Short run fluctuations and long run convergence: a TAR Panel Unit Root Approach

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Abstract

We apply unit root tests in a multivariate TAR model and bootstrapping simulations to assess the incidence of cycle expansions and slumps on real convergence. We use two different groups of countries, which share important business cycle characteristics, over the period 1950-2007. Our study points out two important results, On the first place, the cycle has a significant effect on the convergence process among countries. In other words, convergence is not uniform along the business cycle. On the second place, the specific way through which the cycle affects convergence depends on the countries among which convergence is examined. However, the general result is that real convergence tends to be stronger in the middle of the cycle; by the same token, convergence is hindered during periods in which the rich countries reach a peak and/or in which the economies of the poorest countries reach a trough.

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1. Introduction

Over the last two decades many papers have analysed two important aspects of real economic convergence within specific groups of countries. The first is *income* convergence, which measures the extent to which national levels of per capita income and development tend to equalise, and the second is convergence in *business cycles*; that is the degree to which national business cycles tend to become more uniform or to conform similar patterns.

Both, income convergence and cyclical conformity have received abundant attention in the empirical literature, but the possible connections between the two concepts have not been explored in the empirical tests. Moreover, there are noticeable differences between the consensuses degrees reached in each group of analysis. The general result of authors that have studied income convergence is that levels of income per capita have converged within groups of similar economies, such as industrialised countries (see, for instance, the seminal paper by Barro and Sala-i-Martin 1992), but not throughout the world (Ben-David 2002)[1].

The results concerning cyclical conformity are less unanimous. Most of them are referred to the Eurozone or the EU-15 area. Whereas some authors believe that there is a unique business cycle for that zone (Artis, Kontolemis and Osborn 1997, del Negro and Ottrok 2003, Mansour 2003, Bower and Guilleminau 2006)[2], other economists consider that there is no monotone movement towards the emergence of a European business cycle (Artis 2003, De Haan, Inklaar and Jong-a-Pin 2007). In this line, Camacho, Pérez-Quirós and Saiz (2006a) calculated different measures of co-movements across European economies, and did not find evidence of a Euro-economies attractor. Mink, Jacobs and De Han (2007) applied multivariate measures of synchronicity and co-movement of business cycles in the Euro Area, and concluded that national business cycles still remain diverse.

[1] There are also many papers that analyse the convergence patterns in the Central and Eastern Economies (CEE) (Matkowski, 2004), and the economic convergence of CEE countries with the European Union. See, for example, Breuss, 2001, European Commission 2001 and Kutan and Yigit (2004).
[2] Lumsdaine and Prasad (2003), Canova, Ciccarelli and Ortega (2004) found symptoms of a world business cycle.

The bulk of papers on cyclical conformity take the degree of synchronicity and co-movement as the bases for their verdict. However, Camacho, Pérez-Quirós and Saiz (2006b) focused on other characteristics of the business cycles, such as duration, deepness and shape, and analysed the extent to which different groups of OECD countries fit into common business cycles. As a result, they obtained four clusters of countries, each one with its own and common characteristics, and concluded that some EU countries are located in different clusters, which confirm that their business cycles still substantially differ in duration, deepness and shape.

Despite the fact that income convergence and cyclical conformity are somehow related, there are no works that examine the relationships between the two concepts. On the one hand, the empirical analyses on the income convergence have sought to unveil the main determinants of the process without considering any influence of the cyclical phases. For instance, García-Solanes and María-Dolores (2002) analysed the relevance of the European structural funds along the period 1987-2001, and found that they contributed positively to the income convergence in the EU-15 countries and regions during the whole period. Proudman, Redding and Bianchi (1997) emphasised the relevance of economic openness in promoting the convergence of average income per capita between several groups of countries, independently of the cyclical nature of the periods analysed. On the other hand, the empirical works devoted to the determinants of business cycle conformity do not investigate the impact of business cycles on income convergence. So, Frankel and Rose (1998) showed that closer integration, created not only by international trade but also by FDI flows, leads to more synchronised business cycles, without examining further implications on economic convergence[3]. Camacho, Pérez-Quirós and Saiz (2006) showed that an important proportion of the distances between business cycles may be explained by macroeconomic variables, the direction of trade and the size of the public sector.

In this paper we empirically assess the role of business cycles expansions and recessions on the process of income convergence. Our analysis assumes that the convergence

[3] These results are contested by the new geography economics (Krugman 1991), according to which trade openness leads firms to concentrate business in order to reap economies of scale, which, in turn, increases economic regional divergence.

process is not linear, so that it may accelerate during certain periods or phases, and slow down or even fall into divergence, during other periods. For that purpose, we need to apply a two-regime econometric model. Since the convergence process may not be uniform, the application of linear panel data models, as made in previous literature, may produce misleading results. We adopt and adapt here the methodology of Beyaert and Camacho (2008) consisting of a panel data threshold autoregressive (TAR) specification in which the series of the panel may exhibit unit roots. We apply unit root tests in a multivariate TAR model and bootstrapping simulations to test per capita income convergence within the two clusters. Our tests take into account that the countries might converge under one regime and diverge under the other, and that their data are contemporaneously correlated.

This kind of analysis requires that the set of countries under study share important characteristics of their business cycles. Moreover, it is important that the length of the sample period be sufficiently long to uncover both long term trends and short run fluctuations. For these reasons, we base our analysis on two clusters – clusters A and B - delimited by Camacho, Pérez-Quirós and Saiz (2006b)[4]. Each of them includes richer and poorer countries that have, moreover, cycle similarities in duration, deepness and shape. The cluster B contains the majority of EU-15 countries. We use the per capita GDP in PPP terms for the sample 1950-2008.

To advance some of our results, we obtain that in cluster A convergence is affected by the phase of the cycle variable of the whole set of countries belonging to the cluster. Moreover, the TAR convergence tests unveil that the richest countries converge to each other almost all the time, except in cases of very negative values of the cycle variable. Once we add the poorer countries (Italy, Greece and Portugal) to the initial rich core, convergence is present in both regimes, but it is stronger under Regime *I* (broadly lower phase of the cycle in rich countries) than under Regime *II* (broadly upper part of the cycle). Consequently, sharp recessions stop convergence between rich countries, but help the poorer reduce their gap with respect to the richer. In cluster B, there are three core countries (Denmark, Austria and Canada) for which linear convergence is not rejected. However, the inclusion of a poorer country (Spain) makes the cycle relevant

[4] Clusters A and B in this study coincide with clusters 3 and 2, respectively, of Camacho, Pérez-Quirós and Saiz (2006b).

for convergence, and the transition variable from one to the other regime turns out to be the cycle of Spain. Convergence of Spain to the core takes place in phases in which the Spanish cycle variable is above a slightly negative threshold, i.e. when the Spanish economy virtually stands in the upper half of its cycle. When the US is included, convergence requires that the US economic does not stand in the highest part of its own cycle.

The rest of the paper is organised as follows. Section 2 explains briefly the econometric methodology that we apply in our empirical tests; section 3 presents the empirical results, and section 4 concludes and derives some policy implications.

2. Brief summary of the econometric methodology

The econometric methodology used in this paper is inherited from Beyaert and Camacho (2008). These authors develop a panel data methodology aimed at testing real convergence in a non-linear framework. They combine three approaches: the threshold (TAR) model, panel data unit root tests and the use of bootstrap simulation techniques to compute critical values that are able to take into account the possible contemporaneous correlations between countries.

Let $Y_{n,t}$ be the per-capita income of country *n* in year *t* in real terms. Define the

$g_{n,t} = y_{n,t} - \bar{y}_t$, where $y_{n,t} = \log(Y_{n,t})$ and $\bar{y}_t = \frac{1}{N}\sum_{n=1}^{N} y_{n,t}$ is the cross-country average log

of per capita income at time t. The fundamental equation of Beyaert and Camacho (2008) is:

$$\begin{aligned}\Delta g_{n,t} = & \left[\delta_n^I + \rho_n^I g_{n,t-1} + \sum_{i=1}^{p} \varphi_{n,i}^I \Delta g_{n,t-i}\right] I_{\{z_{t-1}<\lambda\}} + \\ & + \left[\delta_n^{II} + \rho_n^{II} g_{n,t-1} + \sum_{i=1}^{p} \varphi_{n,i}^{II} \Delta g_{n,t-i}\right] I_{\{z_{t-1}\geq\lambda\}} + \varepsilon_{n,t}\end{aligned} \quad (1)$$

with $n = 1,\cdots,N$ and $t = 1,\cdots,T$ and where $I\{x\}$ is an indicator which takes value 1 when *x* is true and zero otherwise. It therefore acts as a dummy variable which takes a unit value if the condition $z_{t-1} < \lambda$ is fulfilled. So, when $z_{t-1} < \lambda$, the model is $\Delta g_{n,t} = \delta_n^I + \rho_n^I g_{n,t-1} + \sum_{i=1}^{p} \varphi_{n,i}^I \Delta g_{n,t-i} + \varepsilon_{n,t}$ and the economy is in "Regime I"; otherwise, the model is $\Delta g_{n,t} = \delta_n^{II} + \rho_n^{II} g_{n,t-1} + \sum_{i=1}^{p} \varphi_{n,i}^{II} \Delta g_{n,t-i} + \varepsilon_{n,t}$ and the economy stands in "Regime II". The parameter λ is called the "threshold parameter" and the variable z is the transition variable that pushes the economy at t into one or the other regime depending on the value it took at *(t-1)*compared to the threshold parameter. As usual in this type of model, the value of the threshold parameter is unknown and has to be estimated along with the other coefficients of the model. By the same token, the transition variable can be fixed from outside by the analyst or be determined endogenously among a list of possible variables, as part of the estimation process.

In our case, since we are interested in determining whether the cycle might affect the possible real convergence process of the economies, the transition variable must necessarily be related with a variable that measures the cycle position of a single economy of the group between which convergence is tested, or alternatively, with a measure of the cycle position of a group of economies that shares the same cyclical characteristics.

In model (1), divergence takes place in both regimes if $\rho_n^I = \rho_n^{II} = 0$ for all *n*. Alternatively, real convergence takes place in both regimes if $0 < -\rho_n^i < 1,\ \ i = I, II,\ \ \forall n = 1, \cdots N$. Partial convergence (or partial divergence) takes place if the countries converge under one regime but not under the other.

In (1), *p* is assumed to be high enough so that the error is a white noise process for each *n*. So serial correlation is excluded, but cross-country contemporaneous correlation is not.

Following Beyaert and Camacho (2008), model (1) is estimated by least squares combining a Feasible Generalized Least Squares procedure with a grid-search procedure[5].

The testing procedure runs then as follows. First, a linearity test is carried out in order to check whether Model (1) is preferable to a linear model, in which all the coefficients would be equal under both regimes. This test is based on the likelihood-ratio principle although it does not follow a standard distribution because the parameters related to the threshold process are not identified under the null. The critical values are obtained by bootstrap simulation. Additionally, when this linearity test is run we do not know whether the countries converge or diverge, so that the test is carried out under both hypothesis, obtaining therefore two values of the test statistics and two bootstrap probability values (see again Beyaert and Camacho , 2008, for details).

If the linear model is rejected, the next step consists of testing convergence against divergence in (1). On the contrary, if the linear model is accepted, convergence is tested in a linear framework, as developed by Evans and Karras (1996) and extended with bootstrap simulations by Beyaert (2006). Note here that confirmation of the non linear model implies that the cycle position of the economies has some influence on the convergence process. On the contrary, if the linear model is accepted the conclusion is that the cycle has no effect on convergence.

To test convergence against divergence, we apply the tests t_1 and t_2 of Beyaert and Camacho (2008), where $t_i = \hat{\rho}^i / s_{\hat{\rho}^i}$, $i = I, II$ and where $\hat{\rho}^i$ is the grid-FGLS estimation of ρ_n^i in (1) under the restriction that $\rho_n^i = \rho^i \ \forall n$. Large values of these statistics are favourable to convergence: a large value of t_i favours convergence under Regime *i* (*i=I,II*). Here again, bootstrap critical values are calculated by simulation.

Finally the last step of the econometric procedure consists of testing absolute against conditional convergence for the regime under which convergence is established. In terms of model (1), under the maintained hypothesis $\rho_n^i < 0, \forall n$, absolute convergence

[5] The interested reader should consult Beyaert and Camacho (2008).

under Regime i is equivalent to $\delta_n^i = 0, \forall n$. For that null hypothesis, the tests Φ_b and Φ_c of Beyaert and Camacho (2008) are used. Once again, the critical values are computed by bootstrap simulation.

3. Empirical results

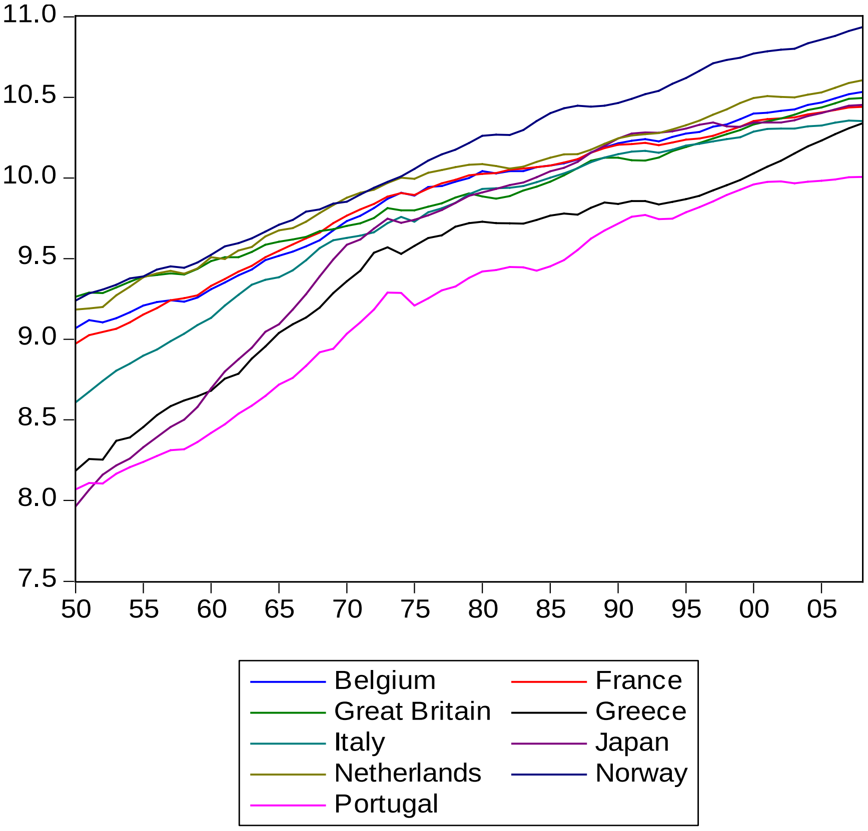
In this section we describe the empirical results that we have obtained using the approach of Beyaert and Camacho (2008) . As explained above, our analysis is applied to two clusters of countries that share important business cycle features, delimited in Camacho, Pérez-Quirós and Saiz (2006b). Cluster A is made of Belgium, France, Great Britain, Greece, Italy, Japan, Netherlands, Norway and Portugal. Cluster B comprises Austria, Canada, Denmark, Finland, Luxemburg, Spain, Sweden and the USA. The data are expressed in 1990 constant and international Geary Khamis (GK) PPP dollars and cover the period 1950-2007. They have been derived from the database of the University of Groningen (Groningen Growth and Development Centre and The Conference Board, Total Economy Database, http://www.ggdc.net).

It is to be borne in mind that these non linear unit root tests are applied on country deviations of income per capita from the panel average income per capita. This implies that if one country diverges from the others the whole panel of country deviations presents a unit root (see Beyaert, 2007 for details). So the first step of the empirical strategy consists of detecting a small group of converging countries; the following steps consist then of adding countries to this starting group in order to appropriately evaluate their convergence properties.

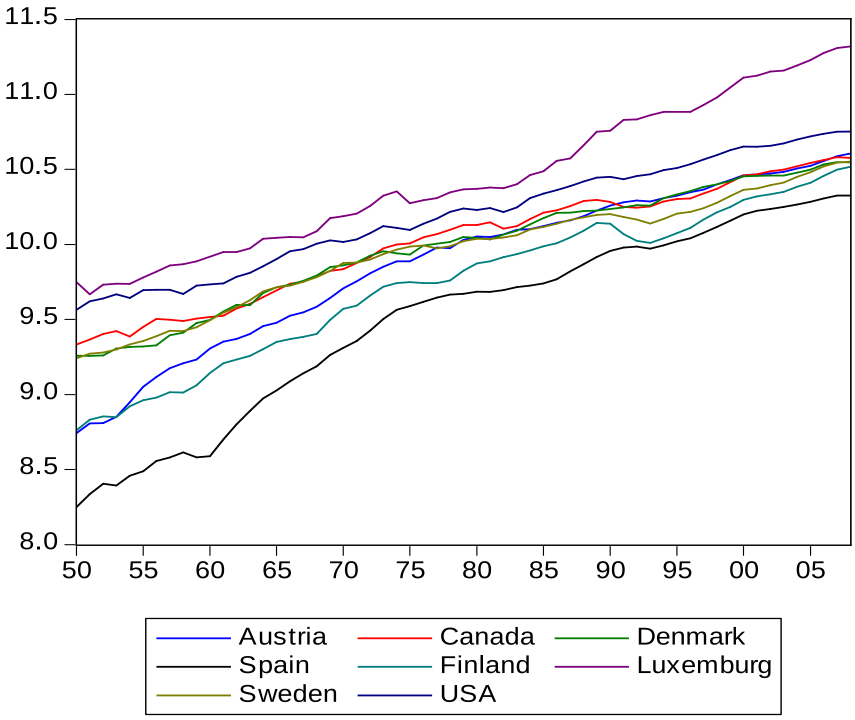
3.1.1 *The core group and the transition variable*

The selection of countries for the starting group and of the countries to be added afterwards in each cluster is to be guided by the objective of the study. In our case, we are interested in testing whether the cyclical position of the economies affects to some extent their convergence properties in general and the convergence characteristics of the poorer countries to the richer in particular. So, the starting group has to be formed exclusively of relatively richer and converging countries. The poorer countries have to be added later on. As we will see, an intermediate step might also consist of adding rich countries to the core of starting converging countries before adding poorer. For an initial illustration of the relative positions of the countries in each cluster over the period 1950-2007, we present in Figures 1 and 2 the evolution of the real income per capita in PPP of the countries in Cluster A and Cluster B respectively.

Figure 1: Per capita GDP in PPP of countries of Cluster A (logarithms)



Graph 2: Per capita GDP in PPP – countries of Cluster B (logarithms)



In Figure 1, it is easy to appreciate that the poorer countries at the end of the period are Italy, Greece and Portugal. On the opposite, Norway is the richest one and its distance from the others increases over time. The second richest are the Netherlands. The converging core is formed by Belgium, France, Great Britain and Japan. So it makes sense to start with this group and to exclude Norway from the convergence study.

In Figure 2, Luxemburg is the richest one and its distance to the others increases over time. The second richest is USA. The poorest is Spain. As far as Finland and Sweden are concerned, there is a substantial decrease of their per capita income at the beginning of the nineties. It can be associated with the economic difficulties of the former communist countries at that period, as a result of the fall of the communist block, and its impact on these two Scandinavian countries. So these decreases correspond more with a structural change than with a cyclical variation. In order to avoid possible ambiguities in the empirical results, these two countries are not considered in the convergence study. The initial core countries are therefore Canada, Austria and Denmark.

In order to apply the TAR panel unit root tests of Beyaert and Camacho (2008) on these data, we need to make a decision concerning the transition variable. This variable must be I(0) and, according to our objective, it has to be related with the cycles of the countries. So, one question is how we measure the cycle. In this paper we opt for the cycle defined as the residual of the Hodrick-Prescott long term trend component of the total real GDP in PPP of the country or countries of interest.

Another question that we must solve from the outset is the steering convergence variable. Is it better to use the cycle of the whole cluster or the cycle of a specific country? In the first case, the transition variable is fixed from outside, whereas in the second one, it should be picked endogenously by the estimation and testing of the TAR unit-root test strategy. At first sight, we might consider as reasonable that the cycle of the cluster would be representative of the country-specific cycles, since the clusters are formed according to the similarities of the cycle properties of the component countries.

However, since these clusters are built on the basis of similarities in duration, shape and amplitude, and not on the basis of synchronization, a closer look at the country-specific cycles compared to the cluster cycle is necessary.

Tables 1 and 2 provide information about the cross-correlation between both types of cycles in Cluster A and B, respectively. This table has to be interpreted as follows: the higher the contemporaneous cross correlation and the lower the lagged cross correlations between the cluster cycle and the country X cycle, the more synchronized is the cycle of country X with the cluster cycle. In Cluster A, most countries are synchronized. The only strong exception is Norway (which moreover has been already excluded from the convergence analysis). Note also that the average degree of synchronisation over the whole sample is relatively high (almost 70% if Norway is excluded). In other words, the cluster cycle can be considered as representative of the individual cyclical situations. This justifies the use of this cluster cycle as the unique transition variable.

Table 1
Cluster A: Cross-correlations between the Hodrick-Prescott cycle of the cluster and the country-specific Hodrick-Prescott cycle

Country	Synchronization (contemporaneous cross-correlation)	Cross-correlation lag 1	Cross-correlation lead 1	General characteristic
Belgium	**0.786**	0.320	0.667	**Syn**
France	**0.791**	0.460	0.617	**Syn**
Great Britain	0.581	**0.676**	0.047	Lag
Greece	**0.627**	0.472	0.409	**Syn**
Italy	**0.734**	0.390	0.465	**Syn**
Japan	**0.811**	0.488	0.628	**Syn**
Netherlands	**0.563**	0.295	0.461	**Syn**
Norway	-0.166	-0.090	-.329	-
Portugal	**0.676**	0.301	0.629	**Syn**
Mean level of synchronization	**0.600 (0.302)** w/o Norway: **0.696(0.098)**			

On the opposite, in Cluster B (Table 2), most countries are not synchronized with the cluster cycle. The important exception is the US cycle which exhibits a contemporaneous cross-correlation with the cluster cycle of 98.3%, which indicates that the cluster cycle is virtually the US one. The average degree of synchronization is moreover low and presents a large standard deviation. Therefore, country-specific cycles are used in this cluster and the testing strategy will determine endogenously the country cycle that acts as the transition variable between regimes.

Table 2
Cluster B Cross-correlations between the Hodrick-Prescott cycle of the cluster and of the country

Country	Synchronization (contemporaneous cross-correlation)	Cross-correlation lag 1	Cross-correlation lead 1	General characteristic
Austria	0.121	**0.340**	-0.222	Lag?
Canada	**0.827**	0.631	0.400	**Syn**
Denmark	**0.591**	0.506	0.243	**Syn**
Spain	0.416	0.038	**0.607**	Lead
Finland	0.539	0.260	**0.568**	Lead
Luxemburg	0.382	-0.137	**0.556**	Lead
Sweden	**0.622**	0.323	0.589	**Syn**
USA	**0.983**	0.606	0.533	**Syn**
Mean level of synchronization	**0.523 (0.274)** w/o Austria: **0.623(0.216)**			

3.1.2 *The core group and the transition variable*

We now apply the TAR unit root tests of Beyaert and Camacho (2008) on subgroups of countries of Clusters A and B. The question to be answered is twofold. First, we ask whether there is an effect of the cycle on the convergence process. If the answer is affirmative, the second question is how the phases of the cycle affect this process, especially for the case of the poorer countries. The answer to the first question is provided by the result of the linearity test, which is part of Beyaert and Camacho (2008) methodology. The answer to the second question is afforded by the results of their two-regime TAR panel unit root test.

The results for Cluster A are in Table 3. As mentioned before, the transition variable for this cluster is fixed exogenously and corresponds to the Hodrick-Prescott cycle of the whole cluster.

Table 3
Countries of Cluster A Threshold variable: Hodrick-Prescott Cycle of Cluster A

Group of countries	Linearity tests (1)	TAR panel convergence tests				
		Threshold value; % of data below it	Reg.1 (below threshold) (2)	Reg.2 (above threshold) (2)	Abs. cvgce reg.1 (3)	Abs. cvgce reg.2 (3)
Belgium, France, Great Britain, Japan	0.018 0.015	-20730 47.27%	0.272	0.000	-	0.879
Belgium, France, Great Britain, Japan, Italy, Greece, Portugal	0.000 0.000	10307 56.6%	0.020	0.020	0.046	0.805
Belgium, France, Great Britain, Japan, Netherlands	0.043 0.032	-87435 16.36%	0.824	0.000	-	0.953
Belgium, France, Great Britain, Japan, Netherlands Italy, Greece, Portugal	0.000 0.002	22108 63.0%	0.010	0.001	0.605	0.504

(1) A p-value below 0.05 implies rejection of linearity at 5%. (2) A p-value below 0.05 implies convergence at 5% under the corresponding regime. (3) A p-value below 0.05 implies conditional convergence at 5%.

For the core countries (Belgium, France, Great Britain and Japan), the linearity tests rejects a linear approach to convergence in favour of the TAR non linear one (see column 2 of Table 3). So the first conclusion is that the cycle does have an effect on convergence.

As far as the TAR convergence tests are concerned, the threshold value is estimated at -20730, which corresponds to a slightly negative value of the cluster cycle variable (see the Boxplot for cluster A in Figure 3). The data below these values, i.e. Regime *I*, corresponds to 47.27% of the sample, whereas 52.73% of the data fall above this threshold, under Regime *II*. According to the tests, convergence takes place only under Regime *II*. In other words, the core countries do converge to each other as long as they are not in the lower phase of the cycle.

Once we add Italy, Greece and Portugal to this core group, the influence of the cycle on convergence is confirmed because linearity is rejected again. However, the threshold characteristics as well as the convergence results are altered. The threshold increases to slightly positive values and the convergence extends to both regimes. However, the estimated convergence coefficient ρ of equation (1) is slightly higher under Regime *II* (0.956) than under Regime *I* (0.947). Taking into account that the standard deviations of these estimations are not very different, this could be interpreted as an indication of more convergence under Regime *I* (broadly lower cyclical phase) than under Regime *II* (broadly upper part of the cycle). This impression is reinforced by the values of the convergence coefficients of the individual countries under Regime *I* and Regime *II*, especially for the poorer countries. Under Regime *I*, the estimated values of the convergence parameter for Italy, Greece and Portugal are equal to 0.945, 0.953 and 0.953, respectively. On the opposite, under Regime *II* they are equal to 0.995, 1.239 and 1.007[6]. Bearing in mind that the cluster cycle is dominated by the weight of the richer countries, there are symptoms that good economic conditions favour more the richer than the poorer as far as real convergence is concerned.

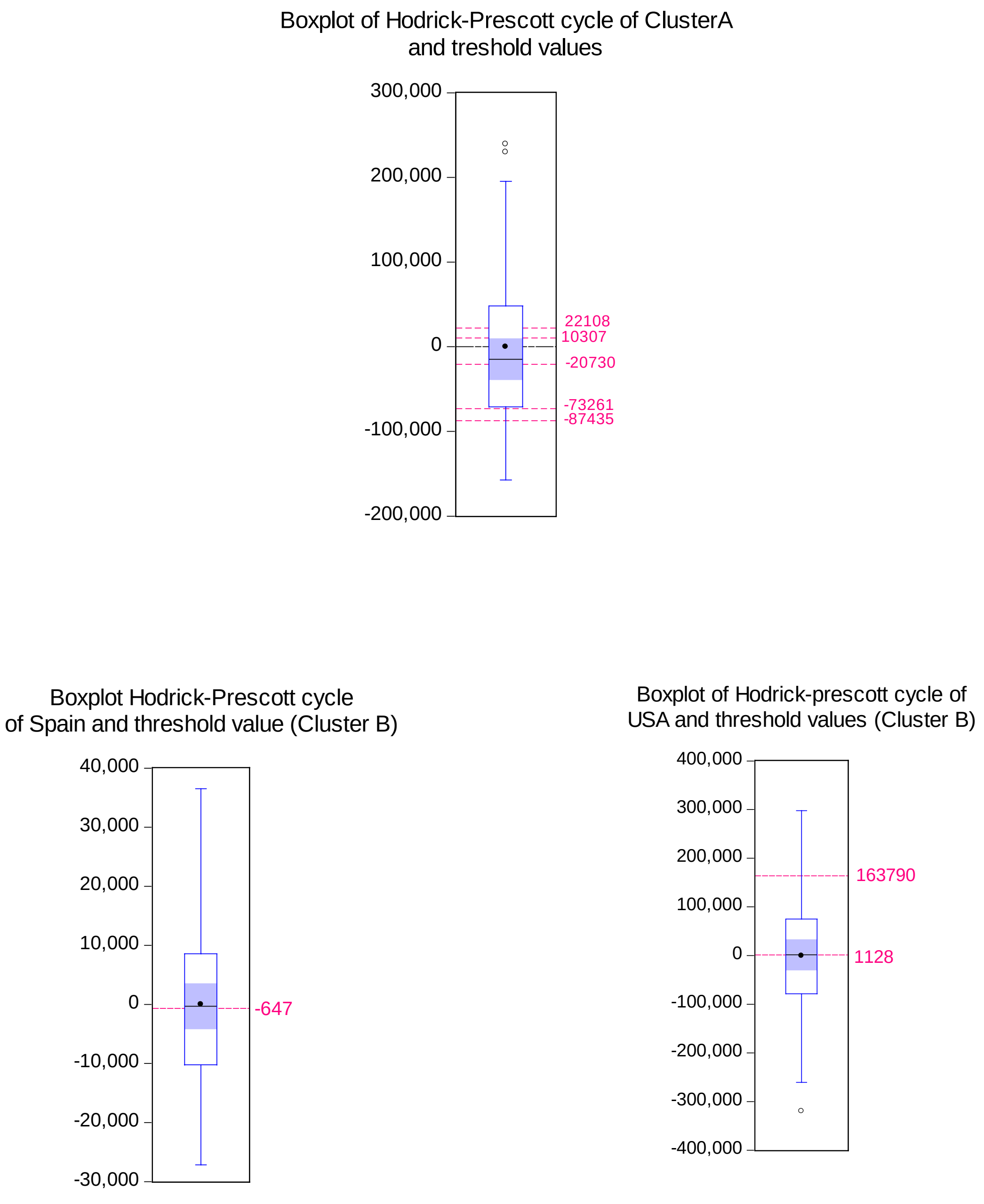
Similar results are obtained if we add Netherlands to the core group. Again, convergence depends on the cyclical conditions (since linearity is rejected). Convergence among the richer countries takes place as long as they are not in very bad economic situations; it is present in 83.64% of the period covered by the sample. However, this result is again changed when we add Italy, Greece and Portugal: the threshold takes slightly positive values, indicating that the two regimes correspond virtually to the lower and the upper phase of the cycle, respectively (see the Boxplot for Cluster A in Figure 3). On the other hand, convergence now takes place under both regimes. So the message is similar: rich countries converge to each other, except when

[6] We are aware that these are estimated values, so that a formal statistical test would enable to draw stronger conclusions. This test requires to run booststrap simulations that we will carry out in a later version of this paper, For this preliminary version, we think that these informal comparisons are worth mentioning since they present certain consistency.

they are in worse situations; and when that happens, this helps the poorer to reduce more their distance.

Figure 3

Boxplots of the Hodrick-Prescott cycles that act as transition variables in Cluster A and Cluster B, along with the values of the threshold parameter values



Turning now to countries of Cluster B, the preceding results are extensible, broadly speaking, to this group of countries. They are summed up in Table 4. In this case, for the reasons explained before, the transition variable is the cycle of an individual country, which is endogenously selected.

Table 4

Countries of Cluster B. Threshold variable: country Hodrick-Prescott Cycle (endogenously selected)

Group of countries	Linearity tests (unrestricted and restricted tests) (1)	TAR panel convergence tests					
		Country of transition variable	Threshold value; % of data below it	Cvgce in Reg.1 (below threshold) (2)	Cvgce in Reg.2 (above threshold) (2)	Abs. cvgce reg.1 (3)	Abs. cvgce reg.2 (3)
Denmark, Austria, Canada	0.068 0.103 (test linear cvge: 0.004)	-	-	-	-	-	-
Denmark, Austria, Canada, Spain	0.003 0.002	Spain	-647 47,3%	0.128	0.011	-	0.030
Denmark, Austria, Canada, USA	0.025 0.025	USA	1637908 89,3%	0.002	0.421	0.219	-
Denmark, Austria, Canada, USA, Spain	0.615 0.518	USA	1128 48,2%	0.019	0.120	0.360	

(1) A p-value below 0.05 implies rejection of linearity at 5%. (2) A p-value below 0.05 implies convergence at 5% under the corresponding regime. (3) A p-value below 0.05 implies conditional convergence at 5%.

Starting with the core countries -Denmark, Austria and Canada- it turns out that this is the only group where the linear convergence test is not rejected: the three countries linearly converge to each other and their cyclical situation does not affect that process.

The addition of a poorer country, which is Spain in this case, modifies the results. First, linearity is now rejected, so that the cycle of the countries affect their convergence process. Second, the cycle selected as transition variable belongs to Spain. It is worth noting that it is one of the poorest countries of the group. Third, the threshold is negative although close to zero (see the Boxplot of the Hodrick-Prescott cycle for Spain in Figure 3). Spain stands below this value in 47% of the period 1950-2008. Fourth, convergence takes place only above that threshold. In other words, Spain reduced income distance with respect to the rest of the group only when this poorest country was in a good economic situation.

What happens if we add the USA instead of Spain to the core group? The transition cycle is now the US cycle, which is by far precisely the richest country (see Graph 2). Moreover, its threshold value is quite high, since the country stands below this threshold in 89.3% of the time see the Boxplot for the US cycle in Figure 3). Convergence takes place between the US and the core countries as long as the US stands below that threshold, that is, as long as this country does not stand too close to a peak.

When Spain is added to the last group, the US cycle is again selected as the transition variable but now with a threshold valued very close to zero (see again Figure 3). So, the two regimes again are associated with the lower and upper parts of the cycle (Regime *II* and *I,* respectively). The results of the convergence tests indicate as before that US good economic conditions work against the convergence of lower income countries to the richer.

The general message is therefore the following: cycle slumps and expansions do affect the convergence processes between countries. Convergence takes place as far as either the poorest countries do not stand too close to a trough or the richest ones do not approach a peak. Fortunately, growth of per capita GDP rates of poor and rich countries have been within the convergence bands during a large part of the period under analysis, so that real convergence has been the net result. Interestingly, our empirical analysis discerns the conditions and characteristics of the cyclical phases during which convergence has taken place within each of the two analysed clusters.

4. Summary and concluding remarks

In this paper we have analysed the extent to which per capita GDP convergence is affected by the phases of the business cycle. For this purpose, we have used two clusters composed of countries whose business cycles share important characteristics. The underlying motivation is that the convergence process is not linear neither gradually decreasing as stipulated in the traditional theory of economic growth. Rather, we should expect that the convergence process within groups of countries that have common business cycle characteristics is differently affected by different situations in the business cycle.

Our study represents a new approach towards the empirical assessment of real convergence under the possible effects of the business cycle. The theory of *real convergence* is rooted in the neoclassical model of economic growth, and its main postulates are formulated as long-term tendencies, without any reference to *cyclical fluctuations* of output. For example, the Solow (1956)'s model establishes that, for given values of the structural parameters, the speed of convergence of each country towards its stationary equilibrium is directly linked to the gap between two long-term economic values: the stationary per capita GDP level, and the current per capita potential output. Accordingly, relatively poor countries should, under any phase of the business cycle, approach their stationary level of real income at a higher speed than more developed countries. For that reason, empirical models that test this proposition, such as the β-convergence theory, quantify the average rate of annual convergence within a group of countries, ignoring the influence of the cycle during the analysed period.

In order to deal with the fact that countries might converge differently under each of two alternative business cycle regimes, we have applied unit root tests in a multivariate TAR model, and bootstrapping simulations to test per capita income convergence within each cluster during the period 1950-2007. We obtain that in cluster A convergence between rich and poor countries takes place in both regimes, but it is stronger under broadly recessions than under broadly expansions; sharp recessions only stop convergence among the rich countries of the cluster. In cluster B, the transition variable is guided either by the Spanish cycle or by the US cycle, and convergence is present in phases where the Spanish GDP cycle variable stands above a slightly negative threshold, or when the US does not overcome a very positive value of the GDP cycle variable.

One important implication of our empirical results is that, although growth-led actions that increase economic growth, such as generalised R&D and human capital investments, are advised in each cluster during any phase of the business cycle, they are particularly advisable in countries of cluster B. Apart from rising the stationary values of per capita income, we have shown that they could also foster general real convergence across the cluster, provided that real GDP of the most developed country (the USA in this case) does not exceed an abnormally high level.

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