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IS REAL GDP PER CAPITA A STATIONARY PROCESS? SMOOTH TRANSITIONS, NONLINEAR TRENDS AND UNIT ROOT TESTING

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Is real GDP per capita a stationary process? Smooth transitions, nonlinear trends and unit root testing

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Abstract

The aim of this paper is to provide additional evidence about the order of integration of constant price GDP per capita in a selection of countries. It does so by taking into account the possibility of non-linear deterministic trends and of asymmetric adjustment towards equilibrium. We find evidence of a global stationary ESTAR process around a nonlinear deterministic trend in almost half of the selected countries. These results show that nonlinearities affect real GDP series. By neglecting them, one can draw misleading conclusions from unit root tests. Specifically, the paper questions the so-called stylised fact of a near unit root which has so influenced macroeconomic thought over the past two decades.

J.E.L. Classification : C22; E31; E32.
Key words: Real GDP per capita, unit root tests, persistence, nonlinearities, smooth transitions.

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1 Introduction

The analysis of the statistical properties of real GDP and real GDP per capita has attracted the attention of a number of authors since Nelson and Plosser's (1982) seminal paper. They argue that the question of whether real GDP is a unit root or a stationary process has both theoretical and policy implications. On the one hand, if real GDP is characterised as a unit root process, shocks affecting the variable have permanent effects. On the other hand, if real GDP is characterised as a stationary process around a deterministic trend there exists a time varying equilibrium real GDP with fluctuations around it depicting the business cycle.

Durlauf (1989) describes the near unit root in measures of aggregate activity, such as constant price per capita GDP, as a 'significant stylised fact'. Its significance has had a major impact on macroeconomic thinking. Nelson and Plosser (1982) argue that the result shows the need for macroeconomists to focus on real shocks which have permanent effects. Specifically, they argue that these shocks are innovations in technology which are frequent and random. The result is that we will observe fluctuations in constant price per capita GDP mapping out the business cycle. Their emphasis was to downplay fluctuations emanating from aggregate demand and to unite the work on short run and long run growth. But, Durlauf (1989) reminds us that the persistence characteristic of GDP need not be associated with one particular school of thought or one model of the economy. For instance, he argues that the persistence can arise out of co-ordination failures, such as the stickiness of prices arising from menu costs. Clearly, the ‘stylised fact’ has affected the development of theory across a diversity of macroeconomic traditions.

Whether or not the GDP series is characterised as having a near unit root is more than a theoretical curiosity. Its importance crucially extends to policy, though exactly how is dependent on the theoretical interpretation given to the result. For example, Li (2000) argues, in the context of China, that the impact on GDP of government policies, such as structural reform, is particularly difficult to predict in the face of other potentially off-setting shocks. Indeed he goes so far as to suggest that it might not be worth pursuing. If, however, GDP is a stationary process around a deterministic trend, Li believes that there is scope for policy-makers to change the long run equilibrium value of the GDP. In contrast, Durlauf (1989) argues that in the presence of persistence stabilisation policy can result in ‘very large’ social welfare improvements.

The literature on the long run behaviour of real GDP has mainly focussed on testing for unit roots over the series of real GDP, by means of applying traditional (linear) unit root tests, although controlling for structural changes in most cases. Although the literature is very vast, the results are far from conclusive and not wholly supportive of the unit root being a ‘stylised fact’. While some authors find that real GDP is a unit root process (Murray and Nelson, 2000; Perron, 1989; and Evans, 1989, among others), others find empirical evidence to reject the null hypothesis of a I(1) process (Ben-David and Papell, 1995; Vougas, 2007) in US real GDP series. In an empirical study of African countries, Chang, Nieh and Wei (2005) apply the Leybourne, Newbold and Vougas (1998) unit root test to detrend the data by means of a logistic function. Their results point to the rejection of the null for some of the countries analysed.

Michael, Nobay and Peel (1997) and Kapetanios, Shin and Snell (2003) (KSS) among others, consider how traditional unit root tests may suffer from a power problem when applied to series characterised by a nonlinear data generating process. Therefore, these tests tend to confuse a unit root process with a globally stationary smooth transition process, i.e. asymmetric speed of mean reversion, for which nonstationarity may characterise one of the regimes. Thus, KSS propose a unit root test based upon the alternative that the series are a globally stationary exponential smooth transition autoregressive (ESTAR) process. Applying this test to the detrending series, by means of a linear trend and a drift, Beechey and Österholm (2008) find evidence of stationarity of the US real GDP per capita.

This paper aims to contribute to the empirical literature on the order of integration of the real GDP per capita in a pool of developed countries, by applying the KSS test to the detrended and demeaned data, following the Beechey and Österholm (2008) approach. While our initial results point to the non-rejection of the unit root hypothesis for all of the countries, it is well known within the literature of unit root testing that misspecification of the deterministic components can affect the power of the tests (Perron and Phillips, 1987; West, 1988; and Bierens, 1997, among others). This is related to need to take into account structural breaks in unit root testing (Perron, 1989, 1990) and a broken time trend is a particular case of a nonlinear time trend. In order to take into account the possibility of nonlinear trends, as well as asymmetric adjustment in mean reversion, we also apply the KSS test for the demeaned and detrended data. In doing this, the nonlinear trend is approximated by a cubic function so as to take into account the descriptive features of the data.

2 Econometric methodology and results

In this section we apply several linear and nonlinear unit root techniques in order to test for the order of integration of the real GDP per capita in a panel of developed countries. The data cover annual real GDP per capita from 1870 until 2003, obtained from Professor Angus Maddison's webpage[1].

As a preliminary analysis, we apply the linear unit root tests developed by Ng and Perron (2001). These authors propose some modifications of existing unit root tests, in order to improve their power and size: MZ_α and MZ_t that are the modified versions of the Phillips (1987) and Phillips and Perron (1988) Z_α and Z_t tests; the MSB that is related to the Bhargava (1986) R_1 test; and, finally, the MP_T test that is a modified version of the Elliot, Rothenberg and Stock (1996) Point Optimal Test. The results of applying these tests are reported in Table 1. The proper lag length has been selected

[1]http://www.ggdc.net/maddison.

by the Akaike Information Criterion, from a maximum of 4 lags. We find, even after including a deterministic trend and intercept in the auxiliary regressions, that it is not possible to reject the null hypothesis of a unit root.

As mentioned before, linear unit root tests can suffer from power problems in the presence of nonlinearities in the data. Therefore, their results may be biased towards the non-rejection of the null hypothesis. Thus, KSS propose a unit root test based on the following modified Augmented Dickey Fuller (ADF) regression,

$$\Delta y_t = \alpha y_{t-1} + \gamma y_{t-1}(1 - exp\{-\theta y_{t-1}^2\}) + \epsilon_t. \tag{2.1}$$

in order to test for unit roots. Note that this regression implies that the autoregressive parameter changes smoothly depending on the values of the variable y_t. Since KSS impose $\alpha = 0$, the variable is assumed to be a unit root in the central regime. In order to test the null hypothesis of a unit root, $H_0 : \theta = 0$, against the alternative of a globally ESTAR process, $H_1 : \theta > 0$, Kapetanios et al. (2003) propose the following Taylor approximation of model (2.1), given that the coefficient γ cannot be identified under H_0,

$$\Delta y_t = \delta y_{t-1}^3 + error \tag{2.2}$$

It is now possible to apply a t-statistic to test whether y_t is a I(1) process, $H_0 : \delta = 0$, or is a I(0) process, $H_1 : \delta < 0$. Of course, equation (2.2) may also incorporate lags to control for autocorrelation in the residuals.

In Table 2 we report the results of the KSS test[2]. Although KSS report the critical values for various sample sizes, in the present paper we obtain the critical values for the exact sample size used by Monte Carlo simulations based on 50,000 replications. The second column contains the results for the unit root analysis of the demeaned and linearly detrended data, i.e. $y_t = y_t^R - \hat{\alpha} - \hat{\beta}t$, where y_t^R is the raw data. These results still point to the non-rejection of the null hypothesis. Nevertheless, as aforementioned, incorrectly specifying the deterministic components may produce misleading results in favour of the null. In figure 1 we plot the series of real GDP per capita for some of the countries[3]. The long run path of this variable appears to follow a nonlinear trend, where a cubic function seems to be appropriate as a proxy of the deterministic trend. Therefore, we have also applied the KSS test to the detrended data, following the specification $y_t = y_t^R - \hat{\alpha} - \hat{\beta}t - \hat{\delta}t^2 - \hat{\gamma}t^3$. The results are reported in the last column, table 2, which point to the rejection of the null hypothesis of unit root against the alternative of globally stationary ESTAR process around a (cubic) nonlinear deterministic trend in 9 of the 19 countries.

[2]As in the case of the Ng and Perron (2001) results, the lag length has been chosen by the Akaike Information Criterion, from a maximum of 4 lags.

[3]Similar paths are followed by the rest of the countries that for space matters have been omitted. However, they are available upon request to the corresponding author.

3 Conclusions

This paper aims to contribute to the literature on the order of integration of the real GDP per capita. To do so we have applied a group of unit root tests, taking into account the possibility of asymmetric adjustment and nonlinear trends. The results show that once these two sources of nonlinearities have been controlled for the real GDP per capita series in some of the selected countries is a stationary process. This finding is highly significant for macroeconomists. It refutes, for some countries at least, the so-called stylised fact that measures of aggregate activity, like GDP per capita, have a near unit root. Hence, it fuels the debate over the persistence of shocks to GDP series. Our results show that we can indeed portray GDP as mean-reverting around a deterministic trend. Nonetheless, there remains much to be done to deepen our understanding of both the properties and determination of the deterministic trend. Indeed our findings raise intriguing questions about possible differences across countries in the persistence of GDP shocks.

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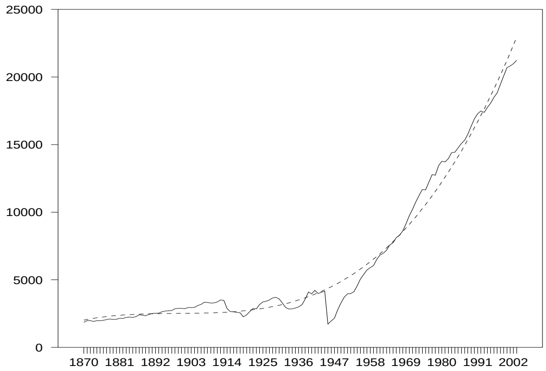
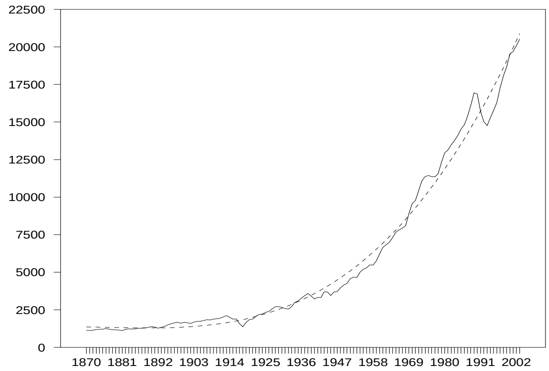
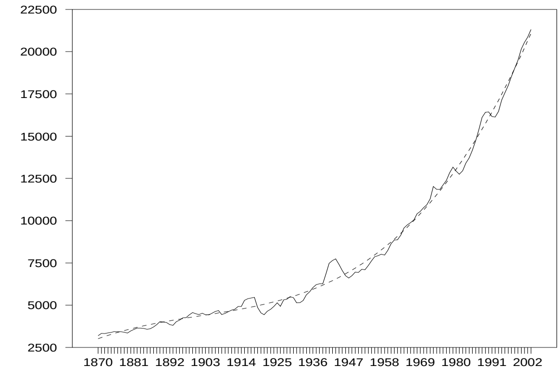
Figure 1: Real GDP per capita and nonlinear trends



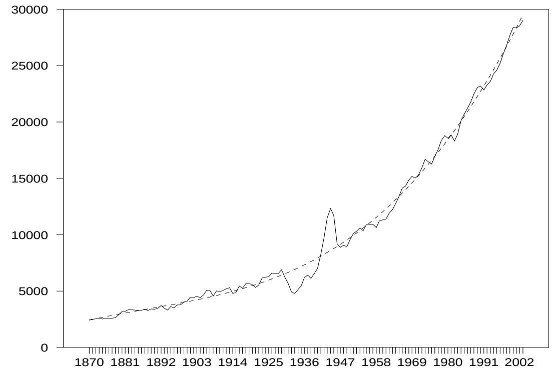
(a) Australia



(b) Finland



(c) United Kingdom



(d) United States

Table 1: **Ng and Perron (2001) unit root tests results**

Country	MZ_α	MZ_t	MSB	MP_T
Australia	0.39665	0.17511	0.44147	52.1362
Austria	-0.41135	-0.19426	0.47225	52.3966
Belgium	-1.78104	-0.65471	0.36760	32.0920
Canada	-0.57350	-0.25263	0.44051	46.5535
Denmark	-0.26768	-0.13231	0.49427	57.0345
Finland	0.26163	0.13354	0.51042	63.8351
France	-1.27426	-0.53192	0.41743	39.7574
Germany	-1.66170	-0.69288	0.41697	37.7623
Italy	0.18739	0.11790	0.62920	88.6784
Japan	-2.27265	-0.85440	0.37595	30.9051
Netherlands	-0.30985	-0.15416	0.49752	57.2960
New Zealand	-1.20392	-0.47044	0.39075	36.9282
Norway	-2.61080	-0.82630	0.31649	25.1201
Portugal	0.22092	0.11727	0.53084	67.5398
Spain	-1.50929	-0.50652	0.33560	30.0255
Sweden	-0.55393	-0.25503	0.46040	49.6433
Switzerland	-1.59257	-0.78657	0.49390	47.6669
United Kingdom	0.33548	0.14351	0.42779	49.5120
United States	-1.62077	-0.58288	0.35963	31.9296

Note: The order of lag to compute the test has been chosen using the modified AIC (MAIC) suggested by Ng and Perron (2001). Rejection of the null hypothesis at the 10% significance level is given by *. The critical values for the above tests have been taken from Ng and Perron (2001):

Model with constant and linear trend

	MZ_α	MZ_t	MSB	MP_T
1%	- 23.80	-3.42	0.14	4.03
5%	-17.30	-2.91	0.16	5.48
10%	-14.20	-2.62	0.18	6.67

Table 2: KSS nonlinear unit root test results

Country	**KSS(t)**	**KSS(t^3)**
Australia	1.97196	-4.60951***
Austria	-1.44213	-2.73429
Belgium	-0.15549	-2.43742
Canada	-0.93022	-3.30643
Denmark	-1.14022	-2.98435
Finland	-0.33715	-5.75477***
France	-2.04724	-3.54531
Germany	-2.82152	-3.28761
Italy	-0.96981	-3.12118
Japan	-1.72213	-1.44496
Netherlands	-2.34353	-5.17520***
New Zealand	-0.91824	-2.75196
Norway	0.01040	-5.83889***
Portugal	-0.64843	-4.88731***
Spain	1.11371	-2.30296
Sweden	-0.58825	-4.12540**
Switzerland	-2.74087	-3.80560*
United Kingdom	1.26174	-3.86867*
United States	-0.25982	-4.71937***

Note: The test has been computed including a constant and a linear time trend as deterministic component. The order of lag for the auxiliary regression has been selected by the AIC. Critical values at the 10%, 5% and 1% for the KSS(t)test are -3.103877, -3.388891 and -3.942044, whereas for the KSS(t^3) test are -3.729372, -4.028135 and -4.608279, respectively and have been computed by Monte Carlo simulation with 50,000 replications. Rejection of the null hypothesis at the 10%, 5% and 1% significance level are given by the symbols *, ** and ***, respectively.

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