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

Is Per Capita Real GDP Stationary in Latin American Countries? Evidence from a Panel Stationary Test with Structural Breaks

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Abstract

In this note, we use the newly-developed and refined panel stationary test with structural breaks, as advanced by Carrion-i-Silvestre et al. (2005), to investigate the time-series properties of per capita real GDP for 20 Latin American countries during the 1960-2000 period. The empirical results from numerous earlier panel-based unit root tests which do not take structural breaks into account indicate that the per capita real GDP for all the countries we study here are non-stationary; but when we employ Carrion-i-Silvestre et al.¡¦s (2005) panel stationary test with structural breaks, we find the null hypothesis of stationarity in per capita real GDP can not be rejected for any of the 20 countries.

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I. INTRODUCTION

Since the seminal work of the Nelson and Plosser (1982), various studies have been devoted to investigating the potential non-stationarity of important macroeconomic variables. Researchers have been especially interested in the time-series properties of real output levels. In this regard, Nelson and Plosser (1982) pointed out that whether real output levels are modeled as a trend stationary or as a difference stationary process has important implications vis-ȧ-vis macroeconomic policy-making, modeling and testing, not to mention forecasting. Studies on this issue are of considerable concern to researchers conducting empirical studies and policy-makers alike.

Granted that numerous studies have found support a unit root in real output levels, but critics have staunchly contended that the drawing such a conclusion may be attributed to the lower power of the conventional unit root tests employed when compared with near-unit-root but stationary alternatives. More than that, conventional unit root tests have reportedly failed to consider information across regions, thereby yielding less efficient estimations. It should therefore not be unexpected that these shortcomings have seriously called into questions many of the earlier findings which are based on a unit root in real output levels.

One feasible way to increase power when testing for a unit root is, of course, to use panel data. True that in the extant literature, several tests have been proposed, but putting the focus on the presence of structural changes in the time series in a panel has, at best, been scarce. Yet, it must be kept in mind that the erroneous omission of structural breaks in a series can result in to inaccurate and misleading conclusions when the univariate integration order analysis is performed cannot be discredited (see Perron, 1989). Nevertheless, this concern with the use of panel data is properly addressed in the work of Im and Lee (2001) and Carrion-i-Silvestre et al. (2005) and Carrion-i-Silvestre (2005).

Here, we investigate the time-series properties of per capita real GDP for 20 Latin American countries by using the panel stationary test with multiple structural breaks, as advanced by Carrion-i-Silvestre et al. (2005). To the best of our knowledge, the present paper is the first to examine non-stationarity in real output levels for Latin American countries. This empirical note contributes to field of empirical research by determining whether or not the unit root process is characteristic of the Latin American countries

The remainder of this study is organized as follows. Section II presents the data used. Section III first describes the methodology employed and then discusses the empirical findings and policy implications. Section IV presents a wrap up of the conclusions we draw.

II. DATA

This empirical study uses annual per capita real GDP for 20 Latin American countries over the 1960-2000 period. We obtain the data from the *Penn World Tables (PWT)* 6.1 of Heston, Summers and Aten (2002) and present the summary statistics in Table 1. The per capita real GDP datasets indicate that Barbados and Bolivia respectively have the highest and lowest average per capita incomes of US$9,586.756 and US$2,664.244. The Jarque-Bera test results indicate that for most of the Latin American countries we study, the per capita real GDP datasets approximate normal.

III. PANEL STATIONARY METHODOLOGY AND EMPIRICAL RESULTS

A. Carrion-i-Silvestre et al's (2005) Panel Stationary Test with Structural Breaks

Carrion-i-Silvestre et al's (2005) panel stationary test **i**s a modification of Hadri's (2000) stationarity test, which allows for multiple structural breaks through the incorporation of dummy variables in the deterministic specification of the model. In this case, under the null hypothesis the data generating process (DGP) for the variable is assumed to be:

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

With dummy variable $DT^{*}_{i,k,t} = t - T^{i}_{b,k}$ for $t > T^{i}_{b,k}$ and 0 elsewhere; another dummy variable $DU_{i,k,t} = 1$ for $t > T^{i}_{b,k}$ and 0 elsewhere, with $T^{i}_{b,k}$ denoting the *kth* date of the break for the *ith* individual, $k = \{1,\ldots,m_i\}$; and $m_i \geq 1$. The model in [1] includes individual effects, i.e., *individual structural break* effects, that is, shifts in the mean caused by the structural breaks, temporal effects if $\beta_i \neq 0$ and *temporal structural break* effects if $\gamma_{i,k} \neq 0$, that is when there are shifts in the individual time trend. This specification is the panel data counterpart of models with breaks proposed in the univariate framework. Thus, when $\beta_i = \gamma_{i,k} = 0$ the model in [1] is the counterpart of the one analyzed by Perron and Vogelsang (1992), whereas when $\beta_i \neq \gamma_{i,k} \neq 0$ we revert to the specification given by Perron (1989)'s model C. Although other specifications might be adopted, e.g. the panel data counterparts of models A and B in Perron (1989), the asymptotic distribution of the test proposed below for those cases cannot be asymptotically distinguished from the one with. $\beta_i \neq \gamma_{i,k} \neq 0$. Thus, these models can be rewritten in a way that their representation becomes equivalent, therefore sharing the limit distribution – se Carrion-i-silvestre et al. (2005). According to Carrion-i-Silvestre et al. (2005), the specification given by [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:

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

where $S_{i,t} = \sum_{j=1}^{t}\hat{\varepsilon}_{i,j}$ denotes the partial sum process that is obtained when we use the estimated OLS residuals of [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 [2] to denote the dependence of the test on the dates of the break. For each individual i, it is defined as the vector $\lambda_i = (\lambda_{i,1}, \ldots, \lambda_{i,m_i})' = (T_{b,1}^{i}/T, \ldots, T_{b,m_i}^{i}/T)'$, which indicates the relative positions 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 $SSR(T_{b,1}^{i}, \ldots T_{b,m_i}^{i})$ computed from [1]. Once we estimate the dates of all possible $m_i \leq m^{\max}$, $i = \{1, \ldots, N\}$, 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 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.

B. Empirical results

Tables 2 and 3 present the country-by-country and panel data test statistics, respectively, for the unit root and stationary tests that do not allow for the presence of structural breaks (i.e., the ADF, PP and KPSS). At the first glance, the individual test statistics seem to offer mixed results. More to the point, they show non-stationarity for most countries, with the exceptions of the Bolivia, Jamaica, Panama, Peru and El Salvador (using the ADF test). One potential for these contractions can be the lack of power that is afforded by these tests when they are applied in a finite sample. In this situation, the panel data tests are found to be of great help provided that they allow an increase in the power of the order of the integration analysis by the combination of the cross-section and temporal dimensions. The results shown in Table 3 clearly indicate that the Levin-Lin-Chu (Levin et al., 2002), Im-Pesaran-Shin (Im et al., 2003) and MW (Maddala and Wu, 1999) tests all fail to reject the null of non-stationary per capita real GDP for all 20 countries. The Hardi (2000) test also yields the same results. We obtain the same result irrespective of the assumption made concerning the cross-section dependence. Panel B of Table 3 also displays the percentiles of the bootstrap distribution, as described in Maddala and Wu (1999). We have performed 10,000 replications for the parametric bootstrap. Details about the bootstrap procedure, interested reader please refer to Maddala and Wu (1999)'s paper (pages 645-647).

Cheung and Chinn (1996) correctly 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.

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 = 41) 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). Table 4A shows our results. We find that the stationary null hypothesis is not rejected in any of the cases. We compute the finite sample critical values by means of Monte Carlo simulations using 10,000 replications, and these are presented in Table 4A. One notable characteristic worth noting is that most of the time series are affected by multiple breaks. Costa Rica and Trinidad & Tobago exhibit one break, nine countries have two breaks, and the remaining countries have at least three breaks. Paraguay is the only country with five breaks. 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.

When we introduce individual information into the panel data test and the individuals are assumed to be cross-section independent and assume the individuals are cross-section independent, we strongly reject the stationarity hypothesis for both homogeneous and heterogeneous long-run variance in all cases.

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 of stationarity cannot be rejected by either the homogeneous or the heterogeneous long-run version of the test if we use the bootstrap critical values, as shown in Panel C of Table 4. Taken together, our results suggest that the panel data set of per capita real GDP is stationary when we introduce structural breaks into the model. These results agrees with those of Jewell et al. (2003), Carrion-i-Silvestre et al. (2005) and Carrion-i-Silvestre (2005) and strongly supports 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 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) and Rapach (2002), which support the notion of non-stationaity in real

GDP for various panels of OECD countries.

IV. CONCLUSIONS

In this empirical study, we employ the Carrion-i-Silvestre et al.'s (2005) panel stationary test with structural breaks to assess the non-stationarity properties of per capita real GDP for 20 Latin American countries over the 1960 to 2000 period. Carrion-i-Silvestre et al's (2005) panel stationary test indicates that a unit root in real output levels is flatly rejected for all 20 countries we study here.

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Table 1 Summary Statistics of per capita Real Gross Domestic Product

Country(US dollar)	Mean	Std	Max.	Min.	Skewness	Kurtosis	J-B
1.Bolivia	2664.244	233.236	3148	2354	0.650	2.365	3.573
2.Brazil	5198.951	1565.225	7190	2371	-0.607	1.814	**4.923***
3.Chile	5715.390	1794.455	9926	3853	1.224	3.228	**10.334*****
4.Colombia	4082.634	988.340	5645	2530	-0.049	1.745	2.709
5.Costa Rica	4666.927	696.929	5870	3311	-0.395	2.237	2.062
6.Dominican Republic	2866.683	921.050	5270	1618	0.668	3.126	3.078
7.Ecuador	3295.000	816.997	4260	1985	-0.616	1.660	**5.658***
8.Guatemala	3370.707	512.255	4057	2344	-0.757	2.209	**4.987***
9.Jamaica	3601.561	390.737	4595	2746	-0.183	3.151	0.269
10.Mexico	6556.805	1313.824	8762	3978	-0.615	2.189	3.706
11.Nicaragua	3065.512	909.282	4453	1628	-0.152	1.707	3.016
12.Panama	4615.878	1147.768	6066	2325	-0.453	1.894	3.489
13.Peru	4438.390	552.585	5340	3228	-0.335	2.289	1.631
14.Paraguay	3903.195	1033.270	5362	2425	-0.163	1.444	4.320
15.El Salvador	3999.146	424.459	4949	3310	0.288	2.142	1.826
16.Trinidad&Tobago	8207.829	1931.590	11175	4370	-0.308	1.912	2.670
17.Uruguay	7103.390	1361.263	10151	5554	0.757	2.421	4.484
18.Venezuela	8062.512	1159.332	10528	6415	0.467	1.972	3.291
19.Barbados	9586.756	4039.479	16415	3398	0.018	1.714	2.826
20.Guyana	2530.341	471.282	3865	1836	0.984	3.561	**7.152****

Note: Std denotes standard deviation and J-B denotes the Jarque-Bera Test for Normality. The ***, ** and * indicate significance at the 0.01, 0.05 and 0.1 level, respectively.

Table 2 Univariate Unit Root Tests

Country	*Levels*			*First Differences*		
	ADF	PP	KPSS	ADF	PP	KPSS
1.Bolivia	**-2.715(2)***	-2.073(3)	0.116(5)	**-4.817(0)******	**-4.870(2)******	0.125(3)
2.Brazil	-2.841(0)	-2.373(3)	**0.698(5)*****	**-4.258(0)******	**-4.322(2)******	0.428(2)*
3.Chile	0.633(0)	0.512(1)	**0.685(5)*****	**-5.166(0)******	**-5.170(2)******	0.215(2)
4.Colombia	-1.558(1)	-1.880(1)	**0.771(5)******	**-4.010(0)******	**-4.010(0)******	0.302(2)
5.Costa Rica	-2.144(1)	-1.049(0)	**0.629(5)*****	**-4.084(1)******	**-4.220(3)******	0.117(1)
6.Dominican Republic	0.101(1)	0.543(2)	**0.772(5)******	**-5.250(0)******	**-5.287(1)******	0.152(2)
7.Ecuador	-1.895(1)	-1.664(4)	**0.583(5)*****	**-3.900(0)******	**-3.950(3)******	0.335(4)
8.Guatemala	-1.888(1)	-2.201(4)	**0.619(5)*****	**-3.395(0)*****	**-3.4367(3)*****	0.331(4)
9.Jamaica	**-3.007(2)*****	-2.517(2)	0.290(5)	**-5.016(0)******	**-5.079(2)******	0.215(3)
10.Mexico	-2.009(0)	-1.931(1)	**0.691(5)*****	**-4.230(0)******	**-4.228(2)******	0.272(3)
11.Nicaragua	0.265(0)	-0.084(3)	**0.608(5)*****	**-4.393(0)******	**-4.344(2)******	**0.404(3)***
12.Panama	**-2.947(0)*****	**-2.883(5)***	**0.723(5)*****	**-4.332(0)******	**-4.164(8)******	**0.559(0)*****
13.Peru	**-2.911(1)***	**-2.620(3)***	0.179(4)	**-4.847(1)******	**-3.782(12)******	0.238(3)
14.Paraguay	-1.250(1)	-1.405(3)	**0.734(5)*****	**-3.886(0)******	**-3.823(1)******	0.244(3)
15.El Salvador	**-2.924(1)***	-2.009(3)	0.099(5)	**-3.330(1)*****	**-2.877(5)***	0.143(3)
16.Trinidad & Tobago	-2.076(0)	-2.114(1)	**0.674(5)*****	**-7.455(0)******	**-7.465(1)******	0.219(1)
17.Uruguay	-1.040(1)	-0.288(4)	**0.698(5)*****	**-4.937(2)******	**-3.337(13)*****	0.128(5)
18.Venezuela	-0.243(0)	-0.541(2)	**0.642(5)*****	**-4.680(0)******	**-4.647(1)******	0.253(2)
19.Barbados	-1.815(0)	-1.815(0)	**0.765(5)******	**-6.370(0)******	**-6.366(3)******	0.273(2)
20.Guyana	-0.826(0)	-0.923(4)	**0.358(5)***	**-7.120(0)******	**-7.059(4)******	0.159(4)

Note: ***, ** and * indicate significance at the 0.01, 0.05 and 0.1 level, respectively. The number in the brackets indicates the truncation for the Bartlett Kernel, as suggested by the Newey-West test (1987). The number in parenthesis indicates the lag order selected based on the recursive t-statistic, as suggested by Perron (1989).

Table 3 Panel unit and stationary tests without structural breaks

Panel A	Per Capita Real Gross Domestic product	*p*-Value
$\Psi_{\bar{t}}$	0.874	0.809
$\Psi_{\overline{LM}}$	-0.854	0.803
MW	22.716	0.987
Hardi (hom)	7.748	0.000
Hardi (het)	6.677	0.000

Panel B: Bootstrap distribution (%)

	1	2.5	5	10	90	95	97.5	99
Industry Earnings								
$\Psi_{\bar{t}}$	-5.006	-4.466	-3.974	-3.422	0.506	1.125	1.656	2.253
$\Psi_{\overline{LM}}$	-1.618	-1.164	-0.756	-0.246	3.302	3.839	4.284	4.825
MW	26.570	30.793	34.196	38.637	79.642	87.421	94.469	103.963
Hardi (hom)	-2.682	-2.366	-2.069	-1.682	3.858	5.318	6.698	8.520
Hardi (het)	-2.414	-2.132	-1.829	-1.458	3.419	4.651	5.798	7.266

Note: Hardi (hom) and Hardi (het) denote the Hadri KPSS test assuming homogeneity and heterogeneity, respectively, in the estimation of the long-run variance.

Table 4 Panel stationary test with structural breaks for the per capita Real Gross Domestic product

Panel A: Country-by- Country tests

	KPSS	*m*	$T_{b,1}$	$T_{b,2}$	$T_{b,3}$	$T_{b,4}$	$T_{b,5}$	Finite sample critical values (%)			
								90	95	97.5	99
1.Bolivia	0.033	3	1967	1978	1985			0.037	0.042	0.046	0.052
2.Brazil	0.044	2	1966	1976				0.055	0.065	0.075	0.088
3.Chile	0.050	2	1974	1981				0.072	0.087	0.102	0.122
4.Colombia	0.027	3	1969	1981	1994			0.042	0.049	0.056	0.065
5.Costa Rica	0.069	1	1980					0.113	0.144	0.173	0.216
6.Dominican Republic	0.031	3	1969	1981	1992			0.040	0.047	0.054	0.063
7.Ecuador	0.048	2	1971	1977				0.066	0.077	0.088	0.101
8.Guatemala	0.026	3	1967	1979	1986			0.036	0.041	0.046	0.051
9.Jamaica	0.039	3	1971	1984	1985			0.049	0.059	0.069	0.081
10.Mexico	0.058	3	1980	1987	1994			0.115	0.150	0.182	0.227
11.Nicaragua	0.039	3	1965	1978	1987			0.032	0.036	0.039	0.043
12.Panama	0.036	3	1970	1979	1987			0.044	0.052	0.061	0.072
13.Peru	0.037	2	1975	1988				0.073	0.091	0.108	0.132
14.Paraguay	0.021	5	1966	1975	1981	1987	1994	0.025	0.029	0.033	0.038
15.El Salvador	0.053	2	1979	1991				0.103	0.131	0.160	0.195
16.Trinidad & Tobago	0.059	1	1984					0.149	0.190	0.236	0.286
17.Uruguay	0.033	2	1967	1982				0.045	0.051	0.056	0.063
18.Venezuela	0.045	2	1970	1990				0.055	0.064	0.072	0.083
19.Barbados	0.046	2	1980	1989				0.112	0.145	0.178	0.221
20.Guyana	0.039	2	1981	1993				0.120	0.157	0.194	0.237

Panel B: Panel stationary test: assuming cross-section independence

	Tests	*p*-Value
LM(λ)(hom)	10.015	0.000
LM(λ)(het)	8.179	0.000

Panel C: Bootstrap distribution (%)

	1	2.5	5	10	90	95	97.5	99
LM(λ)(hom)	8.532	8.911	9.241	9.646	**12.743**	**13.268**	**13.752**	**14.343**
LM(λ)(het)	7.704	8.052	8.339	8.663	**11.274**	**11.690**	**12.071**	**12.561**

Note: The finite sample critical values are computed by means of Monte Carlo simulations using 10,000 replications. LM(λ) (hom) and LM(λ) (het) denote the Carrion-i-Silvestre et al. (2005) KPSS test assuming homogeneity and heterogeneity, respectively, in the estimation of the long-run variance. The ***, ** and * indicate significance at the 0.01, 0.05 and 0.1 level, respectively.