DEUTSCHE BUNDESBANK
EUROSYSTEM

Discussion Paper

Deutsche Bundesbank
No 28/2013

The evolution of economic convergence in the European Union

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Internet http://www.bundesbank.de

ISBN 978–3–86558–941–5 (Printversion)
ISBN 978–3–86558–942–2 (Internetversion)

Non-technical summary

Western European countries took major steps toward economic integration in recent decades, including the liberalization of capital and labor markets and the foundation of the European Economic and Monetary Union (EMU). The 1992 Maastricht Treaty set an agenda for macroeconomic convergence prior to entering the monetary union, and the European Commission has put forward numerous policy initiatives aimed at the reduction of regional economic disparities and improving competitiveness among EU members. Meanwhile, in Central and Eastern European countries (CEEC) important political and institutional changes were undertaken in the 1990s. These involved sizable macroeconomic adjustment processes, e.g., transition from planned to market economy, liberalization of prices, and privatization of state assets.

Starting from the hypothesis that closer economic integration between countries may lead to increased real income per capita convergence, this paper investigates convergence in real incomes per person between the 27 current member states of the EU for the time horizon 1970-2010. We employ an empirical convergence test derived from a neoclassical growth model augmented with endogenous technological progress which differs across countries and over time. The model implies that the transition path of each economy toward the steady state level of per capita real income depends on country-specific technological growth rates. This approach enables us to study various types of economic transition behavior, e.g., temporary divergence followed by catching-up and convergence. In addition, the convergence test is applied in an iterative manner in order to identify convergent country groups, or so-called 'convergence clubs'.

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 experienced in recent decades. The main results can be summarized as follows. We do not find overall real income per capita convergence in the EU. This result is robust to any time horizon considered. Instead, we discover country groups that converge to different income levels in the long-run. Regional linkages seem to play a significant role in determining the formation of convergence clubs. Yet, eurozone countries belong to distinct subgroups, thus clustering is not necessarily related to EMU membership. Moreover, 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 income 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. Finally, we observe a South-East vs. North-West division of European economies by the mid-nineties.

Our results draw attention to the lack of growth-enhancing structural reforms in EU countries, 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, policymakers should consider the persistent differences documented in this paper in the light of further enlargement of the European Union.

Nicht-technische Zusammenfassung

In den letzten Jahrzehnten haben die westeuropäischen Länder wichtige Schritte hin zu einer wirtschaftlichen Integration unternommen, wozu auch die Liberalisierung der Kapital- und Arbeitsmärkte sowie die Gründung der Europäischen Wirtschafts- und Währungsunion (WWU) gehören. Der Maastricht-Vertrag von 1992 hat den vor Eintritt in die Währungsunion zu beschreitenden Weg zur makroökonomischen Konvergenz festgelegt, und die Europäische Kommission hat zahlreiche politische Initiativen zur Verringerung regionaler wirtschaftlicher Ungleichheiten und zur Verbesserung der Wettbewerbsfähigkeit zwischen den EU-Mitgliedstaaten angestoßen. Unterdessen kam es in den mittel- und osteuropäischen Ländern (MOEL) in den 1990er-Jahren zu wichtigen politischen und institutionellen Veränderungen. Diese zogen umfangreiche makroökonomische Anpassungsprozesse nach sich, z. B. den Übergang von einer Plan- zu einer Marktwirtschaft, die Freigabe der Preise sowie die Privatisierung von Staatsvermögen.

Ausgehend von der Annahme, dass eine engere wirtschaftliche Integration der Länder zu einer stärkeren Konvergenz der realen Pro-Kopf-Einkommen führen kann, wird im vorliegenden Papier die Konvergenz dieser Realeinkommen in den 27 derzeitigen EU-Mitgliedstaaten für die Zeit von 1970 bis 2010 untersucht. Es wird ein empirischer Konvergenztest angewandt, der aus einem neoklassischen, den endogenen technischen Fortschritt modellierenden Wachstumsmodell, das sich im Zeitverlauf von Land zu Land unterscheidet, abgeleitet wurde. Das Modell lässt erkennen, dass in jeder Volkswirtschaft der Übergang zu einem im langfristigen Gleichgewicht befindlichen realen Pro-Kopf-Einkommen von den länderspezifischen technologischen Wachstumsraten abhängt. Mithilfe dieses Ansatzes lässt sich das unterschiedliche wirtschaftliche Übergangsverhalten untersuchen, beispielsweise vorübergehende Divergenzen, denen Aufholbewegungen und Konvergenz folgen. Zudem wird der Konvergenztest iterativ angewendet, um konvergierende Ländergruppen (die sogenannten Konvergenzclubs) zu identifizieren.

Die Ergebnisse dieser Untersuchung bieten wichtige Erkenntnisse hinsichtlich der wirtschaftlichen Aufholbewegungen in den neuen EU-Mitgliedstaaten vor dem Hintergrund der dort in den letzten Jahrzehnten durchlaufenen institutionellen Veränderungen und makroökonomischen Anpassungsprozesse. Die wichtigsten Ergebnisse können wie folgt zusammengefasst werden: Insgesamt gibt es in der EU keine Konvergenz der realen Pro-Kopf-Einkommen. Dieses Ergebnis ist für jeden betrachteten Zeithorizont robust. Stattdessen gibt es Gruppen von Ländern, die auf lange Sicht hin zu unterschiedlichen Einkommensniveaus konvergieren. Bei der Herausbildung von Konvergenzclubs scheinen regionale Verflechtungen eine besondere Rolle zu spielen. Allerdings gehören die Euro-Länder zu klar erkennbaren Untergruppen, sodass eine Clusterbildung nicht notwendigerweise mit der Zugehörigkeit zur WWU zusammenhängt. Zudem existiert eine klare Trennung zwischen den MOEL und den alten EU-Mitgliedstaaten, die darauf hindeutet, dass – obschon die MOEL beim Realeinkommen höhere Wachstumsraten als der EU-Durchschnitt der zurückliegenden 40 Jahre aufweisen – dieser Aufholprozess nicht ausgereicht hat, um die länderübergreifenden Unterschiede zu beseitigen. Schließlich wird für die europäischen Volkswirtschaften ab Mitte der 1990er-Jahre eine Spaltung in eine südöstliche und eine nordwestliche Zone beobachtet.

Die Ergebnisse der Untersuchung machen deutlich, dass in den EU-Ländern wachstumsfördernde Strukturreformen fehlen, wodurch das Erreichen der realen Konvergenz in

naher Zukunft bedroht wird. Zwar waren die MOEL-Volkswirtschaften seit Beginn der 1990er-Jahre tiefgreifenden Änderungen unterworfen, die auf eine gewisse Konvergenz mit dem Westen hindeuten, aber vor dem Hintergrund einer erneuten Erweiterung der Europäischen Union sollten die politischen Entscheidungsträger die im vorliegenden Papier dokumentierten anhaltenden Unterschiede nicht außer Acht lassen.

Bundesbank Discussion Paper No 28/2013

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 and 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 real income per capita convergence in the EU, however, we identify subgroups that converge to different steady states using an iterative testing procedure. Regional linkages play a significant role in determining the formation of convergence clubs. The empirical evidence suggests a clear separation between the new and old EU member states in the long run.

Keywords: Club convergence; Dynamic factor model; Economic integration; Growth; New member states.

JEL classification: C33; O47.

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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 (see, e.g., Sachs, 1996). Economic convergence constitutes an essential ingredient for common structural and monetary policies, and there are good reasons to expect increased per capita real income 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. This controversy has spurred a wide range of convergence definitions and empirical testing methodologies. From a theoretical perspective, several modifications to the original neoclassical model have been proposed. For example, Parente and Prescott (1994), Barro and Sala-i-Martin (1997), Basu and Weil (1998), Perez-Sebastian (2000), and Howitt and Mayer-Foulkes (2005) replace the assumption of homogeneous technological progress in the neoclassical production function with cross-country technological heterogeneity. Moreover, Azariadis (1996), and Galor (1996) show that 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.

The most widely applied concepts, originating with Baumol (1986), Barro and Sala-i-Martin (1992), and Mankiw, Romer, and Weil (1992), are those of β-*convergence*, understood as a tendency of poorer economies to grow faster than rich ones, and σ-*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*. Finally, 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*). Most empirical methods fall under two categories: cross-section augmented Solow regressions (Barro and Sala-i-Martin, 1992;

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

Mankiw et al., 1992) and time series tests of unit root and cointegration (e.g., Evans and Karras, 1996; Evans, 1998; Siklos, 2010; Kutan and Yigit, 2005; Guetat and Serranito, 2007; Lopez and Papell, 2012). For an overview of the empirical techniques and their potential drawbacks, see Bernard and Durlauf (1996), Binder and Pesaran (1999), and Islam (2003).

This paper investigates whether European economic integration has been accompanied by convergence in per capita real income among old and new members of the EU between 1970 and 2010, in light of the institutional reforms and macroeconomic adjustment processes that took place during the last few decades. In quest for an answer, we test for convergence in a comprehensive sample including all 27 members of the enlarged EU, and we use a non-linear factor model proposed by Phillips and Sul (2007a, b, 2009), which considers a form of panel convergence comparable to the concept of conditional σ-convergence. This approach has several appealing features. From a theoretical point of view, it does not rely on homogeneous technological progress across countries and over time, a limiting assumption widely used in the existing literature. Another considerable advantage of the technique is that, unlike other time series methodologies, it does not require the existence of common stochastic trends, and therefore allows individual transition paths to be transitionally divergent. In addition, 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 identified within the panels under study based on a clustering algorithm developed by Phillips and Sul (2007b). Moreover, the factor model measures both the speed and degree of convergence, which allows us to empirically discriminate between relative and absolute convergence. Finally, Phillips and Sul (2007b) provide a method to trace the transition path of an economy toward the steady-state; hence, we can analyze the diverse shapes of economic transition, including transitional divergence followed by catching-up and convergence.

We provide important insights on the evolution of transition behavior exhibited by the old and new EU member states, and our findings can be summarized as follows. There is no overall real income per capita convergence in the EU-27, and we identify subgroups that converge to different steady-state equilibria. This is a central result, as it highlights that the hypothesis of a "multi-speed" Europe prevails nearly a decade after the eastern enlargement.[2] We do not find a clear relation between clustering and EMU membership in that euro area countries do not form a single convergence club. Instead, convergence clubs are formed mainly on the basis of geographic region, and a separation is found between post-communist economies and the 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 European economies by the mid-

[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., Alesina and Grilli, 1993; von Hagen and Neumann, 1994; Stubb, 1996).

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 summarizes the related literature on economic convergence in the EU. Section 3 offers a brief description of the methodological framework, while the data used in the analysis is presented in Section 4. The main empirical results are contained in Section 5, and finally, Section 6 summarizes our conclusions.

2 Related literature

There is a large body of empirical studies on macroeconomic convergence in Europe.[3] A variety of different methods as well as sample periods have been previously considered, and the literature has so far led to mixed conclusions, the issue of real income convergence among European countries remains thus highly controversial. One strand of the literature analyzes convergence at the regional level. For example, in an early paper, Quah (1996) argues that European regions cannot be viewed in isolation, instead physical location and geographical spillovers account for a considerable amount of regional income distribution dynamics. In a related paper, Sala-i-Martin (1996) analyzes β- and σ-convergence in real income per capita for 90 regions spanning eight European countries (Belgium, Denmark, France, Germany, Italy, the Netherlands, Spain, and the United Kingdom) between 1950-1990. He finds that regional incomes converge at a speed of two percent per year, which is about 5-6 percentage points lower than the speed predicted by the neoclassical growth model, concluding that parameterizations of the model used by economists are inconsistent with the observed evidence. More recently, Canova (2004) finds separation into convergence clubs along the North-South, rich-poor dimension between 1980-1992, using a predictive density approach and data on NUTS2 Western European regions. Similarly, Corrado, Martin, and Weeks (2005) find no overall convergence in per capita real income within the EU-15 plus Norway before the foundation of the EMU. They use time series methods on NUTS1 data between 1975-1999, and show that geographical location as well as socio-demographic characteristics are highly correlated with the formation of convergence clubs. Ramajo, Marquez, Hewings, and Salinas (2008) apply spatial econometric methods to estimate the speed of convergence for a sample of 163 EU regions over the period 1981-1996. Their results provide further evidence in support of separate spatial convergence clubs, where the regions in the EU cohesion-fund countries (Ireland, Greece, Portugal and Spain) are found to converge faster than the rest of the regions.

The aggregate macroeconomic evidence has likewise led to mixed results. Carvalho and Harvey (2005) fit a multivariate structural time series model on real income per capita of 11 euro area countries from 1950 to 1997. They distinguish between two possible convergence clubs, a high-income group (five core economies, Austria, and Finland) and a low-income group (Spain, Greece, and Portugal) that converge in a relative sense. In

[3] In our literature review we focus on papers that analyze real income per capita convergence in Europe. However, there is also a burgeoning literature that we do not survey here, which investigates the nominal effects of the common currency area (see, e.g., Goldberg and Verboven, 2005; Candelon, Kool, Raabe, and Van Veen, 2007; Rogers, 2007; Siklos, 2010; Ehrmann, Fratzscher, Gürkaynak, and Swanson, 2011; Lopez and Papell, 2012; Fischer, 2012).

addition, they find that Ireland diverges from the rest of the countries, following its own growth path. Crespo Cuaresma, Ritzberger-Grünwald, and Silgoner (2008) assess β-convergence in per capita real GDP between 1960-1998 for the EU-15 and show that EU membership significantly improves the degree of economic integration and long-term growth. They further argue that the positive effect of EU membership on growth is relatively higher for poorer countries. Cunado and Perez de Gracia (2006) analyze real convergence in five Central and East European countries (both towards the German and the US economies) in a time series testing framework between 1950-2003. They reject the hypothesis of real convergence for the whole period considered. However, when allowing for structural breaks, they provide evidence in favor of a catch-up process during the 1990s-2003 period for three of the CEEC (Poland, the Czech Republic, and Hungary) towards Germany and only for Poland towards the US economy. Finally, Cavenaile and Dubois (2011) find conditional β-convergence of real income per capita for the EU-27 between 1990-2007. Nevertheless, they show that the rates of convergence of the new entrants from Central and Eastern Europe and of the 15 Western countries significantly differ, pointing to the existence of different groups of convergence in the European Union.

In a series of papers, Kutan and Yigit (2004, 2005, 2007) and Brada, Kutan, and Zhou (2005) analyze convergence in industrial output, prices, monetary aggregates and nominal and real interest rate spreads for the EU-15 and the ten countries that joined the EU in 2004. Kutan and Yigit (2004, 2005) find significant real, but rather weak nominal convergence for most of the new member countries between 1993-2003. In a corresponding work, Brada et al. (2005) present mixed evidence on monetary and real output convergence of the CEEC to the euro area between 1980-2000 and conclude that the benefits of EMU accession are yet limited. In contrast, Kutan and Yigit (2007) study productivity growth and real convergence in the EU over the period 1980-2004 and conclude that economic integration is beneficial for both the founding and the new members in the long run.

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 (2007b). The model has been applied by Bartkowska and Riedl (2012) 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. Further, Fritsche and Kuzin (2011) use the same procedure 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.

3 Methodology

3.1 Theoretical 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 homogeneous technology is assumed, so that regardless of their initial conditions, all countries undergo technological progress

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. Several papers, including Parente and Prescott (1994), Barro and Sala-i-Martin (1997), Basu and Weil (1998), and Howitt and Mayer-Foulkes (2005) have proposed variants of the neoclassical growth model with endogenous technological progress, which differs across countries and over time, such that the transition path of each economy toward the steady state level of per capita real income depends on country-specific technological growth rates.

Following Parente and Prescott (1994), Howitt and Mayer-Foulkes (2005), and Phillips and Sul (2007b), the neoclassical growth model augmented with technological heterogeneity yields the following expression for log per capita real income:

$$y_{it} = y_i^* + (y_{i0} - y_i^*)e^{-\beta_{it}} + a_{it}, \tag{1}$$

where y_{i0} and y_i^* are the initial and steady-state levels of log per capita income, respectively, β_{it} is the time-varying speed of convergence rate, and a_{it} is the log of technology accumulation for economy i at time t. Technology can be decomposed as $a_{it} = a_{i0} + \gamma_{it}a_t$, into initial technology accumulation a_{i0} and the distance of country i from publicly available advanced technology at time t, $\gamma_{it}a_t$. The parameter that measures this distance, γ_{it}, varies over time and across countries. Under the assumption that advanced technology a_t evolves according to a common trend μ_t, the growth model with heterogeneous technology admits a time-varying latent factor representation which can be expressed as:

$$y_{it} = (\frac{y_i^* + (y_{i0} - y_i^*)e^{-\beta_{it}} + a_{i0} + \gamma_{it}a_t}{\mu_t})\mu_t = \delta_{it}\mu_t, \tag{2}$$

see Phillips and Sul (2007b). The factor μ_t is a common steady-state trend function which may follow either a non-stationary stochastic trend with drift or a trend-stationary process, and the country-specific transition path of country i to the common trend μ_t is captured by the time-varying loadings δ_{it}, which absorb any idiosyncratic movements in y_{it}. The loadings represent a form of economic distance of each economy from the common trend, which may arise from differences in technological progress. Therefore, the extent to which individual country characteristics differ across economies will be reflected in the diverse shapes of economic transition encompassed in δ_{it}. As proposed by Phillips and Sul (2007b), the loadings are assumed to follow a semiparametric process of the form:

$$\delta_{it} = \delta_i + \sigma_{it}\xi_{it}, \qquad \sigma_{it} = \frac{\sigma_i}{\log(t)t^{\alpha}}, \qquad \sigma_i > 0, \tag{3}$$

where the idiosyncratic terms ξ_{it} are $i.i.d.(0,1)$ across i but weakly dependent over t. The loadings δ_{it} converge slowly to the constant δ_i as $t \to \infty$ for $\alpha \geq 0$, and scaling by the slowly varying function $\log(t)$ ensures a smooth transition path. Relative income differentials between economies i and j can be written as:

$$y_{it} - y_{jt} = (\delta_{it} - \delta_{jt})\mu_t. \tag{4}$$

Thus, the convergence of all N economies to the common trend μ_t requires that δ_{it} and δ_{jt} converge to some common constant $\delta_i = \delta_j = \delta$ as $t \to \infty$ for $i, j = 1, 2, ..., N$ and $i \neq j$, which implies that country-specific differences are eliminated over the long run.

The parameter α in Equation 3 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 $\alpha < 0$.

3.2 The log(t) convergence test

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

$$h_{it} = \frac{y_{it}}{N^{-1}\sum_{i=1}^{N} y_{it}} = \frac{\delta_{it}}{N^{-1}\sum_{i=1}^{N} \delta_{it}}, \tag{5}$$

which measure the loadings δ_{it} in relation to the panel average at time t, while removing the common steady-state trend μ_t (Phillips and Sul, 2007b). 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 δ_{it} converge to δ, 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:

$$H_t = N^{-1}\sum_{i=1}^{N}(h_{it} - 1)^2 \to 0 \qquad \text{as} \qquad t \to \infty, \tag{6}$$

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 goes to infinity.

Phillips and Sul (2007b) propose a test for economic convergence based on the asymptotic convergence property given in Equation 6. This involves estimating the following regression by ordinary least squares:

$$\log\left(\frac{H_1}{H_t}\right) - 2\log\left(\log(t)\right) = a + b\log(t) + u_t, \tag{7}$$

where $t = [rT], [rT]+1, \ldots, T$, for some fraction $r > 0$.[4] The regression coefficient b provides a scaled estimator of the speed of convergence parameter α, specifically $b =$

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

2α.[5] Thus, the null hypothesis of convergence can be tested by a one-sided t-test of the inequality $\alpha \geq 0$ using the estimate $\hat{b}$ and a heteroscedasticity and autocorrelation consistent (HAC) standard error. The null hypothesis is rejected at 95% significance level if $t_{\hat{b}} < -1.65$. 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 detect all possible subgroups in the panel, based on a set of criteria (see Appendix A 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 6 holds in the long-run. Second, we can distinguish empirically between absolute (level) and relative (growth rate) convergence. In particular, if the estimate $\hat{b} \geq 2$ and accordingly $\hat{\alpha} \geq 1$, this implies absolute convergence within the panel. However, $0 \leq \hat{b} < 2$ indicates only relative convergence, that is, convergence of growth rates over time.[6] Finally, we do not have to rely on any particular assumptions regarding the deterministic or stochastic trending behavior of y_{it} and μ_t.

4 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 income is measured by PPP converted annual real GDP per capita at 2005 constant prices from the Penn World Tables (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 assess some elementary time series properties of the data, focusing our attention on characterizing the long-run behavior. First, 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. In the sequel, we turn to a more formal econometric approach to shed further light on the nature of the data.

[5] See Appendix B in Phillips and Sul (2007b).

[6] Notice that μ_t follows either a stochastic trend with drift or a trend-stationary process, both of which diverge at an $O_p(t)$ rate as t goes to infinity. Hence, if δ_{it} converges at a faster rate than $O_p(t)$ to the constant δ (as determined by the convergence speed α), then relative convergence implies absolute convergence, however, if δ_{it} converges at a slower rate than $O_p(t)$, then relative convergence holds while absolute convergence does not.

4.1 Stylized facts

Our empirical approach hinges upon the idea that European economies differ substantially in terms of the technology used in the production process. Recent studies of total factor productivity (TFP) for the EU-27 show that differences in per capita income between new an old EU members reflect to a large extent differences in aggregate TFP (see Burda and Severgnini, 2009; Marrocu, Paci, and Usai, 2012). According to Marrocu et al. (2012), the technological heterogeneity observed in the EU stems from differences in the production structure and the level and scope of sectoral specialization between Western Europe and the CEEC. They show that over the last decade, the old EU members have specialized their production in knowledge-intensive services and gradually outsourced a large portion of their low-tech manufacturing to the new accession countries. This process is associated with significant differences in TFP levels and growth rates between European countries. Table 1 reports the TFP levels estimated by Marrocu et al. (2012) for 1999 and 2007 and the average TFP growth rates between 1999 and 2007, considering TFP as an index number with the European average set equal to 100. The table provides a good illustration

Table 1: Total factor productivity

	1999	2007	Annual average growth rate %, 1999-2007
EU-15, Norway, Switzerland	115	113	0.48
12 new accession countries	41	50	2.80
Whole Europe	100	100	0.95

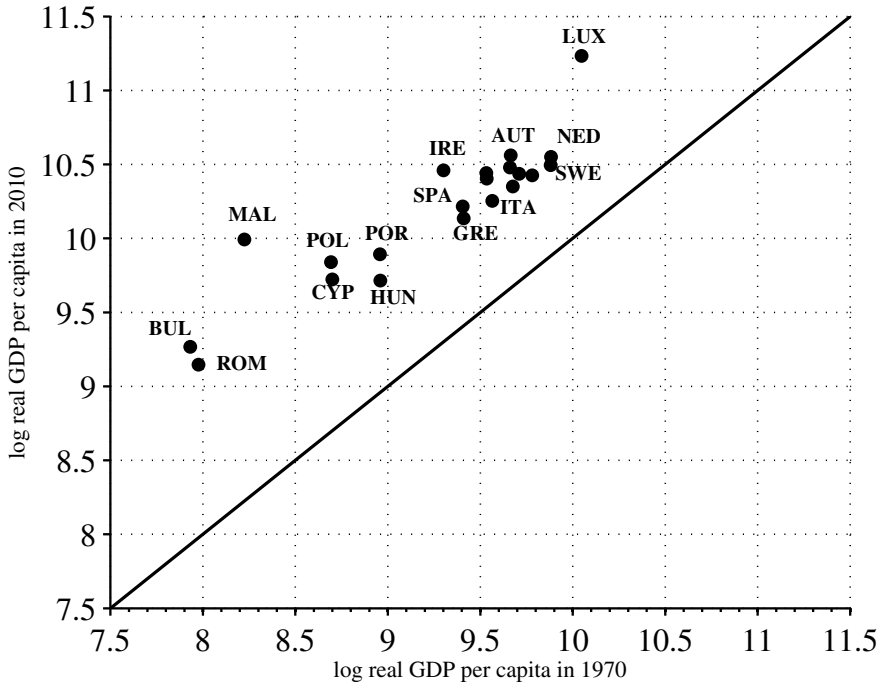
Note: Source: Marrocu et al. (2012), page 8.

of differences in productivity among European economies. In particular, while the new member states are still lagging behind the TFP levels of the old EU members, Marrocu et al. (2012) argue that a convergence process is at work and growth rates have been much higher in CEEC than in the West over the recent decade. This stylized fact underlies our choice for an empirical methodology that accounts for technological heterogeneity in a convergence testing framework.

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 income per person on average.[7] 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

[7]For a detailed comparison, Table 5 in Appendix B shows real per capita income for the initial and last observations of the two samples considered.

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



interesting pattern: while log real income 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 2 illustrates the evolution of cross-sectional real income dispersion over time, it thus reflects a notion of σ-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 are in line with the dispersion dynamics observed.

4.2 Panel unit root tests

Next, we test for the presence of stochastic trends in real per capita income. From a statistical perspective, the presence of a – stochastic or deterministic – trend in the data

Figure 2: Dispersion of real income 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.

is an important assumption underlying the non-linear factor model proposed by Phillips and Sul (2007b). Moreover, evidence for a unit root in the panel also has economic implications. Notably, in the standard Solow (1956) growth model, each economy converges to its unique balanced growth path and any country-specific deviation from the steady state is eventually eliminated. Consequently, deviations of each variable from the average across economies ($y_{it} - \bar{y}_t$) should follow a stationary process (see Evans and Karras, 1996).[8] Therefore, panel tests for a unit root in $y_{it} - \bar{y}_t$ have been widely applied to assess economic convergence in the literature, see e.g. Evans and Karras (1996), Evans (1998), Kutan and Yigit (2005), Guetat and Serranito (2007), and Lopez and Papell (2012).

Given the differences in economic structure and development between our sample countries, we employ two panel unit root tests which are suitable for the analysis of dynamic heterogeneous panels. The first test, proposed by Im, Pesaran, and Shin (2003), is based on pooled univariate augmented Dickey-Fuller (ADF) regressions, with the null hypothesis of a unit root in the panel (no overall economic convergence), against the alternative of stationarity of at least one series (at least one economy converges to the cross-sectional average $\bar{y}_t$). In contrast, the second test, developed by Hadri (2000), has stationarity (overall economic convergence) under the null hypothesis. In addition to considering convergence with respect to the cross-sectional average, we follow Kutan and Yigit (2005) by testing for convergence to a benchmark country, and we opt for Germany as the economy that reflects core EU standards. The test regressions may generally contain an intercept and linear time trend. We include country-specific constants in order to allow for the possibility of relative convergence, consistent with Evans and Karras (1996). Besides, we consider a deterministic trend under the stationarity hypothesis in line with the non-linear factor model, such that the hypothesis of trend-stationarity is tested against stochastic non-stationarity. The lag length in the ADF regressions is chosen based on the Schwartz information criterion. Table 2 reports the test results.

In summary, the unit root tests lead to an unanimous rejection of overall economic

[8] If this process is mean zero, there is level convergence between economies, otherwise each economy will converge to its own parallel growth path, i.e., convergence will occur between growth rates.

Table 2: Panel unit root test results

Sample: EU-21, 1970-2010			
Test	Benchmark	Statistic	P-value
Im-Pesaran-Shin	$\bar{y}_t$	0.523	0.70
Im-Pesaran-Shin	y_{GERt}	1.228	0.89
Hadri	$\bar{y}_t$	7.413	0.00
Hadri	y_{GERt}	6.007	0.00
Sample: EU-27, 1995-2010			
Test	Benchmark	Statistic	P-value
Im-Pesaran-Shin	$\bar{y}_t$	-0.294	0.38
Im-Pesaran-Shin	y_{GERt}	5.608	1.00
Hadri	$\bar{y}_t$	8.376	0.00
Hadri	y_{GERt}	9.198	0.00

Note: Test statistics and p-values corresponding to the panel unit root test proposed by Im et al. (2003) (W-statistics), and the panel stationarity test proposed by Hadri (2000) (Z-statistics). The dependent variable is the time series of each economy relative to a benchmark that is either the panel average ($y_{it} - \bar{y}_t$), or Germany ($y_{it} - y_{GERt}$).

convergence within the EU-27. This result is robust to the choice of the benchmark as well as the employed test statistic. Nevertheless, the presence of stochastic trends in the panel does not necessarily imply that all economies are on diverging growth paths, since the tests do not rule out a situation in which one or more subgroups of countries converge to the respective subgroup-average, while others diverge. Moreover, when technological progress varies over time and in the cross-section, convergence may fail to hold even in the absence of stochastic trends in the data as shown by Phillips and Sul (2009). In the next section we present results from the log(t) approach that tackles precisely these issues.

5 Empirical results

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

Fact 1. There is no overall real income per capita 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 geographic region, and 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.

5.1 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").[9] 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 3.[10] Moreover, 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 δ_{it} converge to a common constant δ, the transition paths h_{it} converge to unity. Other than that, the economic transition behavior can significantly differ across economies.

The null hypothesis of overall economic convergence is rejected at the 5% level in all three panels. 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. 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 Bulgaria and Romania form the weakest convergence club. 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 (see Figure 3/(b)). The average 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.

Regarding our analysis for the EU-27 (and EU-21) sample for 1995-2010, only relative

[9] Phillips and Sul (2007b) show in a series of Monte Carlo experiments that the log(t) test attains good empirical size and power in finite samples, like the ones considered here.

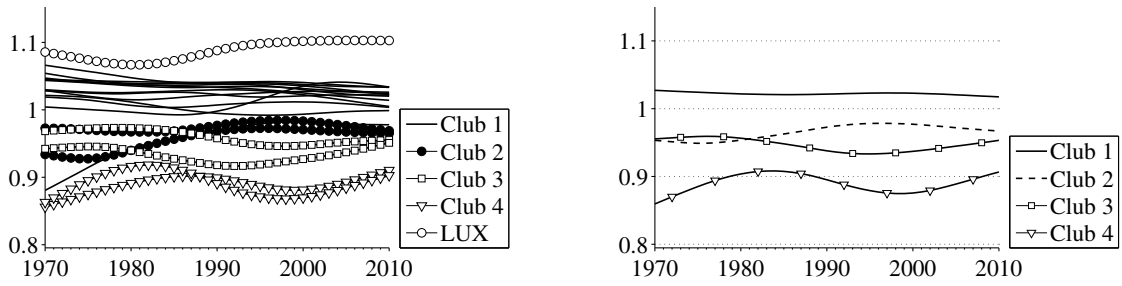
[10] Several recessions occurred during the period under study, such as the first and second oil crisis of the 1970s, the ERM crisis of the 1990s and the global financial and economic crisis of 2007-2009, which are captured in the cyclical component of the series. Yet, our objective is to describe the long-run evolution of the time series, while isolating dynamics at all other frequencies. Thus, we present empirical results from log(t) regressions performed on time series filtered for business cycle fluctuations with the Hodrick and Prescott (1997) filter as suggested by Phillips and Sul (2007b). Filtering the data may have an impact on the empirical results and the choice of the business cycle filter is debatable. Therefore, we performed a series of robustness checks, including estimation on the raw series and on series filtered by a band-pass filter, and our main results have remained unchanged in that we have obtained similar club classification outcomes regardless of the applied technique. In addition, the transition paths estimated from the Hodrick-Prescott filtered series retain a smooth, economically meaningful pattern, which constitutes a clear advantage compared to other methods.

Table 3: Convergence club classification: Baseline results

Sample: EU-21, 1970-2010				
Club	Countries	$t_{\hat{b}}$	$\hat{b}(s.e.)$	$\hat{\alpha}$
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: 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 $t_{\hat{b}} < -1.65$.

Figure 3: Relative transition paths



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

Note: (a) Relative transition curves for EU-21 countries. (b) Average relative transition curve for each convergence club. 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.

convergence is detected, which points to the transitional nature of the period considered, involving economic as well as socio-political changes.[11] 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 3 highlights some interesting results. 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 (see Svejnar, 2002; Adam, Kristan, and Tomsic, 2009). 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.

[11] Notice that the results are robust to omitting the 6 CEEC from the short panel.

5.2 Patterns of economic transition

European countries introduced several policies with the aim of achieving economic integration, including the liberalization of goods, capital, and labor markets, harmonization of tax policy, and the foundation of the EMU. Empirical studies have shown that stronger integration promotes catching-up and convergence in the long run (see, e.g., Crespo Cuaresma et al., 2008). 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 transition paths along which this catching-up can be achieved over time.

Table 4 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 4 also reveals some evidence on the underlying transition across clubs over time. In particular, club 1 from the long panel of Table 3 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),[12] 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.

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

[12] A decline in per capita real income in Germany can be attributed to the reunification in 1990 (see Canova and Ravn, 2000).

Table 4: Convergence club classification: Subsample results

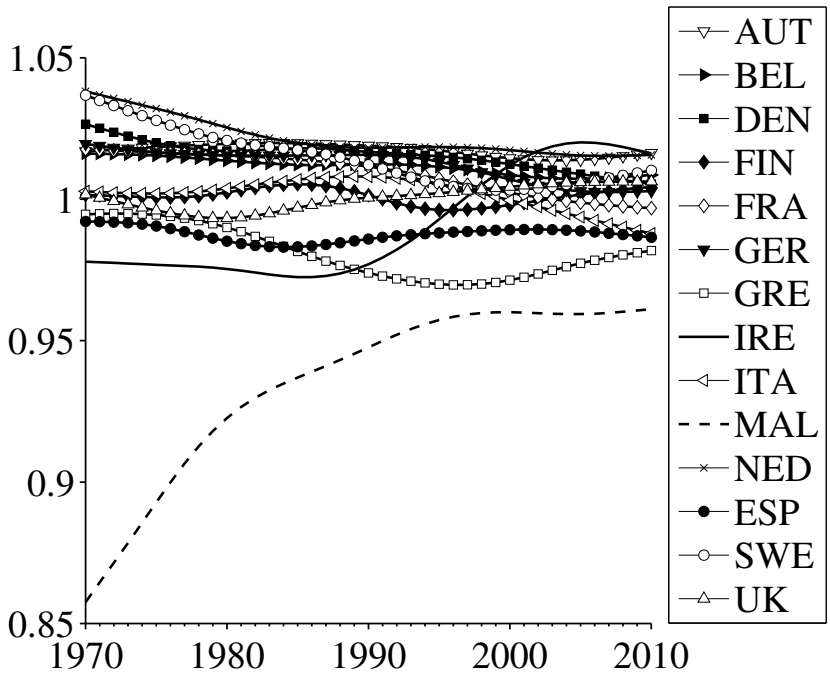
Sample: EU-21, 1980-2010				
Club	Countries	$t_{\hat{b}}$	$\hat{b}(s.e.)$	$\hat{\alpha}$
Full Sample		-4.704	-0.539 (0.115)	-0.270
Club 1	AUT, BEL, DEN, FIN, FRA, GER, GRE IRE, ITA, NED, ESP, SWE, UK	-1.428	-0.042 (0.029)	-0.021
Club 2	CYP, HUN, MAL, POL, POR	1.308	0.519 (0.397)	0.260
Club 3	BUL, ROM	-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: 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 $t_{\hat{b}} < -1.65$.

(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

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.

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.

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 beginning of the 21st 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. The rapid economic growth of Malta until the late nineties was driven by a combination of favorable economic climate and a change in the policy orientation. High domestic and external demand, significant inflows of foreign direct investment, trade liberalization, reduction in income and corporate tax

rates, privatization in sectors including financial services and telecommunications have all contributed to Malta's catching-up process (see Montfort, 2002; Farrugia, 2004). The economy of Ireland was characterized by slow growth, high inflation, and increasing public debt by the early eighties. However, the economic and public sector reforms – facilitated by EU Structural Funds – in the late 1980s contributed to a catch-up and continuous growth over the last 20 years. Besides, Ireland's favorable performance was further stimulated by a rise in consumer spending and a huge inflow of foreign direct investment. This period was also marked by the transformation into an export-orientated economy and well-functioning markets for goods and services (European Commission, 2008).

Other examples of type (i) transition include Austria, Denmark, the Netherlands, and Sweden, while Finland, Greece, Italy, Spain, and the UK are 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.

6 Concluding remarks

In this paper we have analyzed convergence of real income per capita 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 of economies driven by country-specific technological progress between 1970 and 2010. The most appealing feature of this econometric framework is that it allows for heterogeneity and transitional divergence of individual transition paths.

Our main findings can be summarized as follows. First of all, there is no overall real per capita income 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 seem to play a significant role in determining the formation of convergence clubs. Yet, eurozone countries belong to distinct subgroups, thus clustering is not necessarily related to EMU membership. Moreover, 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 income 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. Finally, we observe a South-East vs. North-West division of European economies by the mid-nineties.

Our results draw attention to the lack of growth-enhancing structural reforms in EU countries, 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, policymakers should consider the persistent differences documented in this paper in the light of further enlargement of the European Union.

A Clustering algorithm

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

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^*.[13] 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, i.e. $t_{\hat{b}} > -1.65$, conclude that there are two convergence clubs in the panel. If not, repeat Steps 1-3 on the same group 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.

B Real income per capita in the EU-27

[13] 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.

Table 5: Real income per capita in the EU-27

Country	1970	1995	2010
Luxembourg	23111.007	51367.205	75589.760
Austria	15743.317	29356.418	38585.630
Netherlands	19581.641	29514.920	38189.654
Sweden	19548.956	25667.433	36132.559
Belgium	15679.025	27822.912	35558.524
Ireland	10953.969	22303.426	34902.262
United Kingdom	13798.897	24707.670	34266.968
Germany	16483.607	28473.073	34085.346
Denmark	17688.715	28972.758	33716.831
Finland	13829.095	22967.100	32991.911
France	15935.165	26491.975	31299.300
Italy	14258.224	26155.285	28380.924
Spain	12152.591	21504.875	27332.008
Greece	12209.975	17922.117	25225.516
Slovenia	n.a.	15499.753	24901.650
Czech Republic	n.a.	15063.235	23394.381
Malta	3732.066	16282.593	21851.198
Portugal	7768.615	16340.401	19785.703
Slovakia	n.a.	10252.410	19288.380
Cyprus	5958.584	15553.178	18753.764
Estonia	n.a.	7660.251	17017.475
Poland	6004.309	8785.942	16700.899
Hungary	7778.832	11386.959	16556.196
Lithuania	n.a.	7342.425	14136.059
Latvia	n.a.	6019.117	12425.171
Bulgaria	2784.463	6690.730	10588.961
Romania	2910.499	5620.943	9376.188

Note: PPP-converted GDP per capita at 2005 constant prices (in USD) for the first (1970 for EU-21 and 1995 for EU-27) and last observation (n.a. refers to missing observations). Countries are listed in descending order on the basis of 2010 GDP per capita.

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