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

Are 19 Developed Countries' Real Per Capita GDP levels Non-stationary? A Revisit

Shyh-Wei Chen
Department of Finance, Dayeh University

Abstract

By using an extended dataset for 19 developed countries, this study employs a recent unit root test to re-examine the issue of the non-stationarity of real per capita GDP. The results convincingly support the view that the real per capita GDPs of Australia, France, Germany, Japan, the UK and the USA are characterized by a stationary process if the one-break unit root test is employed. Moreover, we can reject 11 of 19 countries' real per capita GDP if the two-break unit root test is employed. This is consistent with the view that business cycles exhibit stationary fluctuations around a deterministic trend.

Citation: Chen, Shyh-Wei, (2008) "Are 19 Developed Countries' Real Per Capita GDP levels Non-stationary? A Revisit." *Economics Bulletin,* Vol. 3, No. 2 pp. 1-11
Submitted: December 16, 2007. **Accepted:** January 13, 2008.
URL: http://economicsbulletin.vanderbilt.edu/2008/volume3/EB-07C20156A.pdf

1 Introduction

Testing for a unit root in long-term real output has attracted substantial interest ever since the pivotal study of Nelson and Plosser (1982). This is because if there is a unit root in real output, then this implies that shocks have permanent effects. This implication is, however, inconsistent with the view that business cycles exhibit stationary fluctuations around a deterministic trend. A wealth of researches has been devoted to this issue, for example, Raj (1992), Perron (1994), Ben-David and Papell (1995, 1998), Li and Papell (1999), Ben-David et al. (2003) and Narayan (2004, 2006).

Two important features characterize these studies. First, the findings are mixed, if not contradictory, which means that no corroborative conclusion is reached vis-à-vis the stationarity property for aggregate real output or real per capita output. Second, the bulk of these studies adopt the traditional ADF-type unit root test with or without structural breaks to investigate the stationary property of real output (except Narayan, 2006). It is well-known that the traditional unit root test is powerless if the true data generating process of a series exhibits structural breaks (Perron, 1989). Banerjee et al. (1992), Zivot and Andrews (1992), Christiano (1992), Park and Sung (1994), Perron (1997) and Lumsdaine and Papell (1997) attempt to resolve this problem by extending the ADF test to include one break and two breaks. However, a shortcoming of these studies (with one or two breaks) is that they all assume there are no breaks under the unit root null and derive their critical values accordingly. Thus, the alternative hypothesis would be that structural breaks are present, which includes the possibility of a unit root with a break. The rejection of the null hypothesis does not necessarily imply rejection of a unit root *per se*, but would imply rejection of a unit root without breaks.

Lee and Strazicich's (2003a, b) method can avoid such a problem. They propose the adoption of structural break Lagrange multiplier (LM) unit root tests, which have the advantage of being unaffected by breaks under the null. In this study, we employ their test to re-examine the non-stationary property of the real per capita GDP of 19 developed countries in order to avoid their spurious inference. We find that we can reject the unit root null hypothesis for 6 out of 19 real per capita GDPs, i.e., Australia, France, Germany, Japan, the UK and the USA, if the one-break unit root test is employed. Moreover, we can reject 11 of the 19 countries' per capita GDP if the two-break unit root test is employed. This is consistent with the view that business cycles exhibit stationary fluctuations around a deterministic trend.

The reminder of the paper is organized as follows. Section 2 introduces the econometric methodology that we employ, and Section 3 describes the data and the empirical test results. Section 4 presents the conclusions that we draw from this research.

2 Testing Methodology

Let y_t denote the logarithm of real per capita GDP. Then, Lee and Strazicich's (2003b, hereafter LS) minimum LM unit root test with two structural breaks is obtained by running the following regression:

$$\Delta y_t = \alpha \tilde{S}_{t-1} + \zeta' \Delta Z_t + \sum_{j=1}^{k} c_j \Delta \tilde{S}_{t-j} + \varepsilon_t, \tag{1}$$

where $\tilde{S}_t$ is a de-trended series such that $\tilde{S}_t = y_t - \tilde{\psi}_x - Z_t \tilde{\xi},\ t = 2, ..., T$. The $\tilde{\xi}$ are coefficients in the regression of Δy_t on ΔZ_t, and $\tilde{\psi}_x = y_1 - Z_1 \tilde{\xi}$, where y_1 and Z_1 are the first observations of y_t and Z_t, respectively. Term Δ is a difference operator. The terms $\Delta \tilde{S}_{t-j},\ j = 1, ..., k$ are added in the regression to correct for potential serial correlation.

Z_t is a vector of exogenous variables. For the two-break test with two changes in level and trend, Z_t is described by $[1,\ t,\ D_{1t},\ D_{2t},\ DT^*_{1t},\ D^*_{2t}]'$, where D_{jt} for $t \geq T_{B_j} + 1,\ j = 1, 2$ and zero otherwise, and $DT^*_{jt} = t$ for $t \geq T_{B_j} + 1,\ j = 1, 2$ and zero otherwise. T_{B_j} denotes the time period when a break occurs. For the one-break minimum LM test (model C), Z_t is described by $[1,\ t,\ D_{1t},\ DT^*_{1t}]'$. Note that the LM testing regression (1) involves ΔZ_t instead of Z_t, so that ΔZ_t becomes $[1,\ B_{1t},\ B_{2t},\ D_{1t},\ D_{2t}]'$ for model CC, where $B_{jt} = \Delta D_{jt}$ and $D_{jt} = \Delta DT^*_{jt},\ j = 1, 2$.

The unit root null hypothesis (with two breaks) is described by $H_0 : \alpha = 0$ and the LM test statistic is defined by

$$\hat{\tau}(\lambda) = \frac{\hat{\alpha}_T}{s.e.(\hat{\alpha}_T)}. \tag{2}$$

To endogenously determine the location of the two breaks i.e., $\lambda = [T_{B_1}/T,\ T_{B_2}/T]$, the minimum LM test uses a grid search as follow:

$$LM_\tau = \inf_\lambda \ \hat{\tau}(\lambda). \tag{3}$$

LS (2003b) show that the critical values for model CC are not invariant to the break location described by λ but are nearly so. In the testing regression, B_{jt} and D_{jt} denote one period jumps in level and permanent shifts in level, respectively, under the null hypothesis. However, B_{jt} and D_{jt} denote shifts in level and trend, respectively, under the alternative hypothesis.

3 Data and Results

The data on the real per capita GDP of 19 countries were extracted from Professor Angus Maddison's homepage at `http://www.ggdc.net/maddison/`. All data are annual and cover the period from 1870 to 2003. First, we apply the Schmidt and Phillips (1992) Lagrange multiplier unit root test to ascertain the order of integration of the variables, but we do not report the results here due to space limitations. They are, however, available from the author upon request.[1] We find no additional evidence against the unit root hypothesis based on the LM test in their level data. When we apply the LM test to the first difference of these series, we must reject the null hypothesis of a unit root at the 5% level or better.

However, as Perron (1989) pointed out, in the presence of a structural break, the power to reject a unit root decreases if the stationary alternative is true and the structural break is ignored.

[1] To select the lag length (k) we use the 't-sig' approach proposed by Hall (1994).

To address this, we use Lee and Strazicich's (2003a) one-break LM unit root test to investigate the order of the empirical variables. We report the results in Table 1. We find that for the USA, the UK, Germany and the Netherlands we are able to reject the unit root null hypothesis at the 5 percent level; for Australia and France, we are able to reject the unit root null hypothesis at the 10 percent level. However, we are unable to reject the unit root null hypothesis for the other countries. By examining the unit root test results with one break, we can reject the unit root null hypothesis for 6 of the 19 per capita GDP series. These findings, to some extent, echo the findings of Perron (1989), so that we may conclude that there will be a spurious unit root if the structural break is ignored.

It is expected that there will be a loss of power from ignoring two, or more, breaks in the one-break test if breaks do exist in a series. Therefore, we apply LS's (2003b) two-break unit root test to these series and report the test results in Table 2. We find that, for the USA, the UK, France, Austria and the Netherlands, we are able to reject the unit root null hypothesis at the 5 percent level; for Australia, Belgium, Denmark, Finland, Japan and Sweden we are able to reject the unit root null hypothesis at the 10 percent level. However, we are unable to reject the unit root null hypothesis for Germany. There are two different findings from the two-break unit root test (model CC) compared to the one-break unit root test (model C). First, we can reject the unit root null hypothesis for 11 of the 19 series from the two-break unit root test in comparison to the one-break unit root test. Second, the test statistics obtained from model CC are greater (in absolute terms) than those obtained from model C.

We compare our results with those of three related studies, i.e., Ben-David and Papell (1995), Ben-David et al. (2003) and Narayan (2006). Both the Ben-David and Papell (1995) and Ben-David et al. (2003) studies use data beginning in the early 1860s or 1870s and ending in 1989, while Narayan (2006) uses data beginning in 1870 and ending in 2001. Ben-David and Papell (1995) investigate the unit root null hypothesis by employing Zivot and Andrew's (1992) method, which accounts for one structural break in the real per capita GDP of 16 developed countries, while Ben-David et al. (2003) investigate the unit root null hypothesis by adopting Lumsdaine and

Papell's (1997) method, which accounts for two structural breaks in real per capita GDP also for 16 countries. In both these studies, the null hypothesis has a unit root (without any breaks) and the alternative hypothesis is that there is trend-stationarity. Narayan (2006) also employs LS's (2003b) method and investigates the unit root null hypothesis by accounting for one and two structural breaks in the real per capita GDP of G7 countries only. Our test results are based on annual data from 1870 to 2003 and are also based on LS's (2003b) method. A summary of the results of the three studies as well as ours are reported in Table 3.[2]

For the case of the one-break test model (model C), our results, basically, show that we can reject the unit root null hypothesis for the per capita GDP of Australia, France, Germany, Japan, the UK and the USA, which is in line with Narayan (2006), but is different from the findings of Ben-David and Papell (1995). In the case of the two-break model (model CC), our results are also consistent with those of Ben-David et al. (2003) and Narayan (2006) with the exception of Canada and the Netherlands. Ben-David et al. (2003) and Narayan (2006) reject the unit root null hypothesis for Canada while our results show that we cannot reject the unit root null hypothesis. Moreover, Ben-David et al. (2003) and Narayan (2006) cannot reject the unit root null hypothesis for the Netherlands while our results show that we can reject the unit root null hypothesis. As addressed by Narayan (2006), there may be two reasons for these different results. First, the results may be due to the different sample sizes. Second, because the Ben-David and Papell (1995) and Ben-David et al. (2003) studies are based on the ADF-type models for which the critical values are derived on the assumption of no break(s) under the null hypothesis, there may be potential size distortions (see Lee and Strazicich, 2003b).

[2] Narayan (2006) also compared his results with those of Ben-David and Papell (1995) and Ben-David et al. (2003).

4 Concluding Remarks

The purpose of this study is to re-investigate the issue of the non-stationarity of real per capita GDP for 19 developed countries by using an extended dataset and a recent unit root test. We find that we can reject the unit root null hypothesis for the per capita GDP of Australia, France, Germany, Japan, the UK and the USA if a one-break unit root test is employed. Moreover, we can reject 11 of 19 countries' per capita GDPs if a two-break unit root test is employed. This findings is consistent with the view that business cycles exhibit stationary fluctuations around a deterministic trend. We also find some parallel as well as different results when a comparison is made with three previous related studies.

References

Banerjee A., R. L. Lumsdaine, and J. H. Stock (1992), Recursive and sequential tests of the unit root and trend break hypotheses: Theory and international evidence, *Journal of Business and Economic Statistics*, 10, 271–287.

Ben-David, D. and D. H. Papell (1995), The great wars, the great crash, and steady state growth: Some new evidence about an old stylized fact, *Journal of Monetary Economics*, 36, 453–475.

Ben-David, D. and D. H. Papell (1998), Slowdowns and meltdowns: Post-war growth evidence from 74 countries, *Review of Economics and Statistics*, 80, 561–571.

Ben-David, D., R. L. Lumsdaine, and D. H. Papell (2003), Unit roots, postwar slowdowns and long-run growth: Evidence from two structural breaks, *Empirical Economics*, 28, 303–319.

Christiano, L. (1992), Searching for a break in GNP, *Journal of Business and Economic Statistics*, 10, 237–250.

Hall, A. (1994), Testing for a unit root in time series with pretest data-based model selection, *Journal of Business and Economic Statistics*, 12, 461–470.

Lee, J. and M. C. Strazicich (2003a), Minimum LM unit root test with one structural break, Mimeo.

Lee, J. and M. C. Strazicich (2003b), Minimum LM unit root tests with two structural breaks, *The Review of Economics and Statistics*, 85, 1082–1089.

Li, Q. and D. Papell (1999), Convergence of international output: Time series evidence for 16 OECD countries, *International Review of Economics and Finance*, 9, 267–280.

Lumsdaine, R. and D. Papell (1997), Multiple trend breaks and the unit-root hypothesis, *Review of Economics and Statistics*, 79, 212–218.

Narayan, P.K. (2004), Are output fluctuations transitory? New evidence from 24 Chinese provinces, *Pacific Economic Review*, 9, 327V336.

Narayan, P.K. (2006), Are G7 real per capita GDP levels non-stationary, 1870–2001? *Japan and the World Economy*, doi:10.1016/j-japwor.2006.08.001.

Nelson, C. R. and C. I. Plosser (1982), Trends and random walks in macroeconomic time series: Some evidence and implications, *Journal of Monetary Economics*, 10, 139–162.

Park, J. amd J. Sung (1994), Testing for unit roots in models with structural change, *Econometric Theory*, 10, 917–936.

Perron, P. (1989), The Great Crash, the oil price shock, and the unit root hypothesis, *Econometrica*, 57, 1361–1401.

Perron, P. (1994), Trend, unit root and structural change in macroeconomic time series, In Rao B. B. (ed.) Cointegration for the Applied Economist. London: Macmillan.

Perron, P. (1997), Further evidence on breaking trend functions in macroeconomic variables, *Journal of Econometrics*, 80, 355–385.

Schmidt, P. and P. C. B. Phillips (1992), LM tests for a unit root in the presence of deterministic trends, *Oxford Bulletin of Economics and Statistics*, 54, 257–287.

Raj, B. (1992), International evidence on persistence in output in the presence of an episodic change, *Journal of Applied Econometrics*, 7, 281–293.

Zivot, E. and D. W. K. Andrews (1992), Further evidence on the Great Crash, the oil-price shock and the unit root hypothesis, *Journal of Business and Economic Statistics*, 10, 251–70.

Table 1: One Break Minimum LM Unit Root Test

Country	$\hat{k}$	$\hat{T}_B$	Test Statistic	Break Points
Australia	2	1933	-4.367*	$\lambda = 0.5$
Austria	6	1950	-4.103	$\lambda = 0.6$
Belgium	3	1948	-3.745	$\lambda = 0.6$
Canada	2	1921	-3.192	$\lambda = 0.4$
Denmark	3	1958	-3.886	$\lambda = 0.7$
Finland	4	1931	-3.166	$\lambda = 0.5$
France	3	1953	-4.313*	$\lambda = 0.6$
Germany	1	1954	-4.510**	$\lambda = 0.6$
Italy	1	1956	-3.661	$\lambda = 0.6$
Japan	0	1959	-3.024	$\lambda = 0.6$
Netherlands	1	1947	-4.518**	$\lambda = 0.6$
New Zealand	5	1940	-3.428	$\lambda = 0.5$
Norway	5	1948	-3.680	$\lambda = 0.6$
Portugal	0	1952	-2.813	$\lambda = 0.6$
Spain	5	1944	-2.934	$\lambda = 0.5$
Sweden	5	1940	-2.578	$\lambda = 0.5$
Switzerland	1	1949	-3.469	$\lambda = 0.6$
UK	1	1925	-4.500**	$\lambda = 0.4$
USA	6	1920	-4.557**	$\lambda = 0.4$

* denotes significance at the 10% level.

** denotes significance at the 5% level.

*** denotes significance at the 1% level.

t-statistics are in parenthesis.

Critical values at 1%, 5% and 10% are -5.11, -4.50, -4.21 for $\lambda = 0.1$, respectively.

Critical values at 1%, 5% and 10% are -5.07, -4.47, -4.20 for $\lambda = 0.2$, respectively.

Critical values at 1%, 5% and 10% are -5.15, -4.45, -4.18 for $\lambda = 0.3$, respectively.

Critical values at 1%, 5% and 10% are -5.05, -4.50, -4.18 for $\lambda = 0.4$, respectively.

Critical values at 1%, 5% and 10% are -5.11, -4.51, -4.17 for $\lambda = 0.5$, respectively.

Table 2: Two Break Minimum LM Unit Root Test

Country	$\hat{k}$	$\hat{T}_B$	Test Statistic	Break Points
Australia	8	1890, 1945	-5.675*	$\lambda = (0.2, 0.6)$
Austria	5	1912, 1954	-5.959**	$\lambda = (0.2, 0.8)$
Belgium	4	1940, 1970	-5.651*	$\lambda = (0.6, 0.8)$
Canada	2	1905, 1939	-4.451	$\lambda = (0.2, 0.6)$
Denmark	7	1938, 1965	-5.317*	$\lambda = (0.6, 0.8)$
Finland	3	1914, 1970	-5.390*	$\lambda = (0.2, 0.8)$
France	3	1938, 1952	-6.159**	$\lambda = (0.4, 0.8)$
Germany	1	1912, 1955	-5.210	$\lambda = (0.2, 0.8)$
Italy	1	1952, 1974	-4.234	$\lambda = (0.6, 0.8)$
Japan	5	1943, 1966	-5.601*	$\lambda = (0.6, 0.8)$
Netherlands	1	1938, 1948	-5.740**	$\lambda = (0.4, 0.6)$
New Zealand	5	1919, 1942	-4.207	$\lambda = (0.2, 0.6)$
Norway	4	1918, 1958	-5.136	$\lambda = (0.2, 0.8)$
Portugal	4	1943, 1968	-4.387	$\lambda = (0.6, 0.8)$
Spain	8	1943, 1970	-4.596	$\lambda = (0.6, 0.8)$
Sweden	4	1932, 1979	-5.479*	$\lambda = (0.4, 0.8)$
Switzerland	1	1939, 1970	-4.805	$\lambda = (0.6, 0.8)$
UK	2	1917, 1925	-5.874**	$\lambda = (0.2, 0.6)$
USA	8	1928, 1940	-7.750**	$\lambda = (0.4, 0.6)$

* denotes significance at the 10% level.

** denotes significance at the 5% level.

*** denotes significance at the 1% level.

t-statistics are in parenthesis.

Critical values at 1%, 5% and 10% are -6.16, -5.59, -5.28 for $\lambda = (0.2, 0.4)$, respectively.

Critical values at 1%, 5% and 10% are -6.40, -5.74, -5.32 for $\lambda = (0.2, 0.6)$, respectively.

Critical values at 1%, 5% and 10% are -6.33, -5.71, -5.33 for $\lambda = (0.2, 0.8)$, respectively.

Critical values at 1%, 5% and 10% are -6.46, -5.67, -5.31 for $\lambda = (0.4, 0.6)$, respectively.

Critical values at 1%, 5% and 10% are -6.42, -5.65, -5.32 for $\lambda = (0.4, 0.8)$, respectively.

Critical values at 1%, 5% and 10% are -6.32, -5.74, -5.32 for $\lambda = (0.6, 0.8)$, respectively.

Table 3: Comparison with Previous Studies

Country	BP (1995) model C	Ben-David et al. (2003) model CC	Narayan (2006) model C	Narayan (2006) model CC	this paper moedl C	this paper moedl CC
Australia		*			*	*
Austria	***	***				**
Belgium	***	**				*
Canada	***	***		*		
Denmark	***	***				*
Finland		***				*
France	***	***	*	**	*	**
Germany	***		**		**	
Italy	*					
Japan	***	***		**		*
Netherlands					**	**
New Zealand						
Norway		***				
Portugal						
Spain						
Sweden	***	***				*
Switzerland						
UK	***	**	***	**	**	**
USA	**	***	***	***	**	**

* denotes significance at the 10% level.

** denotes significance at the 5% level.

*** denotes significance at the 1% level.