Analysing Convergence in Europe Using a Non-linear Single Factor Model[§]

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Abstract

We investigate convergence in European price level, unit labor cost, income, and productivity data over the period of 1960-2006 using the non-linear time-varying coefficients factor model proposed by Phillips and Sul (2007). This approach is extremely flexible on order to model a large number of transition paths to convergence. We find regional clusters in consumer price level data. GDP deflator data and unit labor cost data are far less clustered than CPI data. Income per capita data indicate the existence of three convergence clubs without strong regional linkages; Italy and Germany are not converging to any of those clubs. Total factor productivity data indicate the existence of a small club including fast-growing countries and a club consisting of all other countries.

Keywords: Price level, Income, Productivity, Convergence, Factor Model, European Monetary Union
JEL classification: E31, O47, C32, C33

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1 Introduction

The paper investigates the process of convergence in price indices, income, and total factor productivity in a number of European countries – most of these countries share a common currency now.[1] In the course of the paper, we apply a new and – as the authors convincingly argue – appropriate time-varying econometric framework (Phillips and Sul, 2007) which allows for total or subgroup convergence under a variety of possible transition paths.

The last four decades saw several waves in the process of European integration: in 1968, a tariff union was established, followed by the exchange rate regime nicely labeled as a "snake in the tunnel" in 1972, the forerunner of the European monetary system. The European internal market was initiated in the 1980s and almost completed in 1992. The most remarkable part of integration process however lies in the process of monetary integration, culminating in the creation of a single currency and the euro cash changeover in 2002. Since then, numerous countries in the Middle and East as well as in the South of Europe have joined the club. As Barry Eichengreen argues, there is no comparable predecessor in history, therefore historical analogies to study the effects of European integration have their limits (Eichengreen, 2008). In general, the European integration process and especially the introduction of a common currency has long been seen as an huge step forward in the convergence of income and living conditions (Emerson et al., 1992). Several arguments why a common monetary regime should foster integration and convergence across countries in Europe have been raised. The most prominent refers to individual price and price level convergence: falling trade barriers as well as increased arbitrage possibilities should speed up convergence in individual prices – at least for tradable goods. This process should be reinforced by a stepwise harmonization of financial and product market regulations (Cuaresma et al., 2007): firms from outside the EMU will set prices for the overall union (Devereux et al., 2003). Even if the exact size of the effect is disputed (Rose and Engel, 2002), it is clear that increasing trade (Rose, 2000) should spur individual price convergence further. Diminishing differentials in relative prices do not necessarily imply price level convergence as the demand elasticities might differ. As Cecchetti et al. (2002) show for the U.S., price level convergence is slow across cities due to a large share of non-traded goods (and possibly different weights in consumption baskets across cities). Over the long-run, differences in consumption baskets should however diminish (Corsetti, 2008).[2]

[1] We apply the tests on a panel of EU 15 countries, keeping three countries which are not members of the currency union in the sample as a control group exercise.

[2] Due to a lack of available data, we are not able to investigate this issue more deeply here.

Beyond the much-disputed argument of enforced price level convergence, however, the level of other macroeconomic variables stressed in growth models – e.g. per-capita income or total factor productivity – may be altered by forming a currency union. Alesina and Barro (2002) and Tenreyro and Barro (2007) argue that entering a common currency area enhances trade (Rose, 2000), increases price co-movement across the member states but decreases the co-movement of shocks to real GDP. This line of argumentation is consistent with a view that currency unions in general will lead to greater specialization. Nonetheless, the changes in market-based and policy-supported adjustment mechanisms under the irreversible loss of nominal exchange rate policy instruments with respect to the majority of trading partners may not be easy (Allsopp and Artis, 2003).

However, over the last couple of years, the observed phenomena of persistently large inflation differentials and diverging business cycle movements (Lane, 2006; Eichengreen, 2007; Altissimo et al., 2006; Angeloni and Ehrmann, 2004; Angeloni et al., 2006; Campolmi and Faia, 2006; European Central Bank, 2003) raised some doubts on the importance and strength of convergence tendencies in Europe. To illustrate the argument, we employed the publicly available data from the price level comparison project of Eurostat and calculated coefficients of variation, measured against the average of EU 15, for all EU 15 countries for each year from 1995 to 2005. We plot the coefficients of variation using a Box-Plot for each year, allowing a birds-eye view on the distribution over time.[3] As can be seen from this exercise, we observe a falling price dispersion until 2001, a widening distribution after 2002 and some tendency for a narrowing distribution afterwards. The study presented here tries to add to the literature by using a flexible convergence testing procedure on European data.[4]

Insert figure 1 here.

The question of the empirical convergence testing – initiated by the very influential papers by Barro and Sala-i-Martin (1991) and Barro and Sala-i-Martin (1992) – is typically based on the concepts of β- and σ-convergence. Presence of β-convergence implies that panel members show a mean reverting behavior to a common level. In contrast, σ-convergence measures the reduction of the overall cross-section dispersion of the time series. Islam (2003) argues that β-convergence can be seen as a neccessary but not sufficient condition for σ-convergence – but is useful since it allows for a more

[3]The median is plotted by a line in the center of a box together with shaded areas denoting a significance area, a box denoting the borders to the first and third quartile, and a whisker denoting the inner fences (1.5 times the interquartile range). Data points with a circle denote near outliers, stars indicate a far outlier.

[4]We discuss pros and cons in section **??** in more detail.

appropriate interpretation of results in terms of growth model frameworks. Islam (2003), Durlauf and Quah (1999), and Bernard and Durlauf (1996) discuss several problematic issues in empirical convergence testing. First, from a theoretical perspective, the implications of growth models for the final result of convergence (absolute convergence, convergence "clubs") are not clear. There are different tests concerning the existence of "convergence clubs" (Hobijn and Franses, 2000; Busetti et al., 2006), however these approaches often only test for certain aspects of convergence. Second, the different null hypotheses of the tests are not directly comparable – therefore the results are not easy to interpret.[5] Third, time series approaches as well as the majority of distribution approaches both rely on different and to some extent very specific assumptions. To apply the tests, someone has to consider e.g. stationarity properties. Quite often, the tests assume very specific characteristics of the underlying panel structures – a reason why we observe the development of dynamic panel models and related tests in econometrics to overcome these restrictive assumptions.

A new and encompassing approach for the discussion of the convergence topic was recently proposed by Phillips and Sul (2007), in which the structure of the panel is modelled as a "non-linear, time-varying coefficients factor model". Phillips and Sul (2007) show that the asymptotic properties of convergence are well defined. A regression-based test is proposed, jointly with the development of a clustering procedure. This approach does not depend on stationarity assumptions and is comprehensive because it covers a wide variety of possible transition paths towards convergence (incl. subgroup convergence). Furthermore, one and the same test is applied for the overall test and in the clustering procedure which strengthens methodological coherence.

In this paper we apply the procedure on price level, income and total factor productivity data of EU 15 member countries. The paper is structured as follows: Section 2 explains the theoretical framework, section 3 discusses the test procedures suggested by Phillips and Sul (2007). Sections 4 and 5 present the data and the empirical results for the final observation year 2006, whereas section 6 presents a recursive analysis for the period 1997 to 2006. Finally, section 7 concludes.

[5] E.g. whereas β-convergence is necessary for σ-convergence in most models, this does not hold vice versa.

2 The Non-linear Factor Model and Convergence

2.1 Convergence of Factor Loadings

Over the past few years, factor models became a standard tool in analyzing panel data sets of different types. The instrument provides a very straightforward and appealing approach for modelling a large number of time series in a parsimonious way. The simplest example is a single factor model

$$X_{it} = \delta_i \mu_t + \epsilon_{it}, \tag{1}$$

where X_{it} are observable time series, δ_i and μ_t represent unit specific factor loadings and the common factor respectively, whereas ϵ_{it} stands for unit specific idiosyncratic components. All quantities on the right side of equation (1) are unobservable but in many cases their can be easily estimated by the method of principal components even if the number of time series is large, see for example Bai (2003).

However, without imposing additional non-linear structure, parametric modelling of (1) requires time independent factor loadings and covariance stationary idiosyncratic components, which in turn makes the analysis of converging time series problematic. Phillips and Sul (2007) suggest a different specification of (1) allowing for time variation in factor loadings as follows

$$X_{it} = \delta_{it} \mu_t, \tag{2}$$

where δ_{it} absorbs ϵ_{it}. Furthermore, Phillips and Sul (2007) model the time-varying factor loadings δ_{it} in a semi-parametric form implying non-stationary transitional behavior in the following way

$$\delta_{it} = \delta_i + \sigma_i \xi_{it} L(t)^{-1} t^{-\alpha}, \tag{3}$$

where δ_i is fixed, ξ_{it} is $iid(0, 1)$ across i and weakly dependent over t, and $L(t)$ is a slowly varying function, for example $L(t) = \log t$, so that $L(t) \to \infty$ as $t \to \infty$. Obviously, for all $\alpha \geq 0$ the loadings δ_{it} converge to δ_i, allowing to establish statistical hypothesis testing concerning the convergence or divergence of the observed panel of time series X_{it}. For a particular cross section unit $\alpha \geq 0$ is the appropriate null hypothesis of interest, but convergence testing in the whole panel leads to a null hypothesis in terms of δ_i, namely $H_0 : \delta_{it} \to \delta$ for some δ as $t \to \infty$.

The setup proposed by Phillips and Sul (2007) has several interesting features. First of all, the approach does not rely on any particular assumptions about trend stationarity or stochastic non-stationarity of X_{it} or μ_t. Second, by focusing on the time-varying loadings δ_{it} a lot of information is provided about the individual transition behavior of a particular cross section unit. Moreover, the time-varying factor representation allows empirical modelling of long run equilibria outside of the co-integration framework. For the purpose of analyzing co-movement and convergence within a heterogenous panel, long run equilibria can be defined in relative terms as follows:

$$\lim_{k\to\infty} X_{i,t+k}/X_{j,t+k} = 1 \text{ for all } i \text{ and } j. \tag{4}$$

This in turn implies convergence of the loadings in the time-varying factor representation (2):

$$\lim_{k\to\infty} \delta_{i,t+k} = \delta. \tag{5}$$

2.2 Relative Transition Paths

Estimation of the time-varying factor loadings δ_{it} is a central issue of the approach proposed by Phillips and Sul (2007), since the estimates deliver information about transition behavior of particular panel units. A simple and practical way to extract information about δ_{it} is suggested by using its relative version as follows

$$h_{it} = \frac{X_{it}}{\frac{1}{N}\sum_{i=1}^{N} X_{it}} = \frac{\delta_{it}}{\frac{1}{N}\sum_{i=1}^{N} \delta_{it}}, \tag{6}$$

under the assumption that the panel average $N^{-1}\sum_{i=1}^{N} X_{it}$ is positive in small samples as well as asymptotically, which is satisfied for many relevant economic time series like prices, gross domestic product or other aggregates. The so-called relative transition parameter h_{it} measures δ_{it} in relation to the panel average at time t and still describes the transition path of unit i.

Obviously, if panel units converge and all δ_{it} approach some fixed δ within the limit, then the relative transition parameters h_{it} converge to unity. In this case cross sectional variance of h_{it} vanishes asymptotically, so that

$$\sigma_t^2 = \frac{1}{N}\sum_{i=1} (h_{it} - 1)^2 \to 0 \text{ as } t \to \infty. \tag{7}$$

This property is employed to test the null hypothesis of convergence as well as to group particular panel units into convergence clubs.

However, in many macroeconomic applications the underlying time series often contain business cycle components, which renders the representation (2) inappropriate. Equation (2) can be extended by adding a business cycle component

$$X_{it} = \delta_{it}\mu_t + \kappa_{it}. \tag{8}$$

At this stage some smoothing technique is required to extract the long run component $\delta_{it}\mu_t$. Phillips and Sul (2007) suggest employing the Hodrick-Prescott filter or the coordinate trend filtering method proposed by Phillips

(2005) to estimate the common component $\hat{\theta}_{it} = \widehat{\delta_{it}\mu_t}$, so that the estimated transition coefficients $\hat{h}_{it}$ can be calculated. Under the assumption that estimation errors of $\hat{\theta}_{it}$ are asymptotically dominated by μ_t the consistency of $\hat{h}_{it}$ is easily shown.

3 Empirical Convergence Testing

3.1 The $\log t$ Regression

Phillips and Sul (2007) propose a simple regression-based testing procedure in order to test the null of convergence in the non-linear factor model (2). The test has power against the hypothesis of divergence in terms of different δ_i as well as divergence if $\alpha < 0$, so that $H_0 : \delta_i = \delta$ and $\alpha \geq 0$ is tested against $H_A : \delta_i \neq \delta$ for all i or $\alpha < 0$.

The procedure includes three steps. First, the cross sectional variance ratio H_1/H_t is calculated, where

$$H_t = \frac{1}{N}\sum_{i=1}^{N}(h_{it} - 1)^2 . \tag{9}$$

Second, the following OLS regression is performed:

$$\log\left(\frac{H_1}{H_t}\right) - 2\log L(t) = \hat{a} + \hat{b}\log t + \hat{u}_t, \tag{10}$$

for $t = [rT], [rT]+1, \ldots, T$ with some $r > 0$. $L(t)$ is some slowly varying function, where $L(t) = \log(t+1)$ is the simplest and obvious choice, and $\hat{b} = 2\hat{\alpha}$ is the estimate of α under the null. The initial part of sample $[rT]-1$ is discarded in the regression putting major weight on observations that are typical for large samples. Since both, the limit distribution and the power properties, depend on this discarded sample fraction, the choice of r has an important role. Phillips and Sul (2007) suggest $r = 0.3$ based on their simulation experiments.

The third step consists of applying one sided t test of null $\alpha \geq 0$ using $\hat{b}$ and a HAC standard error. Under some conditions stated in Phillips and Sul (2007) the test statistic $t_{\hat{b}}$ is standard normally distributed asymptotically, so that standard critical values can be employed. The null is rejected for large negative values of $t_{\hat{b}}$.

3.2 Clubs and Clusters

The convergence of all individual loadings δ_{it} to some fixed value δ or their overall divergence, where $\delta_{it} \to \delta_i$ and $\delta_i \neq \delta_j$ for $i \neq j$, are obviously not the unique possible alternatives. There may be one or more converging unit clusters as well as single diverging units in the panel. Identifying these kind of clusters by data driven methods can be of considerable interest for empirical researchers.

Based on the $\log t$ test, Phillips and Sul (2007) propose a simple algorithm to sort panel units into converging subgroups given some critical value. The algorithm consists of four steps, which are shortly illustrated below:

1. Last Observation Ordering: panel units X_{it} are ordered accordingly to the last observation X_{iT}.

2. Core Group Formation: the first k highest units are selected to form the subgroup G_k for some $N > k \geq 2$ and the convergence test statistic $t_{\hat{b}}(k)$ is calculated for each k. Then the core group size k^* is chosen by maximizing $t_{\hat{b}}(k)$ over k under the condition $\min\left\{t_{\hat{b}}(k)\right\} > -1.65$. If $k^* = N$, there are no separate convergence clusters and the panel is convergent. If the condition $\min\left\{t_{\hat{b}}(k)\right\} > -1.65$ does not hold for $k = 2$, then the first unit is dropped and the same procedure is performed for remaining units. If the same condition does not hold for every subsequent pair of units, then there are no convergence clusters in the panel. In all other cases a core group can be detected.

3. Sieve Individuals for Club Membership: after having formed the core group each remaining unit is added separately to the core group and the $\log t$ regression is run. If the corresponding test statistic $t_{\hat{b}}$ exceeds some chosen critical value c, then the unit is included into the current subgroup. The composition of the subgroup is followed by the $\log t$ test for the whole subgroup. If $t_{\hat{b}} > -1.65$, the forming of the subgroup is finished, otherwise the critical value c is raised and the procedure has to be repeated.

4. Stopping Rule: after forming a subgroup of convergent units all remaining units are tested for convergence jointly. If the null is not rejected, there is only one additional convergence subgroup in the panel. In case of rejection steps 1, 2, and 3 are repeated for remaining units. If no other subgroups were detected, it can be concluded that the remaining units are divergent.

The exposed algorithm possesses notable flexibility, since it can identify cluster formations of all possible configurations: overall convergence, overall divergence, converging subgroups and single diverging units.

4 Data

The countries considered for our analysis are the twelve member states of the Euro area (before 2007), furthermore Denmark, Sweden and United Kingdom. We mainly focus on price level convergence. To that end, we use three different panels of time series: consumer price index, GDP deflator and the nominal unit labor costs (index). All data are from the AMECO database of the European Commission, DG ECFIN. The results for consumer prices indices (CPI) and GDP deflator series may differ because CPI data refer to consumer expenditure categories only, whereby in contrast the GDP deflator sums up information from a lot of other expenditure categories as well. Effects like the often-mentioned Balassa-Samuelson effect might impact both price series differently. Nominal unit labor costs have been taken into account because in a class of macroeconomic models – especially since the revival of New “Keynesian” or New “Neoclassical Synthesis” models – price setting is typically modelled as a (stationary) mark-up on unit labor costs. Assuming stable income distribution, price level convergence should be accompanied by unit labor cost convergence.

In addition to price indices, we also test for income convergence – measured by GDP per capita – and productivity convergence – measured by total factor productivity. Both time series again have been extracted from AMECO (see the AMECO homepage for details).

Convergence is by definition a long-run concept. Obviously, reliable results can only be achieved if the time series that are available are long enough to draw statistical inference from – sometimes the cross-section variance helps as well of course. The AMECO database contains all the described time series for a time span from 1960 to present (here 2007), plus the 2 upcoming years which in fact are the commission’s official forecasts. Since we use the Hodrick-Prescott filter for the the investigation, we kept the two data forecasted data points for the application of the filter (due to its nature, the HP filter has an “endpoint problem”, therefore more reliable results can always be expected if the conditional forecast of the time series can be added). However, we did not consider the forecasted data points for the convergence analysis.[6]

Following the suggestion in Phillips and Sul (2007), all data were in-

[6]However, one could argue, that our results are in a sense conditional on the rationality of the EU commission’s forecasts and indeed, this is right. We assume the forecasts to be unbiased and efficient – and the errors are small. This is in line with the EU commissions own results from the evaluation of past forecast errors, see Melander et al. (2007).

dexed in line with their respective starting point (here: 1960) and logarithms are considered. The idea behind this strategy is simply grounded in the fact, that a base year effect diminishes when logarithms of time series are considered depending from the distance to the starting point. Phillips and Sul (2007) propose a trimming of the first part of the sample to keep the base year effect as small as possible. In our case we were not able to trim the time series by 40 observations – as in the original paper – and considered a trimming of 15 years. The main reason was to focus on the convergence in the time span from 1975 to 2007 – a period of institutional progress in the European real and monetary integration process.

In our approach we generally and quite strictly follow Phillips and Sul (2007). The authors employ CPI indices to test for convergence in price levels across U.S. cities. However such a strategy is at the expense of sizeable measurement errors. Strictly speaking, the results have to be checked for robustness by using e.g. international price level comparison studies or purchasing power parity studies. This is true because of the fact, that the choosen base year is of course somewhat arbitrary. In our case, the problem could be worse than in the original paper because of the fact, that the data set under investigation here, covers a shorter time span than the one investigated by Phillips and Sul (2007). Because of the arbitrarily choosen base year and a lack of long enough data sets, it could be possible that measurement errors do not diminish fast enough. On the other hand, international price level comparison projects are a quite recent field even if the efforts by organizations like the OECD, the World Bank and Eurostat are tremendous and reliable data are more or less available for the last 12-15 years only. This in turn makes a long-run analysis quite complicated. Either one can choose data of higher quality with a relatively short time span or longer time series with drawbacks. We follow the arguments in Phillips and Sul (2007) and opted for the strategy outlined there.

5 End-of Sample Convergence Analysis for EU 15 Countries

In the following we present evidence for convergence/ convergence clubs based on the evidence measured at the final year 2007. Later on, we will also turn on recursive estimates to see how the picture might have had changed over time.

5.1 Results for Consumer Price Data

As outlined in section 3.2, we start with the definition of a base entity (last observation ordering) and the core group formation. For all countries we use the log t regression and try to enlarge the group by adding all other individuals separately (sieve individuals for membership). Once a group is established as a convergence group, we proceed by searching for clusters in the rest – always following the steps outlined above. The tables contain all relevant t-statistics from the log t regressions.

In the CPI data set, we identify Greece as the base entity in the panel. The core group test reveals, that Greece and Portugal – in fact two of the fast-growing and catching-up countries – form a first core group. We followed Phillips and Sul (2007) and set $c = 0$. Using this threshold, we are not able to add further countries to this group. We proceed as proposed and exclude both countries from the further investigation. In the next round, we start again with a base country – now Spain is selected because Greece was already excluded in the first round. The core group exercise gives the result, that United Kingdom and Ireland form a core group which was not to be extended using $c = 0$. In the third round we identify two Scandinavian countries – Denmark and Sweden – as another core group, however, the test indicates that we can savely add Finland to this group – which is the missing Scandinavian country for a third cluster. In the forth round and by repeating the procedure, we identify Belgium and Netherlands as members of a fourth cluster. We are neither able to expand this cluster nor find any sign of convergence in the remaining time series – which are threfore classified as “diverging”.

The results indicate, that regional clustering exists. Catching-up countries in the South of Europe (Greece and Portugal), English-speaking countries (United Kingdom and Ireland) as well as the Scandinavian countries in the sample form separate clusters. Also Belgium and the Netherlands form a fourth cluster – and only by leaving out Luxembourg they miss the traditional “Benelux” definition. The fact that Greece and Portugal (and Spain) are found to be the series with the highest value at the sample end (they are ordered first), points to a general problem when using indices instead of direct price level comparison data. The base year effect might not diminish strongly enough over the trimming time span to compensate for that drawback and the overproportional increase of these series (mainly in the 1970s and 1980s) might reflect a catching-up phenomenon.

We also find, that the CPI level data for large countries do not belong to any cluster (this holds for Germany, Italy, France, and Spain). This is true for Austria and Luxemburg as well.

Insert table 1 here.

5.2 Results for GDP Deflator and Unit Labor Cost Data

We discuss results for GDP deflator and unit labor cost data jointly because results and conclusions do not differ very much. Compared to the results for CPI data, however, the results do alter.

First, we turn to the results for the GDP deflator data set. Using the data for Spain as the base entity and starting to identify a core group, we identify a group of five countries – Netherlands, Denmark, Ireland, Austria and Italy. These countries form the first subgroup. The cluster can easily be enlarged to contain data for United Kingdom, Greece and Luxemburg as well. So the majority of countries form a first convergence club. In the next round, the GDP deflator series for Germany is the base series – but the time series does not belong to the second core group. In fact, we stop here as the data for all remaining countries except Germany form a second core group (France, Sweden together with Finland and Belgium). Germany is divergent as it does not belong to any group.

Insert table 2 here.

Second, we had a look at the unit labor cost data set. The results are qualitatively similar. Again, we find that a majority of countries forms a first convergence club and a minority of countries forms a second club. France and Sweden are once more members of the second club – but this time accompanied by Ireland, Greece and Finland. In contrast to the results above, Germany is found to be a member of the first club.

Insert table 3 here.

5.3 Results for GDP per Capita Data

GDP per capita data show stronger clustering compared to GDP deflator or unit labor cost data – but the regional structure is more diverse. The procedure is again applied in the same way as before. A cluster of catching-up countries (Ireland and Portugal) is easily identified. A second cluster contains the Southern countries Greece and Spain but also Luxemburg, Finland, Austria and Belgium. A third cluster is found to be formed by France and some Scandinavian countries. Germany and Italy do not belong to any of the identified clusters.

Insert table 4 here.

5.4 Results for Total Factor Productivity Data

Turning to the analysis of total factor productivity data, the results show quite strong signs of convergence for the majority of countries in the sample. This is a promising result in terms of convergence because throughout the standard growth theory literature differences in productivity explain the bulk of income convergence in the long-run (Weil, 2004).

Starting with a base country – Portugal here – we define again a core group in the first round. The group consists of Portugal and Ireland – two fast-growing countries. In the next step, we again try to add countries to this group. Finland and Spain pass the test. So we end up with a first convergence group – which are mainly catchig-up countries. The procedure is then applied to the rest. Interestingly, all other countries form a convergence club in the first test. So we can stop here with the result, that the majority of countries form a convergence club.

Insert table 5 here.

As an intuitive graphical representation to summarize all results up to here, we use a greyscaled map of Europe, where the respective countries which form a subgroup as well as those countries which do not belong to any subgroup, are colored in the same manner. From the respective figure, the end-of-sample clustering can be distraced quite well.

Insert figure 2 here.

6 Recursive Convergence Analysis: 1997-2006

In this section, we change the focus. The question now becomes: how did convergence pattern change over the last decade of observations?

To illustrate the point it is worthwhile to have a look at the transition curves.

Insert figure 3 here.

As one can easily see, there were quite substantial oscillations over the investigation period. This makes it worthwhile to ask how an assessment of divergence would have looked like if one had a look at different points in the past, and how did the pattern of convergence change over time.

6.1 Recursive Analysis: CPI data

Looking at the transition curve subgraph for CPI data – we used the same style for all lines belonging to the same cluster and labelled the clusters –, there is no indication that the transition to the panel mean changed after 2002. In contrast, the relative position of the subgroups seems to be quite stable.

To shed more light to the issue, we used the convergence/ convergence club test procedure as described above to form respective convergence clusters recursively for each end-of-sample year starting from 1997 to 2006. The results are given in tables 6 to 10

Insert table 6 here.

The results indicate a large degree of divergence in the first years of divergence – up to seven countries are found to be classified as “divergent” – which stabilizes at a high level. It is remarkable that almost all large countries – i.e. Germany, France, Italy, Spain – are found to be divergent for (almost) the full period. Furthermore, it is interesting, that the result shows a clear break pattern between 1999 and 2000 where the number of divergent countries fell from seven to five and regional clusters became stronger. This seems to hold in principle until the end of the sample.

6.2 Recursive Analysis: GDP deflator and unit labor cost data

Looking at the respective transition curves for GDP deflator data, we observe remarkable swings, but this holds for the 1980s and 1990s and therefore this feature seems to be not related to the introduction of the common currency (even if we would allow for announcement effects). A view on the respective transition curves for ULC data reveals that within the first sub-group there is recently a tendency observable to form two separate clusters within the subgroup. According to that Luxembourg, Germany, Austria and Belgium seem to form a separate cluster in the last couple of years. Italy is a member of this subcluster as well but shows some tendency for higher ULC growth.

Insert tables 7 and 8 here.

The results for GDP deflator data as well as unit labour cost data show stronger signs of convergence behavior when compared to CPI data. For GDP deflator data, two convergence clubs emerged over time which remained quite stable until the end of the sample. There are two notable outliers for GDP deflator data, namely Spain and Germany. Both countries were found at the extreme bounds of the distribution with their respective inflation rates over the investigated end-point years – so it is not astonishing that they are found to be divergent (Dullien and Fritsche, 2008). Unit labor cost data show a much less divergent picture – which is a hopeful result in a way. It indicates, that the lasting differences in CPI data are not much driven by different levels in the costs of the factors of production. Possible sources of the divergence in CPI data could be the existence of non-tradable goods on the one hand and service and the fact, that price level convergence is to a significant extent driven by regional factors (e.g. trade and labor market relations, cultural factors, regional development) on the other hand.

6.3 Recursive Analysis: GDP per capita data

Looking at the respective transition curves for GDP per capita delivers that in fact, Greece and Portugal seem to have converged in 2007, the procedure however has clustered Portugal with Ireland for that year. Furthermore, there is evidence, that Belgium could possibly be better counted as a member of the high-income club. Besides this, there is no evidence for large changes in the transition behaviour over the last couple of years.

Insert table 9 here.

The recursive estimation results show that a large cluster of fast-growing, catching-up countries existed in the early part of the sample – which is decreasing in size. The second cluster seems to "absorb" a huge part of the first cluster and forms the largest group at the end of the sample. Furthermore, there is a segregation going on in the high-income group which lead to the splitting of the original third cluster into two sub-clusters.

6.4 Recursive Analysis: total factor productivity data

The transition curves for total factor productivity show that Spain should possibly be counted as a member of the first club and Greece seems to have a tendency to move out of the second club – but again there is no evidence for a dramatic change in transition curves over the last couple of years.

Insert table 10 here.

This result is confirmed by the recursive estimates. TFP data in EU 15 shows the emergence of two quite stable convergence clubs since the early 2000s. This in turn indicates that the integration process has some merits in bringing closer together technological progress and labour productivity development in Europe – which is a good sign for long-run convergence prospects.

7 Conclusion

In the paper, we applied a new convergence test procedure on EU 15 data from 1960 to present. This procedure is quite general and easily applicable and will definitely become a workhorse of convergence testing within the next years. In general, our results reveal interesting stylized facts on the convergence process in Europe.

- Consumer prices suggest clustering along the lines of geographical distance. Countries with common borders as well as strong economic interactions (Benelux, Scandinvian countries, UK and Ireland) show convergence. There is no overall convergence.
- GDP deflator and unit labor cost data indicate two clusters: a large group of about $\frac{2}{3}$ of all countries on the one hand and the rest on the other hand. Sweden and France always belonged to the second cluster, other countries differ in their membership. Spain and Germany are divergent for GDP deflator series. However, there are signs, that possibly a change around the mid 1990s /early 2000s occurred which would speak in favour of a further subclustering. However, so far evidence for such an event is still quite weak.
- GDP per capita data show the existence of three distinctive clusters: catching-up countries, middle-income countries and high-income countries. Italy and Germany seem to be inconclusive about their membership. For the case of Germany surely the reunification has led to a level shift in per-capita income downwards which makes it difficult for the procedure to cope with.
- The highest level of convergence is reached in total factor productivity. There is clear evidence for a catching-up cluster and all other countries seem to form a large cluster. This is the most promising result as it indicates that the long-run prospects for convergence in income and prices can be judged as reasonably good.
- Recursive estimates revealed, that the CPI clustering is quite stable since the majority of countries entered the monetary union. Furthermore, clustering in GDP deflator and unit labor cost data is less pronounced and stable. GDP per capita shows signs of increasing divergence among higher-income countries. Convergence for total factor productivity is high and quite stable. Especially the very last result gives some hope for further progress in long-run convergence.

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Appendix

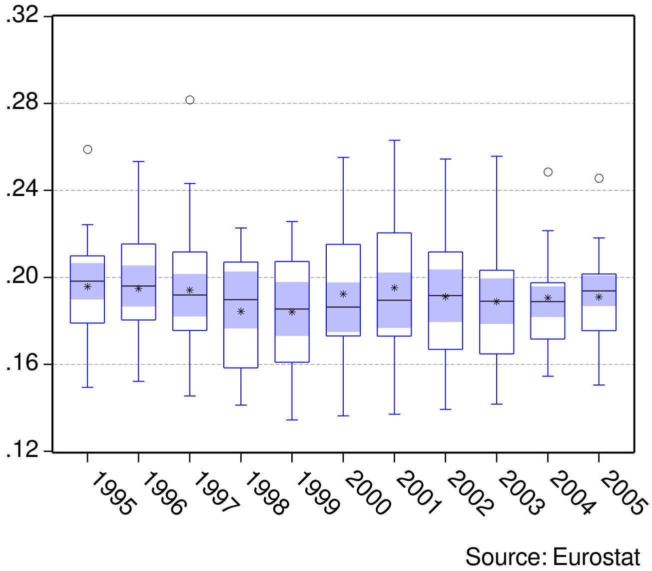


Figure 1: Cross-section distribution of coefficients of variation in EU 15, 1995-2005, measured against EU 15 average, 41 product categories in eaxh country, Source: Eurostat

Table 1: Results for CPI data

Last T order	Name	Step 1	Step 2	Step 1	Step 2	Step 1	Step 2	Step 1	Step 2	Step 1	Classification
1	Greece	**Base**	**Core**								1
2	Portugal	**4.48**	**Core**								1
3	Spain	-94.99	-94.99	Base	-28.79	Base	-351.68	Base	-18.24	Base	divergence
4	Italy		-612.21	-134.72	-15.96	-134.72	-57.46	-134.72	-13.49	-134.72	divergence
5	Ireland		-606.31	**-3.71**	**Core**						2
6	United Kingdom		-34.22	**26.61**	**Core**						2
7	Finland		-53.74	-74.80	-74.80	-23.01	**32.51**				3
8	Denmark		-39.84		-61.21	**-5.66**	**Core**				3
9	Sweden		-43.77		-48.18	**27.80**	**Core**				3
10	France		-68.39		-373.42	-4.03	-4.03	-120.02	-3.19	-120.02	divergence
11	Belgium		-27.95		-44.56		-33.97	**-4.98**	**Core**		4
12	Netherlands		-16.73		-11.96		-7.47	**-0.70**	**Core**		4
13	Luxemburg		-28.22		-34.78		-27.60	-19.34	-19.34	-5.18	divergence
14	Austria		-20.65		-28.10		-11.13		-13.73	-2.69	divergence
15	Germany		-19.60		-25.96		-12.03		-32.82	-16.92	divergence
Test Club							32.51				
Test Convergence Club	-26.61		-18.10		-16.82		-17.23		-18.70		

Table 2: Results for GDP Deflator Data

Last T order	Name	Step 1	Step 2	Step 1	Step 2	Classification
1	Spain	Base	-16.54	Base	-147.83	divergence
2	Netherlands	**-3.78**	**Core**			1
3	Denmark	**1.53**	**Core**			1
4	Ireland	**35.84**	**Core**			1
5	Austria	**20.21**	**Core**			1
6	Italy	**71.80**	**Core**			1
7	Portugal	11.14	**11.14**			1
8	United Kingdom	9.71	**8.03**			1
9	Greece	8.36	**8.91**			1
10	Germany	8.47	-1.62	-65.68	-14.40	divergence
11	Luxemburg	7.20	**8.61**			1
12	Finland	10.93	-12.62	**-28.62**	**Core**	2
13	Belgium	16.41	-242.10	**10.81**	**Core**	2
14	France	27.71	-30.17	**7.84**	**Core**	2
15	Sweden	-17.2594	-16.7756	**13.65**	**Core**	2
Test Club			7.49			
Test Convergence Club	-22.93		-260.66		-65.68	

Table 3: Results for Unit Labor Cost Data

Last T order	Name	Step 1	Step 2	Classification
1	Spain	**Base**	**Core**	1
2	Netherlands	**-1.18**	**Core**	1
3	Denmark	**0.12**	**Core**	1
4	United Kingdom	**6.39**	**Core**	1
5	Portugal	**7.74**	**Core**	1
6	Luxemburg	**6.81**	**Core**	1
7	Austria	**11.18**	**Core**	1
8	Germany	**29.55**	**Core**	1
9	Italy	**21.09**	**Core**	1
10	Belgium	**36.75**	**Core**	1
11	Ireland	-4.04	-4.04	1
12	France		-87.69	2
13	Sweden		-19.40	2
14	Finland		-62.31	2
15	Greece		-0.02	2
Test Club				
Test Convergence Club	48.83		10.19	

Table 4: Results for GDP per Capita Data

Last T order	Name	Step 1	Step 2	Step 1	Step 2*	Step 1	Step 2	Classification
1	Ireland	**Base**	**Core**					1
2	Portugal	**2.08**	**Core**					1
3	Greece	-7.20	-7.20	**Base**	**Core**			2
4	Spain		-27.35	**1.8096**	**Core**			2
5	Luxemburg		-33.84	**49.0264**	**Core**			2
6	Finland		-30.38	**108.344**	**Core**			2
7	Austria		-33.32	38.06	**38.06**			2
8	Italy		-30.52	6.66	7.52	Base	-8.36	divergence
9	Belgium		-26.99	-36.44	**11.75**			2
10	France		-24.16		-5.10	**-12.11**	**Core**	3
11	Denmark		-23.77		-6.37	**102.04**	**Core**	3
12	Netherlands		-86.12		-16.95	8.96	**8.96**	3
13	Sweden		-5841.59		-4.87	2.68	**0.12**	3
14	United Kingdom		-39.85		-11.02	12.02	**171.47**	3
15	Germany		-35.89		-6.03	-13.05	-40.64	divergence
Test Club					-0.14			
Test Convergence Club	-14.00		-18.37		-16.62		-37.91	

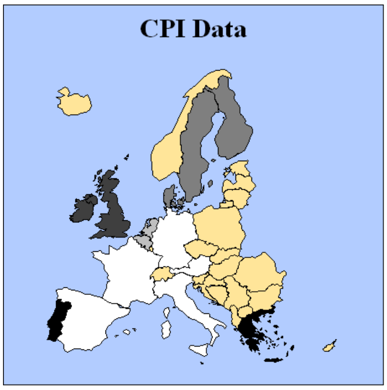
Legend: * We increased c unless the $t_{\hat{b}} > -1.65$, which was achieved at $c = 8$.

Table 5: Results for Total Factor Productivity Data

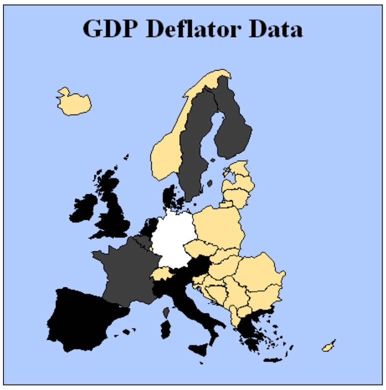
Last T order	Name	Step 1	Step 2	Classification
1	Portugal	**Base**	**Core**	1
2	Ireland	**470.55**	**Core**	1
3	Finland	37.22	**37.22**	1
4	Spain	6.56	**16.39**	1
5	Greece	-9.20	-400.55	2
6	Austria		-5.39	2
7	Italy		-27.03	2
8	Belgium		-22.44	2
9	France		-46.74	2
10	Luxemburg		-2012.43	2
11	Denmark		-9.86	2
12	Germany		-13.07	2
13	United Kingdom		-30.60	2
14	Netherlands		-25.40	2
15	Sweden		-34.73	2
Test Club			6.56	
Test Convergence Club	-268.89		14.70	

Figure 2: Regional Clustering 2006

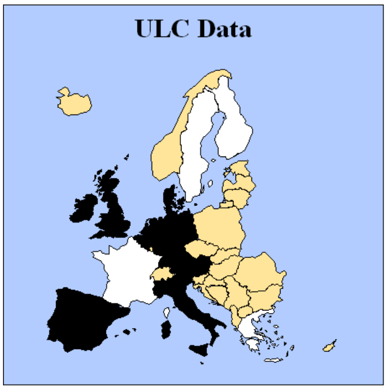
(a) log(CPI)



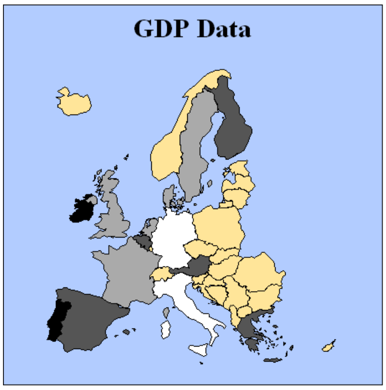
(b) log(Deflator)



(c) log(Unit Labor Costs)



(d) log(GDP)



(e) log(TFP)

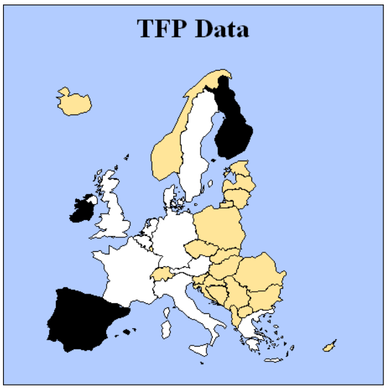
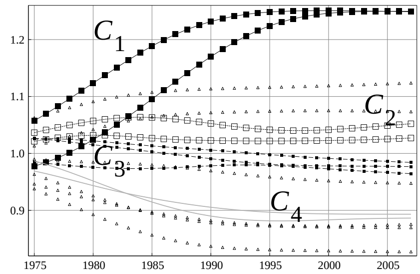
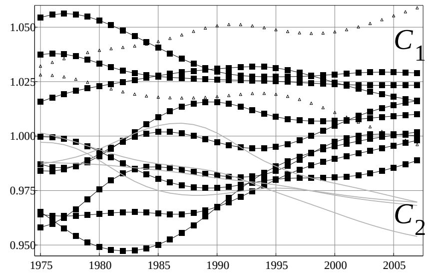


Figure 3: Transition Curves

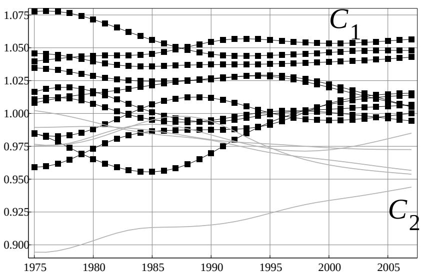
(a) log(CPI)



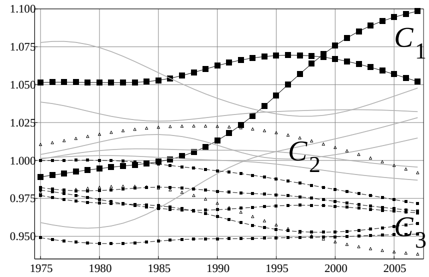
(b) log(Deflator)



(c) log(Unit Labor Costs)



(d) log(GDP)



(e) log(TFP)

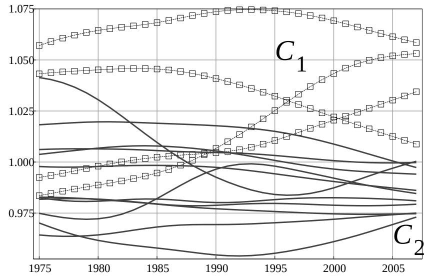


Table 6: Recursive clustering, CPI data

Country	Endpoint 1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Greece	1	1	1	1	1	1	1	1	1	1
Portugal	1	1	1	1	1	1	1	1	1	1
Spain	div	div	div	div	div	div	div	div	div	div
Italy	div	div	div	div	div	div	div	div	div	div
Ireland	2	2	2	2	2	2	2	2	2	2
United Kingdom	2	2	2	2	2	2	2	2	2	2
Finland	div	div	div	3	3	3	3	3	3	3
Denmark	3	div	div	3	3	3	3	3	3	3
Sweden	3	2	2	3	3	3	3	3	3	3
France	2	div	div	div	div	div	div	div	div	div
Belgium	div	div	div	div	div	div	div	4	4	4
Netherlands	3	3	3	4	4	4	4	4	4	4
Luxemburg	3	3	3	4	4	4	4	5	5	div
Austria	3	3	3	4	4	4	4	5	5	div
Germany	div	div	div	div	div	div	div	div	div	div
Sum div.	5	7	7	5	5	5	5	4	4	6

Legend: Numbers indicate membership to the respective convergence cluster; "div" indicates divergence.

Table 7: Recursive clustering, GDP deflator data

	Endpoint 1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Spain	div	1	div	1	div	div	div	div	div	div
Netherlands	1	1	1	1	1	1	1	1	1	1
Denmark	1	1	1	1	1	1	1	1	1	1
Ireland	div	1	2	1	1	1	1	1	1	1
Austria	1	1	1	1	1	1	1	1	1	1
Italy	1	1	1	1	1	1	1	1	1	1
Portugal	1	1	1	1	1	1	1	1	1	1
United Kingdom	2	1	2	1	1	1	1	1	1	1
Greece	1	1	1	1	1	1	1	1	1	1
Germany	1	1	1	1	1	1	div	1	1	div
Luxemburg	2	1	2	1	2	2	2	2	2	1
Finland	2	2	2	1	2	2	2	2	2	2
Belgium	2	2	2	2	2	2	2	2	2	2
France	2	2	3	2	2	2	2	2	2	2
Sweden	div	2	3	2	2	2	2	2	2	2
Sum div.	3	0	1	0	1	1	2	1	1	2

Legend: Numbers indicate membership to the respective convergence cluster; “div” indicates divergence.

Table 8: Recursive clustering, ULC data

	Endpoint 1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Spain	1	1	1	1	1	1	1	1	1	1
Netherlands	1	1	1	1	1	1	1	1	1	1
Denmark	1	1	1	1	1	1	1	1	1	1
United Kingdom	2	1	2	1	1	1	1	1	1	1
Portugal	1	1	1	1	1	1	1	1	1	1
Luxemburg	2	1	3	3	3	3	2	1	1	1
Austria	1	1	1	2	2	2	2	1	1	1
Germany	1	1	2	2	2	2	2	1	1	1
Italy	2	1	3	3	3	3	3	2	1	1
Belgium	2	1	3	3	3	3	2	2	1	1
Ireland	3	2	3	4	4	4	3	2	2	2
France	3	2	3	4	4	4	3	2	2	2
Sweden	3	2	3	4	4	4	3	2	3	3
Finland	3	2	3	4	4	4	3	2	3	3
Greece	3	2	3	4	4	4	3	2	1	1
Sum div.	0	0	0	0	0	0	0	0	0	0

Legend: Numbers indicate membership to the respective convergence cluster; “div” indicates divergence.

Table 9: Recursive clustering, GDP per capita data

	Endpoint 1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Ireland	1	1	1	1	1	1	1	1	1	1
Portugal	1	1	1	1	1	1	1	1	1	1
Greece	1	1	1	1	1	1	1	1	2	2
Spain	1	1	1	1	1	div	div	2	2	2
Luxemburg	1	1	1	1	1	1	1	2	2	2
Finland	1	2	1	2	2	2	2	2	2	2
Austria	1	2	div	2	2	2	2	2	2	2
Italy	1	div	1	1	2	2	2	2	2	2
Belgium	div	2	div	2	div	div	div	div	2	2
France	2	3	2	3	3	3	3	3	3	3
Denmark	2	3	2	3	3	3	3	3	3	3
Netherlands	2	3	2	3	3	3	3	3	3	3
Sweden	3	3	3	3	3	4	4	4	4	4
United Kingdom	3	3	2	3	3	3	3	3	3	3
Germany	3	3	3	3	3	4	4	4	4	4
Sum div.	1	1	2	0	1	2	2	1	0	0

Legend: Numbers indicate membership to the respective convergence cluster; “div” indicates divergence.

Table 10: Recursive clustering, TFP data

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Portugal	1	1	1	1	1	1	1	1	1	1
Ireland	1	1	1	1	1	1	1	1	1	1
Finland	2	2	1	1	1	1	1	1	1	1
Spain	1	1	1	1	1	1	1	1	1	1
Greece	3	3	2	3	2	2	2	2	2	2
Austria	2	2	2	2	2	2	2	2	2	2
Italy	2	2	2	2	2	2	2	2	2	2
Belgium	3	3	2	3	2	2	2	2	2	2
France	3	3	2	3	2	2	2	2	2	2
Luxemburg	2	2	2	2	2	2	2	2	2	2
Denmark	3	3	2	3	2	2	2	2	2	2
Germany	3	3	2	3	2	2	2	2	2	2
United Kingdom	3	3	2	3	2	2	2	2	2	2
Netherlands	3	3	div	3	2	2	2	2	2	2
Sweden	3	3	div	3	2	2	2	2	2	2
Sum div.	0	0	2	0	0	0	0	0	0	0

Legend: Numbers indicate membership to the respective convergence cluster; “div” indicates divergence.