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**Is real GDP stationary?
Evidence from a panel unit root test with cross-
sectional dependence and historical data.**

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Abstract

We use historical data that cover more than one century on real GDP for industrial countries and employ the Pesaran panel unit root test that allows for cross-sectional dependence to test for a unit root on real GDP. At first, we find strong evidence against the unit root null. Our results seem to be robust to the chosen group of countries and, in most cases, the sample period. However, the sequential panel selection method reveals that the rejection of the unit root null is due to the stationarity of real GDP in a few countries only. Real GDP is less stationary mostly in fixed exchange rate regimes like the Gold Standard and the Bretton Woods system.

Key words: real GDP stationarity, cross-sectional dependence, CIPS test, sequential panel selection method

JEL Classification: C23, E32

1. Introduction

The issue of the stationarity of real output has been the focus of considerable research following the seminal paper by Nelson and Plosser (1982). In this paper, Nelson and Plosser found that real output along with another eighteen macroeconomic time series is a nonstationary process, thus requiring first differencing in further work. Given the development of time series techniques and the outgrowth of unit root tests, the issue of a unit root in real GDP has been on the agenda of many applied econometricians. More recently, panel unit root tests (Baltagi 2008) have been employed to test the robustness of the nonstationarity of real GDP (Rapach 2002). Rapach (2002) finds robust evidence against the stationarity of real GDP using four different panel unit root tests and using both postwar data and data covering most of the 20th century. In addition, the issue of structural breaks has also been examined in the performance of several time series (Ben-David and Papell 1995; Papell and Prodan 2004) as well as panel unit root tests (Hegwood and Papell 2007). For instance, Hegwood and Papell (2007), find evidence against the unit root null, but in favour of trend-break stationarity with one or two structural breaks. However, the overwhelming majority of studies testing for the stationarity of real GDP still conclude that real GDP has a unit root.

In this paper we purport to test the unit root null hypothesis in a panel data setting that includes data that span over one century for several industrial countries. More importantly, we make use of the Cross-sectionally Augmented IPS (CIPS) panel unit root test advanced by Pesaran (2007). The major attribute of this test is that it allows for cross-sectional dependence, a rather realistic possibility that has been overlooked in the empirical panel literature. Baltagi et al (2007) examine the relative performance of several panel unit root tests under cross sectional dependence that arises in the presence of spatial effects. It is now well known that, in the presence of cross-sectional dependence, earlier panel unit root tests (e.g., Im et al., 2003) might deliver inconsistent estimates. Moreover, we combine the CIPS test with the sequential panel selection method (SPSM) of Chortareas and Kapetanios (2009). This combination adds flexibility to the CIPS test by allowing us to distinguish the individual real GDP series that are stationary within the panel.

Our findings are quite interesting. When applied to the entire panel, the CIPS test suggests stationarity of real GDP. At first, this finding appears to be robust to the

sample period used and the group of countries included in the panel. However, the sequential panel selection method reveals that the rejection of the unit root null is due to the stationarity of real GDP in a few countries only.

The paper is structured as follows. Section 2 outlines our methodological approach. Section 3 discusses the data and presents the major results. Finally, section 4 concludes the paper.

2. Empirical methodology

We use Pesaran's (2007) panel unit root test with cross-sectional dependence. This test is preferable to earlier panel unit root tests that did not allow for cross-sectional dependence, such as the Im et al. (2003) test, and recently has been employed in tests for PPP (Snaith 2012). In the presence of cross-country regressions as in this paper, it is most likely that residuals are correlated across the individual time series.

The Cross-sectionally Augmented Dickey-Fuller (CADF) regression in Pesaran (2007) is given by:

$$\Delta y_{it} = a_i + g_i t + b_i y_{i,t-1} + c_i \bar{y}_{t-1} + \sum_{j=0}^p d_{ij} \Delta \bar{y}_{t-j} + \sum_{j=1}^p \delta_{ij} \Delta y_{i,t-j} + e_{it} \quad (1)$$

where $y_{it} = \ln(Y_{it})$ is the logarithm of real GDP in country i in year t . This is a standard Dickey Fuller regression augmented with the lagged level and the first differences of the cross-section average of the individual time series. Regression (1) is based on a one-factor residual model, where the cross-section mean of y_{it} and its lagged value proxy for the common factor. We test the null hypothesis $H_0: b_i = 0, \forall i$ (non-stationary process) against the alternative $H_1: b_i < 0$, for at least some i (partially stationary process).

In words, the null hypothesis is a unit root for all time series in the panel. The alternative hypothesis is a stationary process for at least one of the time series. In practice, we obtain the Cross-sectionally Augmented Dickey-Fuller (CADF) statistics for each of the time series in the panel. Then, we calculate their simple average, thus obtaining the CIPS (Cross-sectionally Augmented IPS) statistic. This statistic is a modification of the t -bar (IPS) statistic proposed by Im et al. (2003).

Notice that the null hypothesis of non-stationarity may be rejected even if only one of the real GDP series is stationary in the panel. Thus, under the alternative we cannot conclude that all individual real GDP processes are stationary. Chortareas and Kapetanios (2009) deal with this issue by proposing a sequence of panel unit root tests to separate the individual GDP series that are stationary within the panel. We adopt their method as follows. First, we run the CIPS test for the full sample. If the null of unit root is not rejected, we accept non-stationarity for the entire panel. However, if the null is rejected, we drop the country (real GDP series) that shows the most evidence of stationarity (minimum individual CADF t -statistic). Then, we repeat the CIPS test with successively smaller panels until you fail to reject the null hypothesis or all the series are removed from the panel. This way we can distinguish the stationary series from the non-stationary ones.

3. Data and results

3.1 Data

We use annual historical data of real GDP on nineteen industrial countries, namely, Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, UK, and USA. Our sample covers the 1870-2008 period. The data source is the database constructed by Maddison. To establish the robustness of our results to the group of countries and to the sample period, we test for non-stationarity of real GDP in four different country panels and in five different sample periods. The country panels are (i) all countries, (ii) Europe, (iii) EU-12 (including Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Portugal, Spain, Sweden, and UK) and (iv) Eurozone-9 (including Austria, Belgium, Finland, France, Germany, Italy, Netherlands, Portugal and Spain). On the other hand, the five sample periods are: the full sample (1870-2008), the post-Bretton Woods period (1974-2008), the Gold Standard period (1970-1914), the Bretton Woods period (1944-1973) and the post-WWII period (1946-2008).

3.2 Results

As a benchmark, we report the t -bar statistic (IPS test) proposed by Im et al (2003). The results for the full sample of countries are reported in Table 1. As seen, the choice of the time period affects the results. For the entire sample, the unit root

hypothesis cannot be rejected while for the sub-sample periods we see a completely different picture. However, the IPS test is not valid under cross-sectional dependence. Thus, as a natural next step we consider the unit root test proposed by Pesaran (2007) that accounts for such dependence.

Before considering the CIPS test, it is important to determine whether the cross-sectional dependence is statistically significant. Table 2 (first two columns) reports tests for cross-sectional dependence (the CD statistic of Pesaran 2007) on real GDP for the panel of 19 industrial countries (all countries). The CD test is normally distributed. We report results for two cases: zero lags and one lag since the data are annual and one lag is sufficient to capture the autoregressive dynamics in the series.

We find strong evidence for cross-sectional dependence in all five sample periods as the relevant statistic is statistically significant. Hence, we proceed with the application of the CIPS test that allows for cross-sectional dependence. The results are reported in columns three and four of Table 2. As observed, the unit root null is rejected for all samples except for the post-Bretton Woods period.

The results for various country subgroups, i.e., European countries, the European Union-12, and the Eurozone-9 are reported in Tables 3, 4, and 5, respectively. These results are almost fully consistent with the results of Table 2. For these three subgroups of countries, the unit root null is rejected for each sample period, the only exception being the post-Bretton Woods sample. Cross-sectional dependence applies in all cases but the Bretton Woods era for the Eurozone-9 countries. According to these results, real GDP appears to be stationary.

Tables 6-9 provide the results from the SPSM (Chortareas and Kapetanios 2009) as applied to the Pesaran test in order to obtain country specific stationarity results. This methodology makes the CIPS test results more interpretable. For the entire and the post-WWII periods, the SPSM implies that only up to six out of 19 series are stationary. Such are the GDP of Belgium, Finland, France, Italy, New Zealand and Spain (lag 1) for the full sample. Only seven of 19 countries are stationary for the Bretton Woods period (no lags). In addition, the GDP of Austria, Denmark, France, Germany, and Spain (lag 1) for the post-WWII period are also stationary. Some of the European countries (Austria, Belgium, Finland, France, Germany, and Spain) are found stationary regardless of the country subgroup employed. However, for the Bretton Woods, and especially, the Gold Standard and post-Bretton Woods periods, the evidence of stationarity is scant. In fact, for the post-

Bretton Woods period not a single country is stationary. It is interesting to note that fixed exchange rate regimes like the Gold Standard and the Bretton Woods system are associated with little evidence for stationarity of real GDP. Note that during the Gold Standard and the Bretton Woods, there was a strong link between money supply and gold supply. Thus, the evidence of little stationarity is not surprising given that fixed exchange rate regimes make countries more vulnerable to shocks originating abroad in the absence of the insulation offered by a flexible exchange rate. According to our results, real GDP is not stationary for any of the 19 countries (irrespective of the country panel) also for the 1974-2008 period that coincides with the floating exchange rate regime. This may be explained by the two oil price shocks that took place during this period and affected significantly real GDP.

The results are consistent across three country panels (Europe, EU-12 and Eurozone-9) with regards to the individual real GDP series found stationary. All in all, we conclude that using the CIPS test combined with the SPSM we find that most of the GDP series appear non-stationary, and the rejection of the null for the whole sample is due to a few stationary countries.

Comparing to the earlier relevant literature, our results are broadly in line with Hegwood and Papell (2007) that rejects the unit root null in favour of broken trend-stationary allowing for one or two structural breaks (panel tests). One of these breaks coincides with WWII. Indeed, we find evidence of stationarity for the entire period possibly due to the post-WWII period. On the other hand, our results differ substantially from those in Rapach (2002). The author uses early developed panel unit root tests that do not account for cross-sectional dependence (e.g., IPS test) and finds evidence for nonstationarity of real GDP (and real per capita GDP) in all industrial countries examined. It is true though that our study uses a different data set than previous studies as it includes historical real GDP data for several industrial countries in various groups that, in addition to the full sample, they include time subsamples associated with different exchange rate regimes and country subsamples.

4. Conclusions

In this paper we contribute to the literature examining the stationarity of real GDP by applying a panel unit root test that allows for cross-sectional dependence to historical data on industrial countries that cover more than one century. We find strong evidence against the unit root null, when no allowance for cross-sectional

dependence is made. This result is broadly supported when such allowance is made using the CIPS test. However, such evidence should be taken with a grain of salt as it is due to the real GDP stationarity of a few countries only (less than half of the sample) as shown by the use of the sequential panel selection method. Our findings highlight the importance of accounting for cross-sectional dependence in the panel, an attribute missing in the available literature. They also highlight the relevance of the exchange rate regime as our evidence suggests that fixed exchange rate regime periods, such as the Gold Standard and the Bretton Woods system, are associated with less stationarity of national real GDP.

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Table 1: Tests for non-stationarity of real GDP (no cross-sectional dependence)
(All countries)

Sample period	<i>t</i> -bar statistic	
	No lags	One lag
1870-2008	-2.016 (0.817)	-2.374 (0.136)
1974-2008	-2.043 (0.753)	-2.808 (0.001)
1870-1914	-2.632 (0.006)	-2.529 (0.031)
1944-1973	-3.271 (0.000)	-3.668 (0.000)
1946-2008	-2.775 (0.001)	-3.019 (0.000)

Notes: The *t*-bar statistics of Im et al (2003) and *p*-values are reported in parentheses. A constant term and a linear trend are included in the test regression.

Table 2: Tests for cross-sectional dependence and nonstationarity of real GDP
(All countries)

Sample period	CD Test		CIPS Test		
	No lags	One lag	No lags	One lag	CV(5%)
1870-2008	28.01*	26.31*	-3.088**	-3.283**	-2.57
1974-2008	22.02*	20.18*	-2.044	-2.208	-2.67
1870-1914	10.48*	10.32*	-3.059**	-2.780**	-2.62
1944-1973	6.45*	6.52*	-5.138**	-3.465**	-2.67
1946-2008	29.51*	27.87*	-3.612**	-3.635**	-2.59

Notes: CD is the cross-sectional dependence test which follows the standard normal distribution. CIPS test is the cross-sectional augmented panel unit root IPS test. A constant term and a linear trend are included in the test regression. The critical values are taken from Table II(c) on page 281 in Pesaran (2007). * and ** refer to statistical significance at 5% and 1%, respectively.

Table 3: Tests for cross-sectional dependence and nonstationarity of real GDP
(Europe-14)

Sample period	CD Test		CIPS Test		
	No lags	One lag	No lags	One lag	CV(5%)
1870-2008	24.17*	22.53*	-3.361**	-3.252**	-2.60
1974-2008	19.57*	18.10*	-1.960	-2.139	-2.70
1870-1914	8.06*	7.41*	-2.970**	-2.635	-2.66
1944-1973	5.94*	5.99*	-4.973**	-3.789**	-2.70
1946-2008	25.18*	24.26*	-3.764**	-3.844**	-2.62

Notes: As in Table 2

Table 4: Tests for cross-sectional dependence and nonstationarity of real GDP
(European Union-12)

Sample period	CD Test		CIPS Test		
	No lags	One lag	No lags	One lag	CV(5%)
1870-2008	21.18*	19.78*	-3.477**	-3.306**	-2.79
1974-2008	19.92*	17.71*	-1.941	-2.021	-2.92
1870-1914	6.99*	6.56*	-2.908*	-2.505	-2.88
1944-1973	4.68*	4.53*	-5.711**	-3.433**	-2.94
1946-2008	23.84*	22.53*	-4.142**	-3.925**	-2.82

Notes: As in Table 2

Table 5: Tests for cross-sectional dependence and nonstationarity of real GDP
(Eurozone-9)

Sample period	CD Test		CIPS Test		
	No lags	One lag	No lags	One lag	CV(5%)
1870-2008	15.91*	14.48*	-3.650**	-3.317**	-2.79
1974-2008	15.99*	13.35*	-1.928	-2.067	-2.92
1870-1914	7.91*	7.59*	-2.997*	-2.655	-2.88
1944-1973	1.89	1.52	-5.824**	-2.716	-2.94
1946-2008	17.24*	16.00*	-4.256**	-4.394**	-2.82

Notes: As in Table 2

Table 6: Stationary series
(All countries)

Sample period	CIPS Test	
	No lags	One lag
1870-2008	Fin, Neth, NZ, Sp	Bg, Fin, Fr, Ita, NZ, Sp
1974-2008		
1870-1914	Fr, Jap, Sp	Sp
1944-1973	Fr, Ita, Jap, Neth, Nor, Swi, US	Fr, Neth
1946-2008	Aut, Den, Fr, Ger, Sp, US	Aut, Den, Fr, Ger, Sp

Notes: Sequential panel selection method (SPSM) based on CIPS test.

Aut: Austria, Bg: Belgium, Den: Denmark, Fr: France, Fin: Finland, Ger: Germany, Ita: Italy, Jap: Japan, Neth: Netherlands, NZ: New Zealand, Nor: Norway, Sp: Spain, Swi: Switzerland, UK: United Kingdom, US: United States.

Table 7: Stationary series
(Europe-14)

Sample period	CIPS Test	
	No lags	One lag
1870-2008	Den, Fin, Fr, Neth	Bg, Fin, Fr, Ita, Sp
1974-2008		
1870-1914	Bg, Fr	
1944-1973	Fr, Neth, Nor	Fr, Neth
1946-2008	Aut, Fr, Sp, UK	Aut, Fr, Ger, Sp

Notes: As in Table 6.

Table 8: Stationary series
(European Union-12)

Sample period	CIPS Test	
	No lags	One lag
1870-2008	Aut, Den, Fin, Fr, Neth	Bg, Fin, Fr, Ita, Sp
1974-2008		
1870-1914	Fr	
1944-1973	Fr, Neth	Fr
1946-2008	Aut, Ger, Sp, UK	Aut, Fr, Ger, Sp

Notes: As in Table 6.

Table 9: Stationary series
(Eurozone-9)

Sample period	CIPS Test	
	No lags	One lag
1870-2008	Aut, Fin, Fr, Neth	Bg, Fr
1974-2008		
1870-1914	Fr	
1944-1973	Fr, Neth	
1946-2008	Aut, Ger, Sp	Aut, Fr, Ger

Notes: As in Table 6.