E C O N O M I C S B U L L E T I N

IS Per Capita Real GDP Stationary in China¡H Evidence Based on A Panel SURADF Approach

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Abstract

In this study we use newly developed Panel SURADF tests of the Breuer et al., (2001) to investigate the time-series properties of 25 Chinese provinces¡¦ per capita real GDP for the 1952-1998 period. While the other Panel-based unit root tests are joint tests of a unit root for all members of the panel and are incapable of determining the mix of I(0) and I(1) series in the panel setting, the Panel SURADF tests a separate unit-root null hypothesis for each individual panel member and, therefore identifies how many and which series in the panel are stationary processes. The empirical results indicate that for all the provinces studied per capita real GDP are non-stationary, except Hebei, Jeilongjiang, Qinghai and Shaanxi when Breuer et al.¡¦s (2001) Panel SURADF tests are conducted.

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1. INTRODUCTION

Ever since the seminar work of Nelson and Plosser (1982), studies have been devoted to investigating the potential non-stationarity of important macroeconomic variables. The time-series properties of real output levels have been of special interest to researchers. A pointed by Nelson and Plosser, the modeling of real output levels as either a trend stationary or a difference stationary process has important implications for macroeconomic policy, modeling, testing and forecasting. Studies on this issue are critical not only for empirical researcher but also for policymakers.

While a large literature generally supported a unit root in real output levels and, critics have claimed that the drawing of such conclusions may be attributed to the lower power of the conventional unit root tests employed. More recently, in fact, it has been reported that conventional unit root tests not only fail to consider information across regions, thereby leading to less efficient estimations, but also have low power against near-unit-root but stationary alternatives. It is not surprising that these factors should expectedly have cast considerable doubt on many of the earlier findings of a unit root in real output levels.

One proposed approach to increasing power in testing for a unit root involves the use of panel data. Levin and Lin (1992) and Im et al., (1997) developed the asymptotic theory and the finite-sample properties of ADF tests of panel data, and both have demonstrated that even relatively small panels yield large improvements with respect to power. However, the problem of cross-sectional dependence is inherent in both the Levin-Lin and Im-Pesaran-Shin panel-based unit root tests. O'Connell (1998) has in fact shown that the true size of both tests can be far greater than the normal size when the underlying data-generating process (DGP) is characterized by $\mathrm{cov}(\varepsilon_{it}, \varepsilon_{jt}) \neq 0$ for $i \neq j$. Though Levin and Lin (1992) and Im et al., (1997) both proposed controlling for cross-sectional dependence by subtracting the cross-sectional means prior to performing estimations in order to remove the effect of a common time component, Mark (2001) has indicated that if common time effects are generated by a multi-factor process, then transforming the observations by subtracting the cross-sectional means will still leave some residual dependence across individuals. Such residual cross-sectional dependence has the potential to generate errors resulting in misleading inferences. O'Connell (1998) has also shown that the same procedure will do little to reduce cross-sectional dependence and size distortions when the time component varies across regions. A straightforward way to handle cross-sectional dependence that may vary across regions is to estimate equation using the seemingly unrelated regression (SUR) estimator (Zellner, 1962). O'Connell (1998) has found that size distortions can be avoided with little loss of power by basing the panel-based test on the SUR as opposed to the OLS estimation. However, the SUR panel-based test also shares a drawback with the Levin-Lin panel-based test in that autoregressive parameter (β) is restricted to being remain identical across regions under the alternative hypothesis. In light of this, Taylor and Sarno (1998) have suggested a modified version of the SUR panel-based test that allow for different β values under the alternative hypothesis and controls for cross-sectional dependence. Taylor and Sarno (1998) call this the MADF test and it is based on the SUR estimation. The same authors also noted that the MADF test is quite powerful in finite samples for the Monte Carlo experiments that they performed.

Breuer et al., (2001) showed the recent methodological refinements of the Levin and Lin test fail to fully address the "all-or-nothing" nature of the test. It is true that Im et al. (1997) and Taylor and Sarno (1998) developed tests that permit the autoregressive parameters to differ across panel members under the stationary alternative, but because they are joint tests of the null hypothesis, they are not informative about the number of series that are stationary processes when the null hypothesis is rejected. Breuer et al. (2001) further claimed that, by analogy to simple regression, when an F-statistic rejects the null that a vector of coefficients is equal to zero, it does not follow that each coefficient is nonzero. Similarly, when the unit-root null hypothesis is rejected, it may be erroneous to conclude that all series in the panel are stationary.

This empirical study contributes to this line of research by determining whether unit root process is characteristic of the Chinese real output levels. We test the non-stationarity of per capita real GDP for 25 Chinese provinces' data sets using the Breuer et al., (2001) Panel SURADF unit root tests.

The remainder of this empirical study is organized as follows. Section 2 presents the data used, and Section 3 describes the methodology used. Section 4 discusses the empirical findings and policy implications. Finally, Section 5 presents some concluding remarks.

2. DATA

This empirical study employs annual per capita real GDP for 25 Chinese provinces over the 1952 and 1998 period. The source for the data is

Comprehensive Statistical Data and Materials on 50 Years of New China, and summary statistics are given in Table 1. The per capita real GDP data sets indicate that Beijing and Heilongjiang have the highest and lowest average per capita income, respectively. The Jarque-Bera test results meanwhile indicate that all 25 Chinese provinces' per capita real GDP data sets are not approximately normal.

Table 1 Summary Statistics of Per Capita Real GDP Data Sets

Country name	Mean	Std	Max.	Min.	Skewness	Kurtosis	J-B
1. Anhui	252.3	207.8	920	92.4	1.803	5.466	37.363*
2. Beijing	1189.4	1151.9	4654.8	100	1.424	4.167	18.543*
3. Fujian	454.7	525.3	2207	100	1.982	6.028	48.712*
4. Gansu	317.8	255.4	1028.1	75.5	1.298	3.616	13.941*
5. Guangdong	457.2	530.9	2095.9	100	1.831	5.213	35.864*
6. Guangxi	381.6	307.4	1287.1	100	1.534	4.446	22.528*
7. Guizhoul	288.7	209.9	851.5	100	1.217	3.291	11.768*
8. Hebei	377.7	376.6	1572.8	80	1.703	5.093	31.295*
9. Heilongjiang	210.3	129.0	587.1	80.4	1.365	3.957	16.382*
10. Henan	300.9	273.2	1134.4	71.5	1.606	4.706	25.900*
11.Hubei	310.3	354.3	1377	59	1.706	4.866	29.619*
12.Hunan	323.9	254.5	1087.1	100	1.471	4.311	20.325*
13.Inner Mongolia	273.9	207.5	885	100	1.455	4.093	18.929*
14.Jiangsu	434.8	503.9	2045.4	89.2	1.802	5.316	35.946*
15.Juangxi	245.6	198.7	868.6	99.3	1.759	5.196	33.697*
16.Jilin	313.6	256.7	1057.8	100	1.429	3.987	17.893*
17.Liaoning	487.5	412.5	1646.6	100	1.314	3.741	14.612*
18.Ningxia	404.2	281.6	1135.9	96.8	1.049	3.043	8.621**
19. Qinghai	405.2	250.7	1062.3	100	0.982	2.983	7.553**
20.Shaanxi	517	448.6	1767.3	100	1.302	3.611	14.018*
21.Shandong	526.5	588.9	2395.8	100	1.764	5.224	34.054*
22.Shanghai	858.8	844.4	3499.8	100	1.558	4.776	25.177*
23.Tianjin	473.9	410.5	1744.6	100	1.504	4.625	22.893*
24.Yunnan	369.4	300.8	1232.8	100	1.433	3.973	17.952*
25.Zhejiang	524.4	637	2569.8	100	1.864	5.518	39.633*

Note: Std denotes standard deviation and J-B denotes the Jarque-Bera Test for Normality. ***, **, and * indicate significance at the 0.10, 0.05 and 0.01 levels, respectively.

3. PANEL UNIT ROOT METHODOLOGY

Breuer, McNown and Wallace's (2001) Seemingly Unrelated Regressions Augmented Dickey-Fuller Test (SURADF)

Breuer et al. (2001) claimed that, by analogy to simple regression, when an F-statistic rejects the null that a vector of coefficients is equal to zero, it does not follow that each coefficient is nonzero. Similarly, when the unit-root null hypothesis is rejected, it may be erroneous to conclude that all series in the panel are stationary. To avoid the problem, Breuer et al. (2001) introduced the "seemingly unrelated regressions augmented Dickey-Fuller" (SURADF) test, which is an augmented Dickey-Fuller test based on the panel estimation method of seemingly unrelated regression (SUR). The system of the ADF equations we estimate here are:

$$\Delta X_{1,t} = \alpha_1 + \beta_1 X_{1,t-1} + \gamma t + \sum_{j=1}^{k1} \theta_{1,j} \Delta X_{1,t-j} + \varepsilon_{1,t} \qquad t = 1,2,....,T$$

$$\Delta X_{2,t} = \alpha_2 + \beta_2 X_{2,t-1} + \gamma t + \sum_{j=1}^{k2} \theta_{2,j} \Delta X_{2,t-j} + \varepsilon_{2,t} \qquad t = 1,2,....,T$$

. . . .

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$$\Delta X_{N,t} = \alpha_N + \beta_N X_{N,t-1} + \gamma t + \sum_{j=1}^{kN} \theta_{N,j} \Delta X_{N,t-j} + \varepsilon_{N,t} \qquad t = 1,2,....,T \qquad [1]$$

We test the N null and alternative hypotheses individually:

$$H_0^1 : \beta_1 = 0; H_A^1 : \beta_1 < 0$$

$$H_0^2 : \beta_2 = 0; H_A^2 : \beta_2 < 0$$

. .

. .

$$H_0^N : \beta_N = 0; H_A^N : \beta_N < 0$$

where $(\beta_i - 1)$ is the autoregressive coefficient for series *i*. With the test statistics are computed from the SUR estimates of system [1], and the significance of each β_i is tested against critical values generated through simulation. That is, we relax the restriction of $\beta_1 = \beta_2 = \cdots = \beta_N$ and avoid the joint null hypothesis that all series contain a unit root and the corresponding alternative hypothesis that all series with the same autoregressive coefficient. SUR estimation takes account of contemporaneous cross-correlation of the error terms, it has an information advantage over single-equation augmented Dickey-Fuller tests and Levin and Lin (1992) tests. As Breuer et al. (2001) showed the imposition of an identical lag structure across panel members could bias test statistics, we select the lag structures for each equation are selected following the approach proposed by Perron (1989).

The major difference between the SURADF and other panel unit tests, such as those of Levin and Lin (1992) and Im et al. (1997), derives from the formulation of the null hypothesis. While the others are joint tests of a unit root for all members of the panel, the SURADF tests a separate unit-root null hypothesis for each individual panel member and, therefore, identifies how many and which series in the panel are stationary processes.

4. EMPIRICAL RESULTS

For comparison, we first apply several conventional unit root tests to examine the null of a unit root in the per capita real GDP of each Chinese province. We select the lag order of the test based on the Schwarts Information Criterion (SIC). The results in Table 2 clearly indicate that the ADF, DF-GLS (of Elliott et al., 1996), the P-P and NP (of Ng and Perron, 2001) tests all fail to reject the null of non-stationary per capita real GDP for all 25 provinces, except Guangdong when NP test is conducted. The KPSS test also yields the same results. Since the single-equation ADF test has low power with short time spans, as pointed out by Shiller and Perron (1985), here we only have annual observations spanning a 47-year period, perhaps indicating that the failure of the ADF test to have previously rejected the unit root null was due to the time span of the data. We investigate this possibility by exploiting the cross-section variability among regions by applying the Breuer et al. (2001) panel-based unit root tests and examine the non-stationarity of real output levels.

Table 2 Univariate Unit Root Tests (ADF, DF-GLS, KPSS and NP)

Country name	ADF	DF-GLS	KPSS	NP
1. Anhui	2.011(0)	1.913(1)	0.819[5]*	3.059(1)
2. Beijing	-0.041(2)	1.526(2)	0.889[5]*	1.909(2)
3. Fujian	2.497(0)	1.711(1)	0.810[5]*	2.814(1)
4. Gansu	1.497(4)	1.311(2)	0.849[5]*	1.999(2)
5. Guangdong	3.239(0)	-0.110(7)	0.811[5]*	-3.471 (7)*
6. Guangxi	1.416(0)	1.409(1)	0.873[5]*	2.272(1)
7. Guizhou	-0.891(3)	0.584(1)	0.781[5]	1.137(1)

8. Hebei	2.470(3)	0.886(5)	0.852[5]*	1.804(5)
9. Heilongjiang	4.549(9)	1.239(0)	0.824[5]*	2.214(0)
10. Henan	1.599(3)	1.111(1)	0.829[5]*	1.990(1)
11. Hubei	1.145(0)	1.327(0)	0.753[5]*	1.889(0)
12. Hunan	2.078(4)	2.354(0)	0.862[5]*	2.696(0)
13. Inner Mongolia	0.764(0)	1.556(0)	0.787[5]*	2.449(0)
14. Jiangsu	3.794(0)	1.637(1)	0.835[5]*	2.443(1)
15. Jiangxi	2.979(0)	1.607(1)	0.807[5]*	2.881(1)
16. Jilin	1.087(0)	2.048(0)	0.839[5]*	2.540(0)
17. Liaoning	2.482(8)	0.567(1)	0.862[5]*	1.158(1)
18. Ningxia	0.058(2)	1.394(2)	0.887[5]*	1.889(2)
19. Qinghai	-0.784(0)	1.297(0)	0.897[5]*	1.928(0)
20. Shannxi	0.503(3)	1.442(0)	0.872[5]*	2.053(0)
21. Shandong	2.144(0)	3.251(0)	0.861[5]*	2.749(0)
22. Shanghai	0.481(5)	1.126(5)	0.897[5]*	1.849(5)
23. Tianjin	0.411(2)	1.327(2)	0.883[5]*	2.248(2)
24. Yunnan	0.817(0)	2.220(0)	0.839[5]*	2.625(0)
25. Zhejiang	1.489(1)	1.245(1)	0.826[5]*	2.183(1)

Note: ***, **, and * indicate significance at the 0.10, 0.05 and 0.01 levels, respectively. The number in parenthesis indicates the lag order selected based on the Schwartz Information Criterion. The number in the brackets indicates the lag truncation for the Bartlett Kernel, as suggested by the Newey-West test (1987). The critical values for the KPSS are taken from Kwiatkowski et al. (1992). The NP test was based on the MZa statistic.

For comparison, in the present study, several panel-based unit root tests are first applied to examine the null of a unit root in the per capita real GDP. The critical values, based on Monte Carlo simulations using 10,000 replications for each test, are given in Table 3, and there is no question that the Levin-Lin-Chu (Levin et al., 2002), Im-Pesaran-Shin (Im et al., 2003) and MW (Maddala and Wu, 1999) tests all can not reject the null of the non-stationary per capita real GDP for all 25 Chinese provinces. Table 4 presents Breuer et al.'s (2001) Panel SURADF test results, which indicates a unit root in real output levels holds true for all the provinces studied here with the exception of Hebei, Heilongjiang, Qinghai and Shannxi four provinces. The estimated 1%, 5%, and 10% critical values, obtained from simulations based on 47 observations for each series and 4,000 replications using the lag structure and covariance matrix from the panel of per capita real GDP data series. In the data generation phase of the simulation, the error series were generated to be normally distributed with the variance-covariance matrix obtained from SUR estimation on the real GDP data. The results for each of the 25 panel members are also reported in Table 4. Figures 1 and 2 plot the per capita real GDP for both the Shaanxi (showing rejection of a unit root in series) and Jiangus (showing a unit root in series), respectively. Due to space constraints, we do not report the figures for the rest of provinces, but are available upon requests.

Table 3 Panel Unit Root Test Results

Method	Statistics	P-value	Critical value		
			1%	5%	10%
Levin, Lin & Chu	-5.181	0.389	-11.170	-10.620	-10.30
IPS $\varphi_{\bar{t}}$	-0.185	0.200	-10.464	-6.711	-5.605
$\varphi_{L\bar{M}}$	1.702	0.176	10.714	7.011	5.836
MW-Fisher Chi-square	29.9437	0.2268	162.404	120.749	107.426

Notes: 1. ***, ** and * indicate significance at the 0.1, 0.05 and 0.01 level, respectively.
2. Critical values are based on Monte Carlo simulations using 10,000 replications.

Table 4 SURADF Tests and Critical Values

Country panel label	SURADF	Critical values 0.01	0.05	0.10
1. Anhui	-0.757	-5.187	-4.156	-3.809
2. Beijing	-2.291	-3.706	-3.244	-2.991
3. Fujian	-1.306	-4.686	-3.817	-3.525
4. Gansu	-0.495	-3.625	-3.183	-2.871
5. Guangdong	-0.764	-3.974	-3.207	-2.986
6. Guangxi	-1.091	-4.887	-4.151	-3.790
7. Guizhou	-1.409	-3.888	-3.355	-3.097
8. Hebei	-3.643***	-4.460	-3.747	-3.387
9. Heilongjiang	-3.380***	-4.159	-3.430	-3.039
10. Henan	-2.609	-3.921	-3.277	-2.995
11. Hubi	-1.095	-4.916	-4.307	-3.881
12. Hunan	-2.937	-3.799	-3.234	-2.874
13. Inner Mongolia	-2.389	-4.474	-3.977	-3.616
14. Jiangus	-0.118	-3.812	-3.262	-2.851
15. Jiangxi	0.462	-3.808	-3.346	-2.990
16. Jilin	-2.627	-5.228	-4.234	-3.820
17. Liaoning	0.188	-4.039	-3.545	-3.177
18. Ningxia	-1.140	-4.710	-3.729	-3.380
19. Qinghai	-3.066***	-3.772	-3.143	-2.878

20. Shaanxi	-3.279***	-3.918	-3.397	-3.051
21. Shandong	-1.596	-4.707	-4.107	-3.737
22. Shanghai	1.489	-3.974	-3.357	-3.008
23. Tianjin	-1.463	-4.257	-3.823	-3.445
24. Yunnan	-2.074	-4.011	-3.425	-3.117
25. Zhejiang	-1.081	-3.657	-3.265	-2.888

Note: ***, **, and * indicate significance at the 0.10, 0.05 and 0.01 levels, respectively. Critical values are calculated by Monte Carlo simulation with 4,000 draws, tailored to the present sample size. (For details of this simulation, see Breuer et al., 2001)

Figure 1. Per Capita Real GDP of Shaanxi

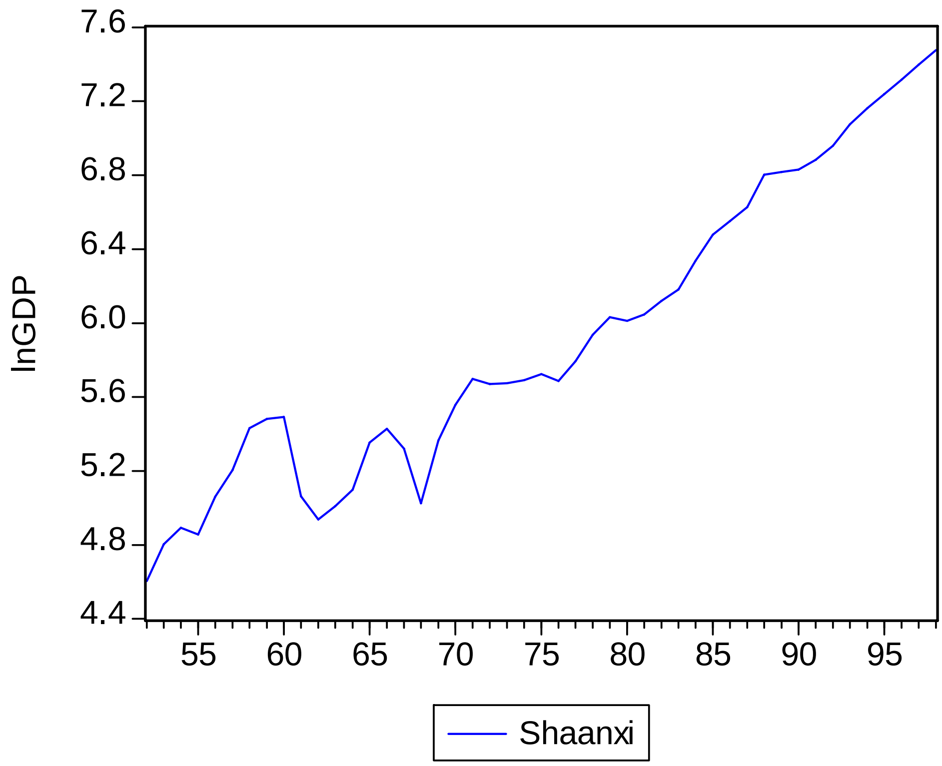
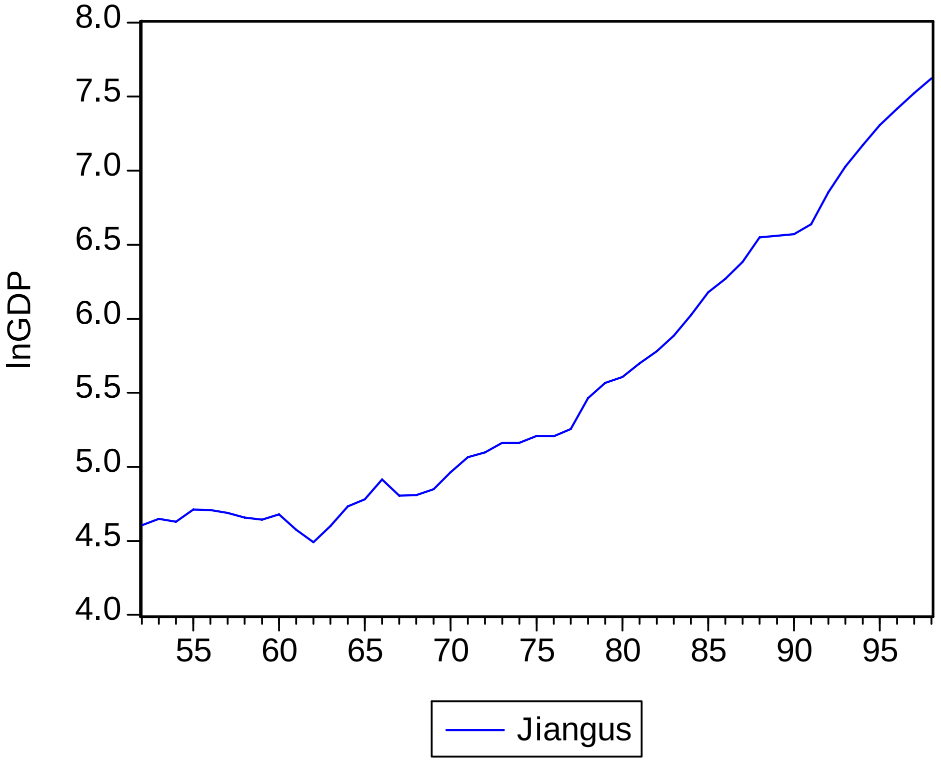


Figure 2. Per Capita Real GDP of Jiangus



Worth noting is that the results here are not consistent with those of SMYTH (2003) which, based on the same data sets for 24 Chinese provinces using different panel-based unit root tests of Im-Pesaran-Shin, reject the null hypothesis of a unit root in per capita real GDP for most of the provinces studied. Results are also not consistent with those of Fleissig and Strauss (1999) that they found per capita real GDP for OECD countries are trend stationary, using three different panel-based unit root tests. Our results, nevertheless, are consistent with those of Cheung and Chinn (1996) and Rapach (2002), which support the notion of unit root in real GDP for various panels of OECD countries.

However, what are the most effective policies for a stabilization policy on the output level of the most Chinese provinces studied here? To answer this, the underlying reasons first be identified, but as this is beyond the scope of this paper, it will be investigated in a future study.

5. CONCLUSIONS

In this empirical study, we employ the Breuer et al, (2001) Panel SURADR unit tests to assess the non-stationarity properties of per capita real GDP from 25 Chinese provinces over the 1952 to 1998 period. Breuer et al’s (2001) Panel SURADF tests indicate a unit root in real output levels is supported for all the provinces studied here with the exception of Hebei, Heilongjiang, Qinghai and Shannxi four provinces. .

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