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root test with cross-sectional dependence and
historical data

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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. We find strong evidence against the unit root null. Our results are robust to the chosen group of countries and the sample period.

Key words: real GDP stationarity, cross-sectional dependence, CIPS test
JEL Classification: C23, E32

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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 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 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 unit root tests (Ben-David and Papell, 1995; Papell and Prodan, 2004). Papell and Prodan (2004) use annual US real GDP data for 1870-1998 and employ unit root tests allowing for two endogenous breaks. They find evidence against the unit root null but in favour of trend-break stationarity. However, the overwhelming majority of studies testing for the stationarity of real GDP 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. We make use of the 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. Moreover, in the presence of cross-sectional dependence, earlier panel unit root tests (Im et al., 2003 and Levin et al., 2002, among other) might deliver inconsistent estimates. Our results are quite interesting. In contrast to the majority of the findings reported in previous studies, we provide strong evidence for stationarity of real GDP. This evidence is robust to the sample period used and the group of countries included in the panel.

This note 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 the Levin et al. (2002) test. In the presence of cross-country regressions as in this paper, it is likely that residuals are correlated across the individual time series.

The Cross-sectionally Augmented Dickey-Fuller (CADF) regression (0 lags) corresponds to equation (6) in Pesaran (2007, p. 269) and is given below:

$$\Delta y_{it} = a_i + b_i y_{i,t-1} + c_i \ \bar{y}_{t-1} + d_i \Delta \bar{y}_t + e_{it} \tag{1}$$

Regression (1) above is a standard Dickey Fuller regression augmented with the lagged level and the first difference of the cross-section average of the individual time series. We test the H_0: $b_i=0$, $\forall \ i$ (non-stationary process) against the 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. We calculate the Cross-sectionally Augmented Dickey-Fuller (CADF) statistics for each of the time series in the panel.

Adding one lag, the above test regression is modified as follows (see equation (54), Pesaran, 2007, p. 283):

$$\Delta y_{it} = a_i + b_i y_{i,t-1} + c_i \ \bar{y}_{t-1} + \sum_{j=0}^{1} d_{ij} \Delta \bar{y}_{t-j} + d_{i1} \Delta y_{i,t-1} + e_{it} \tag{2}$$

This is the CADF regression including one lag. The unit root null hypothesis is as above. From equation (1) or (2), we obtain the individual CADF statistics and calculate their simple average, thus obtaining the CIPS (cross-sectionally augmented IPS) statistic. This statistic is a modification to the t-bar (IPS) statistic proposed by Im

et al. (2003) being calculated as a simple average of the individual CADF statistics.

3. Data and results

(i)   Data

We use annual historical data of real GDP on eighteen industrial countries, namely, Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, 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. We test for nonstationarity of real GDP in four different panels for alternative time periods. The 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 (including Austria, Belgium, Finland, France, Germany, Italy, Netherlands, Portugal and Spain). The time periods examined are: the full sample, the gold standard (1870-1914), the Bretton Woods system (1944-1973), the post-Bretton Woods period (1974-2008), and the post-WWII period (1946-2008).

(ii) Results

Table 1 reports tests for cross-sectional dependence (the CD statistic) and the unit root null hypothesis (the CIPS statistic) on real GDP for the panel of 18 industrial countries. The CD test is normally distributed. We report results for two cases: zero lags and one lag in the CADF regression corresponding to equations (1) and (2), respectively. To establish the sensitivity of our results to the sample period, we report results for five sample periods: the full sample (1870-2008), the post-Bretton Woods period (1974-2008), the Gold Standard (1970-1914), the Bretton Woods system (1944-1973) and the post-WWII period (1946-2008).

We report evidence for residual CD in all five samples as the relevant statistic is statistically significant. Hence, we proceed with the application of the CIPS test that allows for cross-sectional dependence. The unit root null is rejected for all samples except for the post-Bretton Woods period. To establish the robustness of our stationarity results to the group of countries included in the panel, we report results for various country subgroups, i.e., European countries, the European Union-12, and

the eurozone-9 in Tables 2, 3, and 4, respectively. These results are almost fully consistent wit the results of Table 1. 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 Wood period for the Eurozone countries. These results offer strong evidence in favour of stationarity in real GDP.

Our results differ dramatically from those obtained in earlier relevant literature. For example, Rapach (2002) using early developed panel unit root tests that do not account for cross-sectional dependence (Levin et al., 1992; Im et al., 2003) find evidence for nonstationarity of real GDP (and real per capita GDP) in all industrial countries examined.

4. Conclusions

In this note we attempt to 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. This evidence differs from the majority of relevant studies and is robust to various country subgroups and subsamples that refer to different exchange rate regimes. Our findings highlight the importance of accounting for cross-sectional dependence in the panel, an attribute missing in the available literature.

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Table 1: 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. The first and second columns under each test correspond to equations (1) and (2), respectively in the text. The critical values are taken from Table II(c) on page 281 in Pesaran (2007). 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

(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 1

Table 3: 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 1

Table 4: 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	23.84*	22.53*	-4.142*	-3.925*	-2.82

Notes: As in Table 1