Convergence in Europe in a Non-linear 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 model is extremely flexible to model a large number of transition paths to convergence and allows for convergence clubs as well. We find strong regional clusters in consumer prices. 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 show signs for a the existence of a small club including fast-growing countries and a club consisting of all other countries.

Keywords: Prices, Unit Labour Costs, Income, Total Factor Productivity, European Monetary Union, Convergence, Convergence clubs, Factor Model, Nonlinear Model, Nonlinear Time-Varying Coefficients Factor Model
JEL classification: E31, O47, C32, C33

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1 Introduction

The paper investigates the process of convergence in prices, 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 integration all have enormous drawbacks (Eichengreen, 2008). In general, the European integration process and especially the introduction of a common currency has long been seen as an enormous 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/or convergence across countries in Europe were mentioned in the past. The most prominent of these arguments refers to price convergence: falling trade barriers as well as increased arbitrage possibilities should speed up convergence in prices – at least for tradable goods. This process should be re-inforced by a stepwise harmonization of financial and product market regulations (Cuaresma et al., 2007): firms outside EMU will set prices for the overall union (Devereux et al., 2003). Increasing trade (Rose, 2000) – even if the exact size of the effect is disputed (Rose and Engel, 2002) – should spur price level convergence further. On the other hand, Cecchetti et al. (2002) show that even in the U.S., price level convergence is slow across cities due to a large share of non-traded goods. 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. (Devereux et al., 2003). 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

[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.

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. However, 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). Over the last couple of years the phenomenon of persistently large inflation differentials and diverging business cycle movements were widely discussed (Lane, 2006; Eichengreen, 2007; Altissimo et al., 2006; Angeloni and Ehrmann, 2004; Angeloni et al., 2006; Campolmi and Faia, 2006; European Central Bank, 2003). However, some authors argue, that due to the ongoing process of integration, the traditional arguments in favour of an "optimal currency area" who would postulate inefficiencies in stabilization capabilities when giving up national stabilization policies do not hold anymore. Especially Corsetti (2008) argues that specialization in production and the existence of asymmetric shocks do not make a currency union less efficient in terms of stabilization policy than nationally differentiated policies, mainly because monetary unification may foster the progress in the composition of spending on a national level.

The question of the convergence testing – initiated by the very influential papers by Barro and Sala-i-Martin (1991) and Barro and Sala-i-Martin (1992) – is based on the concept 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 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. Without going too much into detail, the discussion about the appropriateness of empirical methods is inconclusive. 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 for 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.[2] Third, time series approaches as well as the majority of distribution approaches all 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 panel structures

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

– a reason why we observe the development of several generations of dynamic panel models and related tests in the last decades in econometrics to overcome this restrictive assumptions. Especially the idea of cross-section common stochastic trends seems to be very fruitful with respect to the problems outlined here (Bai, 2004).

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 and in the paper a quite simple "log t"-Regression test is proposed, jointly with the development of a convincing clustering procedure. This new approach does not depend on stationarity assumptions and is encompassing 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, section3 discusses the test procedures suggested by Phillips and Sul (2007). Section 4 presents the empirical results and section 5 concludes.

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:

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

where X_{it} are observable time series, δ_i and μ_t unit specific factor loadings and common factor respectively, and ε_{it} 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 form statistical hypothesis concerning 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 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 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 in 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 makes the representation (2) not appropriate. Equation (2) can be extended by adding business cycle component as follows

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

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 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 to test the null of convergence in the non-linear factor model (2). The test has power against 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

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

Second, the following OLS regression is performed:

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

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 the limit distribution and 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 forming 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. After forming the subgroup the $\log t$ test is run for the whole subgroup. If $t_{\hat{b}} > -1.65$, the forming the subgroup is finished, otherwise the critical value c is raised and the procedure is 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 Convergence Analysis for EU 15 countries

4.1 Data

In the following, we present results from the analysis of price level, income and productivity convergence in EU 15 countries. The countries considered here 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 prices, GDP deflator and the nominal unit labor costs. All data are from the AMECO database of the European Commission, DG ECFIN.Consumer prices indices (CPI) as well GDP deflator series are indices which are typically used in price level convergence studies. The results 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 effect both price series differently. Nominal unit labor costs were taken into consideration 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, we test for income convergence – measured by GDP per capita – and productivity convergence – measured by total factor productivity. Both time series again were 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 2006), 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). We did, however, not consider the forecasted data points for the convergence analysis.[3]

Following the suggestion in Phillips and Sul (2007), all data were indexed to their respective starting point (here: 1960) and logarithms are considered. The idea behind this strategy is simply the fact, that a base year effect diminishes when logarithms of time series are considered dependent 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. We considered a trimming of 15 years as the standard case and a trimming of 10 years as a robustness check. In general, we will present the results for the sample

[3]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).

trimmed by the first 15 observations. [4]

4.2 Results for Consumer Price Data

As outlined above, 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 are not able to add further countries to this group and at the same time passing the convergence test regression. Therefore 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. Again, as in the first round, any trial to expand the group according to the statistical criterion of a $t_{\hat{b}}(k) > -1.65$ fails. 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 groups – which is the missing Scandinavian country for a third cluster. In the forth round and by repeating the procedure again, 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 classified as "diverging".

The table shows, that regional clustering existent. Catching-up countries in the South of Europa (Greece and Portugal), Anglosaxon and Celtic countries (United Kingdom and Ireland) as well as all the Scandinavian countries in the sample form cluster separate clusters. Belgium and the Netherlands form a fourth cluster – and only by leaving out Luxembourg as a club member miss the "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. And, indeed, it may well be the case that even the (rather weak) assumption, that the series are equal only at the beginning of the sample (here: in 1960) gives an imprecise picture. The base year effect might not diminish strongly enough over

[4] More detailed results are available from the authors on request.

the trimming time span to compensate for that drawback (we only skip 15 years to keep at least 30 years in the investigation) and the overproportional increase of these series (mainly in the 1970s and 1980s) might well reflect a catching-up in the price levels. We have no conclusive answer to this claims. Direct price-level comparison data are available from Eurostat only for the last 12 years – a time span too short for any convergence analysis in our methodology.

Furthermore we 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.

Looking at the transition curve graphs – see figure 2 – we observe no indication that the transition to the panel mean did change after 2002.

4.3 Results for GDP Deflator and Unit Labor Cost Data

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

First, we present the results for the GDP deflator data set. Using 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 – it does not belong to any group.

Insert table 2 here.

The results from the unit labor cost data set are qualitatively quite similar. Here we find again that a majority of countries forms a first convergence club and a minority of countries forms a second club. France and Sweden are again members of the second club – but this time accompanied by Ireland, Greece and Finland. Germany is found to be a member of the first club this time – in contrast to the results above. When looking at the graphs, it becomes clear that it might well be the case that the first convergence club seems to be splitted into two sub-clusters since the mid 1990s/ early 2000s – a fact which is not (yet) detected by the procedure.

Insert table 3 here.

Looking at the time series graphs and the transition curves – see figures 1 and 2 – we observe that swings in the transition curves can be observed, but this can be seen mainly for the 1980s and 1990s and therefore this tendency seems to be not related to the introduction of the common currency (even if we would allow for announcement effects).

4.4 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 applied 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 and 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.[5]

Insert table 4 here.

4.5 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 results 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

[5]Note, that in the second round, we followed the proposal by Phillips and Sul (2007) and increased the critical value *c* stepwise.

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.

5 Conclusion

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

- Consumer prices show strong 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 show of 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. 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 a 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.

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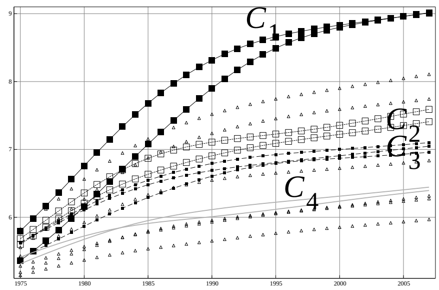
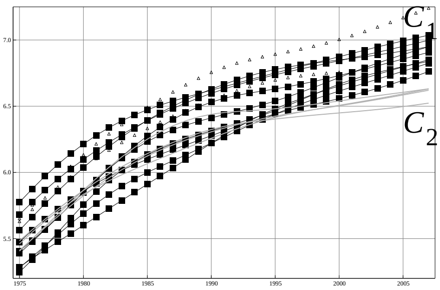
Appendix

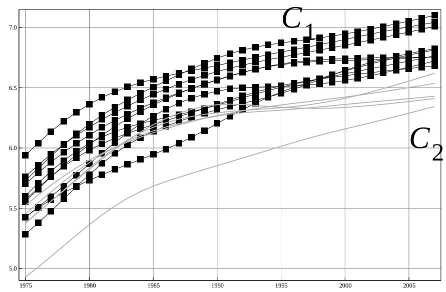
Figure 1: Data



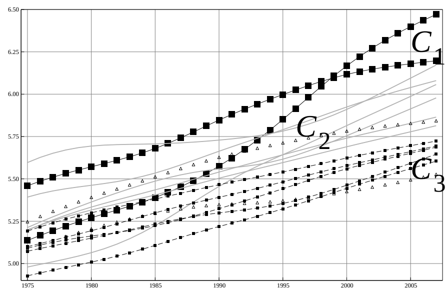
(a) log(CPI)



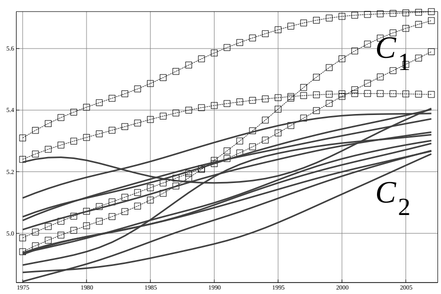
(b) log(Deflator)



(c) log(Unit Labor Costs)



(d) log(GDP)



(e) log(TFP)

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	1
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

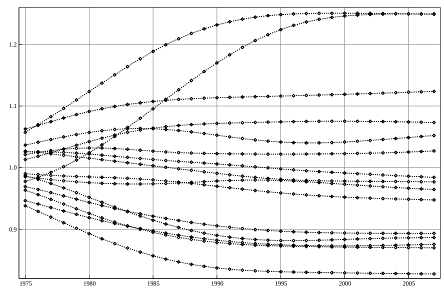
Last T order	Name	Step 1	Step 2	Step 1	Step 2*	Step 1	Step 2	Classification
1	Ireland	**Base**	**Core**					1
2	Portugal	**2.08**	**Core**					1
3	Greece	-7.20	-7.20	**Base**	**Core**			2
4	Spain		-27.35	**1.8096**	**Core**			2
5	Luxemburg		-33.84	**49.0264**	**Core**			2
6	Finland		-30.38	**108.344**	**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 $c = 8$.

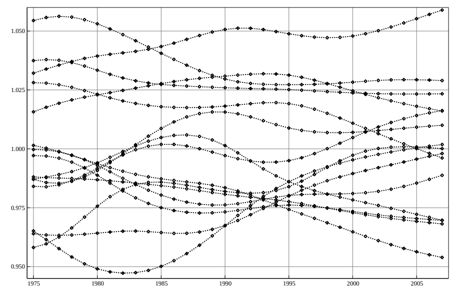
Table 5: Results for Total Factor Productivity Data

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			14.70	

Figure 2: Transition Curves



(a) log(CPI)



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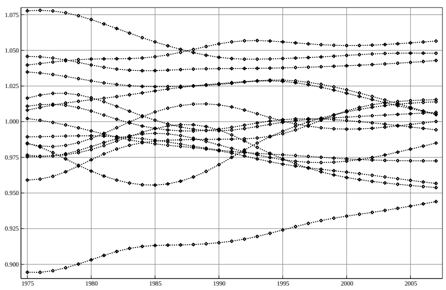
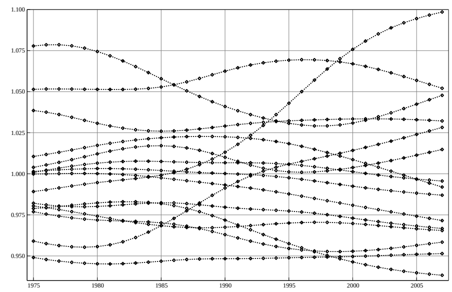
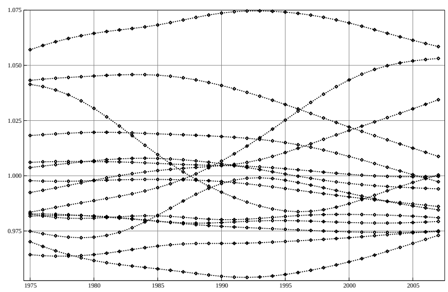


(c) log(Unit Labor Costs)



(d) log(GDP)



(e) log(TFP)