# The evolution of economic convergence in the European Union

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**Abstract**

This paper investigates economic convergence in real income per capita between 27 European Union countries. We employ a non-linear latent factor framework to study transitional behavior among economies between 1970-2010. Our results offer important insights on the economic catch up exhibited by the new EU members in light of the institutional changes and macroeconomic adjustment processes undertaken over the last 40 years. Our main findings suggest no overall economic convergence in the EU, however, we identify subgroups that converge to different steady states using an iterative testing procedure. The results show that clustering is strongly related to economic development and geographic region, while EMU membership does not play a significant role. The empirical evidence suggests a clear separation between the new and old EU member states in the long run.

**J.E.L. Classification:** C33; O47

**Keywords:** Club convergence; Dynamic factor model; Economic integration; Growth;

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# 1 Introduction

The accession of eight Central and Eastern European countries (CEEC),[1] Cyprus, and Malta on 1 May 2004 marks a significant event in the enlargement process of the European Union (EU). Soon thereafter Bulgaria and Romania joined the EU on 1 January 2007, raising the number of former Communist Bloc countries among EU members to ten. Following successful transformation of their political and legal system and the transition from planned to market economy during the early 1990s, these countries were faced with the task of catching up with the economies of Western Europe. Economic convergence constitutes an essential ingredient for common structural and monetary policies, and there are good reasons to expect increased per capita real output convergence along the road to EU accession. European countries took major steps toward economic integration in recent decades, including the liberalization of capital and labor markets, harmonization of tax policy, and the foundation of the European Economic and Monetary Union (EMU). Moreover, the 1992 Maastricht Treaty set an agenda for nominal and real convergence prior to entering the EMU, and the European Commission has put forward numerous policy initiatives aimed at the reduction of regional economic disparities and improving competitiveness among EU members (see, e.g., European Commission, 2007).

The neoclassical growth model introduced by Solow (1956) predicts that, with technological homogeneity and identical preferences, cross-country differences in per capita real income shrink as each economy approaches its balanced growth path in the long run, and *overall convergence* holds between different countries. On the contrary, New Growth Theories, starting with Romer (1986) and Lucas (1988), point out the absence of convergence between poor and rich countries in practice. Galor (1996) shows that

[1] Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia and Slovenia.

the neoclassical growth model can actually generate multiple equilibria. Countries with identical economic structures need not converge to the same equilibrium growth path, instead some countries may converge to a high steady-state income level while others may face a poverty trap, giving rise to the *club convergence* hypothesis. This controversy has spurred a wide range of convergence definitions and empirical testing methodologies. For an overview of empirical techniques and their potential drawbacks, see Bernard and Durlauf (1996), and Islam (2003). The most widely applied concepts, originating with Baumol (1986), Barro and Sala-i-Martin (1992), and Mankiw, Romer, and Weil (1992), are those of *$\beta$-convergence*, understood as a tendency of poorer economies to grow faster than rich ones, and *$\sigma$-convergence*, which refers to a reduction of income dispersion between rich and poor countries; typically after controlling for a country's saving and population growth in which case we are talking about *conditional convergence* as opposed to *unconditional convergence*. Moreover, the existing approaches also differ in their focus on whether economies grow at the same rate in the steady state (*relative convergence*) vs. whether they converge to the same steady-state income level (*absolute convergence*).

This paper investigates whether European economic integration has been accompanied by convergence in per capita real income between old and new members of the EU, in light of the institutional reforms and macroeconomic adjustment processes that took place during the last decades. In quest for an answer, we employ a time-varying factor model proposed by Phillips and Sul (2007, 2009) which considers a form of panel convergence comparable to the concept of conditional $\sigma$-convergence. This approach has several appealing features. Above all, it does not rely on homogeneous technological progress across countries and over time, a limiting assumption widely used in the existing literature. Moreover, it provides an empirical framework to distinguish between (i) convergence to a single steady state shared by all economies as predicted by the neoclassical growth model, (ii) overall divergence, and (iii) club convergence, which may be interpreted as convergence to multiple steady-state equilibria (see Galor, 1996). Convergence clubs can be formed endogenously within the panels under study, based on a clustering algorithm developed by Phillips and Sul (2007). In addition, the factor model measures both the speed and degree of convergence, which allows us to empirically discriminate between relative and absolute convergence.

Our paper is most closely related to a handful of recent works that study economic convergence in Western Europe using the factor model proposed by Phillips and Sul (2007). The model has been applied by Fritsche and Kuzin (2011) to assess price level, unit labor cost, real per capita income, and productivity convergence for 12 members of the euro area, Denmark, Sweden, and the UK between 1960-2006. They provide evidence for club convergence, where geographic distance as well as differences in economic development may contribute to subgroup formation. Further, Bartkowska and Riedl (2012) use the same procedure to test for convergence in per capita income for 206 regions in 17 Western European countries from 1990 to 2002. They detect six separate clubs on the regional level and show that starting conditions, such as the initial level of human capital and per capita income, are significant determinants of a region's club membership, while structural characteristics play a relatively minor role.

We contribute to the existing literature along two main dimensions. First, to the best of our knowledge this is the first study to examine real income per capita convergence in a comprehensive sample including all 27 members of the enlarged EU. Second, the relatively new empirical framework enables us to provide important insights on the evolution of transition behavior exhibited by the old and new EU member states. Our findings can be summarized as follows. There is no overall economic convergence in the EU-27, and we identify subgroups that converge to different steady-state equilibria. This is a central result, as it highlights the persistence of a "multi-speed" Europe nearly a decade after the eastern enlargement.[2] Convergence clubs are formed mainly on the basis of economic development and geographic region, yet clustering is unrelated to EMU membership. We find a clear separation between post-communist economies and old EU members in the long run. The CEEC showed remarkable developments through the implementation of several policies facilitating European cohesion. However, our results reveal that the pace of economic growth was insufficient to narrow the GDP per capita differences compared to Western economies. Moreover, we observe a gradual setback of Mediterranean countries, resulting in a South-East vs. North-West division of the economies by the mid-nineties. Hence, we may conclude that country-specific structural disparities within the European Union will continue to pose further challenges in achieving real per capita income convergence.

The remainder of the paper is organized as follows. Section 2 offers a brief description of the methodological framework, while the data used in the analysis is presented in Section 3. The main empirical results are contained in Section 4, and finally, Section 5 summarizes our conclusions.

# 2 Methodology

## 2.1 General framework

Let $y_{it}$ represent period $t$ log per capita real income in country $i$ (where $i = 1, 2, ..., N$ and $t = 1, ..., T$). In the neoclassical growth model homogenous technology is assumed, so that regardless of their initial conditions, all countries undergo technological progress

[2] The concept of a "multi-speed" Europe refers to differentiated integration between countries. Proponents of this idea argue that different members of the European Union should integrate at different levels and pace, depending on the economic and structural characteristics of each country (see, e.g., Stubb, 1996; Alesina and Grilli, 1993)

at the same rate over time. This condition is overly restrictive, and it fails to account for the cross-country income heterogeneity observed in the data. Phillips and Sul (2009) augment the Solow growth model with technological heterogeneity across countries and over time, such that the individual transition path of an economy toward the common steady state log per capita real income level depends on country-specific technological growth rates. The growth model with heterogeneous technology admits a time-varying latent factor representation proposed by Phillips and Sul (2007), which can be expressed as:

$$y_{it} = \delta_{it}\mu_t. \tag{1}$$

The factor $\mu_t$ is a common trend which may have both deterministic and stochastic components, and the country-specific transition path of country $i$ to the common trend $\mu_t$ is captured by the time-varying loadings $\delta_{it}$ which absorb any idiosyncratic shocks to $y_{it}$. The loadings can be thought of as a form of economic distance of each economy from the common trend, which may arise from differences in technological progress, saving, and population growth across countries and over time. The extent to which such individual country characteristics differ across economies will be reflected in the diverse shapes of economic transition encompassed in $\delta_{it}$.

The loadings are assumed to follow a semi-parametric process of the form:

$$\delta_{it} = \delta_i + \frac{\sigma_i}{\log(t)t^{\alpha}}\xi_{it}, \tag{2}$$

where the idiosyncratic shocks $\xi_{it}$ are $i.i.d.(0,1)$ across $i$ but weakly dependent over $t$; moreover, $\sigma_i > 0$. For $\alpha \geq 0$, $\delta_{it}$ converge slowly to the constant $\delta_i$ as $t \to \infty$, and scaling by the slowly varying function $\log(t)$ ensures a smooth transition path. Furthermore, all $N$ economies converge to the common trend $\mu_t$ if $\delta_{it}$ and $\delta_{jt}$ converge to some common constant $\delta_i = \delta_j = \delta$ (for $i, j = 1, 2, ..., N$ and $i \neq j$) as $t \to \infty$, which implies that country-specific differences are eliminated over the long run. The parameter $\alpha$ represents the rate at which cross-sectional heterogeneity decays to zero over time, that is, the speed of convergence.

We are interested in testing the hypothesis of convergence between all countries (overall convergence), against the alternative of no convergence for some country or countries. The alternative hypothesis includes divergence of all countries in the panel (overall divergence), or a situation in which sub-panels converge to different steady states with possibly some diverging units (club convergence). Our null hypothesis can be expressed as

$$H_0: \qquad \lim_{t\to\infty} \delta_{it} = \delta,$$

or equivalently $\delta_i = \delta$ for all $i$ and $\alpha \geq 0$. The alternative hypothesis is given by

$$H_A: \qquad \lim_{t\to\infty} \delta_{it} \neq \delta,$$

which corresponds to one of two cases, either overall divergence: $\delta_i = \delta$ for all $i$ with $\alpha < 0$; or club convergence: $\delta_i \neq \delta$ for some $i$ with $\alpha \geq 0$, or $\alpha < 0$.

## 2.2 The $\log(t)$ convergence test

The identification and estimation of the factor loadings $\delta_{it}$ is not feasible without imposing additional structure and assumptions on the dynamic latent factor model. However, Phillips and Sul (2007) show that an equally suitable way to extract information about $\delta_{it}$ required to test the hypotheses of interest is offered by constructing the following relative transition paths:

$$h_{it} = \frac{y_{it}}{N^{-1}\sum_{i=1}^{N} y_{it}} = \frac{\delta_{it}}{N^{-1}\sum_{i=1}^{N} \delta_{it}}, \tag{3}$$

which measure the loadings $\delta_{it}$ in relation to the panel average at time $t$. The variable $h_{it}$ traces out an individual transition path over time for economy $i$ in relation to the panel average. If the factor loadings $\delta_{it}$ converge to $\delta$, the relative transition paths given by $h_{it}$ converge to unity. In that case, the cross-sectional variance of $h_{it}$ converges to zero asymptotically:

$$H_t = N^{-1}\sum_{i=1}^{N}(h_{it} - 1)^2 \to 0 \qquad \text{as} \qquad t \to \infty, \tag{4}$$

where $H_t$ measures the distance of economy $i$ from the common limit. The statistical convergence property $H_t \to 0$ translates into the null hypothesis of economic convergence between countries in the panel. If convergence fails to hold, the distance remains positive as $t$ tends to infinity.

Phillips and Sul (2007) propose a test for economic convergence based on the asymptotic convergence property given in Equation 4. This involves estimating the following regression by ordinary least squares (OLS):

$$\log\left(\frac{H_1}{H_t}\right) - 2\log(\log(t)) = \beta_0 + \beta_1 \log(t) + u_t, \tag{5}$$

where $t = [rT],\ [rT]+1,\ \ldots,\ T$, for some fraction $r > 0$.[3] The regression coefficient $\beta_1$ provides a scaled estimator of the speed of convergence parameter $\alpha$, specifically $\beta_1 = 2\alpha$. Thus, the null hypothesis of convergence can be tested by a one-sided $t$-test of the inequality $\alpha \geq 0$ using the estimate $\hat{\beta}_1$ and a heteroscedasticity and autocorrelation

[3] Note that $[rT]$ denotes the integer part of $rT$.

consistent (HAC) standard error. The null hypothesis is rejected at 95% significance level if $t_{\hat{\beta}_1} < -1.65$. When the rejection of the null applies, a clustering procedure is performed, in which the $\log(t)$ test is repeated in an iterative manner in order to endogenously detect all possible subgroups in the panel, based on a set of criteria (see the Appendix for details). If no additional clubs are found, one may conclude that the remaining countries diverge.

Analyzing economic convergence within this framework has several appealing features. First, convergence is treated as an asymptotic property. Hence, the model is consistent with a wide range of transition dynamics toward the steady state. Different countries may follow substantially different relative transition paths outlined by $h_{it}$, including periods of transitional divergence and heterogeneity, yet convergence ultimately occurs when Equation 4 holds in the long-run. Second, we can distinguish empirically between absolute (level) and relative (growth rate) convergence. In particular, if the estimate $\hat{\beta}_1 \geq 2$ and accordingly $\hat{\alpha} \geq 1$, this implies absolute convergence within the panel. However, $0 \leq \hat{\beta}_1 < 2$ indicates only relative convergence, that is, convergence of growth rates over time. Finally, we do not have to rely on any particular assumptions regarding the deterministic or stochastic trending behavior of $y_{it}$ and $\mu_t$.

# 3 Data

We investigate convergence between the 27 members of the European Union. Hence, the countries included are Austria (AUT), Belgium (BEL), Bulgaria (BUL), Cyprus (CYP), Czech Republic (CZE), Denmark (DEN), Estonia (EST), Finland (FIN), France (FRA), Germany (GER), Greece (GRE), Hungary (HUN), Ireland (IRE), Italy (ITA), Latvia (LAT), Lithuania (LIT), Luxembourg (LUX), Malta (MAL), the Netherlands (NED), Poland (POL), Portugal (POR), Romania (ROM), Slovakia (SVK), Slovenia (SLO), Spain

(ESP), Sweden (SWE), and the United Kingdom (UK). Per capita real output is measured by PPP converted annual log real GDP per capita (at 2005 constant prices) from the Penn World Table (Heston, Summers, and Aten, 2012). We have two baseline samples. The first one spans from 1970 till 2010 and contains 21 countries (EU-21). Due to data limitations, time series for the Czech Republic, Estonia, Latvia, Lithuania, Slovakia, and Slovenia are absent from this panel. Therefore, we have chosen the longest time series available for all 27 EU members (EU-27), and the second baseline sample covers the period 1995-2010. In what follows, we take a look at a few stylized facts in order to build some intuition on the economic performance of EU countries since the 1970s.

Figure 1 shows a scatter plot of log real GDP per capita in 1970 against log real GDP per capita in 2010 for the EU-21. The distance between the 45-degree line and each data point reflects the average growth rate over 40 years. As judged by the latter, European countries have been overall quite successful during the last four decades, as no country experienced a decline in real output per person on average. There seems to be, however, substantial heterogeneity over the period considered. While some countries experienced relatively high mean rates of real per capita GDP growth, such as Malta, Bulgaria, Luxembourg, and Romania (4.3%, 3.3%, 2.9%, and 2.9%, respectively), most highly developed countries (e.g., Denmark, Netherlands, and Sweden) have been growing at a slower rate on average (around 1.5-1.6%). These figures suggest an economic catching-up of the relatively poorer countries, and it illustrates a somewhat idiosyncratic path in the case of Luxembourg. Disregarding the high growth countries in the plot reveals another interesting pattern: while log real output per person varied between around 8.7 and 9.9 in 1970, it narrowed down to an interval between approximately 9.7-10.6 by 2010, which hints at a reduction in income dispersion from the initial period.

[Figure 1 about here.]

Figure 2 illustrates the evolution of cross-sectional real income dispersion over time, it thus reflects a notion of $\sigma$-convergence. For each year, we compute the sample standard deviation of log real GDP per capita across countries, and we take 5-year rolling averages to smooth out any short-run patterns. Figure 2/(a) plots cross-section dispersion across the EU-21, while Figure 2/(b) shows the same measure excluding the CEEC (Bulgaria, Hungary, Poland, and Romania). Real income dispersion decreased substantially for the EU-21 from 1970 until the mid-1980s. However, we can subsequently observe a transitional divergence period until the birth of the EMU in the late 1990s. As can be seen from a comparison of the two figures, this divergence was mainly due to the CEEC, while dispersion seems unaffected by the foundation of the monetary union. Regarding the CEEC, the socialist economic system lost its impetus by the 1980s, and these countries were faced with rising debt and severe austerity measures. Hence, in the early 1990s, important political and institutional changes were undertaken, involving sizable macroeconomic adjustment processes, e.g., transition from planned to market economy, liberalization of prices, and privatization of state assets. These developments may provide a plausible explanation for the dispersion dynamics observed.

[Figure 2 about here.]

# 4 Empirical results

Applying the $\log(t)$ convergence test and clustering algorithm to real per capita output, we uncover the following key facts:

**Fact 1.** There is no overall economic convergence in the European Union. The null hypothesis of convergence is clearly rejected in all panels considered. However, we do find subgroups that converge to different steady states.

**Fact 2.** We provide strong evidence of relative convergence within each of the subgroups, which highlights that a "multi-speed" Europe is currently an economic reality.

**Fact 3.** Convergence clubs are formed mainly on the basis of economic development and geographic region, yet clustering is not necessarily related to EMU membership.

**Fact 4.** There is a clear separation between the CEEC and the old members within the EU in the long run. The clubs that include CEEC economies are on predominantly lower transition paths compared to the panel average.

## 4.1 Convergence and clustering

Looking at the empirical results in detail, we consider convergence in two baseline panels. These are real GDP per capita for the EU-21 sample for 1970-2010 ("long panel") and for the EU-27 sample for 1995-2010 ("short panel"). In addition, we investigate the EU-21 between 1995-2010 in order to confirm the robustness of our findings in the absence of the six countries that are missing from the EU-21 sample, namely, the Czech Republic, Estonia, Latvia, Lithuania, Slovakia, and Slovenia. The convergence club classification results are reported in Table 1.[4] The null hypothesis of overall economic convergence is rejected at the 5% level in all three panels. Figure 3 depicts the corresponding relative transition curves of individual countries ($\hat{h}_{it}$) and the average transition curves for each club ($\bar{h}_{clubt}$). Recall that the relative transition path $h_{it}$ measures the departure of each country $i$ from the panel average. If the factor loadings $\delta_{it}$ converge to a common constant

[4]We present empirical results from $\log(t)$ regressions performed on time series filtered for business cycle fluctuations with the Hodrick and Prescott (1997) filter following Phillips and Sul (2007).

$\delta$, the transition paths $h_{it}$ converge to unity. Other than that, the economic transition behavior can significantly differ across economies.

[Table 1 about here.]

Concerning the long panel, we identify four clubs and only one diverging country. Luxembourg shows distinct growth dynamics, being on a transition path permanently above all other countries during the period in question (see Figure 3/(a)), which confirms our earlier conjecture regarding its idiosyncratic growth path. Club 1 comprises the relatively richer Western European countries. Cyprus and Portugal form the second convergence club separating clearly from the more advanced EU countries. The estimated speed of convergence is $\hat{\alpha} = 0.163$ and $\hat{\alpha} = 0.278$ for clubs 1 and 2, respectively. Thus, the countries in both clusters undergo relative convergence in the observed period. The average transition curve for club 1 is flat, providing further evidence that the highly developed countries have been growing at a slower rate on average compared to the rest of the panel. The transition curves of club 2 and the CEEC that constitute clubs 3 and 4 show that these relatively poorer countries have been unable to catch up with the more developed West over the long horizon, in spite of a salient upswing starting from the mid-nineties (see Figure 3/(b)). We find absolute convergence in club 3 ($\hat{\alpha} = 1.200$), which implies that Hungary and Poland converge to a club-specific per capita real GDP level between 1970-2010. Further, note that the point estimate of $b$ in club 4 is negative ($\hat{b} = -0.654$) but not significantly different from zero, suggesting that the fourth subgroup constitutes the weakest convergence club.

[Figure 3 about here.]

Regarding our analysis for the EU-27 (and EU-21) sample for 1995-2010, only relative convergence is detected, which points to the transitional nature of the period considered.

This implies that, within each club, relative growth rate differentials tend to decrease over time. The three diverging countries are France, Luxembourg, and Romania. Based on the transition curves for the shorter sample, the general picture remains unchanged in that the wealthier Western European countries (clubs 1 and 2) are mainly on higher transition paths, while most of the post-communist economies (clubs 3 and 4) tend to cluster below the EU average. Figure 3 hints at the evolution of transition curves between 1995-2010, we thus omit plotting them in order to save space.

The middle panel of Table 1 highlights some interesting results. We observe that some of the CEEC have been catching up, while certain Western economies have experienced a slowdown when focusing on the short panel. On the one hand, Estonia and Slovenia converge to a group of more developed countries and form club 2 together with Belgium, Denmark, Finland, Germany, and the UK. This finding may be attributed to the vigorously pursued economic reforms and integration with the West after gaining independence in 1991. On the other hand, three of the four major Mediterranean countries (Greece, Italy, and Spain) belong to club 3 alongside the Czech Republic, Latvia, Lithuania, and Slovakia. The remaining Mediterranean countries (Cyprus, Malta, and Portugal) form the subgroup with the relatively lowest real income level per person, together with Bulgaria, Hungary, and Poland. Thus, overall we observe a gradual setback of Mediterranean countries, resulting in a South-East vs. North-West separation of European economies by the mid-nineties.

## 4.2 Patterns of economic transition

Our results provide statistical evidence that the process of European economic integration is yet unfinished, in that EU countries do not converge to the same real per capita income level. In this subsection, we examine the evolution of convergence and clustering in a subsample analysis, and we illustrate the typical patterns of economic transition in the EU over the last 40 years. Our aim is to determine whether there is a potential for relatively poorer economies to reduce the gap with wealthier countries (and vice versa) and to identify the potential paths along which this catching up can be achieved over time. Table 2 shows the club classification results for the EU-21 for the sub-periods between 1980-2010, 1990-2010, and for the EU-27 between 2000-2010. On balance, the clustering patterns in the subsamples resemble important similarities with our baseline club classifications, and therefore they confirm the robustness of our main results. The differences between convergence and clustering in each subsample and the longer baseline panel come from the fact that income dispersion was relatively high at the initial period and has significantly reduced by the end of the century. Consequently, economies that converge over the period from 1970 till 2010 do not necessarily form the same cluster when considering panels that begin at a more recent date (i.e., 1980, 1990, and 2000).

[Table 2 about here.]

Table 2 also reveals some evidence on the underlying transition across clubs over time. In particular, club 1 from the long panel of Table 1 splits gradually into the richest four (Austria, Ireland, the Netherlands, and Sweden), a second group of wealthy economies (Belgium, Denmark, Finland, Germany, and the UK), and a third group comprised of three Mediterranean countries (Greece, Italy, and Spain). The second group forms a new club together with the higher-income Estonia and Slovenia by 1995, while the Mediterranean countries are joined by four CEEC (the Czech Republic, Latvia, Lithuania, and Slovakia). Further, club 2 (Cyprus and Portugal) and club 3 (Hungary and Poland) – together with Malta from club 1 – of the long panel start forming the same (relatively poorest) convergence club from 1980 onwards. This club is complemented with Bulgaria and Romania by the early 1990s, even though Romania is among the diverging countries in 1995, followed by Bulgaria in 2000. Finally, the Baltic countries (Estonia, Latvia, and Lithuania) join the least wealthy club by 2000, and Slovenia also falls behind the richer Western economies lately. Hence, the evolution of subgroup formation does not only show that clustering is unrelated to EMU membership, but it also underlines the key fact that convergence clubs are formed primarily on the basis of economic development and regional linkages throughout the period under analysis.

One considerable advantage of the technique employed here is that, unlike other methodologies, it allows for heterogeneity and transitional divergence of individual transition paths. In practice, Phillips and Sul (2009) distinguish between a variety of transition paths that stem from cross-sectional heterogeneity of individual country characteristics. Such trajectories include (i) relative transition paths that converge to unity from an either high or low state of departure, (ii) an initial period of divergence (labeled transition phase A) followed by a catch-up phase (phase B) and later convergence (phase C), and (iii) divergence from the panel toward a state below ($h_{iT} < 1$) or above ($h_{iT} > 1$) unity.

Figure 4 illustrates the transition curves of all countries belonging to the first convergence club from the 1970-2010 panel. We focus on this club because it provides a good basis to study different shapes of economic transition. Note that $h_{it}$ refers here to the transition path of each country relative to all other countries in club 1. As one can see from the figure, countries with superior income levels further split in the last fifteen years. Despite belonging to the same club in the long panel, Austria, Ireland, and the Netherlands manifest transition curves above the rest between 1995-2010. On the other hand, the transition paths of the three major Mediterranean countries (Greece, Italy and Spain) part from the richer EU economies if we consider a more recent period. Thus, the separation scheme described previously is clearly reflected in Figure 4.

[Figure 4 about here.]

The most remarkable type (i) transition curve is displayed by Malta which started from the lowest state in club 1, and achieved a huge rise in real GDP per capita between the 1970s and 1990s. A good example for type (ii) transition is displayed by Ireland, which was in phase A until the early 1980s, however, it managed to turn its performance during the 1980s (phase B) and exhibited a spectacular catching-up and convergence period (phase C) by the end of the 20th century. Malta and Ireland illustrate best the paths along which there is a potential for initially poor countries to reduce their income disparity relative to richer economies in the long run. Other examples of type (i) transition include Austria, Denmark, the Netherlands, and Sweden, while Finland, Greece, Italy, Spain, and the UK are other good examples of type (ii) transition. Furthermore, the transition dynamics of the CEEC are of the second type as well. According to Figure 3, each of these countries were simultaneously on diverging transition paths by the 1980s, – indicating the decline of the socialist economic system – which was followed by a notable catch up as result of the macroeconomic adjustment processes that started in the nineties. Finally, Luxembourg is an obvious type (iii) country, i.e., diverging throughout the entire sample period.

# 5 Concluding remarks

In this paper we have analyzed convergence of real per capita GDP in a comprehensive sample including all 27 members of the enlarged EU. We have applied a novel panel convergence methodology to study the evolution of transitional behavior among economies between 1970 and 2010. One appealing feature of this econometric framework is that it enables us to identify convergence clubs in the panel. In addition, we can empirically distinguish between relative and absolute convergence within the subgroups.

Our main findings can be summarized as follows. First of all, there is no overall economic convergence in the EU. This result is robust to any time horizon considered. Instead, we detect subgroups that converge to different steady-state equilibria. We provide strong evidence in support of relative convergence but little evidence of absolute convergence within each cluster, pointing to the transitional nature of the period under analysis. Economic development and regional linkages play a significant role in determining the formation of convergence clubs, however, clustering is not related to EMU membership. Finally, there is a clear separation between the CEEC and the old EU members in the long run, suggesting that, even though the CEEC have exhibited higher real output growth than the EU average over the last 40 years, catching up was not sufficient in order to eliminate cross-country real income per capita differences.

Our results draw attention to the lack of structural reforms in the less developed economies of the EU, posing a threat to the achievement of real convergence in the near future. Moreover, despite the fact that the CEEC economies went through profound changes starting from the early nineties, indicating some degree of convergence toward the West, policy makers should consider the persisting differences in the light of further enlargement of the European Union.

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## Appendix: Clustering algorithm

To identify convergence clubs we use the following clustering algorithm proposed by Phillips and Sul (2007):

Step 1 *Last observation ordering*: order the $N$ countries in the panel according to the last observation $y_{iT}$.

Step 2 *Core group formation*: form all possible subgroups $G_k$ by selecting the first $k$ highest units for $2 \leq k < N$. Run the log $t$ regression to obtain the test statistic $t_{\hat{b}}$ for each subgroup $k$. Define the core group of size $k^*$ by maximizing $t_{\hat{b}}$ subject to min $t_{\hat{b}} > -1.65$. If the condition min $t_{\hat{b}} > -1.65$ does not hold for $k = 2$, drop the first country in the panel and repeat the same procedure for the rest. Continue until a subsequent pair of units is detected with $t_{\hat{b}} > -1.65$ and a core group $G_k^*$ can be formed. If no such pair is found then conclude that there are no convergence clubs in the panel. In addition, note that if $k^* = N$ all units converge.

Step 3 *Sieve individuals for club membership*: after the core group is detected, add one of the remaining units at a time and run the log $t$ regression for each. Include the unit in the subgroup if the corresponding test statistic $t_{\hat{b}}$ is greater than some critical value $c^*$.[5] Once all units satisfying the sieve criterion are added, run the log $t$ test for the subgroup. If $t_{\hat{b}} > -1.65$, a convergence club is formed, otherwise raise the critical value $c^*$ - to increase the degree of conservativeness of the test - and repeat the procedure until $t_{\hat{b}} > -1.65$ for the entire group. Then conclude that the group constitutes a convergence club. If no remaining units can be sieved to the initial core group, the group itself constitutes a club.

Step 4 *Recursion and stopping rule*: form a second group from all countries that could not be sieved in Step 3 and run the log $t$ test again. If the whole group converges, conclude that there are two clubs in the panel. If not, repeat Steps 1-3 to determine whether there are any smaller subgroups that form convergence clusters. If no other clubs can be detected, conclude that the remaining countries diverge.

[5] Phillips and Sul (2009) suggest to set the sieve criterion $c^* = 0$ when $T$ is small ($T \leq 50$), whereas for large $T$ the usual critical value $-1.65$ can be employed.

Figure 1: Per capita real output growth between 1970 and 2010 in the EU-21

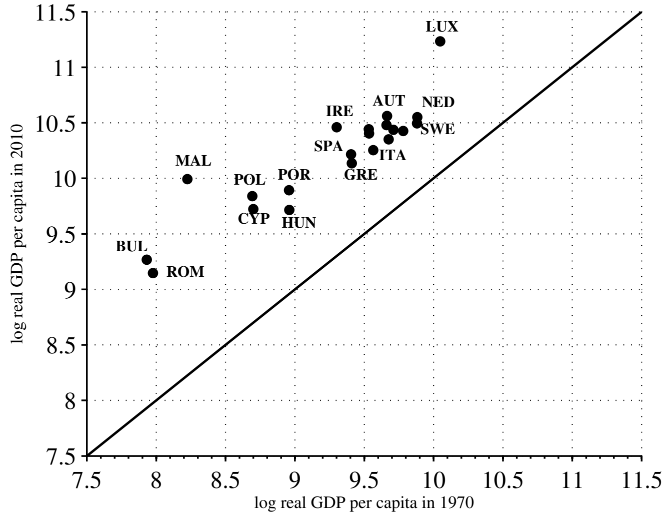
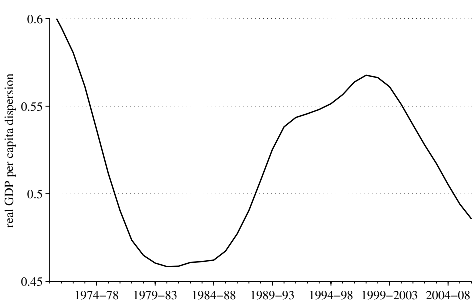
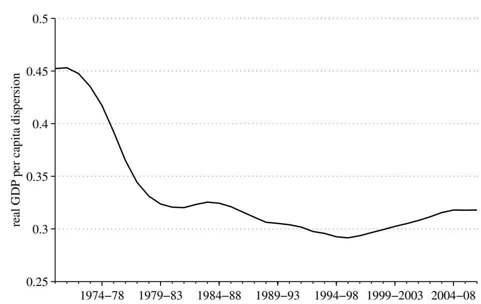



Figure 2: Dispersion of real output per capita between 1970 and 2010 in the EU-21



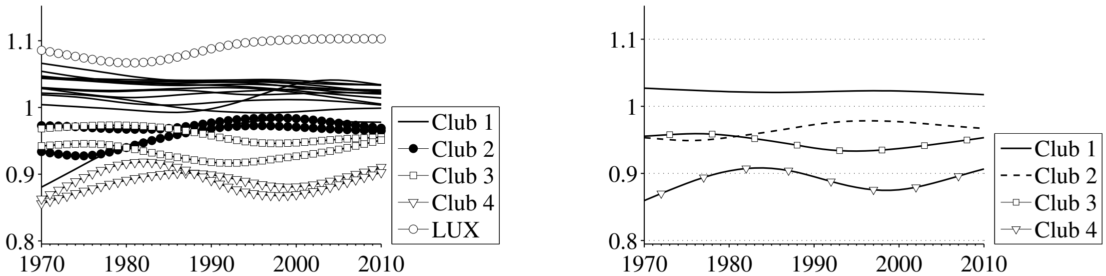

(a) EU-21




(b) EU-21 excluding BUL, HUN, POL, ROM

**Note:** 5-year rolling average of the cross-sectional standard deviation of log real GDP per capita. Sample: EU-21, 1970-2010.

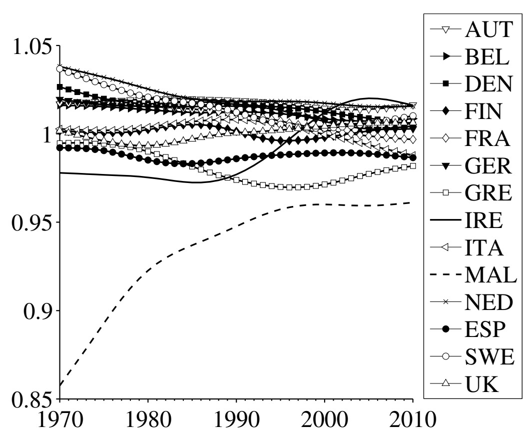
Figure 3: Relative transition paths




(a) $h_{it}$ (b) $\bar{h}_{clubt}$

**Note:** Relative transition curves for EU-21 countries (a). Average relative transition curve for each convergence club (b). Club 1: AUT, BEL, DEN, FIN, FRA, GER, GRE, IRE, ITA, MAL, NED, ESP, SWE, UK. Club 2: CYP, POR. Club 3: HUN, POL. Club 4: BUL, ROM.

Figure 4: Relative transition paths of countries forming club 1 in the EU-21 (1970-2010)




**Note:** Relative transition curves of countries in club 1 for the 1970-2010 sample.

Table 1: Convergence club classification: Baseline results

| Club | Countries | $t_{\hat{b}}$ | $\hat{b}(s.e.)$ | $\hat{\alpha}$ |
|---|---|---|---|---|
| Sample: EU-21, 1970-2010 | | | | |
| Full Sample | | -7.308 | -0.744 (0.102) | -0.372 |
| Club 1 | AUT, BEL, DEN, FIN, FRA, GER, GRE, IRE, ITA, MAL, NED, ESP, SWE, UK | 7.730 | 0.325 (0.042) | 0.163 |
| Club 2 | CYP, POR | 1.333 | 0.557 (0.417) | 0.278 |
| Club 3 | HUN, POL | 4.025 | 2.400 (0.596) | **1.200** |
| Club 4 | BUL, ROM | -0.590 | -0.654 (1.109) | -0.327 |
| Diverging | LUX | | | |
| Sample: EU-27, 1995-2010 | | | | |
| Club | Countries | $t_{\hat{b}}$ | $\hat{b}(s.e.)$ | $\hat{\alpha}$ |
| Full Sample | | -5.937 | -0.437 (0.074) | -0.218 |
| Club 1 | AUT, IRE, NED, SWE | 0.515 | 0.167 (0.325) | 0.084 |
| Club 2 | BEL, DEN, **EST**, FIN, GER, **SLO**, UK | 0.866 | 0.080 (0.093) | 0.040 |
| Club 3 | **CZE**, GRE, ITA, **LAT**, **LIT**, **SVK**, ESP | 0.631 | 0.075 (0.119) | 0.038 |
| Club 4 | BUL, CYP, HUN, MAL, POL, POR | 0.072 | 0.010 (0.142) | 0.005 |
| Diverging | FRA, LUX, ROM | | | |
| Sample: EU-21, 1995-2010 | | | | |
| Club | Countries | $t_{\hat{b}}$ | $\hat{b}(s.e.)$ | $\hat{\alpha}$ |
| Full Sample | | -8.481 | -0.583 (0.069) | -0.291 |
| Club 1 | AUT, IRE, NED, SWE | 0.515 | 0.167 (0.325) | 0.084 |
| Club 2 | BEL, DEN, FIN, GER, UK | 15.090 | 0.918 (0.061) | 0.459 |
| Club 3 | GRE, ITA, ESP | 4.409 | 1.630 (0.370) | 0.815 |
| Club 4 | BUL, CYP, HUN, MAL, POL, POR | 0.072 | 0.010 (0.142) | 0.005 |
| Diverging | FRA, LUX, ROM | | | |

**Note:** We report log($t$) test results for convergence in real GDP per capita for the EU-27 sample for 1995-2010 and for the EU-21 sample for 1995-2010 and 1970-2010. Countries in bold are absent from the EU-21 sample (these are Czech Republic, Estonia, Latvia, Lithuania, Slovakia, and Slovenia). The table contains the speed of convergence ($\hat{\alpha}$), the corresponding coefficient estimates ($\hat{b}$) and $t$-statistics. Newey-West standard errors are given in parentheses. The null hypothesis of convergence is rejected at the 5% level if $t_{\hat{b}} < -1.65$.

Table 2: Convergence club classification: Subsample results

| Sample: EU-21, 1980-2010 | | | | |
|---|---|---|---|---|
| Club | Countries | $t_{\hat{b}}$ | $\hat{b}(s.e.)$ | $\hat{\alpha}$ |
| Full Sample | | -4.704 | -0.539 (0.115) | -0.270 |
| Club 1 | AUT, BEL, DEN, FIN, FRA, GER, GRE IRE, ITA, NED, ESP, SWE, UK | -1.428 | -0.042 (0.029) | -0.021 |
| Club 2 | CYP, HUN, MAL, POL, POR | 1.308 | 0.519 (0.397) | 0.260 |
| Club 3 | BUL, ROM | -0.013 | -0.008 (0.625) | -0.004 |
| Diverging | LUX | | | |
| **Sample: EU-21, 1990-2010** | | | | |
| Club | Countries | $t_{\hat{b}}$ | $\hat{b}(s.e.)$ | $\hat{\alpha}$ |
| Full Sample | | -5.424 | -0.439 (0.081) | -0.219 |
| Club 1 | AUT, BEL, FIN, IRE, NED, SWE, UK | 0.729 | 0.066 (0.090) | 0.033 |
| Club 2 | DEN, FRA, GER, GRE, ITA, POL, ESP | 1.118 | 0.134 (0.120) | 0.067 |
| Club 3 | BUL, CYP, HUN, MAL, POR, ROM | 0.355 | 0.065 (0.184) | 0.033 |
| Diverging | LUX | | | |
| **Sample: EU-27, 2000-2010** | | | | |
| Club | Countries | $t_{\hat{b}}$ | $\hat{b}(s.e.)$ | $\hat{\alpha}$ |
| Full Sample | | -11.348 | -0.663 (0.058) | -0.331 |
| Club 1 | AUT, BEL, IRE, NED, SWE | 1.337 | 0.236 (0.176) | 0.176 |
| Club 2 | DEN, FIN, GER, UK | 3.700 | 1.196 (0.323) | 0.323 |
| Club 3 | **CZE**, FRA, GRE, ITA, **SVK**, **SLO**, ESP | 1.030 | 0.164 (0.159) | 0.159 |
| Club 4 | CYP, **EST**, HUN, **LAT**, **LIT**, MAL, POL, POR | 2.129 | 0.236(0.111) | 0.111 |
| Diverging | BUL, LUX, ROM | | | |

**Note:** We report log($t$) test results for convergence in real GDP per capita for the EU-21 sample for 1980-2010, and 1990-2010 and for the EU-27 sample for 2000-2010. Countries in bold are absent from the EU-21 sample (these are Czech Republic, Estonia, Latvia, Lithuania, Slovakia, and Slovenia). The table contains the speed of convergence ($\hat{\alpha}$), the corresponding coefficient estimates ($\hat{b}$) and $t$-statistics. Newey-West standard errors are given in parentheses. The null hypothesis of convergence is rejected at the 5% level if $t_{\hat{b}} < -1.65$.