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PRODUCTIVITY IN THE EURO AREA

ANY EVIDENCE OF CONVERGENCE?

by David Sondermann

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Abstract

Sizable prevailing real economic disparities among countries in a currency union potentially involve costs for those countries for which the aggregate policy stance is not appropriate. This paper contributes to the literature by testing for productivity convergence among euro area countries. While no convergence can be found on the aggregate level, selected service sectors and manufacturing sub-industries indicate evidence of convergence. In a search for factors influencing productivity, investments in research and development as well as a high skill level of employees are shown to be beneficial whereas regulations constitute a burden. Consequently, euro area countries should engage in structural reforms where necessary to provide a more competitive environment, eventually facilitating economic convergence.

JEL Classification: C33, O47, J24, L60, L80

Keywords: Productivity, Convergence, Panel Unit Root Test, Manufacturing and Service Sector

Non-Technical Summary

Although similar levels of output are not imperative for a currency union to function, the costs for the individual member states tend to rise when economic disparities are firmly entrenched. This follows from a common policy stance, which will be too loose for some countries and too tight for others (Hallett and Weymark 2002). In order to shed light on convergence in real economic activity in the euro area, productivity developments among member states are analysed.

From a theoretical standpoint we are agnostic about whether or not convergence should be expected. While the neoclassical growth models postulate convergence between higher and lower income countries, the endogenous growth theory allows for scenarios of persistent divergence among countries. Given the European economic and monetary integration since the 1950s, however, capital, labour and knowledge barriers have abated, which might have facilitated convergence. In adition, deregulation of some service sectors and advances in ICT technology could have been supportive.

The convergence hypothesis is transformed into an empirically testable form by making use of recent advances in panel unit root tests. The paper contributes to the literature in that it provides empirical evidence on whether productivity convergence among euro area countries has taken place. Besides the look at the total economy, nine main euro area sectors (and eleven manufacturing sub-sectors) are put to test. In addition to the broad dataset used, this study captures the changes in labour market patterns by drawing on hours worked as input measure in contrast to total people employed as done for most earlier studies.

We find no evidence of productivity convergence among euro area countries at the aggregate level and only little indications of sectoral convergence. While overall manufacturing has not converged, at the lower level of aggregation some manufacturing sub-industries suggest the opposite. Concerning the service sectors, the empirical results indicate convergence in transport and communication, financial services and non-market-services. Test with non PPP-adjusted data, although economically not meaningful, indicate that the convergence in price levels since the 1970s has partly driven the results of PPP-adjusted productivity levels.

The limited evidence of convergence patterns among euro area countries calls for an investigation of possible determinants, which is conducted in a second step. The applied panel analysis, using different industry classifications, suggests the following conclusions. First, higher regulatory burden seems to weigh on productivity growth across euro area countries, especially in the service sector. Second, highly educated employees tend to boost productivity of euro area service sector firms. Third, investment in research and developments is triggering a higher growth of productivity in particular in the manufacturing industries.

Overall, in these three areas structural reforms should be pursued by economic policy makers which enhance euro area countries' performance in productivity and growth. The right direction has already been agreed upon given the Europe 2020 targets, explicitly promoting R&D spending and tertiary education, and the recent Euro-Plus pact which among others should enhance competitiveness of euro area countries.

1 Introduction

Economic convergence in a currency union facilitates the task of the common monetary policy which is ultimately focussed on the aggregate. For the euro area, the Maastricht treaty specifies nominal convergence criteria (e.g. in interest rates and prices) as requirement for participation. Yet nominal convergence among countries is not necessarily implying real convergence.[1] Although similar levels of output are not imperative for a currency union to function, the costs for the individual member states tend to rise when economic disparities are firmly entrenched. This follows from a common policy stance, which will be too loose for some countries and too tight for others (Hallett and Weymark 2002). In order to shed light on convergence in real economic activity in the euro area, productivity developments among member states are analysed. Productivity is the key driver of economic growth in the long run and therefore deserves particular attention.

Theoretical models are split about whether or not convergence between lower and higher income countries should be expected. Following the standard neoclassical growth models (Solow 1956), decreasing returns to capital and complete factor mobility are expected to lead to increasing capital flows towards lower income countries permitting them to catch-up over time. By contrast, endogenous growth theory (Romer 1986; Lucas 1988), which abstracts from the diminishing returns to physical capital assumption, allows for scenarios where divergence persists. Growth in these models (where technological change is determined endogenously) can be sustained through accumulation of human capital and knowledge generation following investments in research and development (R&D) or learning by doing (see Klenow and Rodriquez-Clare 1997 for a survey of the literature). Since the return to (human) capital is not diminishing in these approaches and given a situation of under-investments in R&D or education, some endogenous growth models (e.g. Lucas 1988 or Robelo 1991) postulate no-convergence.

Empirical definitions of convergence tend to follow Barro and Sala-i-Martin's (1991) notion of β- and σ-convergence. The latter refers to decreasing cross-country dispersion in productivity, i.e. that differences in productivity levels become smaller over time. However, σ-convergence does not necessarily imply β-convergence, where countries with initially lower levels of productivity are expected to grow faster than countries already closer to the common steady state. With the European economic and monetary integration initiated by various European treaties (starting with the European Coal and Steel Community in the 1950s) capital, labour and knowledge barriers have significantly abated. This might in particular apply to the manufacturing sectors, where technology transfer within Europe was facilitated. For the service sectors the progress in information and communication technologies and deregulation (in particular of network industries) could have had a positive influence on productivity growth and convergence. Against this backdrop, one could infer that that productivity levels among euro area countries might have converged since the 1970s (our start of the dataset).

[1] While this paper examines real convergence in the euro area, several studies have analysed nominal convergence (see e.g. Busetti et al 2007). In terms of methodology applied, Byrne and Fiess (2010) come closest to our analysis. Overall inflation differentials are found to be quite persistent. Altissimo et al (2009) finds some convergence looking at disaggregate data, while Fritsche and Kuzin (2011) apply non-linearity and find some regional clustering.

However, given the different economic structures, it is unlikely that their steady states are identical (Dullien and Fritsche 2008). This needs to be taken into account when empirically testing the convergence hypothesis.

In contrast to this hypothesis, the overall picture of the existing empirical evidence on productivity convergence is only mixed. This is to a large extent due to the application of different empirical methodologies. Cross-sectional approaches, which have been criticized for producing biased results, tend to find evidence of convergence for a set of European countries or regions (e.g. Gugler and Pfaffmayer 2004; Villaverde and Maza 2008). On the contrary, tests relying on time series or panel frameworks do not confirm these findings (e.g. Galli 1997; Tsionas 2000). Within the already scarce literature of productivity convergence which looks at European country samples, to the best of our knowledge, no study has specifically focused on the euro area.

Hence, this paper contributes to the literature in that it provides empirical evidence on whether productivity convergence among euro area countries has taken place. Besides the look at the total economy, all main euro area sectors (and additionally manufacturing subsectors) are put to test. In addition to the broad dataset used, this study captures the changes in labour market patterns by drawing on hours worked as input measure in contrast to total people employed as done for most earlier studies.[2] Moreover, the paper takes account of the widespread critique of traditional empirical approaches to test convergence and applies recently developed advances in panel unit root tests.

The remainder of the paper is structured as follows. Section 2 introduces the methodology used for convergence testing. Furthermore, it describes the rich dataset and the necessary transformation applied to it. Following some descriptive conclusions about productivity developments across euro area countries, the empirical evidence from panel unit root convergence tests are presented. Section 3 presents empirical evidence of determinants impacting productivity developments in the euro area, before Section 4 offers policy implications and concludes.

2 Testing for Convergence: Methodology, Data and Results

2.1 Methodology

In order to determine whether convergence (of economic variables such as productivity or income) across countries has taken place, researchers usually apply either a cross-sectional or a time series framework. The cross-sectional approach has been applied first by Barro and Sala-i-Martin (1991). They assume that a set of countries is converging if the countries with initially lower levels of income have subsequently experienced higher growth rates compared to countries with higher initial income levels. This hypothesis is estimated in a cross-sectional OLS framework (such as Equation 1), where $\Delta\bar{y}_i$ is the average growth rate of income in country i over a specific time horizon, y_{i0} equals the initial income in country i, and ϵ_i is an

[2]The ratio of hours worked per people employed offers insights into this relationship. For the euro area, it shows, first, an overall decreasing pattern depicting the trend to part-time work. Second, the developments throughout euro area countries are very different, giving rise to the conclusion that a focus on people employed is heavily biasing the results of previous convergence tests (Gardiner et al 2004).

i.i.d. error term. A negative and significant coefficient ß is taken as evidence of convergence. Should the regression specification include a matrix of other country-specific factors (x_{ik} in Equation 1), the convergence is said to be conditional.

$$\Delta \bar{y}_i = \alpha + \beta y_{i0} + \sum_{k=1}^{K} \delta_k x_{ik} + \epsilon_i \tag{1}$$

A similar cross-sectional framework has been applied in several studies succeeding Barro and Sala-i-Martin's seminal analysis by either sticking to the analysis of income convergence or looking at variables determining income such as productivity (e.g. Bernard and Jones 1996a; Carree et al 2002).

However, the cross-sectional approach has been criticised for producing biased results (Quah 1993 and 1997; Bernard and Durlauf 1996; Evans 1998) given that the basic assumption of identical first order properties among countries relies on the prior that x_{ik} is able to control for all cross-country differences. Since the assumption of homogeneity across countries is highly unlikely, the error term tends to be correlated with the initial level of income, which leads to biased estimators. Moreover, the strict cross-sectional perspective ignores the dynamic properties of the data by assuming no modification in the income distribution of the countries under consideration.

As an alternative, time series approaches have been employed to gauge convergence tendencies across countries. The hypothesis is that convergence can be assumed if idiosyncratic country-specific shocks only have temporary effects on productivity (or income) in country A relative to country B (or a country group average). These relative productivity levels would hence follow a stationary process. Without stationarity, however, relative productivity shocks would lead to permanent deviations. This definition of convergence, often referred to as *stochastic convergence* goes back to Carlino and Mills (1993) and Evans and Karras (1996). According to this definition, convergence can be tested in a unit root test framework.

Univariate unit root tests are suitable whenever the convergence process between two countries is under question. In case more countries are considered, panel unit root tests allow for group-wise tests of convergence and they have the advantage of providing a higher power through pooling information across units compared to the univariate variant. Two types of panel unit root tests can in turn be distinguished. The first generation builds on the assumption of cross-sectional independence, while the second generation allows (to different extents) dependence to prevail across units in a panel (see Breitung and Pesaran 2007 for a detailed survey). Examples of first generation panel unit root tests are Levin, Lin and Chu (2002) or Breitung (2000).

$$\Delta y_{it} = \alpha y_{it-1} + \sum_{j=1}^{p_i} \beta_{ij} \Delta y_{it-1} + x_{it}\delta + \epsilon_{it} \tag{2}$$

In these tests the change in output (Δy_{it}) in every country i is regressed on last period's output level, on past output changes and potential exogenous variables, x_{it} (Equation 2). Since α is not modeled to allow for cross-country differences, the null hypothesis of a unit root (i.e. $H_0 : \alpha = 0$) can only be rejected if the cross sectional variables possess the same

degree of mean reversion. Adapted to the convergence tests this implies that countries are assumed to converge at the same pace. A second fairly strict assumption has to hold in the first generation models, given that the cross-sectional units have to be independent from each other. This assumption, however, is unreasonable given that different studies using macroeconomic cross-country data have shown that the time series are contemporaneously correlated (Breitung and Pesaran 2007). Consequently, existing correlation could lead to an overreaction of the null hypothesis of no-convergence. Against the background of these two shortcomings, second generation panel unit root tests have been developed. The panel unit root test suggested by Bai and Ng (2004) and Pesaran (2007) are two such examples. Both tests capture the cross-sectional correlation by a common factor structure.

Pesaran (2007) models the common factor structure by further augmenting the standard augmented Dickey-Fuller (ADF) regression (usually applied for unit root tests) by including cross-sectional averages (the then so-called CADF tests) of lagged levels ($\bar{y}_{t-1}$) and differences ($\Delta\bar{y}_t$) of all time series in the panel (Equation 3). The country specific steady states are captured by the constant (a_i).

$$\Delta y_{it} = a_i + b_i y_{it-1} + c_i \bar{y}_{t-1} + d_i \Delta\bar{y}_t + \epsilon_{it} \tag{3}$$

The panel unit root test is exercised by pooling the individual CADF tests' p-values in the spirit of Im, Pesaran and Shin (2003). Adjusted asymptotic results are tabulated in Pesaran (2007) both for the individual CADF test statistics and their panel unit root counterpart, the cross-sectionally augmented IPS test (CIPS).

In contrast to Pesaran (2007), Bai and Ng (2004) allow for the possibility that non-stationarity can stem from the common component. Bai and Ng (2004) explicitly divide the panel dataset into a common component which is identical across the panel variables and an idiosyncratic component which is country specific. Non-stationarity and hence no-convergence is allowed to be triggered by either (or both) of the components. The panel data (X_{it}) are modeled as a sum of a deterministic component (D_{it}), the common component (a product of the vector of common factors (F_t) and country-specific factor loadings (λ_i) and an error term (e_{it}) which is largely idiosyncratic (Equation 4). Again the deterministic component captures the differences in countries steady states.

$$X_{it} = D_i + \lambda_i^{'} F_t + e_{it} \tag{4}$$

The common component(s) are extracted by applying a principal component analysis (PCA). The number of common components (r) is determined using the information criteria suggested in Bai and Ng (2002). As the components might be integrated, Bai and Ng (2004) suggest standardizing and differencing the data. Applying PCA to the first-differenced data (x_{it}), yields r estimated factors ($\hat{f}_t$) and country-specific factor loadings ($\hat{\lambda}_i$) as well as the estimated residuals ($\hat{z}_{it} = x_{it} - \hat{\lambda}_i^{'}\hat{f}_t$). Once the components have been estimated, both the residuals and the common component are cumulated again to match the integration properties of the original data. Subsequently, the unit root hypothesis is tested separately for both the common and the idiosyncratic component. If there has been only one factor extracted from

the data, a standard ADF regression with a constant is employed, and inference is based on the Dickey Fuller distribution based on the test statistic determined in Bai and Ng (2004).[3] For the idiosyncratic component, i.e. the set of country specific residuals, a Fisher-type pooled ADF test ($ADF_{\hat{e}}(i)$) is applied. Overall, the procedure suggested by Bai and Ng (2004) does not only address the problem of cross-sectional correlation, but also permits to determine whether non-stationarity comes from a pervasive or a variable specific source. In both tests, conditional convergence is allowed for by introducing country-specific deterministic components.

Although, Breitung and Pesaran (2007) acknowledge that allowing the common component to be non-stationary as in Bai and Ng (2004) gains accuracy over Pesaran (2007), they point to the fact that testing for a unit root in the common factor requires a panel dataset with large T.[4] Given the different approaches in modeling the common component, both tests are utilized for the convergence analysis of productivity in the euro area.

2.2 Data and Stylised Facts

Sectoral productivity data are taken from the EU KLEMS (2009) database.[5] EU KLEMS is a project specifically designed to provide a comparable high-quality dataset for growth analysis in the EU. With funding from the EU Commission, the database has been set up by the Groningen Growth and Development Centre, University of Groningen, using mainly national accounts data and input-output-tables. For the purpose of conducting convergence analysis of productivity in the euro area countries, we define productivity as real gross value added per hour worked. This is the commonly used definition also known as *labour productivity*. It should be noted, however, that labour productivity does not only capture productivity gains through the input factor labour, but it covers the main inputs of a production function and its residual, given that it can be broken down into contributions from capital deepening (i.e. capital services per labour input) and the total factor productivity.

Data for value added and hours worked are annually and available from 1970 to 2007 for all EA-12-countries[6]. Apart from the aggregate data for the whole economy, EU KLEMS makes sectoral data available. The analysis is restricted to the main sectors[7] following the NACE 1.1 industry classification. Given the size and, hence, the importance of the manufacturing

[3] In case of multiple common factors extracted Bai and Ng (2004) suggest to use multivariate cointegration methods to check if there is a long-run relationship between the factors. For this, a Johansen trace test could be applied.

[4] Overall, however, the number of observation used in this paper is similar to the simulations in Bai and Ng (2004) and should therefore not pose a limitation.

[5] For a summary overview of the methodology and construction of the EU KLEMS database see O'Mahony and Timmer (2009).

[6] The EA-12 aggregate comprises all countries which joined the euro area until 2001, i.e. Austria, Belgium, Spain, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands and Portugal. The choice of this narrow definition of the euro area stems from limited data available for the remaining euro area countries.

[7] These sectors (with the NACE 1.1 classification in brackets) cover agriculture (A and B), total manufacturing (D), electricity, gas and water (E), construction (F), distributive trades (G), transport, storage and communication (I), financial intermediation (J), real estate, renting and other businesses (K) as well as other non-market services (L to Q). Mining and Quarrying (C) and Hotels and Restaurants (H) are excluded given their negligible size in terms of value added.

sector, a break-down of manufacturing into its eleven sub-industries is analysed in addition.[8]

In order to pursue convergence analysis productivity data are looked at in levels. However, for comparison of the data across countries, gross value added has to be transformed into a single currency unit taking into account (varying) price level differences. In this light, purchasing power parities (PPP) relative to the euro area are applied. They can be utilised for transforming national currency data in two different ways, using current or constant PPPs. The current PPP approach applies time-varying PPPs, thereby incorporating a close map of relative price developments between countries. However, it also includes possible changes in measurement and methodology of PPPs over time. Consequently, after adopting PPPs productivity is expressed in current international prices. The obvious disadvantage is that a change in productivity performance cannot be strictly attributed to an altered relation of input to output variables, but could e.g. also include measurement changes. Hence, for comparisons of shorter time horizons a constant PPP approach is suggested. Following this approach, a base year is selected for which the respective PPP is applied. Productivity comparisons for years before and after the base year are then calculated by extrapolating the base year PPP. This is done by only taking into account the relative price changes in the countries compared to the base year. The clear disadvantage of the latter approach is its strict assumptions of no change in relative prices over time. This assumption is particularly unreasonable for a comparison of nearly forty years as applied in this paper (Schreyer and Koechlin 2002). Therefore, a current PPP approach, using OECD-Eurostat PPPs, is applied.[9]

Productivity developments for the total economy, the nine main sectors and eleven manufacturing sub-sectors are expressed for all countries relative to the euro area average. This relative perspective facilitates the convergence analysis, setting the individual country performance in perspective to the peer group.

[Insert Figure 1 about here]

Turning to the total economy (Figure 1), the PPP-adjusted productivity levels reveal considerable cross-country difference. In 2007, Greece and Portugal were at the end of the spectrum reaching only 67% and 51% of the euro area average performance.

However, Germany, France, the Netherlands and even more so Belgium and Luxembourg outperform their peers when looking at the economy as a whole. Besides the current situation, the dynamics give an interesting insight. While Greece lost considerable grounds for two decades, stabilising at a low level only in the last ten years, Ireland experienced a continuous growth of productivity since the beginning of the dataset. While the Irish economy started in the 1970s at around 67% of the euro area average productivity level, it already exceeded the euro area average in 2002. It is important to reiterate at this point that these developments

[8]The manufacturing sub-industries are food beverage and tobacco (15 and 16), textile leather and footwear (17 to 19), wood and cork (20), pulp, paper, printing and publishing (21 to 22), chemicals, rubber, plastics and fuel (23 to 25), other non-metallic minerals (26), basic and fabricated metals (27 to 28), other machinery (29), electrical and optical equipment (30 to 33), transport equipment (34 to 35) and other manufacturing including recycling (36 to 37).

[9]A necessary simplification has to be applied for the sectoral analysis. Given that OECD-Eurostat PPPs from 1970 on are only available on an aggregate level, sectoral price level differences are assumed to be on average similar to developments for the total economy.

are of course driven by the volume change of value added (and hours worked), but also by the relative price change between countries covered by the PPPs against the euro area average. Especially for Greece and Portugal the change in PPPs since the 1970s is considerable.

Productivity data for the total economy is based on sectoral data, weighted by their share in total value added. Hence, a look at more disaggregate data allows to determine the sectors which are driving the developments described above.

[Insert Table 1 about here]

The most important sectors according to the share in total value added are manufacturing and selected service sectors, such as real estate, distributive trades and non-market services (see Table 1). Productivity levels in the manufacturing sector (Chart 2) reveal that the overall trend found for the total economy seems to a large extent driven by manufacturing industries. While the Irish productivity growth is even stronger than in the total economy, Greece and Portugal fall behind their already weak performance at the aggregate level. For Germany the strong overall position is driven largely by its competitive manufacturing sector. Since the 1970s, productivity levels increased continuously in German manufacturing turning it into the third most productive country in the euro area in this part of the economy, following Ireland and Belgium.

[Insert Figure 2 about here]

A breakdown of the main manufacturing sub-industries gives additional insights. While Belgium's and Ireland's lead in overall manufacturing is predominantly due to their good performance in low-technology industries (Figure 3(a)), the German advantage stems clearly from strong productivity in high-technology industries (Figure 3(b)).[10] For Greece and Portugal a break-down shows that the weak performance is relatively evenly distributed across industries. Most notable is the continuous fall in Greek productivity levels from the 1970 to the 1990s. From mid-1990, however, Greece experienced a rebound in several industries, particularly in the transport equipment and in the chemicals and plastics industries (see Annex 1 for a detailed breakdown of all manufacturing sub-sectors).

[Insert Figure 3 about here]

Turning back to the main sectors, German productivity performance witnessed in the overall manufacturing sector did not recur in the distributive trades sector (Figure 4(a)). By contrast, in Finland, Ireland and France the sector steadily improved competitiveness to above euro area average over time. The developments in Greece show a very pronounced fall in productivity from the relatively most productive sector in all euro area industries in the 1970s to the end of the spectrum in the 2000s.

While developments in the real estate and renting service sector (Figure 4(b)) seem to have been rather balanced across the euro area in the last decade, Germany and Netherlands

[10] According to Götzfried (2005) other machinery, electrical/optical equipment and transport equipment are high-technology (or higher medium-technology) manufacturing industries, whereas the remaining industries are classified to produce low-technology (or lower medium-technology).

lead the league, while Portugal again lingers at the bottom, however, with less distance to other euro area countries compared to other sectors. Interestingly, in the non-market services productivity (Figure 4(c)) grew strongly in Portugal, which together with Luxembourg and Ireland, experienced the strongest growth in productivity compared to the euro area average.[11]

[Insert Figure 4 about here]

Although the look at productivity developments across the main industries already offers interesting insights, clear conclusions on convergence across the euro area seems difficult applying a simple eye-balling approach. At least from the first glance, most sectors have not witnessed a clear-cut convergence process. However, some sectors, such as agriculture, real estate or energy might show more movements of single series towards the euro area average, than other sectors (e.g. manufacturing).

2.3 Results

The panel unit root tests of Bai and Ng (2004)[12] and Pesaran (2007)[13] are applied to the dataset of productivity levels for the total economy, the main industries and the manufacturing sub-industries.

[Insert Table 2 about here]

Both tests indicate that the hypothesis of no-convergence cannot be rejected for the total economy (Table 2), suggesting that productivity developments across euro area economies have not converged. As described in Section 2.1, the Bai and Ng (2004) test distinguishes between non-stationarity, i.e. no convergence, stemming from a common or a variable-specific source. For the total economy the overall indication of no-convergence can be traced back to both factors indicating that not only country specific arguments have to be taken into account. Instead also developments or (e.g. technology) shocks which where commonly experienced have led to more divergence across the euro area. The picture taken from the total economy perspective is confirmed when looking at the main sectors in the euro area.

According to the Bai and Ng test, indication of productivity convergence (i.e. rejected null hypotheses of no-convergence for both the common and the variable-specific component) can only be found for the financial intermediation sector. Half of the remaining sectors show no sign of productivity convergence, whereas for the other half at least one force of convergence has been at play. Taking for example the energy sector, results indicate that some common developments have contributed to a convergence of productivity levels, while some country-specific developments have caused euro area countries' energy sectors not to converge.

[11] Productivity developments in all remaining main sectors are displayed in Annex 2.

[12] The information criterion suggested in Bai and Ng (2002) was applied and in generally favoured one common component in the data. In some cases the information criterion was systematically selecting the maximum number of common components given a priori. This misspecification of the information criterion has already been identified elsewhere in the literature (see Fritsche and Kuzin 2007) and can be largely traced back to the size of the panel. The BIC has been used as alternative.

[13] The lag length has been determined by applying AIC and BIC to the data.

The overall evidence, being that the majority of sectors depict no evidence of convergence, is supported by the Pesaran unit root test. In contrast to the Bai and Ng tests, however, it indicates convergence in three sectors, namely in agriculture, transport and communication, and non-market services. The evidence for the financial sector is not fully confirmed following the Pesaran test. However, the test statistic is close to the critical value necessary to be significant at the 10% level. The general notion that - if at all - productivity convergence can be found in selected service sectors but not in manufacturing is in line with findings from other studies applying time series methodologies (e.g. Bernard and Jones 1996b or Galli 1997). In addition, none of these studies finds evidence of productivity convergence on the aggregate economy level (e.g. Tsionas 2000). In contrast, studies using cross-section regressions tend to find evidence of convergence in total manufacturing (e.g. Gugler and Pfaffmayer 2004 or Carree et al 2002), supporting the earlier stated concern that econometric misspecification could lead to an over-reaction of the no-convergence hypothesis. Notwithstanding this caveat, the findings of no-convergence in the aggregate manufacturing could mask differences in the manufacturing sub-industries. In order to shed light on this assumption, eleven manufacturing sub-sectors are additionally tested for productivity convergence.

[Insert Table 3 about here]

The Bai and Ng test is again more restrictive, finding only evidence of convergence in either the common or the idiosyncratic component of some sub-industries (Table 3). By contrast, the Pesaran test indicates that productivity convergence has taken place in three sub-industries, namely paper, printing and publishing, chemicals and fuels and other manufacturing (incl. recycling). Interestingly, the three sectors are all low-technology industries. Using TFP instead of labour productivity, Garcia Pascual and Westermann (2002) as well look at more disaggregate manufacturing industries in Europe confirming the findings of convergence in chemicals, but not for paper and other manufacturing.

The sample period, 1970-2007, is determined by the data availability of the EU KLEMS dataset. However, given that this study looks at the twelve euro area countries that introduced the euro in 1999[14], it would naturally be interesting to derive insights about any change in convergence patterns before and after the introduction of the common currency. Against this backdrop, the sample is split into two sub-samples, i.e. 1970-1998 and 1999-2007. Since Bai and Ng (2004) explicitly suggest that their panel unit root test may perform inaccurately with very small samples, only the Pesaran (2007) test is applied (see Table 4).[15] While the tests for non-market services indicate strong convergence in both sub-samples, the convergence patterns identified in the full sample for agriculture as well as transport and communication services seem to stem from pre-euro area years only. Moreover, construction and distributive trades seem to have experienced convergence patterns only during the last decade, however, not strong enough to show up in the full sample test. For the distributive trades it seems that innovations in the area of information and telecommunication technologies (e.g. the introduction of bar scanners or in respect of back-office functions[16]) in the late

[14] As stated earlier, Greece is included into this list, although the country joint the euro area only in 2001.

[15] The sub-industries are not shown here, but are available from the author on request.

[16] Owing to the possibility for more careful supply chain and inventory management and the collation of more precise information about customers' purchasing patterns (see ECB Occasional Paper (No. 128/2011)

1980s and early 1990s have substantially increased efficiency and therefore largely contributed to this convergence (van Ark and Piatkowski 2004).

[Insert Table 4 about here]

As elaborated on in Section 2.2 the application of purchasing power parities is necessary to make productivity levels across countries comparable. Although the application is without alternative from an economic point of view, it might be interesting to determine the effect of PPPs on productivity levels.

[Insert Figure 5 about here]

Figure 5 plots the current OECD-Eurostat PPPs from 1970 to 2007. The data suggest that there has been a convergence of price levels over the applied time horizon. Consequently, when applying the PPPs to productivity levels some degree of convergence is likely to stem from the convergence of price levels among euro area countries. In order to test this impact in the panel unit root framework, non-PPP adjusted productivity levels are used for both tests. Indeed, without the impact of PPPs, even most of the few indications of convergence seen before disappear (see Table 5).[17] Although statistically interesting, it is important to remember that non-adjusted PPPs are economically implausible. While bearing this in mind, it is still valid to infer from this exercise that price convergence have had an impact on productivity levels.

[Insert Table 5 about here]

Since there is no other study which uses the second generation unit root tests on productivity convergence in the euro area (or Europe), comparisons with other existing work remains incomplete. Moreover, given the severe shortcomings of the cross-sectional approaches described in Section 2.1, the evidence presented here should only be compared to other studies focussing on time series or panel frameworks. Overall, our results are broadly in line with existing evidence applying a similar approach. In terms of productivity convergence analysis with second generation panel unit root tests, Byrne et al (2009) come closest to this our work, however, examining convergence among Italian regions. Byrne et al (2009) also find little evidence of convergence, which is in particular interesting since one should expect even less boundaries to exist among regions within one country. Galli (1997) uses first generation panel unit root tests to test productivity convergence among 11 EU countries and industries. Although the limitations of first generation tests should be borne in mind, Gali finds similar evidence as we do applying second generation approaches. While no convergence can be found on the aggregate level, some service sectors show tendencies of convergence (e.g. transport and communication as well as non-market services). Tsionas (2000) comes up with similar results, although looking at TFP growth and applies slightly different time series analysis. Examining productivity convergence in 15 EU countries up to 1997, his results confirm that the hypothesis of convergence should not be accepted.

on structural features of the distributive trades).

[17] The same is valid for the sub-industries, not shown here, but available from the author on request.

While our findings are broadly consistent with the overall empirical literature on productivity convergence they are not necessarily consistent with the assumption made upfront. The expected effects from the economic and monetary integration, alleviating the movement of labour and capital throughout the euro area, seem to have been countered by mitigating factors. An explanation which is often put forward (e.g. Bernard and Jones 1996a) centers around the distinction between tradables and non-tradables in the context of increasing specialisation. ICT technologies in the service sectors are easily diffused throughout Europe (such as bar scanner in supermarkets), leading to converging productivity in services offered. On the contrary, comparative advantages and therefore specialisation in the tradeable-good sector could be seen as the reason for countries to have different technologies of production. In contrast to our hypothesis up front, the alleviated diffusion of technology might have enforced this trend. This explanation would be in line with the finding of no convergence in the manufacturing industries which largely produce tradables.

With respect to the service sectors an additional caveat relates to measurement errors in output. In contrast to manufacturing industries, the value added of (some) services is more prone to measurement errors. This relates in particular to the financial services, but to the same extent also to public services. In the first case, the measurement of the output of the banking sector is particularly challenging, for example as banks do not charge explicit fees for many of the services they provide, but rather combine the service payments within the offered interest rates.[18] For public services, difficulties arise from often un-priced output (such as education services) and collectively consumed services (Simpson 2008). In this light, empirical evidence in favour of convergence in services sectors should be interpreted with caution.

3 Determinants of Productivity Growth in Euro Area Countries

The convergence tests above suggest the hypothesis of the neoclassical growth model that countries with lower output or productivity level will catch-up over time cannot be confirmed for the euro area. Despite their economic and monetary union, euro area countries have experienced different productivity developments in most sectors, indicating the presence of factors at work which impact productivity growth systematically and which are - at least partly - susceptible to policy measures. In order to map such factors for the euro area, productivity growth is regressed on a set of explanatory variables in a panel context.

Possible determinants of productivity growth are chosen as to match three broader categories - innovation capacity, human resource impact and regulation.[19] First, the common presumption that innovation is positively impacting productivity and hence economic growth can - among others - be found in the early endogenous growth models. For example Romer (1990, 1994) assumes that the growth of technological knowledge is a function of growth in the number of workers employed in knowledge-producing activities. In an attempt to trace

[18] See Burgess (2011) for a discussion on the topic.

[19] The data are taken from the OECD statistics database if not stated otherwise. Moreover, the data are available on sector level, except the regulatory indicator and the data on research and development.

innovation efforts as well as possible, two different proxies are selected. First, innovations are promoted by investments of firms and government in research and development (R&D). The gross domestic expenditure on R&D is therefore an obvious empirical counterpart. Second, existing technology can be diffused by trade and financial linkages across firms. Foreign direct investment inflows are taken to proxy for international technology infusion in the different sectors. In addition, one specific group of innovations led to important technologies disseminated across companies in nearly all sectors - the information and communication technologies (ICT). These technologies are assumed to have positively impacted the productivity of firms (Van Ark and Inklaar 2005). The share of ICT capital in total capital services (taken from the EU KLEMS database) is hence taken as proxy for the impact of ICT technology on productivity.

Second, the skill level of the human resource factor is supposed to have a positive impact on productivity (Barro 2001). The better educated and the higher qualified the workers employed, the higher is their expected productivity. This argument is included in the empirical exercise through the share of high-skilled worker in total people employed (also taken from the EU KLEMS database).

Third, productivity is said to be higher in markets where the government tends to regulate less (Nicoletti et al 2000). In such an environment, firms are forced to remain competitive through efficient utilisation of their input factors. The regulatory burden is measured through the regulatory indicators constructed by the Fraser Institute.

For the empirical analysis productivity growth is regressed on the explanatory variables in a panel fixed-effects model including time-, country- and sector-fixed effects.[20] The variables are assumed to impact productivity with a lag of one year and are expressed in log differences to account for the non-stationarity of the series. Three different sets of specifications are tested. First, the total economy perspective is taken by looking at productivity determinants for the full set of industries. Second, the manufacturing sub-set of industries, and third, the service sectors are separately analysed.

[Insert Table 6 about here]

For the full set of euro area industries the evidence suggests that first, the innovation capacity, and second, information and communication technology are positively impacting productivity growth (Table 6). The expenditure of R&D and the share of capital which is ICT-related exert a positive impact on productivity, while the regulatory burden, technology infusion via FDI and the share of high-skilled worker are not significant. However, when the large set of naturally heterogeneous industries is separated into manufacturing and service sectors a different picture emerges.

The manufacturing industries, which tend to have stronger utilisation of technology-related or more generally capital-related input factors drive the total economy sensitivity towards R&D spending and ICT capital, as can be seen from the coefficients which are twice as large. Both the positive impact of R&D (e.g. Griffith et al 2004) and ICT capital (e.g. Belorgey et al 2006) is confirmed by studies using other datasets. By contrast, for the set

[20] A hausman test suggests that random effects estimator would be inconsistent (see Table 6).

of service sectors no significant impact of R&D and ICT capital can be claimed. In these sectors, however, a significantly negative impact stems from regulatory burden while a positive impact from higher educated labour force is found. These findings are largely in line with the literature which marks the service sector as especially exposed to regulation (e.g. Baily 1993). Sectors such as telecommunication and energy tend to be more regulated than manufacturing industries given their network industry character (Arnold et al 2008). However, governments have re-regulated these natural monopolies in most euro area countries in the past two decades, therewith enforcing competition and productivity gains. In addition, studies specifically focusing on euro area distributive trades have long stated that the high regulatory burden for most European companies is negatively impacting productivity growth (Boylaud 2000).

The impact of FDI inflows in manufacturing exerts a negative impact on productivity growth. Although it should be stressed that the coefficient is virtually zero, the negative sign seems counterintuitive at the first glance, given that FDI is often seen as source of technology infusion from abroad. Although surprising at the first glance, the negative relation is in line with the evidence presented in several studies (e.g. Van Pottelsberghe de la Potterie and Lichtenberg 2001; Aitken and Harrison 1999; Konings 2000) which find that a negative competition effect could eventually outweigh the positive technology effect, especially for countries with already high technology development. Inward FDI could distort the local market equilibrium, force domestic companies to produce less output, which pushes them up their average cost curve[21] and reduces their productivity performance.

4 Conclusions and Policy Implications

Prevailing disparities in real economic developments tend to bring about costs for countries in a currency union the further they are away from the aggregate or average view that common policy stance takes. In order to gauge whether economic disparities have vanished over time among euro area countries, this paper has presented empirical evidence on labour productivity convergence. Overall, no evidence of convergence at the aggregate level and only little indications of sectoral convergence have been found. While overall manufacturing has not converged at the lower level of aggregation, for some manufacturing sub-industries the opposite is suggested. Concerning the service sectors, panel unit root tests indicate convergence patterns in transport and communication, financial services and non-market-services. Also productivity developments in agriculture across the euro area seem to become increasingly aligned. However, robustness checks reveal that part of the convergence tendencies has been driven by the necessary PPP-adjustment applied to the data. Overall, the evidence on productivity convergence is broadly in line with the existing literature.

From the search for determinants driving productivity performance in the euro area three conclusions can be drawn: First, the regulatory burden seems to weigh on productivity growth across euro area countries, especially in the service industries. Second, investment in research and developments is triggering a higher growth of productivity. Third, highly

[21] Provided the cost curve is downward sloping, i.e. involving a substantial amount of fixed costs.

educated employees tend to boost the productivity of euro area firms. In the light of these results policy actions to improve productivity across euro area countries should target these three areas in order to enhance euro area countries' performance in productivity and growth.

The right direction has already been agreed upon given the Europe 2020 targets, explicitly promoting R&D spending and tertiary education, and the recent Euro-Plus pact which among others should enhance competitiveness of euro area countries.

The perspective of this study is the overall convergence tendency in productivity across the euro area. A further path, which future research should proceed, concerns the identification of convergence clubs within the euro area both for the total economy and the different sectors. Structural determinants of productivity growth could then be elaborated on in a more country-specific way. This would allow to give tailored policy advice to individual countries in addition to the broader suggestions offered in this paper for the euro area as a whole.

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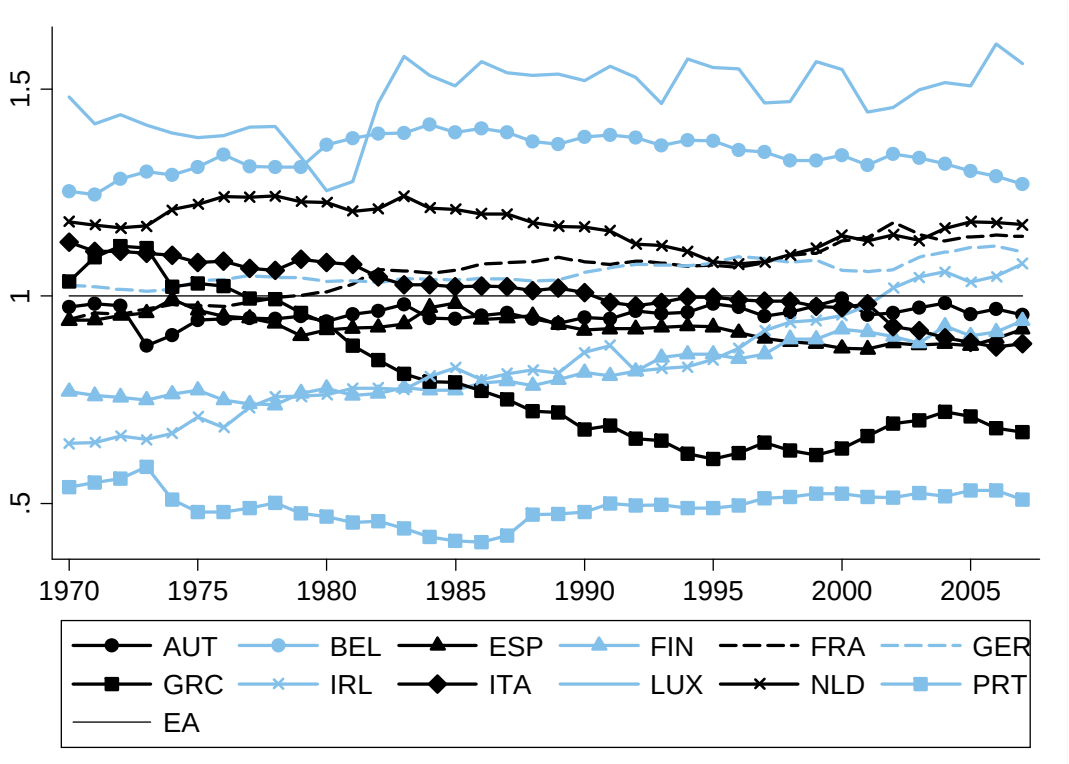
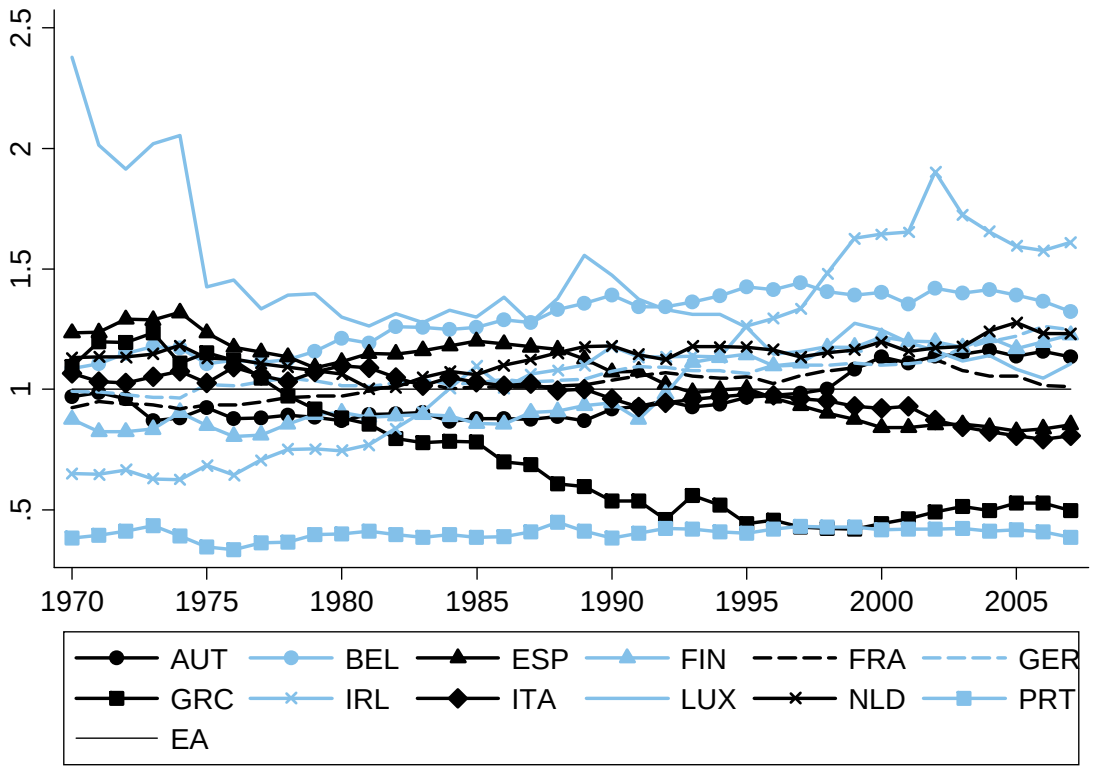
Figures

Figure 1: Countries' productivity levels relative to euro area average; **total economy**



Source: EU KLEMS (2009), OECD-Eurostat PPPs and own calculations.

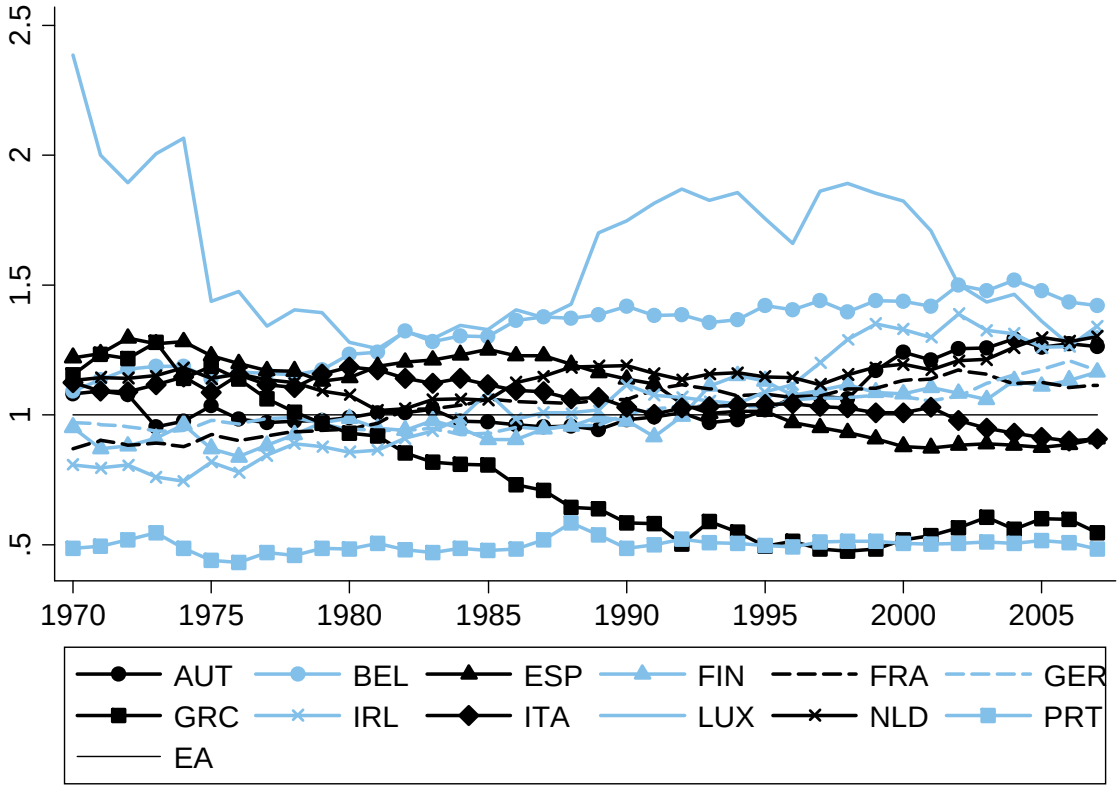
Figure 2: Countries' productivity levels relative to euro area average; **manufacturing**



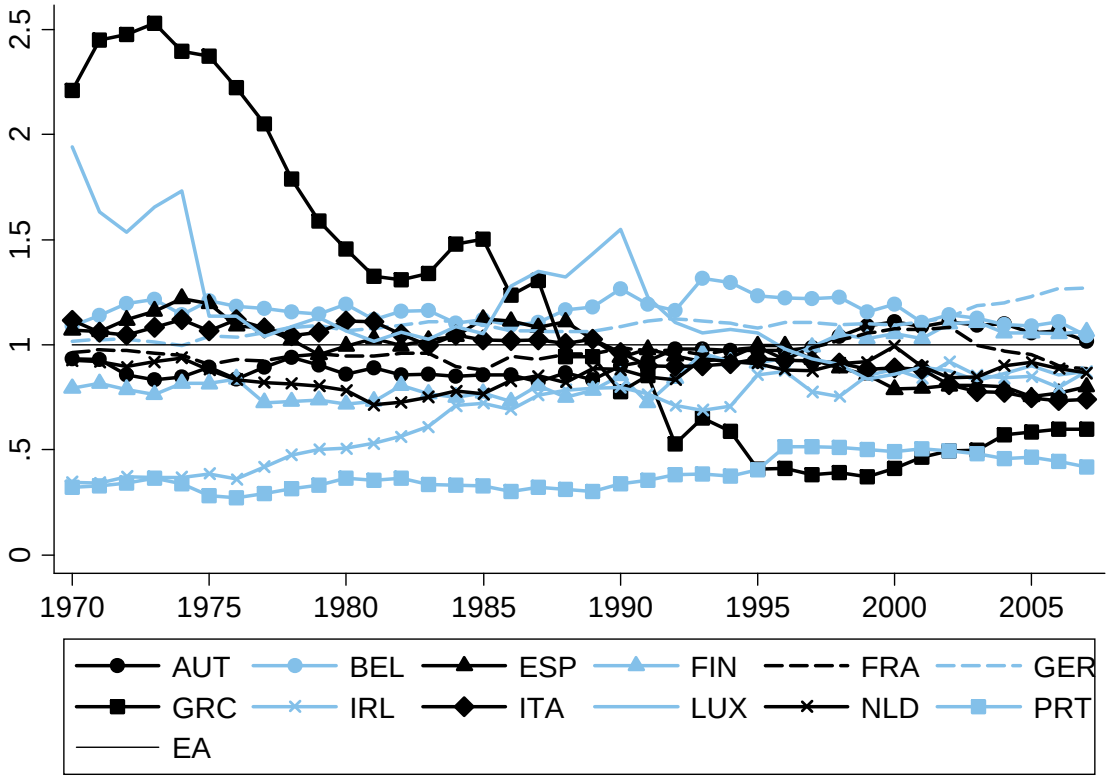
Source: EU KLEMS (2009), OECD-Eurostat PPPs and own calculations.

Figure 3: Countries' productivity levels relative to euro area average; **low- and high-technology manufacturing sub-sectors**

(a) low-technology



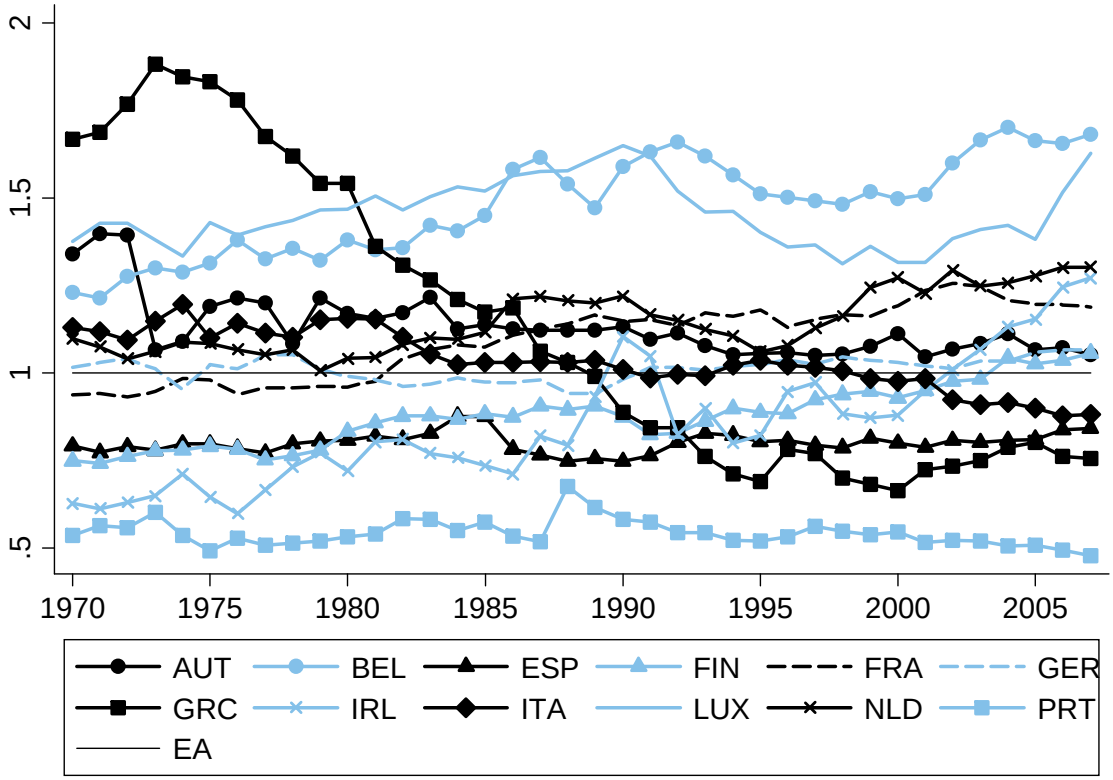
(b) high-technology



Source: EU KLEMS (2009), OECD-Eurostat PPPs and own calculations. Note: Other machinery, electrical/optical equipment and transport equipment are considered high-technology industries, whereas all other manufacturing industries (see fn. 7) are defined to produce low-technology.

Figure 4: Countries' productivity levels relative to euro area average; **main service sectors**

(a) distributive trades



(b) financial intermediation

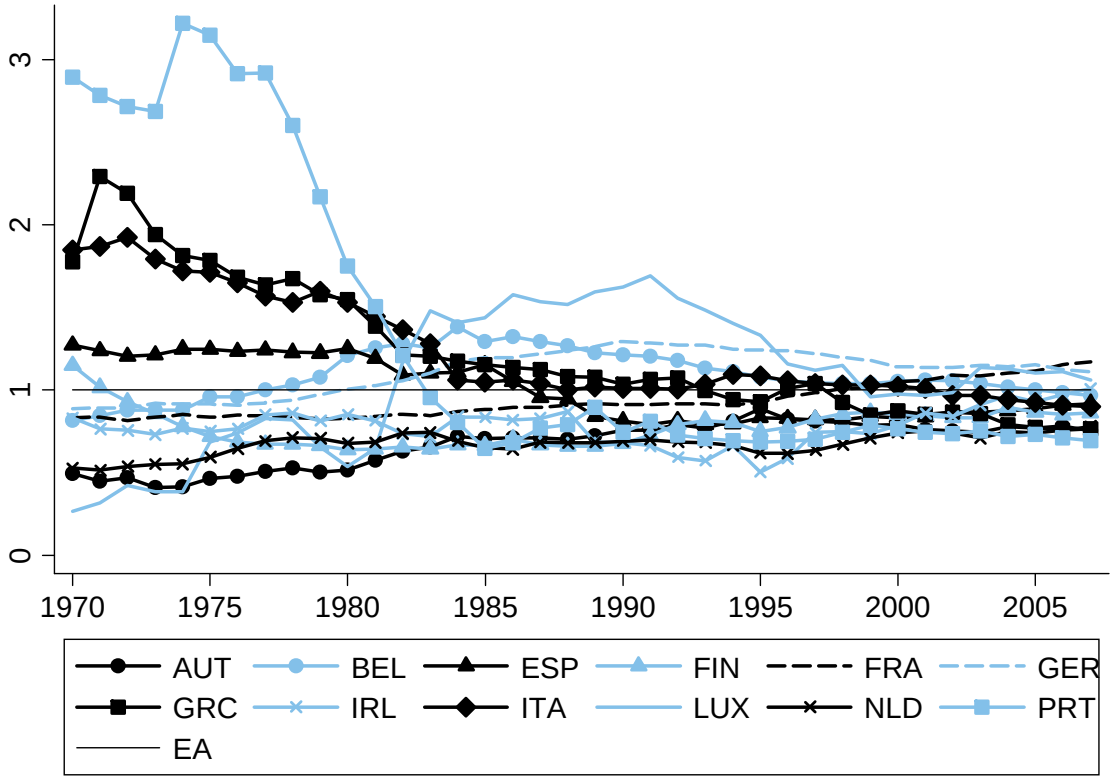
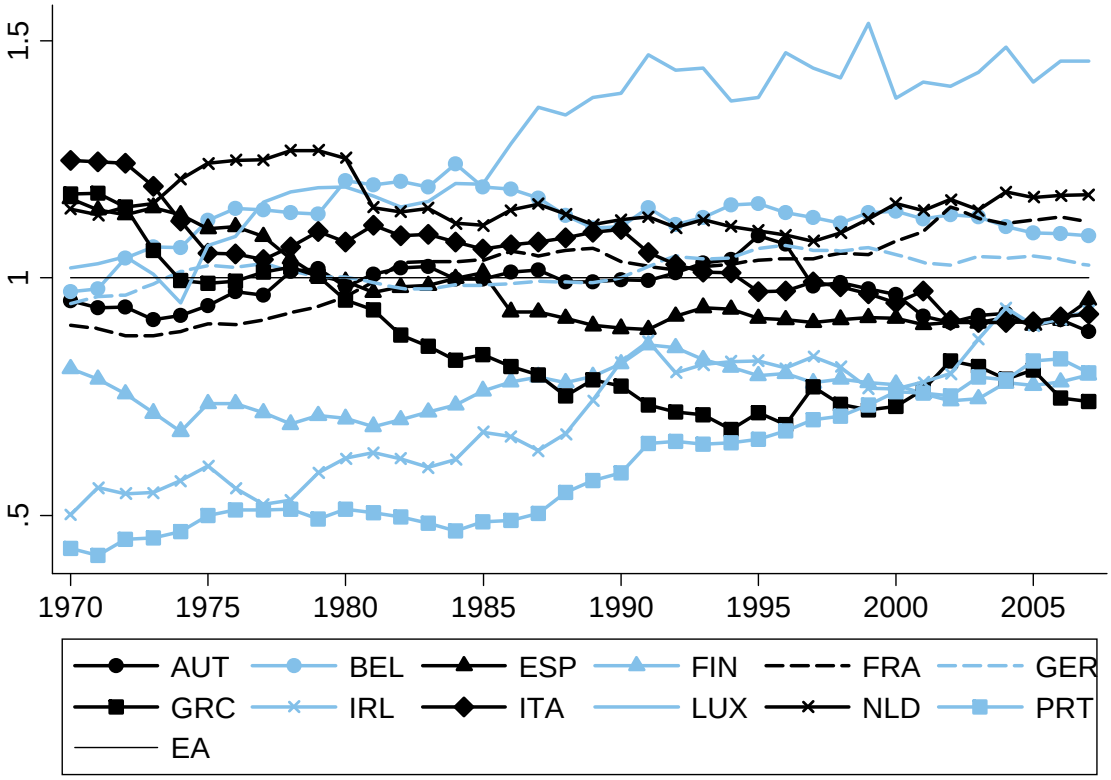


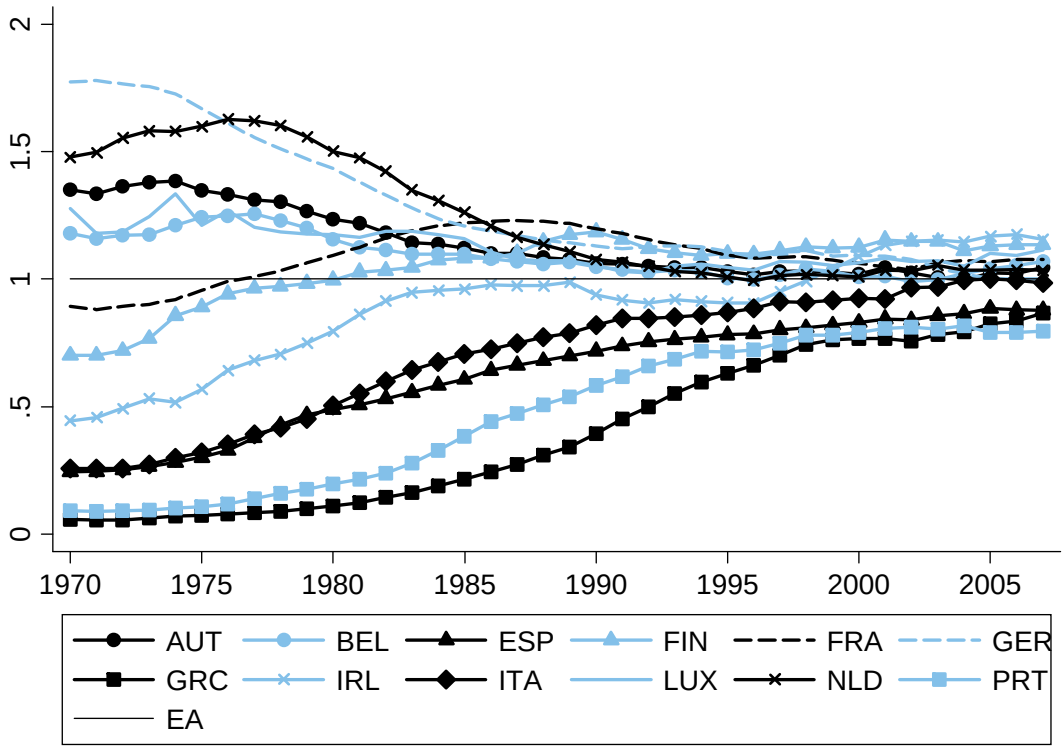
Figure 4

(c) non-market services



Source: EU KLEMS (2009), OECD-Eurostat PPPs and own calculations.

Figure 5: Countries' purchasing power parities relative to the euro area average;



Source: OECD and own calculations.

Tables

Table 1: Size of main sectors (in terms of value added) in the euro area

	1970-1979	1980-1989	1990-1999	2000-2007
agriculture	6%	4%	2%	2%
manufacturing	26%	24%	21%	20%
construction	8%	7%	7%	7%
market services	37%	40%	44%	46%
energy	*2%*	*3%*	*3%*	*2%*
distributive trades	*11%*	*10%*	*10%*	*10%*
transport and communication	*7%*	*8%*	*7%*	*7%*
financial intermediation	*4%*	*5%*	*5%*	*6%*
real estate and renting	*14%*	*17%*	*21%*	*23%*
non-market services	21%	22%	23%	23%

Source: EU KLEMS (2009).

Table 2: Panel unit root tests for the total economy and main industries

	BN (2004) *Common factor*	BN (2004) *Idiosyncratic component*	Convergence?	P (2007)	Convergence?
total economy	-1.72	-0.604	No Convergence	-1.902	No Convergence
agriculture	0.796	-1.024	No Convergence	-2.468^{**}	**Convergence**
manufacturing	-1.223	-1.639^{*}	No Convergence	-1.627	No Convergence
energy	-2.743^{*}	0.005	No Convergence	-1.609	No Convergence
construction	-1.9	1.395^{*}	No Convergence	-2.125	No Convergence
distributive trades	-0.994	0.707	No Convergence	-2.174	No Convergence
transport and communication	-1.722	-0.991	No Convergence	-2.223^{*}	**Convergence**
financial intermediation	-2.82^{*}	-1.739^{**}	**Convergence**	-1.911	No Convergence
real estate and renting	-4.349^{***}	0.366	No Convergence	-0.96	No Convergence
non-market services	-2.111	-0.673	No Convergence	-2.271^{*}	**Convergence**

Notes: H_0 of a unit root for both tests, i.e. no convergence; Numbers in columns display relevant test statistics; *** denote the 1% significance level, ** denote the 5% significance level, * denote the 10% significance level; BN stands for the Bai and Ng (2004) test, whereas P stands for the Pesaran (2007) test.

Table 3: Panel unit root tests for the manufacturing sub-industries

	BN (2004) *Common factor*	BN (2004) *Idiosyncratic component*	Convergence?	P (2007)	Convergence?
food, beverages & tobacco	−0.82	−0.854	No Convergence	−2.044	No Convergence
textiles & footwear	−1.995	−1.434	No Convergence	−1.477	No Convergence
wood & cork	−1.673	−1.608	No Convergence	−2.019	No Convergence
paper, printing & publishing	0.915	2.27**	No Convergence	−2.747***	**Convergence**
chemicals, plastics & fuel	−1.558	−0.898	No Convergence	−2.425**	**Convergence**
other non-metallic mineral	−2.523*	−1.198	No Convergence	−1.813	No Convergence
basic metals & fabricated metal	−1.891	−1.369*	No Convergence	−1.441	No Convergence
other machinery	−1.365	0.949	No Convergence	−1.422	No Convergence
electrical & optical equipment	−2.894	−0.949	No Convergence	−1.558	No Convergence
transport equipment	−1.918	−0.407	No Convergence	−1.709	No Convergence
other manuf. (incl. recycling)	−1.48	−1.177	No Convergence	−2.245*	**Convergence**

Notes: H_0 of a unit root for both tests, i.e. no convergence; Numbers in columns display relevant test statistics; *** denote the 1% significance level, ** denote the 5% significance level, * denote the 10% significance level; BN stands for the Bai and Ng (2004) test, whereas P stands for the Pesaran (2007) test.

Table 4: Panel unit root tests for the total economy and main industries (sub-samples for pre- and post-EMU)

	Pesaran (2007) *1970-1998*	Convergence? *1970-1998*	Pesaran (2007) *1999-2007*	Convergence? *1999-2007*
total economy	−1.532	No Convergence	−1.288	No Convergence
agriculture	−2.65***	**Convergence**	−2.268	No Convergence
manufacturing	−1.203	No Convergence	−0.726	No Convergence
energy	−2.051	No Convergence	−0.902	No Convergence
construction	−1.955	No Convergence	−2.507**	**Convergence**
distributive trades	−1.925	No Convergence	−2.533**	**Convergence**
transport and communication	−2.452**	**Convergence**	−1.204	No Convergence
financial intermediation	−1.611	No Convergence	−0.802	No Convergence
real estate and renting	−1.597	No Convergence	−0.477	No Convergence
non-market services	−2.620***	**Convergence**	2.682**	**Convergence**

Notes: H_0 of a unit root, i.e. no convergence; Numbers in columns display relevant test statistics; *** denote the 1% significance level, ** denote the 5% significance level, * denote the 10% significance level;

Table 5: Panel unit root tests for the total economy and main industries (non-PPP adjusted)

	BN (2004) *Common factor*	BN (2004) *Idiosyncratic component*	Convergence?	P (2007)	Convergence?
total economy	−2.305	0.923	No Convergence	−1.851	No Convergence
agriculture	−1.567	−0.480	No Convergence	−2.005	No Convergence
manufacturing	4.466	−0.501	No Convergence	−1.872	No Convergence
energy	−0.208	−1.455*	No Convergence	−2.087	No Convergence
construction	−0.058	−0.833	No Convergence	−1.505	No Convergence
distributive trades	0.465	2.197**	No Convergence	−1.853	No Convergence
transport and communication	1.014	1.183	No Convergence	−2.075	No Convergence
financial intermediation	−0.234	−0.565	No Convergence	−1.990	No Convergence
real estate and renting	−1.133	−0.076	No Convergence	−1.254	No Convergence
non-market services	−1.941	−0.102	No Convergence	−2.227*	**Convergence**

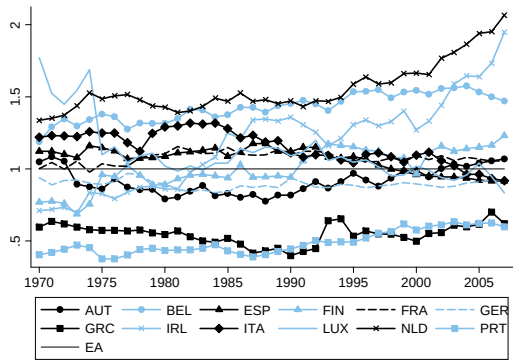
Notes: H_0 of a unit root for both tests, i.e. no convergence; Numbers in columns display relevant test statistics; *** denote the 1% significance level, ** denote the 5% significance level, * denote the 10% significance level; BN stands for the Bai and Ng (2004) test, whereas P stands for the Pesaran (2007) test.

Table 6: Determinants of productivity growth in euro area sectors

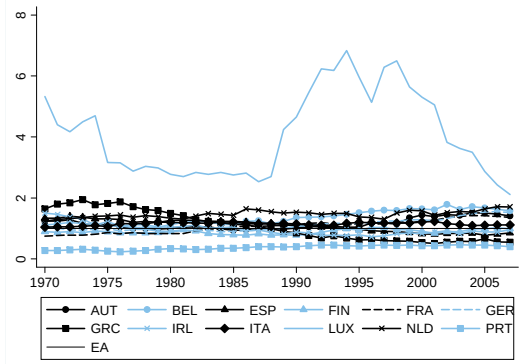
Estimator: panel fixed-effects			
dependent variable: productivity growth	all industries	manufacturing industries	service sectors
independent variables			
(R&D investment/GDP)$_{t-1}$	0.059**	0.103**	−0.004
	(0.028)	(0.043)	(0.037)
(Share of ICT capital)$_{t-1}$	0.014***	0.026***	−0.004
	(0.005)	(0.009)	(0.007)
(Share of high-skilled worker)$_{t-1}$	0.019	−0.009	0.066**
	(0.012)	(0.015)	(0.033)
(Regulatory burden)$_{t-1}$	−0.015	−0.020	−0.105*
	(0.051)	(0.075)	(0.057)
(FDI inflow/GDP)$_{t-1}$	0.000	−0.000**	0.000
	(0.000)	(0.000)	(0.000)
observation	5928	3432	1560
country fixed effects	yes	yes	yes
time fixed effects	yes	yes	yes
sector fixed effects	yes	yes	yes
hausman test	32.25***	62.28***	26.18***
$R^2(overall)$	0.07	0.06	0.15

Notes: Point estimates and heteroscedasticity-robust standard errors are in parentheses. *** denote the 1% significance level, ** denote the 5% significance level, * denote the 10% significance level. Hausman test rejects the null that the differences in coefficients are not systematic (χ^2 statistic displayed).

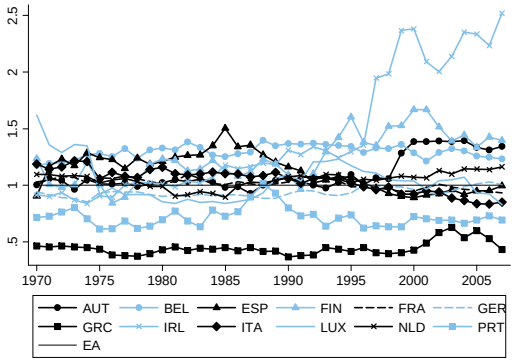
Annex 1: Countries' productivity levels relative to euro area average; manufacturing sub-sectors



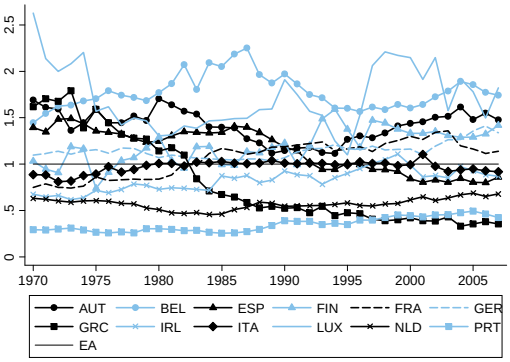
(a) food/beverages/tobacco



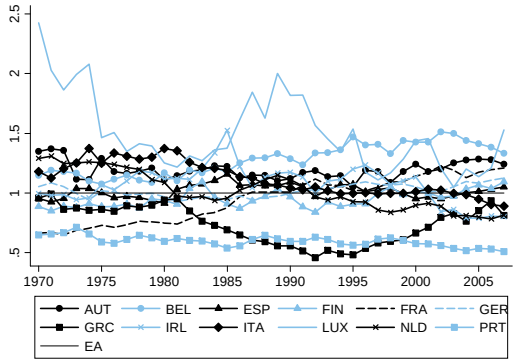
(b) textile/leather/footwear



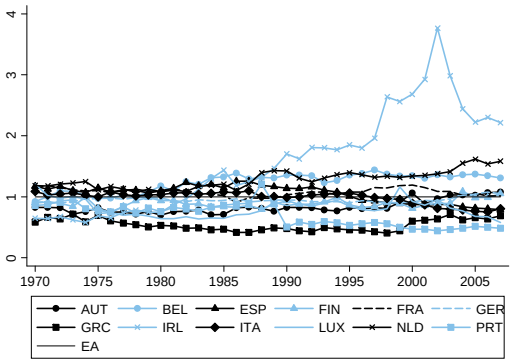
(c) wood and cork



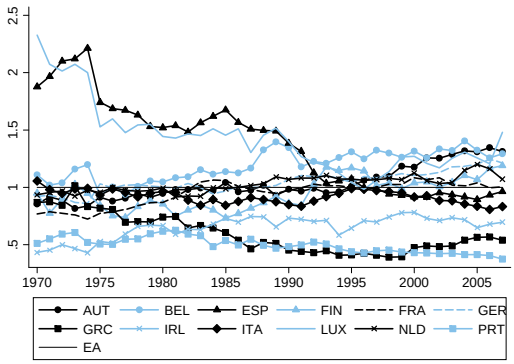
(d) pulp/paper/printing



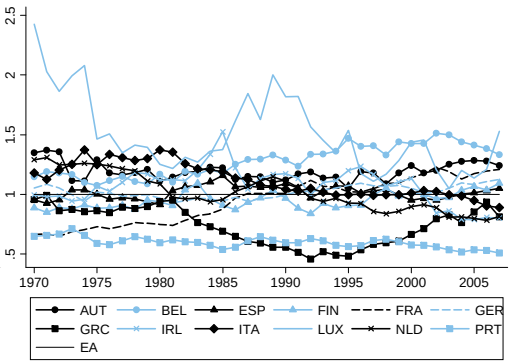
(e) chemicals/plastics/fuel



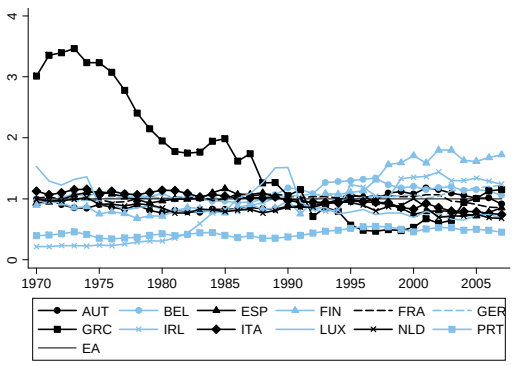
(f) non-metallic minerals



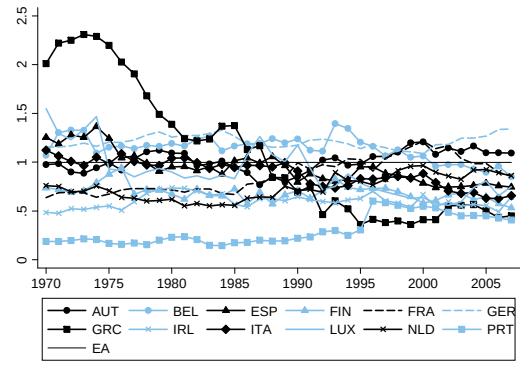
(g) metals



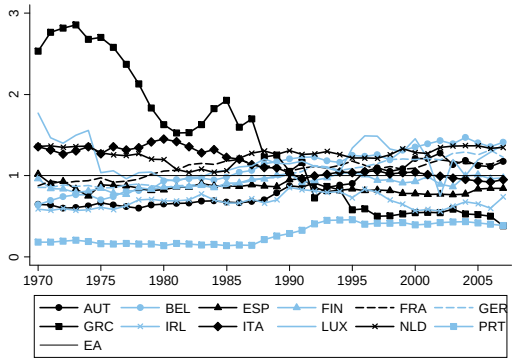
(h) other machinery



(i) electrical/optical equipment



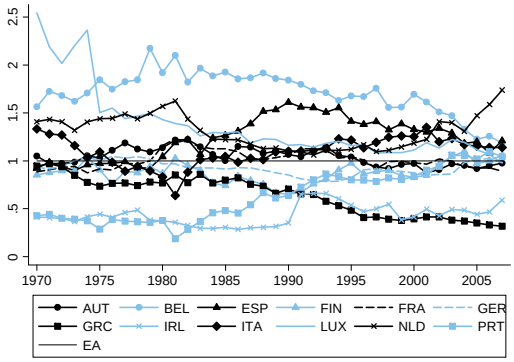
(j) transport equipment



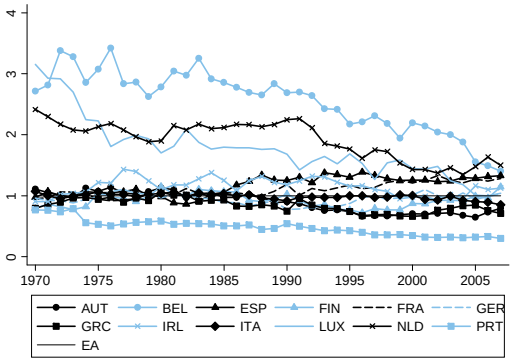
(k) other manufacturing

Source: EU KLEMS (2009), OECD-Eurostat PPPs and own calculations.

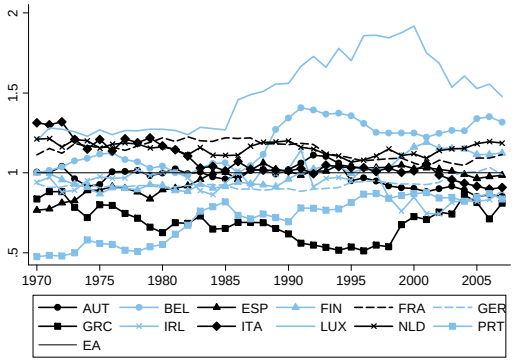
Annex 2: Countries' productivity levels relative to euro area average; main sectors



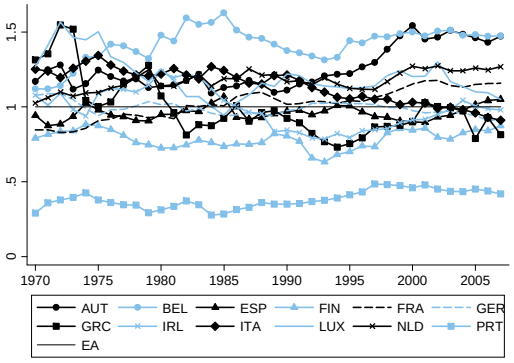
(a) agriculture



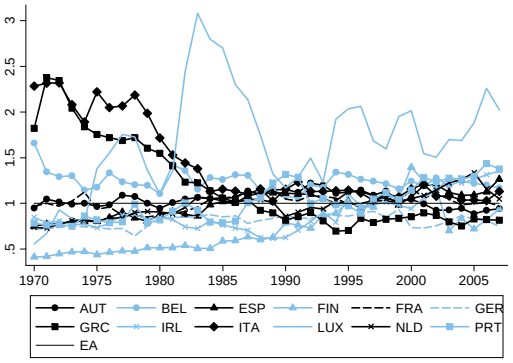
(b) energy



(c) construction



(d) transport and communication



(e) financial intermediation

Source: EU KLEMS (2009), OECD-Eurostat PPPs and own calculations.