minimum size distortions in between 60% to 20% as panel dimension increases from small to large. Similarly, LLC and WT tests have large size distortion at small T but as both panel lengths increases the observed size of these tests drops rapidly and become equal to 5% nominal size. Also, the empirical size shape of BU and BNG tests are approximately same and both approaches to nominal size at large panel dimensions. Similarly, CIPS and CIPS_star tests have very similar empirical size indicating a little over sized at small panel dimensions, however, at large panel dimensions both of the tests gain empirical size approximately equal to the size of 5%.

Moreover, only two tests (DWH and DH) are identified as under sized from the nominal size of 5% corresponding to all possible considered panel dimensions. While, CHO and MW tests are only two tests having empirical size equal to around 5% nominal size at all panel dimensions as these tests are based on p-value. This analysis is performed only in the presence of intercept term in DGP, however, in the presence of both of the deterministic terms a similar situation has been observed.

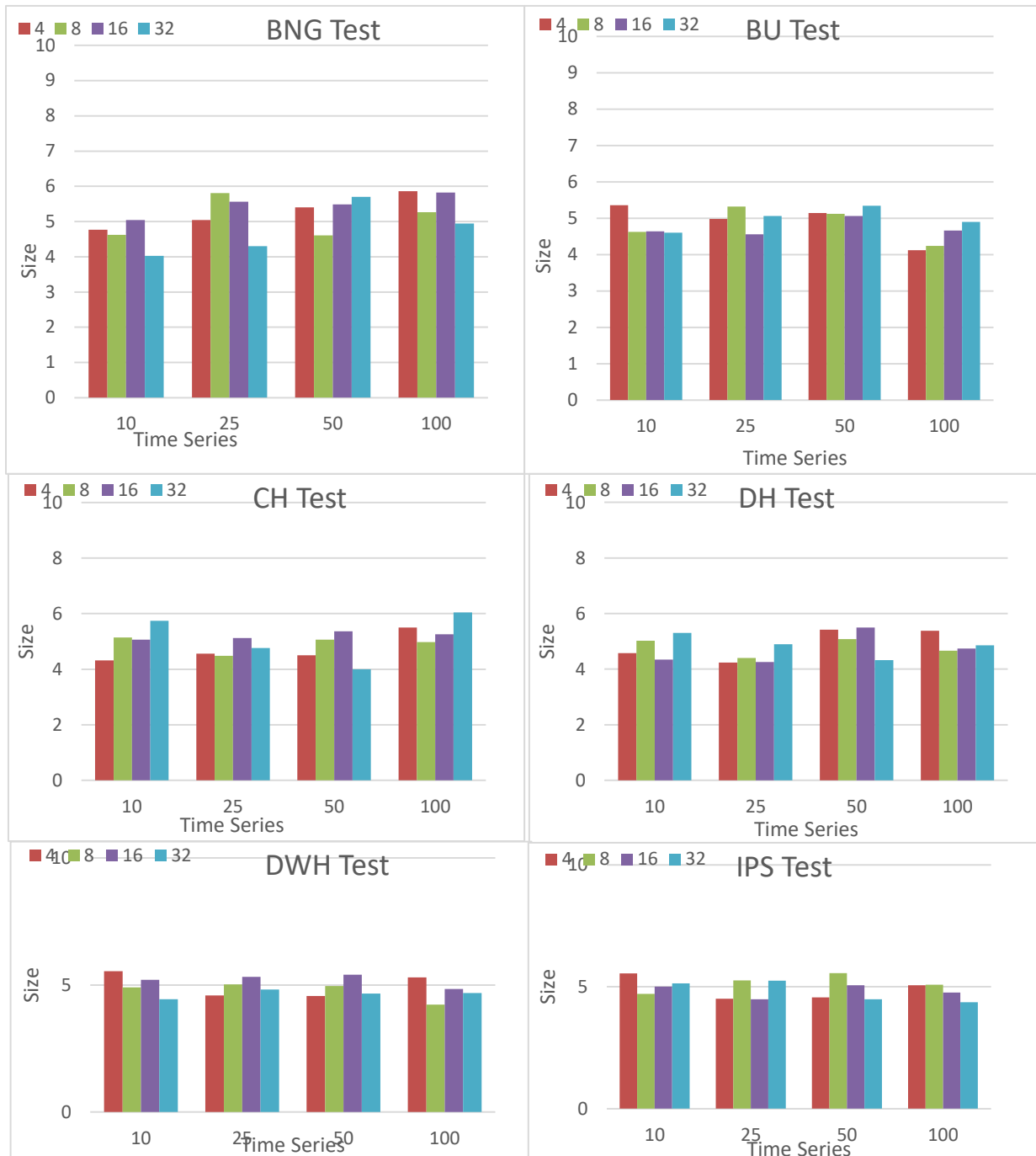
STABILIZED SIZE EVALUATION USING SCV

In order to stabilize the size of under investigated PUR tests SCVs are calculated and utilized for the same panel dimensions as have been considered for the empirical size analysis under ACV.

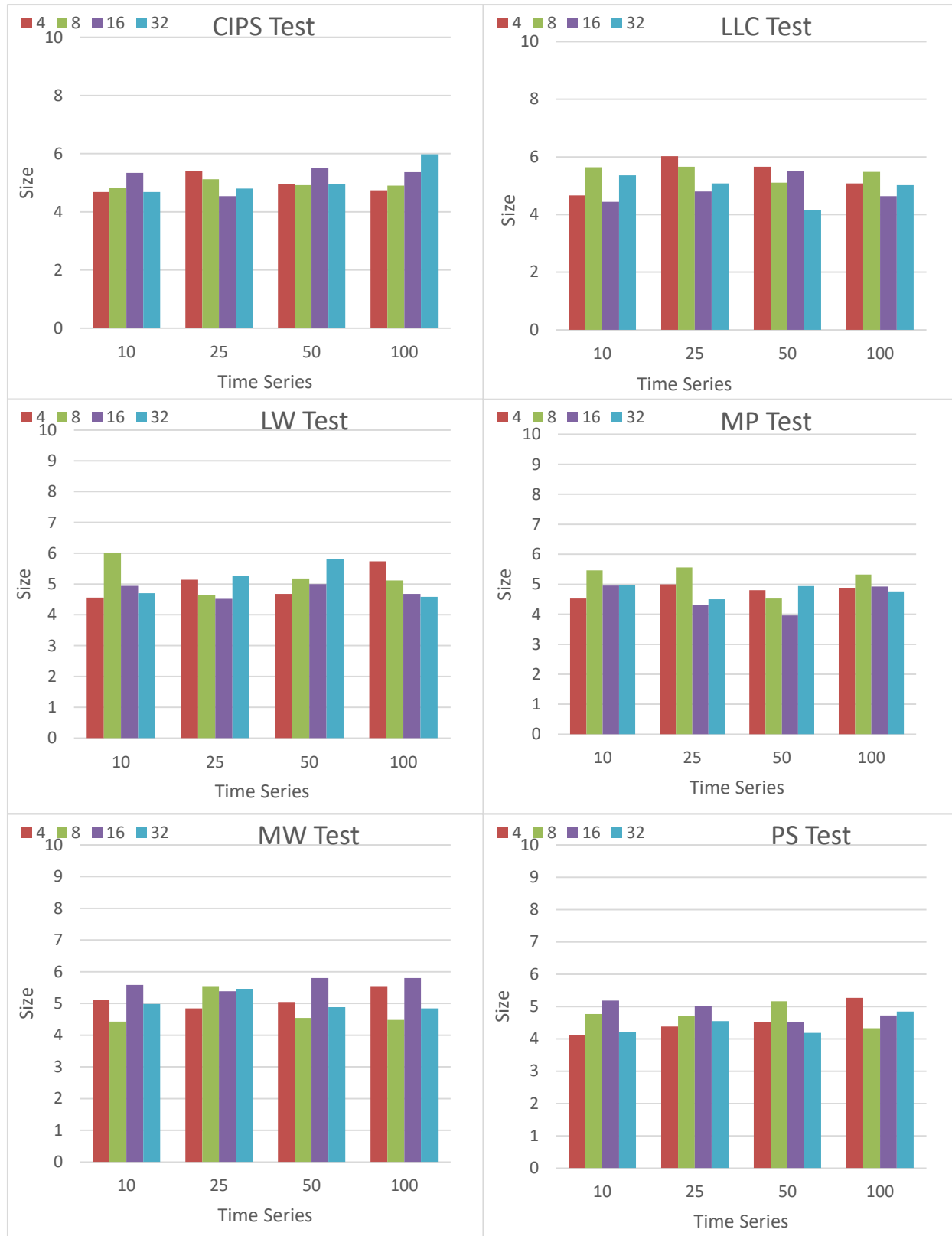
All over sized tests (both convergent towards nominal size of 5% and divergent towards 100% size tests) under ACVs are now become stable around 5% of nominal size for all panel dimensions

under SCVs (see Figure 2). Also, all under sized tests (i.e. DH and DWH) have stabilized size equal to nominal of 5% underutilization of SCVs for all panel dimensions. Moreover, MW and CHO tests remain the only two stabilized size tests if AVCs or SCVs are used whether panel dimensions are small, medium or large. Hence, it is concluded that all PUR tests have stabilized size around 5% if SCVs are used as an alternative of ACVs.

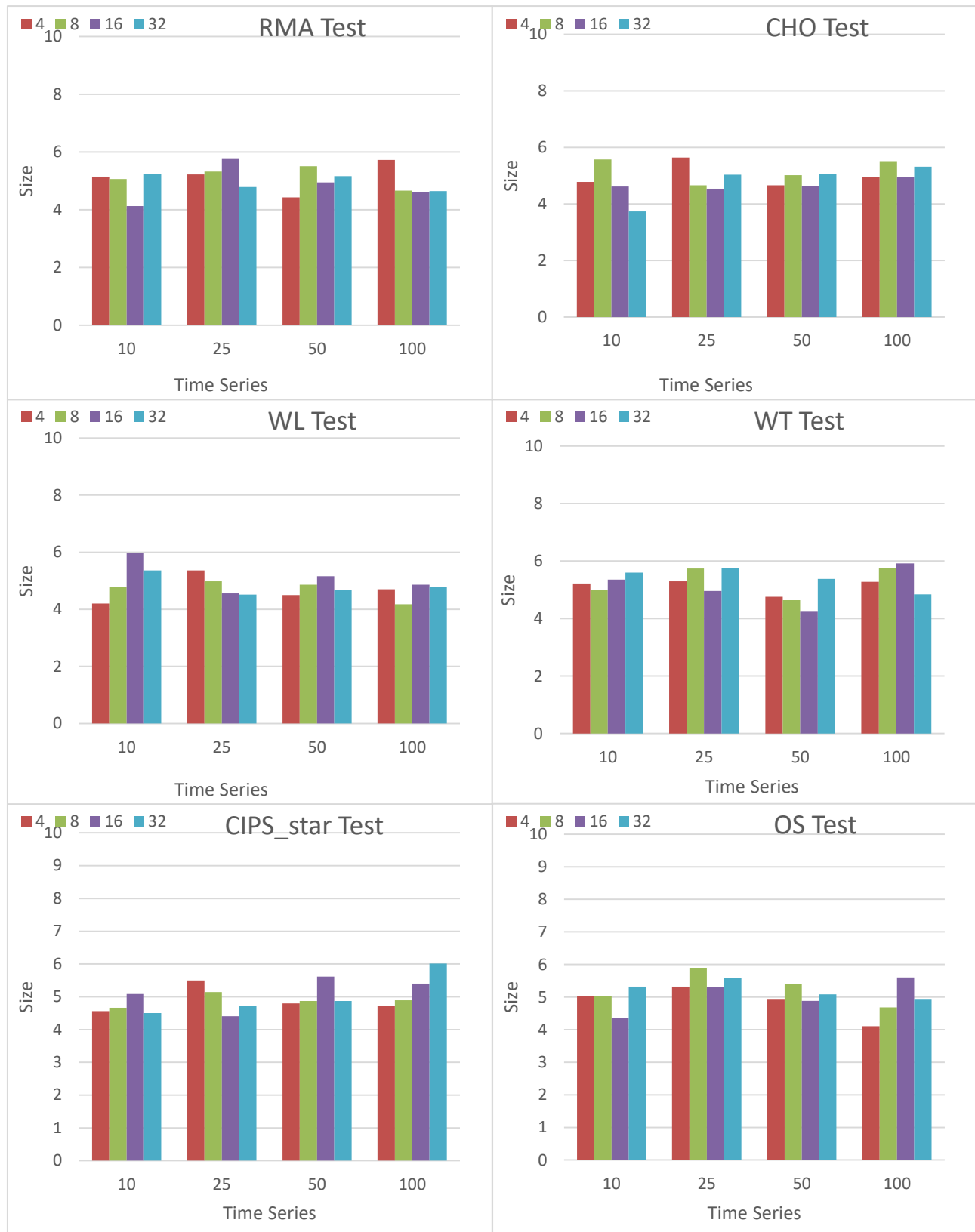
FIGURE 2: Size Of Panel Unit Root Tests Under Simulated Critical Values



Continue.....



Continue.....



CONCLUSIONS AND RECOMMENDATIONS

Based on the findings of this paper, it is concluded that majority of PUR tests having the null hypothesis of unit root have unstable empirical size from nominal size of 5% for different panel dimensions when ACVs are utilized. Moreover, majority of the PUR tests (BNG, BU, IPS, LLC, CIPS, CIPS_star, CH, WT, MP, OS, RMA) with unstable size have convergence pattern towards nominal size of 5% while only three tests (LW, PS, and WL) are detected with divergence behavior from nominal size of 5% under ACVs. Further, MW and CHO tests are recognized as more stable tests regardless of whether panel dimensions are small, medium or large while CIPS and CIPS_star tests are only stable around 5% at medium and large T length but they are a little oversized from nominal size at T=10. Also, DH and DWH tests are the only two under sized tests having 0% empirical size for all panel dimensions under ACVs. Most importantly, all these PUR tests are based on different assumptions, thus indicates another reason of size distortion.

However all PUR tests, yet founded on dissimilar assumptions and structure, have stabilized size around 5% nominal size if SCVs are used instead of ACVs whether panel dimensions are small, medium or large. This evidence is observed for all eighteen PUR tests considered in this study. Hence, SCVs are more superior and recommended to use over ACVs to avoid size distortion in the field of empirical research.

REFERENCES

- Akbar, S., Idrees, M., & Ali, M. (2024a). Fluctuations in electricity prices and the identification of bubbles in Italy during COVID-19. *Journal of Social Sciences and Economics*, 3(2), 241-249.
- Akbar, S., Iqbal, M., & Munir, F. (2024b). A Structural Break Unit Root Test to Test Purchasing Power Parity Hypothesis: An Empirical Analysis of South Asian Economies. *Kashmir Economic Review*, 33(1), 14-23.
- Akbar, S., Raza, A., & Riaz, Y. (2019). A Monte Carlo Simulation Analysis of Panel Stationarity Tests under a Single Framework. *European Online Journal of Natural and Social Sciences: Proceedings*, 8(1 (s)), pp:34-41.
- Bai, J., and Ng, S. (2004). "A PANIC Attack on Unit Roots and Cointegration." *Econometrica* 72: 1127-1177.
- Breitung, J. (1999). "The Local Power of Some Unit Root Tests for Panel Data", *Discussion Papers, Interdisciplinary Research Project 373: Quantification and Simulation of Economic Processes*.
- Chang, Y. (2002). "Nonlinear IV Unit Root Tests in Panels with Cross-Sectional Dependency."

- Journal of Econometrics **110**(2): 261-292.
- Choi, I. (2001). "Unit Root Tests for Panel Data." Journal of International Money and Finance **20**(2): 249-272.
- De Wachter, S., Harris, R. D., and Tzavalis, E. (2007). "Panel Data Unit Roots Tests: The Role of Serial Correlation and The Time Dimension." Journal of Statistical Planning and Inference **137**(1): 230-244.
- Demetrescu, M., and Hanck, C. (2012). "A Simple Nonstationary-Volatility Robust Panel Unit Root Test." Economics Letters **117**(1): 10-13.
- Fisher, R. A. (1934). "Statistical Methods for Research Workers." Oliver & Boyd, Edinburgh, 4th Edition.
- Gutierrez, L. (2006). "Panel Unit- root Tests for Cross- sectionally Correlated Panels: A Monte Carlo Comparison." Oxford Bulletin of Economics and Statistics **68**(4): 519-540.
- Hlouskova, J., and Wagner, M. (2006). "The Performance of Panel Unit Root and Stationarity Tests: Results from a Large Scale Simulation Study." Econometric Reviews **25**(1): 85-116.
- Hussan, M., & Akbar, S. (2019). A Monte Carlo Comparative Simulation Study for Identification of the Best Performing Panel Cointegration Tests. European Online Journal of Natural and Social Sciences, 8(2), pp:366-373.
- Im, K. S., Pesaran, M. H., and Shin, Y. (2003). "Testing for Unit Roots in Heterogeneous Panels." Journal of Econometrics **115**(1): 53-74.
- Khan, W. M. ., Sana, M. ., & Akbar, S. (2023). The Effect of Petroleum Prices on Basic Food and Energy Commodities: An investigation through Sequential ADF tests. *Bulletin of Business and Economics (BBE)*, 12(3), 912-921. <https://doi.org/10.61506/01.00296>
- Lee, C., and Wu, J.-L. (2012). "A Panel Unit-Root Test with Smooth Breaks and Cross-Sectional Dependence." Working Paper, Institute of Economics, National Sun Yat-sen University, Kaohsiung, Taiwan.
- Levin, A., Lin, C.-F., and Chu, C.-S. J. (2002). "Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties." Journal of Econometrics **108**(1): 1-24.
- Maddala, G. S., and Wu, S. (1999). "A Comparative Study of Unit Root Tests with Panel Data and a New Simple Test." Oxford Bulletin of Economics and Statistics **61**(S1): 631-652.
- Moon, H. R., and Perron, B. (2004). "Testing for a Unit Root in Panels with Dynamic Factors." Journal of Econometrics **122**(1): 81-126.
- Oh, Y. J., and So, B. S. (2004). "Robust Tests for Unit Roots in Heterogeneous Panels."

Economics Letters **84**(1): 35-41.

Pesaran, M. H. (2007). "A Simple Panel Unit Root Test in the Presence of Cross- Section Dependence." Journal of Applied Econometrics **22**(2): 265-312.

Phillips, P. C., and Sul, D. (2003). "Dynamic Panel Estimation and Homogeneity Testing under Cross Section Dependence." The Econometrics Journal **6**(1): 217-259.

Raza, A., Akbar, S., & Raza, Z. (2021a). Does Greenfield Foreign Direct Investment Inflow Contribute in Socioeconomic Development? Empirical Evidence from Developing Countries. Pakistan Journal of Humanities and Social Sciences, 9(3), 469-481.

Raza, A., Akbar, S., and Sadiqa, B.A. (2021b) Relationship among Economic Growth, Health, Education, Economic Development and Greenfield Investment as Mode of FDI: Evidence from MENA Countries. *International Review of Social Sciences*, Vol. 9 (5), PP 271-280.

Sul, D. (2009). "Panel Unit Root Tests under Cross-Section Dependence with Recursive Mean Adjustment." Economics Letters **105**(1): 123-126.

Waheed, A., Akbar, S., Siddiq, S.A.B., & Raza, A. (2023). Testing And Identifying Multiple Bubbles In Pak RupeeChinese Yuan Exchange Rate. *Journal of Positive School Psychology*, Vol. 7(2), PP: 1937-1951.

Waheed, A., Rashid, A., & Akbar, S. (2021). Detecting the Best Performing Time-Variant Cointegration Test Using the Consumption Function. *International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies*, 12(4), 1-5.
<http://doi.org/10.14456/ITJEMAST.2021.80>.

Westerlund, J. (2014). "Heteroscedasticity Robust Panel Unit Root Tests." Journal of Business & Economic Statistics **32**(1): 112-135.

Westerlund, J., and Larsson, R. (2012). "Testing for a Unit Root in a Random Coefficient Panel Data Model." Journal of Econometrics **167**(1): 254-273.