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IS PER CAPITA REAL GDP STATIONARY? NON-LINEAR PANEL UNIT-ROOT TESTS FROM EASTERN-EUROPEAN COUNTRIES

Hsu-Ling Chang
Lin Tung University, Taiwan (R.O.C.)

Chi-Wei Su
Tamkang University, Taiwan (R.O.C.)

ABSTRACT: In this study, we apply non-linear panel unit-root test to assess the non-stationary properties of the per capita real GDP for seven Eastern-European Countries. We find that non-linear panel unit-root test has higher power than linear method suggested by Breuer *et al*. (2001) if the true data generating process of exchange rate is in fact a stationary non-liner process. We investigate the stationary of per capita real GDP from the panel non-linear point of view and provide robust evidence clearly indicate that real output is well characterized by a non-linear mean reverting process, namely Czech Republic, Hungary, Malta and Poland. These results have important policy implications for Eastern-European Countries.

KEYWORDS: Non-linear Panel Unit-root Test, Per Capita Real GDP

JEL Classification: O1, O4

Introduction

The modeling of per capita real GDP as either a trend stationary or a difference stationary process has received much attention since Nelson and Plosser (1982). Researchers have been especially interested in the time-series properties of real output levels. The characteristics of real output have important implications for macroeconomic policy making, modeling, testing and forecasting. Studies on this issue are of concern not only to empirical researchers but also policymakers. The question of whether real GDP can be characterized by unit roots has been an issue of particular interest (Wasserfallen, 1986; Ben-David and Papell, 1995; Cheung and Chinn, 1996; Rapach, 2002; Cheung and Westermann, 2002). Nelson and Plosser note that a unit root in real output is inconsistent with the notion that business cycles are stationary fluctuations around a deterministic trend; instead, it suggests that shocks to real output have permanent effects on the system.

The empirical literature cited above reached the conclusion that real GDP levels are nonstationary by using rather univariate unit root statistics (Cheung and Chinn, 1996) or panel unit root tests (Rapach, 2002) along the lines of the Augemented Dickey-Fuller (ADF) statistics. The key feature of all these tests is that they work upon the hypothesis that a symmetric adjustment process exists. However, there are more and more studies allow for non-linear dynamics for unit root testing procedures (Cancer and Hansen, 2001; Shin and Lee, 2001; Kapetanios *et al*., 2003). Taylor (2001) indicates that the power of the conventional augmented Dickey-Fuller (ADF) test is poor if the series follow a non-linear threshold process. To do that, the non-linear unit root test based on an exponential smooth transition autoregressive (ESTAR) proposed by Kapetanios *et al*. (2003) and it shows that the power of their test is higher than that of the ADF test.

While empirical evidence on the stationarity of the real GDP is abundant in developing countries (Rapach, 2002), the literature dealing specifically with the Eastern European countries and other European transition countries is rather spare. The Eastern European countries started their liberalization programs in the late-1980s and early 1990s. This period was characterized by dramatic improvements in budget deficits, debts and inflation in some of these countries. A survey by the Organization of Economic Cooperation and Development (OECD) points out that that even early in the transition process international firms have been impressed at how well the Eastern European countries have adjusted after the transition and to their commitment to a newly adopted market system (OECD,1994). As the reform process (market liberalization and trade opening) becomes intensified, it may expect a reduction in persistent shocks to international parity.

While numerous studies support a unit root in real output levels, 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, 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 lower power when compared with near-unit-root but stationary alternatives. It is not surprising that these factors have cast considerable doubt on many of the earlier findings that have been based on a unit root in real output levels. In order to increase the power in testing for a unit root, many researchers have employed panel data (Taylor and Sarno, 1998; Maddala and Wu, 1999; Levin *et al*., 2002; Im *et al*., 2003; Choi and Chue, 2007; Pesaran, 2007. These tests have been successful in finding evidence of stationarity that cannot be found by univariate methods. The major advantage for adopting panel unit-root tests is their high power by exploiting cross-section dependence.

Furthermore, Taylor and Sarno (1998), Breuer *et al*. (2001), Taylor (2001), Taylor and Taylor (2004) showed that the methodological refinements of Levin *et al*. test fail to fully address the 'all-or-nothing' nature of the tests. Because they are joint tests of the null hypothesis, they are not informative with regard to the number of series that are stationary processes when the null hypothesis is rejected. In this regards, Breuer *et al*. (2001) claim that, by analogy to a simple regression, when an F-statistic rejects the null that a vector of coefficients is equal to zero, it is not necessarily true that each coefficient is nonzero. Likewise, when the unit-root null hypothesis is rejected, it may be erroneous to conclude that all series in the panel are stationary. Breuer *et al*. (2001) propose a series-specific unit-root test that allows researchers to distinguish I(0) and I(1) series in the panel.

In this study, we will propose a series-specific non-linear panel unit-root test that exploits the cross-section information and to test the unit-root hypothesis for each series in the panel by Wu and Lee (2008). According their results, they find that the power of non-linear panel unit-root test is higher than that of the Breuer *et al*. test when the data generating process is significantly non-linear. This empirical note applies the seemingly unrelated regression (SUR) method and handles the issues of contemporaneous correlation and heterogeneous serial correlation. We apply non-linear panel unit-root test to examine whether or not the unit root process of per capita real GDP of 7 Eastern-European countries.

The reminder of this empirical study is organized as follows. Section 2 describes the methodology of the non-linear series-specific unit-root tests. Section 3 presents the data used and discusses the empirical findings. Section 4 concludes.

Non-linear Panel Unit-root tests Methodology

Kapetanios *et al.* (2003) propose a testing procedure to detect the presence of non-stationarity against non-linear but globally stationary ESTAR process. They construct *t*-statistic of test by regressing the following auxiliary equation based on Taylor series using ordinary least squares:

$$\Delta GDP_t = \delta GDP_{t-1}^3 + \sum_{i=1}^{k} b_i \Delta GDP_{t-i} + \varepsilon_t \qquad (1)$$

In this framework, the null hypothesis and alternative hypothesis are expressed as $\delta = 0$ (nonstationary) against $\delta < 0$ (nonlinear ESTAR stationary). Kapetanios *et al.* (2003) show that *t*-statistic of the parameter of interest, that is, δ does not have an asymptotic normal distribution and thus one must resort to simulations for asymptotic critical values.

As stated earlier, Breuer *et al.* (2001) have made the claim that, by analogy to a 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 assume that all series in the panel are stationary. To avoid this problem, Breuer *et al.* (2001) have introduced the "seemingly unrelated regressions augmented Dickey-Fuller" (SURADF) tests, which are augmented Dickey-Fuller tests based on the panel estimation method of SUR. The system of the ADF equations that we estimate here is:

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

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

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$$\Delta GDP_{N,t} = \alpha_N + \beta_N GDP_{N,t-1} + \sum_{j=1}^{kN} \theta_{N,j} \Delta GDP_{N,t-j} + \varepsilon_{N,t} \quad t = 1,2,....,T\ . \qquad (2)$$

We test the N null and alternative hypotheses individually:

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

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

. .

$$\dot{H}_0^N : \dot{\beta}_N = 0; H_A^N : \beta_N < 0$$

where we compute the test statistics from the SUR estimates of equation (2).

To generalize the non-linear unit-root test of Kapetanios *et al.* (2003) to a panel framework and allow for testing stationarity for each series in a panel, we use the following system equations:

$$\Delta GDP_{N,t} = \delta_N GDP_{N,t-1}^3 + \sum_{i=1}^{k_N} \phi_{N,i} \Delta GDP_{N,t-i} + \varepsilon_{N,t} \quad (3)$$

After estimating the equation (3) with SUR, the *t*-statistic for the hypothesis of $\delta_N = 0$ is constructed to test for the stationarity of the series, $\Delta GDP_{N,t}$. However, this test has non-standard distributions and the critical values must be obtained by simulation.

Data and Empirical Findings

This empirical study based on real per capita real GDP data for 7 Eastern-European countries, namely Albania, Bulgaria, Czech Republic, Hungary, Malta, Poland and Romania for the period 1980 to 2008. All the data was converted into natural logarithmic form before the empirical analysis. The source of the data is the World Economic Outlook Database, and the summary statistics are provided in Table 1. Czech Republic and Albania have the highest and lowest average per capita incomes of US$14029.20 and US$3219.23, respectively. The Jarque-Bera test results meanwhile indicate that the per capita real GDP datasets of the 7 Eastern-European countries are all normal.

Table 1: Summary Statistics of Per Capital Real GDP Data Sets

	Mean	Std	Maximum	Minimum	Skewness	Kurtosis	J-B
Albania	3219.23	1377.14	6602.05	1787.81	1.102	3.009	2.928
Bulgaria	6442.25	1877.78	11629.77	3587.88	1.189	4.024	1.229
Czech Republic	14029.20	5069.11	26237.03	6964.91	0.858	2.992	0.634
Hungary	11376.69	4486.27	21943.02	5526.31	0.965	2.863	1.404
Malta	12751.18	5643.11	21718.87	4733.85	0.068	1.545	2.650
Poland	8327.12	3807.28	16921.29	4168.65	0.073	2.456	2.218
Romania	6209.61	1951.84	11513.19	3579.35	1.314	3.994	2.498

Note: Std denotes standard deviation and J-B denotes the Jarque-Bera Test Normality.

For comparison, first, we apply conventional ADF statistic to examine the null of a unit root in the per capita real GDP of each country. The results in Table 2 clearly indicate that ADF tests fail to reject the null of non-stationary per capita real GDP for all 7 countries. This finding is consistent with the real GDP unit root literature and is due to the low power of the ADF test when the real GDP are highly persistent and the processes are likely to be non-linear. Furthermore, we apply the non-linear unit-root test of Kapetanios *et al*. (2003) to re-investigate the mean reversion behavior of real GDP adjustment. However, results from the third column of Table 2 indicate that the unit-root hypothesis is also not rejected for 6 countries except for the Malta at the 1% level.

The reason of failure of rejecting the unit-root hypothesis given linear and non-linear unit-root tests is the power of a single equation is low. One proposed approach to increasing power in testing for a unit root involves the use of panel data (Levin *et al*., 2002; Im *et al*., 2003).therefore, we apply panel data unit-root tests to re-examine the null hypothesis of real GDP. Next, we first apply the panel SURADF test by Breuer *et al*. (2001) to examine the stationarity of real GDP based on the panel of Eastern-European countries. The SURADF results are reported in the fourth column of Table 2. To avoid the small-sample size bias, we estimate the 1%, 5%, and 10% critical values are reported in the fifth, sixth and seventh columns, respectively, obtained from simulations based on observations for each series and 10,000 replications using the lag and covariance structure from the panel of real GDP data series for each of the 7 panel members. Findings from columns only one to seven indicate that real GDP are non-stationary for 6 countries. The results are almost the same with ADF and non-linear unit-root test. Finally, we apply panel framework of non-linear unit-root test to test stationarity for each series in the eighth column of Table 2. It is interesting that the results indicate the stationarity in per capita real GDP holds true four countries (Czech Republic, Hungary, Malta and Poland) here with the exception of Albania, Bulgaria and Romania. Results from Table 2 conclude that failing to control the non-linearity of data leads the SURADF test to be a conservative test relative to the SUR_{KSS} test. Our evidence points that four of seven Eastern-European countries are non-linear stationary, implying that per capita real GDP follows a steady rate of growth, and policy innovations then have temporary effects. As far as major policies are concerned, this study implies that a fiscal and/or monetary stabilization policy would possibly permanently affect the real output levels of most Eastern-European countries under study.

Table 2: Estimation Results

Country	ADF	t_{KSS}	SURADF	1%	5%	10%	SUR_{KSS}	1%	5%	10%
Albania	-0.538	-1.895	-0.568	-4.477	-3.855	-3.525	-0.223	-4.476	-3.859	-3.540
Bulgaria	-1.162	-0.674	-0.024	-3.721	-3.167	-2.817	-0.122	-3.382	-3.156	-2.834
Czech Republic	-1.048	-1.743	-0.718	-4.383	-3.787	-3.428	**-4.258****	-4.360	-3.742	-3.416
Hungary	-0.107	-1.766	0.083	-4.392	-3.688	-3.354	**-3.544***	-4.299	-3.700	-3.342
Malta	-2.116	**-3.054*****	**-2.745***	-3.579	-2.968	-2.652	**-4.352*****	-3.391	-2.833	-2.544
Poland	-0.423	-1.713	0.039	-4.055	-3.488	-3.169	**-4.845*****	-4.009	-3.405	-3.096
Romania	-0.792	-1.076	-0.123	-4.178	-3.543	-3.168	-0.263	-4.024	-3.366	-3.033

NOTES: ***, **, and * indicate significance at the 0.10, 0.05 and 0.01 levels, respectively. Critical values are calculated by Monte Carlo simulation with 10,000 draws, tailored to the present sample size.

Conclusion

Using models that do not assume a linear adjustment, this study investigates per capita real GDP stationarity for seven Eastern-European countries. Standard linear ADF, Kapetanios *et al*. (2003) and Breuer *et al*. (2001) statistics show that the data are basically non-stationary for almost these countries. In contrast, when we adopt a non-linear panel unit-root model which has higher power than a standard univariate, non-linear and panel unit root statistic to reject a false null hypothesis of unit root behavior, the empirical evidence suggests that per capita real GDP is well characterized in Czech Republic, Hungary, Malta and Poland by a non-linear mean reverting process which exhibits periods of exploding behavior. This might offer an alternative explanation for the difficulty researchers have encountered in rejecting the unit root hypothesis for per capita real GDP.

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