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Is volume index of gdp per capita stationary in oecd countries? panel stationary tests with structural breaks

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Abstract

The purpose of this paper is to investigate whether volume index of GDP per capita is stationary for 24 OECD countries during the period 1970 to 2006. We utilize a panel stationary tests that allow for multiple structural breaks, developed by Carrion-i-Silvestre et al. (2005). The empirical findings are threefold: (1) when we employ univariate unit tests, such as ADF and KPSS without structural breaks, we hardly find evidence of I(0) stationarity, except for Switzerland (2) when we employ KPSS stationarity test with multiple structural breaks, we find evidence of I(0) stationarity for 22 out of 24 countries and (3) when we employ KPSS panel I(0) stationarity test with multiple structural breaks and the assumption of cross-section dependence, we find significant evidence of panel I(0) stationarity of per capita GDP for these OECD countries. The findings of this paper have implications for policymaking and econometric modeling for these 24 OECD countries.

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1. Introduction

Ever since the seminal work of Nelson and Plosser (1982), many studies have devoted to investigating the non-stationarity of important macroeconomic variables. The time-series properties of real output levels have been of special interest to researchers. Nelson and Plosser (1982) point out that 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 researchers but also for policymakers. In particular, this investigation can help determine whether fiscal and/or monetary stabilization policies would likely have only temporary effects on real output levels.

Several studies have supported the Nelson and Plosser (1982) finding. Cheung and Chinn (1996), for instance, found real output to be non-stationary for 26 out of 29 high-income countries. Fleissig and Strauss (1999) used panel unit root tests and found OECD per capita output to be trend stationary. Rapach (2002) examined the unit root properties of real GDP and real GDP per capita for OECD countries and argued that real GDP and real GDP per capita were non-stationary.

Most of the empirical studies to date support the existence of a unit root in real output levels, although critics have claimed that this conclusion may be due to the low power of the conventional unit root tests employed. One response to this criticism has been the development of panel unit root tests, such as Levin, Lin, and Chu (2002), Im, Pesaran and Shin (2003), and Maddala and Wu (1999) that exploit the cross-section, as well as the time series dimension of the data in order to increase power. These tests have been successful in finding evidence of I(0) stationarity that cannot be found by univariate methods, particularly for real exchange rates.

Recently, Ozturk et al. (2008) applied the panel unit root test advocated by Im, Pesaran and Shin (1997) and found out that real GDP per capita series among OECD countries are non-stationary. Nevertheless, the complex nature of the interaction and dependence generally exists over time and across the individual units in the panel. For example, observations on regions and countries tend to be cross-correlated as well as serially dependent. Moreover, one notable characteristic worth noting is that most of the time series are affected by multiple structural breaks. The erroneous omission of structural breaks in a series can result in inaccurate and misleading conclusions.

In this paper, we examine whether volume index of GDP per capita is stationary for 24 OECD countries. When we take both the assumption of cross-section dependence and multiple structural breaks into account by using the Carrion-i-Silvestre et al. (2005) panel stationary test, we find significant evidence of panel I(0) stationarity of per capita GDP for these 24 OECD countries. The rest of paper is organized as follows: Section 2 describes the data and econometric methodology. Section 3 provides empirical results while Section 4 offers some conclusions.

2. Data and Methodology

2.1 Data

The empirical analysis in this study is based on volume index of GDP per capita data for 24 OECD countries, namely Australia, Austria, Belgium, Canada, Demark, Finland, Germany, Greece, Iceland, Ireland, Italy, Japan, Korea, Luxemburg, Mexico, Netherland, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, and the United States for the period 1970 to 2006. Volume index of GDP per capita is scaled by OECD=100 in 2000, at 2000 price levels and PPPs. All the annual data are extracted from the OECD.Stat online database. Table 1 shows the statistical summary for volume index of GDP per capita for 24

OECD countries. From Table 1, we find that Luxembourg and Mexico have the highest and lowest means of this index (of 144.95 and 31.70, respectively).

2.2 Multiple Structural Breaks Panel I(0) stationarity Test

In this subsection, we describe the test for the null hypothesis of I(0) stationarity that allows for multiple structural breaks in panel data developed by Carrion-i-Silvestre et al. (2005). Essentially, the Carrion-i-Silvestre et al. (2005) technique allows for two different types of multiple structural break effects. To see this, let us start with the following model:

$$y_{i,t} = \alpha_i + \sum_{k=1}^{m_i} \theta_{i,k} DU_{i,k,t} + \beta_i t + \sum_{k=1}^{m_i} \gamma_{i,k} DT^*_{i,k,t} + \varepsilon_{i,t} \qquad (1)$$

where subscript i = 1, . . . ,N individuals and t = 1, . . . ,T time periods; the dummy variable $DT^*_{i,k,t} = t - T^i_{b,k}$ for $t > T^i_{b,k}$ and 0 elsewhere; and $DU_{i,k,t} = 1$ for $t > T^i_{b,k}$ and 0 elsewhere, where $T^i_{b,k}$ denotes the kth date of the break for the ith individual and k = 1, . . . ,m_i, $m_i \geq 1$. Equation (1) includes: (a) individual structural break effects - shifts in the mean caused by the structural breaks when $\beta_i \neq 0$; and (b) temporal structural break effects - shifts in the trend caused by the structural breaks when $\gamma_{i,k} \neq 0$.

According to Carrion-i-Silvestre et al. (2005), the specification given by equation (1) is general enough to allow for the following characteristics: (i) it permits the individuals to have a different number of structural breaks; (ii) the structural breaks may have different effects on each individual time series – the effects are measured by $\theta_{i,k}$ and $\gamma_{i,k}$; and (iii) they may be located at different dates. The test of the null hypothesis of a stationary panel that we use follows that proposed by Hadri (2000), with the expression given by:

$$LM(\lambda) = N^{-1} \sum_{i=1}^{N} (\hat{\omega}_i^{-2} T^{-2} \sum_{t=1}^{T} \hat{S}^2_{i,t}) \qquad (2)$$

where $\hat{S}_{i,t} = \sum_{j=1}^{t} \hat{\varepsilon}_{i,j}$ denotes the partial sum process that is obtained when we use the estimated OLS residuals of equation (1) and where $\hat{\omega}_i^2$ is a consistent estimate of the long-run variance of $\varepsilon_{i,t}$. The homogeneity of the long-run variance across and individual time series can also be imposed during the testing process. Finally, we use λ in equation (2) to denote the dependence of the test on the dates of the break. For each individual i, it is defined as the vector:

$$\lambda_i = (\lambda_{i,1}, \dots\dots, \lambda_{i,m_i})' = (T^i_{b,1}/T \dots\dots, T^i_{b,m_i}/T)' \qquad (3)$$

which indicates the relative position of the dates of the breaks during the entire time period, T.

We estimate the number of structural breaks and their position by following the procedures put forth by Bai and Perron (1998) that compute the global minimization of the sum of the squared residuals (SSR). Here we make use of these procedures and chose the estimate of the dates of the breaks, we do this based on the argument that minimizes the sequence of individual $SSR(T^i_{b,1}, \dots\dots, T^i_{b,m_i})$ computed from (1). Once we estimate the dates of all possible $m_i \leq m^{max}, i = \{1, \dots\dots, N\}$, we select the most suitable number of structural breaks for each i, if there are any, that is, to obtain the optimal m_i.

Bai and Perron (1998) address this concern by using two different procedures. Briefly stated, the first procedure makes use of information criteria or more specifically, the Bayesian information criterion (BIC) and the modified Schwarz information criterion (LWZ) of Liu et al.

(1997). The second procedure is based on the sequential computation – and detection – of structural breaks with the application of pseudo F-type test statistics. After comparing both procedures, Bai and Perron (2001) concluded that the second procedure outperforms the former. Thus, in line with their recommendation, when the model under the null hypothesis of panel I(0) stationarity does not include trending regressors, the number of structural breaks should be estimated using the sequential procedure. On the other hand, when there are trending regressors, the number of structural breaks should be estimated using the Bayesian (BIC) and the modified Schwarz (LWZ) information criteria. Bai and Perron (2001) conclude that the LWZ criterion performs better than the BIC criterion.

3. Empirical Results

3.1 ADF and KPSS Univariate Tests

We start the empirical analysis with an investigation of the univariate unit root properties of volume index of GDP per capita for each country using both the conventional ADF test and the univariate stationary KPSS test with a time trend but without structural breaks. The empirical results are reported in Table 2. In column 2 of Table 2, we report the ADF t-test statistics, while in column 3 we show the optimal lag length, chosen by Schwarz Information Criterion (SIC). The main finding in ADF test is that we can reject the unit root null hypothesis only for Switzerland at the 5% significant level. For the rest of countries, more than 95% of sample, we cannot find any evidence in favor of a trend stationary for volume index of GDP per capita.

The results from the individual KPSS test are reported in column 4 of Table 2 and its associated bandwidth is shown in the last column. The bandwidth is selected automatically using the Sul *et al.* (2005) method, and it turns out that the optimal bandwidth are ranged between 3 and 5 for countries studied. We are able to reject the null hypothesis of I(0) stationarity for Australia, Greece, Ireland, Italy, Korea, Luxemburg, Netherland, New Zealand, Spain, United Kingdom, and United States at the 5% level, and for Belgium, Demark, Japan, Norway, Portugal, and Sweden at the 10% level. For the rest of the seven countries, namely Austria, Canada, Finland, Germany, Iceland, Mexico, and Switzerland, we cannot reject the null hypothesis of I(0) stationarity. This implies that for less than 30% of sample there is evidence that per capita income is trend stationary.

The results from the ADF and the KPSS tests conclude that for more than 70% of sample, per capita income is non-stationary. Perron (1989) argued that the conventional ADF test has low power to reject the unit root null hypothesis when the true data generating process is stationary around a broken linear trend. The volume index of GDP per capita series for the OECD countries studied here have experienced both internal and external shocks over the timeframe considered that potentially could give rise to a structural break. Structural breaks if present in the data but not modeled, regardless of whether the null hypothesis is a unit root or I(0) stationarity, is likely to produce spurious results. To this end, Vogelsang and Perron (1998) show that the power of a unit root test with structural breaks is in the range 60–90% under alternative scenarios. Following this literature, we consider the KPSS test by allowing for multiple structural breaks in our data series.

In light of these considerations, in this study, we apply the test of Carrion-i-Silvestre et al. (2005). The empirical analysis first specifies a maximum of $m^{max} = 5$ structural breaks, which appears to be reasonable given the number of time observations (T = 37) in our study. Following the suggestion of Bai and Perron (2001), we estimate the number of structural breaks associated with each individual using the modified Schwarz information criterion (LWZ) of Liu et al. (1997). Panel A of Table 4 shows that under the assumption of cross-section independence, we find that the stationary null hypothesis is rejected in both homogeneous and heterogeneous cases at the 1% level.

In column 2 of Table 3, we report the KPSS test statistics, generated through accounting for structural breaks; column 3 to column 7 report the structural break dates, while the final column contains the finite sample critical values at the 10, 5, 2.5 and 1% levels, respectively, obtained through Monte Carlo simulations. Looking at the estimated break points we realize that most of these dates are associated with some major events and around the time of the oil crises. Despite allowing for structural breaks we are still able to reject the null hypothesis of I(0) stationarity for Mexico and Portugal at the 5% level. This result shows that for only two out of the 24 countries per capita income is non-stationary when the individual KPSS statistics with breaks are used.

3.2 Multiple Structural Breaks Panel I(0) Stationarity Test Statistics

Cheung and Chinn (1996) pointed out that a misspecification error in the deterministic component of the ADF and KPSS tests because of the failure to take into account the presence of structural breaks can make the results inconclusive. This is supported by the evidence from Jewell et al. (2003), Carrion-i-Silvestre et al. (2005) and Carrion-i-Silvestre (2005), all of whom conclude that the unit root hypothesis can be strongly rejected once the level and/or slope shifts are taken into account.

When we introduce individual information into the panel data test and assume the individuals are cross-section independent, we strongly reject the I(0) stationarity hypothesis for both homogeneous and heterogeneous long-run variance in all cases (see Panel A of Table 4). It is well-known that independence is not a realistic assumption given the fact that the per capita real GDP of different countries may be contemporaneously correlated. To control for any cross-section dependence found among the data sets, we approximate the bootstrap distribution of the tests. When we take cross-section dependence into account, the evidence is reversed. The null hypothesis of I(0) stationarity cannot be rejected by either the homogeneous or the heterogeneous long-run variance estimation version of the test at the 1% level if we use the bootstrap critical values, as shown in Panel B of Table 4.

Taken together, our results suggest that the panel data set of volume index of GDP per capita is stationary when we introduce both structural breaks and cross-section dependence into the model. These results agree with those of Jewell et al. (2003), Carrion-i-Silvestre et al. (2005) and Carrion-i-Silvestre (2005) and strongly support the view that these time series have been affected by multiple structural breaks. It should be underscored that this finding is robust to the presence of cross-section dependence since it is based on the use of bootstrap critical values. Equally important, the results here are consistent with those of Fleissig and Strauss (1999) who used three different panel-based unit root tests and determined that the per capita real GDP for OECD countries is trend stationary.

Our results correspond strikingly with others which support the notion of I(0) stationarity of the output once the breaking-trend specifications are introduced in the analysis. See Ben-David and Papell (1995) and Ben-David et al. (1996) for the real GDP and GDP per capita and Perron (1997) for the real GNP or GDP in a sample of developed countries. Our results, nevertheless, are not consistent with those of Cheung and Chinn (1996), Rapach (2002), and Ozturk et al. (2008) which support the notion of non-stationarity in real GDP for various panels of OECD countries without taking multiple breaks or cross-section dependence into account. We believe that our study is reliable due to the use of more advanced methods which introduce both structural breaks and cross-section dependence into the model.

4. Conclusions

The purpose of this paper is to investigate whether volume index of GDP per capita is panel I(0) stationarity with structural breaks for 24 OECD countries during the period 1970 to 2006. We utilize a recently developed technique by Carrion-i-Silvestre et al. (2005) that tests the null hypothesis of I(0) stationarity by allowing for at most five structural breaks in both univariate and panel data. Such a finding is important because if income is found to be non-stationary then it is inconsistent with the notion that business cycles are stationary fluctuations around a deterministic trend.

The main finding of our paper is that when we employed both the conventional ADF and KPSS tests, which did not account for any structural breaks, we did not find any evidence for I(0) stationarity of per capita income, except for Switzerland. Nevertheless, when we applied multiple structural breaks to univariate GDP series or GDP panel data with cross-section dependence, we found overwhelming evidence for I(0) stationarity of volume index of GDP per capita for these 24 OECD countries in panel data and 22 out of 24 in univariate series. Our results have important implications for policymaking and econometric modeling.

Our results, in large part, are consistent with the view that business cycles are stationary fluctuations around a deterministic trend. These results also imply that in most cases shocks will have only a transitory effect on per capita income for the bulk of the OECD countries; the exceptions being Mexico and Portugal in univariate GDP series with structural breaks. One salient policy implication that emerges from this study is that a stabilization policy may not have any permanent effects on the output level of these 24 OECD countries we study here.

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Table 1 - Statistical Summary for Volume Index of GDP per Capita (scaled in %, 1970-2006)

Countries	Mean	Median	Max	Min.	Std. Dev.	Skew.	Kurt.
Australia	87.95	85.38	122.52	65.26	18.09	0.52	1.99
Austria	90.58	88.81	125.81	54.81	20.74	0.06	1.84
Belgium	87.57	86.82	119.75	56.08	18.41	0.11	1.87
Canada	91.98	91.95	125.36	62.88	17.47	0.26	2.17
Denmark	91.54	91.53	125.79	63.17	18.75	0.17	1.78
Finland	80.20	78.66	120.68	49.21	19.27	0.35	2.24
Germany	82.49	81.44	110.08	53.47	17.58	-0.05	1.66
Greece	63.76	61.17	93.44	42.66	11.57	0.88	3.52
Iceland	93.13	94.38	135.07	51.05	21.32	0.01	2.47
Ireland	69.53	54.68	141.91	33.14	34.12	0.89	2.38
Italy	81.04	83.69	104.86	50.43	17.76	-0.19	1.73
Japan	82.43	84.92	111.37	48.80	19.85	-0.20	1.54
Korea	39.73	35.17	84.42	11.50	22.94	0.43	1.82
Luxembourg	144.95	133.03	253.31	81.02	53.96	0.51	1.91
Mexico	31.70	31.64	39.56	23.52	3.94	-0.20	2.61
Netherlands	90.66	85.76	125.91	62.35	19.41	0.39	1.82
New Zealand	73.94	72.38	93.90	60.25	9.28	0.72	2.57
Norway	107.16	105.13	159.38	57.66	30.92	0.14	1.82
Portugal	49.22	47.41	69.97	27.40	14.01	0.20	1.59
Spain	64.75	61.86	95.43	40.34	16.18	0.45	1.95
Sweden	90.86	90.64	128.64	66.84	16.96	0.54	2.38
Switzerland	112.00	113.74	133.18	93.32	11.77	0.00	1.72
United Kingdom	80.43	81.24	116.16	54.48	18.53	0.41	1.95
United States	108.88	109.78	151.09	72.97	23.38	0.21	1.83
All	83.19	80.89	253.31	11.50	31.82	0.90	6.14

Table 2 - Univariate Unit Root and Stationarity Tests without Structural Breaks

Countries	***ADF***	***Lag Length***	***KPSS***	***Bandwidth***
Australia	-1.4151	0	0.1838**	5
Austria	-2.7772	1	0.1080	3
Belgium	-2.3251	0	0.1294*	4
Canada	-2.2341	1	0.1137	4
Denmark	-2.7161	1	0.1355*	3
Finland	-2.4644	1	0.1023	4
Germany	-3.2958	1	0.0905	3
Greece	0.3551	0	0.1561**	4
Iceland	-2.1926	1	0.1052	4
Ireland	-0.9274	1	0.1860**	5
Italy	-1.5234	1	0.1669**	4
Japan	-1.8999	1	0.1377*	4
Korea	-1.4693	0	0.1866**	5
Luxembourg	-1.6951	2	0.1751**	5
Mexico	-1.8146	0	0.1015	4
Netherlands	-1.7110	1	0.1664**	5
New Zealand	-1.8391	1	0.1553**	4
Norway	-2.9287	1	0.1251*	4
Portugal	-2.9422	1	0.1281*	4
Spain	-1.9311	1	0.1640**	5
Sweden	-0.9812	1	0.1437*	4
Switzerland	-3.5580**	1	0.0645	3
United Kingdom	-1.6163	1	0.1897**	4
United States	-2.7422	1	0.1586**	4

Note: 1. The finite sample critical values for ADF test are -4.244, -3.544, and -3.205 at the 1%, 5%, and 10% levels.

2. The finite sample critical values for KPSS test are 0.216, 0.146, and 0.119 at the 1%, 5%, and 10% levels.

*3. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels.*

Table 3 - KPSS Test on Volume Index of GDP per Capita for 24 OECD Countries with Structral Breaks

Countries	Statistics	Break Dates					Finite Sample Critical Values			
							90%	95%	97.5%	99%
Australia	0.051	1981	1989				0.063	0.075	0.087	0.102
Austria	0.047	1980					0.082	0.097	0.110	0.128
Belgium	0.040	1981					0.083	0.098	0.110	0.129
Canada	0.024	1981	1987	1992	1998		0.056	0.070	0.086	0.103
Denmark	0.036	1984	1993				0.079	0.098	0.120	0.144
Finland	0.046	1988	1993				0.115	0.144	0.178	0.223
Germany	0.039	1989					0.122	0.156	0.189	0.234
Greece	0.030	1980	1996				0.056	0.065	0.076	0.088
Iceland	0.028	1982	1987	1993			0.065	0.081	0.097	0.115
Ireland	0.058	1988	1994	1999			0.117	0.151	0.188	0.229
Italy	0.038	1987	1999				0.102	0.132	0.158	0.195
Japan	0.050	1985	1991				0.088	0.109	0.132	0.162
Korea	0.038	1984	1997				0.079	0.097	0.119	0.146
Luxembourg	0.037	1983	1994				0.071	0.088	0.104	0.126
Mexico	0.034**	1976	1981	1987	1994	2000	0.028	0.033	0.038	0.044
Netherlands	0.045	1981	1992	2001			0.057	0.070	0.084	0.103
New Zealand	0.028	1974	1979	1985	1990		0.037	0.042	0.048	0.057
Norway	0.024	1981	1986	1991	1996		0.058	0.072	0.086	0.105
Portugal	0.028**	1974	1983	1992	1999		0.026	0.028	0.030	0.032
Spain	0.020	1974	1984	1990	1995	2001	0.024	0.027	0.029	0.033
Sweden	0.040	1981	1988	1993			0.059	0.071	0.083	0.098
Switzerland	0.024	1974	1988	1996			0.034	0.038	0.042	0.047
United Kingdom	0.032	1980	1990				0.056	0.066	0.076	0.090
United States	0.050	1981	1990				0.061	0.073	0.084	0.101

Note: 1. The finite sample critical values are computed by means of Monte Carlo simulations using 20,000 replications.
*2. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels.*

Table 4 - Panel Stationarity Test with Structural Breaks

Panel A: Assuming Cross-Section Independence		
	LM-Statistic	P-Value
LM(λ)-homo	7.719	0.0000
LM(λ)-heter	7.104	0.0000

Panel B: Bootstrap Distribution (Assuming Cross-Section Dependence)								
	1%	5%	7.5%	10%	90%	95%	97.5%	99%
LM(λ)-homo	7.075	7.489	7.870	8.278	11.640	12.109	12.521	12.980
LM(λ)-heter	6.927	7.249	7.536	7.874	10.672	11.118	11.525	11.969

Note: The finite sample critical values are computed by means of Monte Carlo simulations using 20,000 replications.