The Determinants of Total Factor Productivity in the EU:
Insights from Sectoral Data and Common Dynamic Processes

by

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Abstract

This paper examines the development of total factor productivity (TFP) and the drivers of TFP for a panel of 17 EU countries in the period of 1995-2007. The most recent panel data estimation techniques are used and further improved. The purpose of this paper is threefold: First, to estimate aggregated and sectoral TFP for 17 EU countries by means of the augmented mean group estimator to control for endogeneity, cross-section dependence and heterogeneous production technology. Second, to present and discuss stylized facts concerning the development of TFP in different EU countries and different sectors. Third and most importantly, to determine the drivers of TFP. Among them we include FDI, ICT, unit wages and different types of trade openness. We find that although wages are the main driver of TFP, ICT, extra-EU trade and human capital also play a role.

Keywords: sectoral TFP, common dynamic process, European Union

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1. Introduction

Productivity improvements, based on technological progress, play a crucial role in assuring economic growth. This is a crucial insight from the innovation-based endogenous growth models by Romer (1990), Rivera-Batiz and Romer (1991), Grossman and Helpman (1991), and Aghion and Howitt (1992, 1998). They build upon the contribution of R&D-based innovative efforts in leading an economic system on the long-term development path. Furthermore, productivity improvements might be generated by human capital. Its role in fostering economic growth has been analyzed within the framework of the endogenous growth theory by Romer (1986) and Lucas (1998). The role of human capital might be either direct or indirect. Human capital enters directly the production function and may thus directly contribute to output growth. Moreover, thanks to specific creative skills and abilities, human capital could facilitate the generation of innovative outcome, and consequently, to the more efficient output growth. In this context, some authors recognized the complementary character between R&D activities and human capital in spurring productivity growth and, thus, indirectly benefiting the general process of growth.[1]

Apart from the aforementioned contributions, underlying the role of R&D, human capital or both in determining total factor productivity (TFP), there are theoretical and empirical contributions that focus on some other factors explaining TFP. Among such determinants, authors usually stressed the role played by FDI, ICT capital and by imports. These contributions are rather fragmented and, only in a few cases consider these different determinants in a unified framework. More attention has been dedicated to investigate the determinants of economic growth in general, where TFP was often included among them.

The main aim of this research is to investigate TFP and its determinants in a unified framework. Moreover, given that technological knowledge, its generation and exploitation is intrinsic to a certain localized context, we investigate the determinants of TFP in a particular geographic, economic and political environment, namely the European Union (EU) due to the long and still ongoing process of economic integration one could expect some factors to have played a particular role as drivers of the TFP development.

Regarding the European case, there are numerous contributions studying the effects that the European integration process might have on growth in general (Bretschger and Steger, 2004; Gao, 2005; Badinger, 2005, 2008; Kutan and Yigit, 2007).[2] Most authors focused on the influence of different

[1] See, for instance, Redding (1996), Autor *et al.* (1998), Berman *et al.* (1998), and Borensztein *et al.* (1998).
[2] Due to the complexity and dynamics of the process, the broad group of those studies could be distinguished between contributions analyzing the effects of European integration in general as opposed to the analyses focusing on the particular case of the Eastern enlargement. Regarding the latter, Breuss (2002) estimated that the enlargement the gain in terms of real GDP for the Central and Eastern European accession countries would be ten times more from the enlargement than the old EU.

factors on output growth, among which productivity growth as in Notaro (2011).[3] Those contributions might already shed some light on the factors that potentially would play a role in explaining more precisely productivity dynamics, when for instance pointing on the influence played by FDI flows, ICT intensity, or the effects derived from the common regional policy. Indeed, it might be reasonable to ask whether more intensified economic growth is influenced by such factors directly, or rather indirectly, going through productivity improvements. This last question constitutes a central issue motivating our investigation.

There are numerous studies analyzing the development of TFP over time in the European Union, across European economies and sectors (O'Mahony *et al.*, 2009; Burda and Tabellini, 2009) as well as studies focused on the productivity gap between the EU and the US (van Ark *et al.*, 2007). Although those contributions provide valuable insights in getting a general view over TFP and its long-term dynamics, they do not answer the relevant questions concerning its driving factors. There are a few exceptions (Biatour and Dumont, 2011; Bengoa-Calvo and Perez, 2011; Marrocu *et al.*, 2012; Cameron *et al.*, 2005), from which, nevertheless, we depart in several dimensions. To our knowledge, there has been no attempt to assess the determinants of TFP – other than agglomeration externalities - in the EU as a whole.

From a methodological point of view, we are interested in productivity improvements, expressed in terms of TFP. This indicator is often called a measure of ignorance, as little is known about the non-input - often unobservable - determinants of economic growth.[4] Related to the degree of ignorance one can also define TFP in a narrower or wider sense (Eberhardt and Teal, 2010). TFP can either stand for output growth due to technological improvements and efficiency improvements (TFP in the more narrow sense) or output growth due to all sorts of factors, such as a more favorable resource endowment, a better climate, better functioning institutions, less corruption etc. (TFP in the wider sense).

In this paper we will argue that it is highly preferable to estimate TFP taking country heterogeneity into account than doing some TFP accounting based on standard labor and standard capital input shares (with the conventionally assumed elasticities of 2/3 and 1/3 for labour and capital, respectively) given that we are interested in country-specific TFP differences. Therefore, in order to properly estimate country–specific TFPs it is of utmost importance to allow for country-specific production

[3] The observation, confirmed by empirical evidence, that the growth of income per capital in developed countries is to a large extent explained by a residual and not by the accumulation of the factors of production has been the subject of early investigations by Abramovitz (1956) and Solow (1957). It has been subsequently reconfirmed by Islam (1995), Hall and Jones (1999), but some arrived at different conclusions (Jorgenson and Grilliches, 1967; Young, 1995; Jorgenson *et al.*, 2005). In particular, Jorgenson *et al.* (2005) analysed TFP growth by industry in the US over the period 1977-2000 and found TFP growth to be the main determinant of output growth only in seven out of 41 sectors.

[4] The first to label TFP as a „measure of our ignorance“ was Moses Abramovitz (1956: 11) when analysing the causes of economic growth.

technology and country-specific input coefficients as well as to tackle endogeneity in the production function. Endogeneity occurs when inputs not only influence output but output also determines inputs. In terms of inputs, we distinguish between observable inputs (capital , labour) and unobservable inputs (the quality of capital and labour; effort; technological improvements; institutions; work relations; etc).

As we will look at 17 older and newer EU countries (where data were sufficiently available over the period 1995 to 2007), TFP differences are discernible even though common factors influencing all countries, which generate cross-section dependence (CSD). These common factors can be specified and modeled when estimating TFP at the country level.

Apart from an important contribution that we deliver in terms of methodological work, it is, thus, the main objective of this paper to explain why some countries are more successful in terms of TFP, i.e. non-input related output growth, than others and what might be the role played by the degree of openness of an economy, by R&D which determines the extent of innovation, by human capital, by ICT and by unit wages.

This paper is structured as follows. Section 2 outlines the methodology employed to estimate TFP for 17 EU countries. In Section 3, we will present the evolution over time of country-level TFPs for the aggregated manufacturing sector and for 13 sub-sectors, using the estimated time series obtained in Section 2. In Section 4, we will analyze the determinants of TFP by means of an econometric model. Finally, Section 5 will provide some concluding remarks and economic policy lessons.

2. Estimating TFP based on heterogeneous production functions

2.1 Output versus the value added approach

In this section, we follow the value added approach to estimate sector specific TFP levels over time and across countries. According to this approach, TFP is obtained as a residual from the valued added-based Cobb-Douglas production function, in which real value added is used as the target measure.[5] An alternative would be to use the output-based approach, according to which TFP is obtained as a residual from the output-based production function and intermediate production factors (such as raw materials, energy and intermediate goods and services) are included as additional determinants of production in the estimation. It has been argued that this approach is theoretically more appropriate, as

[5] Alternatively, it is possible to calculate TFP as an index in log-levels, given as the difference between the log values of real output/value added and the factors weighted contributions. The factors refer to labour, capital and, in case the real output approach is followed, intermediate inputs. There are dedicated studies that investigate the performance of estimation-based versus calculated measures of TFP (for instance, Van Biesebroeck, 2007). This remains outside of the aims of our analysis. Nevertheless, as a robustness check, we calculated TFP in levels, compared it to our estimated values and also applied them in our estimations. For brevity, we do not show the results here, but the time series of TFP from both methods are comparable and also the results from the empirical estimations, when using calculated instead of estimated TFP, confirm the main findings of section 4.

it permits the explicit consideration of intermediate production factors in the technologically-driven sector-level growth (Jorgenson and Stiroh, 2000). However, some practical reasons (Hall *et al.*, 2009) and the lack of data on deflated intermediate inputs make the value added approach more reliable.

It is also worth noting that TFP can be computed (calculated or estimated) at different aggregation levels.[6] Most of the past contributions in growth accounting framework focused on country-level TFP. Only recently, an increasing number of studies have been dealing with sector- or firm-level productivity. This tendency is mainly driven by the need to avoid a potential aggregation bias which arises from disregarding heterogeneity across sectors/firms. Another motivation to deal with more disaggregated TFP data has to do with the expectation that different determinants of TFP might work differently in particular sectors/firms and it might be crucial, also in terms of policy implications, to detect and interpret such differences.

2.2 Estimation methodology

Let us consider the standard Cobb-Douglas production function:

$$Y_{ikt} = TFP_{ikt} L_{ikt}^{\beta_L} K_{ikt}^{\beta_K} \sum_{m=1}^{M} X_{imkt}^{\beta_m}$$

(1)

where TFP_{ikt} measures technology contribution to output (Y) in country i and sector k at time t, β coefficients refer to each factor's (X) estimated output elasticity and $m = (1, 2 \ldots M)$.

Transforming the production function into a log-log model:

$$\ln Y_{ikt} = \ln TFP_{ikt} + \beta_L \ln L_{ikt} + \beta_K \ln K_{ikt} + \beta_1 \ln X_{i1kt} + \beta_2 \ln X_{i2kt} + \ldots + \beta_m \ln X_{imkt}$$

(2)

the productivity level can be derived as the residual $(\ln T\hat{F}P_{it})$, by subtracting from output the observable input contributions weighted by their corresponding output elasticities:

$$\ln T\hat{F}P_{ikt} = \ln Y_{ikt} - \hat{\beta}_L \ln L_{ikt} - \hat{\beta}_K \ln K_{ikt} - \hat{\beta}_1 \ln X_{i1kt} - \hat{\beta}_2 \ln X_{i2kt} - \ldots - \hat{\beta}_m \ln X_{imkt}$$

(3)

Applying the value added approach and considering that value added (VA) is defined as value of gross output (Y) minus value generated by intermediates ($X_1 \ldots X_m$):

$$\ln VA_{it} = \ln Y_{it} - \hat{\beta}_1 \ln X_1 + \hat{\beta}_2 \ln X_2 + .. + \hat{\beta}_m \ln X_m \qquad ,$$

(4)

[6] Bartelsman (2010) offers an overview of the productivity growth analysis at different levels of aggregation.

TFP can be derived as residual from an analogous log-log model as in (3):

$$\ln T\hat{F}P_{ikt} = \ln VA_{ikt} - \hat{\beta}_L \ln L_{ikt} - \hat{\beta}_K \ln K_{ikt}$$

(5)

Thus, TFP growth $(\ln T\hat{F}P_{ikt} - \ln T\hat{F}P_{ikt-1})$ is defined as the value added growth not caused by an increase in inputs (labour and capital).

In what follows, for the reasons already mentioned, we will follow the value added approach in order to estimate the labour (β_L) and capital (β_K) coefficients and, finally, obtain the logarithmic values of TFP for each country and time included in our analysis.

Most econometric estimations of TFP based on production functions consider homogeneous production functions for all countries, which is an unrealistic and rather restrictive assumption (Eberhardt and Teal, 2010). Given that production technology is localized and thus geographically heterogeneous, we will include production heterogeneity in our model and therefore will base our estimation on equation (4):

$$\ln VA_{ikt} = \alpha_i + \beta_{iL} \ln L_{ikt} + \beta_{iK} \ln K_{ikt} + v_{ikt}$$

(6)

where $v_{ikt} = \mu_{ik} + \lambda_i cf_t$ and where all coefficients ($\alpha_i, \beta_{iL}, \beta_{iK}$) are country specific.

We obtain TFP following the estimation approach suggested by Eberhardt and Teal (2010) called augmented mean group estimator (AMG). This estimator was developed to provide a valid alternative to the common correlated mean group estimator (CCEMG) proposed by Pesaran (2006) and Pesaran *et al.* (2010) that would enable to meaningfully interpret the coefficients of the set of unobservable common factors. [7] Indeed, in CCEMG approach these factors are treated as disturbance for which it is proper to account, but in which no particular interest is put. On the contrary, in the AMG approach, such factors might be interpreted as TFP. In particular, in constructing the AMG estimator, Eberhardt and Teal (2010) account simultaneously for country-specific factors, as well as for cross-section dependence and endogeneity caused by time-varying factors that are common to all countries (cf_t). More precisely, cf_t measure common factors that have an impact on all countries but do so in a country-specific way, i.e. each country reacts to different extent to the common factors (measured by elasticity λ_i). More specifically, the AMG procedure is implemented in three steps. First, based on

[7] CCEMG estimator solves the problem of correlation between inputs with unobserved productivity shocks by augmenting the group-specific regression equation with the cross-section averages of the dependent and independent variables. Consequently, these averages can account for the unobserved common factor and provide estimates for the heterogeneous impact lambda.

equation (6) a regression model with year dummies is estimated in first differences and the coefficients of the (differenced) year dummies are collected. The first stage equation is given by:

$$\Delta \ln VA_{ikt} = b_L \Delta \ln L_{ikt} + b_K \Delta \ln K_{ikt} + \sum_{t=2}^{T} cf_t \Delta DUM_t + u_{ikt} \quad (7)$$

where u_{ikt} is a well behaved error term with iid N(0; σ_u^2), cf_t represent an estimated cross-group average of the evolution of unobservable TFP over time named "common dynamic process". The rest of variables have been described above.

Second, the country-specific regression model (Equation 6, above) is then augmented with this estimated common TFP process and with country- specific time trends. This second stage regression is given by:

$$\ln VA_{it} = \alpha_i + \beta_{iL} \ln L_{it} + \beta_{iK} \ln K_{it} + trend_i + \lambda_i cf_t + w_{it} \ . \quad (8)$$

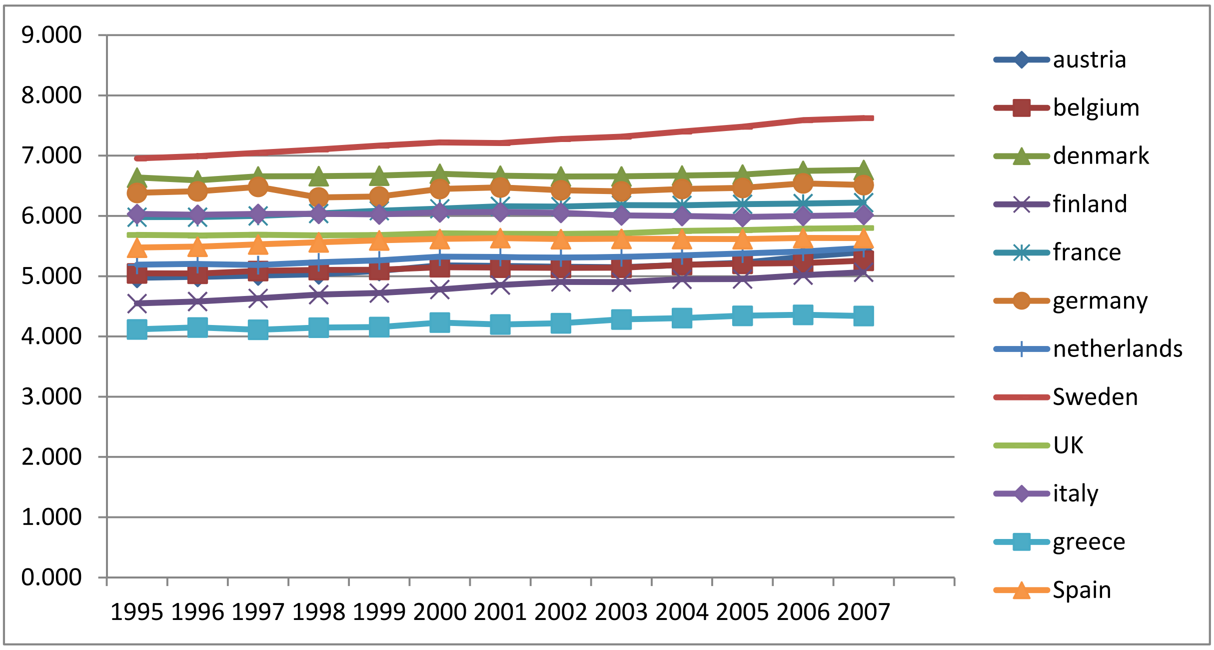
From the above specification it follows that time effects ($trend_i$) are country-specific and that the common dynamic process (common factors such as e.g. financial crisis, EU enlargement) affects each country differently. This differential impact is measured by (λ_i).

Finally, to obtain the group-specific model, parameters are averaged across the panel. In simulations, in terms of bias or RMSE in panels with nonstationary variables (cointegrated or not) and multifactor error terms (cross-section dependence), the AMG performed similarly well as CCEMG estimator.

3. TFP Development in 17 EU countries and 13 sectors: stylized facts

Figure 1 shows the estimated country level TFP (in logarithmic terms) for the aggregate manufacturing activities. We include in our analysis 17 EU members for which the data were available, namely, Austria, Belgium, Denmark, Finland, France, Germany, the Netherlands, Sweden, the UK, Greece, Italy, Portugal, Spain, Czech Republic, Estonia, Slovakia and Slovenia.

Figure 1. Evolution of estimated lnTFP over the period 1995 to 2007 for EU-12



From figure 1 a clear pattern emerges. Aggregate TFP was moderately increasing almost in all countries (in Germany, there was a short period between 1997 and 1999 with decreasing TFP levels) in the entire period under consideration. Regarding the relative positions, the best performing economies are the core EU countries, Sweden, Denmark, Germany and France. Instead, the Southern European countries were lying below the EU-12 averages, with Greece performing the worst in terms of TFP levels. An exception here was Italy in the entire period maintained its position among 5 best performers. Also exceptional, though in the opposite direction, was the below-EU-average performance of Finland - at least in terms of TFP levels.

On the sectoral basis, TFP developed quite smoothly in the 1995 to 2007 period (see figures A.1-A.13 in the Appendix A.1). In many sectors, such as *chemicals, electrical equipment, machinery, manufacturing, metal products, non-metallic products, paper, rubber*, TFP showed on average upward trend.[8] However, such a positive development was interrupted in a few countries: in *chemicals*, Greece, Spain, the Czech Republic and Hungary faced decreases in TFP; in *electrical equipment*, TFP took a dip in Greece, Italy and Spain after 2002; in *machinery*, all countries studied did well, except Estonia; Slovakia and Slovenia had low TFP levels; in *manufacturing n.e.c.*, we can detect slight drops in TFP in 2002 in all countries, but huge drops in France, Greece, Italy and Spain; in *metal products*, all countries did fine except for Spain and in *non-metallic products* the only under-performer was Belgium.

[8] The list of sectors with their full names is included in Appendix A.2.

Sectors with mixed TFP experiences were: *food* where we observe drops of TFP for Germany, Greece, Denmark and Hungary; *textiles* where downward dips for Italy, Spain, Denmark and Hungary become apparent; *transport equipment* where Greece, Italy, Spain and Denmark experienced problems; *wood* where Greece, Netherlands, Spain and Hungary saw some decreases in TFP.

With regard to the production of *coke*, we observe a continuous downward trend for all countries under study. In sum, the countries that were experiencing TFP problems quite often were: Greece, Italy, Spain and Hungary and the countries with good or satisfactory TFP trajectories were: Austria, Belgium, Finland, Germany, Netherlands, Sweden and UK. This outcome confirms that it might be a reasonable choice to consider core EU countries separately from the other more peripheral EU members. But, additionally, regarding the latter, due to obvious differences in the historical experiences of Southern and Eastern EU countries, it makes sense to take this heterogeneity into account as well. Thus, for the purposes of our empirical investigation, we keep the three distinct groups of EU members, core, South and East.

4. Determinants of TFP

4.1 Theoretical transmission channels

Endogenous growth theory suggests two crucial factors that might essentially determine TFP. From innovation-based growth models (Romer, 1990; Rivera-Batiz and Romer, 1991; Grossman and Helpman, 1991; and Aghion and Howitt, 1992 and 1998) *R&D activities* might eventually result in innovations, and consequently, in an increased output. Such positive productivity increases are all the more probable, given the great role played by knowledge externalities in such knowledge generation process (Griliches, 1979). R&D spillovers might be domestic or international in nature. There is a bulk of the empirical literature that investigates both categories of spillovers, with a particular emphasis on the international R&D spillovers that are supposed to be transferred through international trade and FDI (for instance, Coe and Helpman (1995) and Nadiri and Kim (1996)).

Another strand of endogenous growth models emphasizes the role of *human capital* in fostering productivity (Romer, 1986; Lucas, 1998). More precisely, skilled human capital possesses necessary abilities, not only to become familiar with and efficiently use existing innovations, but also to contribute to the generation of brand new innovative outcome. Nevertheless, the empirical evidence on the role of human capital on productivity (growth) was inconclusive.[9] Related to this, we will try to provide evidence that there might be the wage-driven incentive provoking positive impact in terms of TFP.

Merging the two aforementioned approaches, some authors recognized the complementary character between R&D activities and human capital in spurring productivity growth and, thus, indirectly benefiting the general process of growth.[10]

Human capital and R&D activities are the most theoretically and empirically investigated factors that are supposed to determine productivity. Beside them, however, there might be also other factors that have been suggested in separate theoretical models to exercise influence on total factor productivity. More precisely, the role of *ICT* consists in offering a platform, on which network externalities can operate (Schreyer, 2000), and consequently, spur TFP. On the country-level, O'Mahony and Van Ark (2003) and Basu *et al.* (2004) for a sample of OECD countries and Gordon (2000) for the US confirm that ICT exercise significantly positive effect on aggregate productivity.

Another source of growth (and thus potentially of TFP) has been indicated to come through *FDI*.[11] Technology transfer occurring with inward FDI is expected to benefit the receiving economy, all the more if knowledge externalities are positively influencing inter-sectoral relations. Such a positive productivity-increasing effect is potentially more important for less developed economies given their larger distance to the international technological frontier and higher capital return attractiveness. But such a productivity-enhancing impact of FID will operate each time an innovative investor from abroad, due to some kind of profit incentives, establishes his activity in a foreign country, independently of its degree of economic development.

In this same framework of international transactions, also the *degree of international trade* might exercise a positive effect on productivity (Alcalá and Ciccone, 2004; Greenaway and Kneller, 2007; Wagner, 2007). Similarly as in the case of FDI, trade flows of goods and services might instigate domestic sectors to innovate in order to maintain their competitive position at home and abroad. The usual measure of trade used in the past empirical investigations refers to trade openness, expressed in terms of the sum of nominal imports and exports relative to nominal GDP.[12]

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[9] Mankiw *et al.* (1992), Barro and Lee (2001), and Sianesi and van Reenen (2003) report a positive influence of human capital on productivity growth. On the contrary, Prichett (2001) finds strongly significant but negative influence of education capital growth on TFP.

[10] See, for instance, Redding (1996), Autor *et al.* (1998), Berman *et al.* (1998), and Borensztein *et al.* (1998).

[11] An example of evidence confirming positive productivity effects from FDI is the study by Aitken and Harrison (1999).

[12] Alcalá and Ciccone (2004) proposed the use of real openness, defined as the sum of $ exchanged imports and exports relative to GDP in PPP US $. This measure, on the contrary to the traditional measure of trade openness should avoid distortions due to cross-country differences in the relative price of non-tradable goods. Similarly as the studies applying the usual measure of openness (ex. Frankel and Romer, 1999 and Alesina *et al.*, 2000), they arrive at statistically significant and positive influence of trade on aggregate productivity.

We include the above described determinants of TFP in our main estimating framework. Additionally, we exploit two further elements in our investigation, namely, the *reallocation effects* and some specific effects of economic integration in Europe. Regarding the first element, we investigate the hypothesis that TFP might be significantly influenced through the market dynamics transferring productive resources to countries, which are more cost effective (in terms of having a lower labor or a lower capital cost share). Such reallocation dynamics is a driving force of all creative destruction models of growth, as the one by Aghion and Howitt (1992) or a vintage capital model of growth by Caballero and Hammour (1994). But parallel to the beneficial effects of reallocation, there are clearly losers of the process and thus the net welfare outcome is unsure.

Regarding the *effects of economic integration* in the EU, a distinctive role in explaining TFP in the EU might be found in some particular institutional factors related to the common European policy design. In this sense, Notaro (2011) investigated the link between the early effects of completion of the internal market on productivity. Focusing on the measures introduced between 1992 and 1993, he provided evidence on the positive impact of such policies on the productivity of the EU sectors. Among other policies that could be expected to contribute to TFP evolution, we focus on the financial measures within the common regional policy. The main aim of such expenditures is to contribute to the development (growth and especially convergence) of European regions being disadvantaged with respect to the EU average. But their impact on growth and more precisely on productivity is not clear-cut and has been extensively discussed in the past literature, providing mixed evidence. Whereas, Ederveen *et al.* (2003) and more recently Becker *et al.* (2010 and 2012) confirmed a positive output growth effect from the Structural Funds, Fagerberg and Verspagen (1996) reported a negative impact.

Still, the contributions investigating the role played by the aforementioned factors in a unified framework are scarce and fragmented. Moreover, little attention has been dedicated so far to the EU case. The only exception here has been provided by Marrocu *et al.* (2012) who, nevertheless, concentrate on the role played by agglomeration economies in the EU regions. Some other authors, instead, were aiming at disentangling the forces determining TFP growth in single European countries. In particular, Biatour and Dumont (2011) analyse the standard determinants of industry-level TFP in Belgium for the period 1988-2007 and find that R&D significantly influences TFP dynamics. Bengoa and Perez (2011) focus on the Spanish regions and also find positive impact of R&D activities, but depending on the nature of funding (private versus public). Finally, Cameron *et al.* (2005) investigates the case of the UK and detects significantly positive link between R&D expenditures, human capital and the levels of imports, on the one hand, and productivity growth, on the other hand.

4.2 Empirical model

The estimation technique employed to investigate the determinants of TFP is the augmented mean group estimator described in Section 2. This technique allows us to control for cross-section dependence, endogeneity (both produced by common factors) and country heterogeneity.

The dependent variable is the natural logarithm of TFP as estimated in Section 2. The independent variables are the log of R&D/GDP, the log of human capital, the log of ICT investment, the log of openness with respect to the rest of the world, the log of wages and the log of structural funds.

The model is specified as:

$$\left(\ln \hat{\mathrm{TFP}}\right)_{ikt} = \alpha + \beta_1 \ln \mathrm{open}_{ikt} + \beta_2 \ln \mathrm{ICT}_{ikt} + \beta_3 \ln \mathrm{FDI}_{ikt} + \beta_4 \ln \mathrm{R\&D}_{ikt} + \beta_5 \ln \mathrm{HC}_{it} + \beta_6 \ln \mathrm{wage}_{ikt} + \beta_7 \ln \mathrm{SF}_{it} + \phi_i F_t + \varphi_i T + \varepsilon_{ikt}$$

(9)

Where the dependent variable is the estimated total factor productivity level for industry k, country i and at time t (as described in Section 2 above). As proxies for O*pen* we use sectoral trade openness [(I+E)/GDP] and EU external exports over GDP, *HC* stays for human capital indicator that in our case is proxied by secondary education as a percent of total population. Wage measures sector-level unit wages (in thousand € divided by number of workers). R&D is measured as research and development expenditure in a percentage of GDP. SF measures overall structural actions of the EU including expenditures from the Structural Funds, Cohesion Funds and other specific structural actions.[13] F_t denotes the "dynamic common factor process" and *T* is a time trend. The error term (ε_{ikt}) is assumed to be well behaved.

Since R&D has not statistically significant it has been excluded from the model. The same happens to be the case for structural funds. As regards the proxy for openness, exports to non-EU countries over GDP have been used.

4.3 Empirical results and interpretation

The main determinants of TFP are estimated according to specification (9) using sectoral data over the period 1995 to 2007 for the above mentioned 17 countries and their 13 sectors. The main estimation method is the AMG described in section 2.2. For comparison, we will also present results based on

[13] Expenditures related to the Structural Funds are the highest, constituting almost 90% of the overall structural actions. Other specific structural actions appear rather sporadically.

Pesaran and Smith (1995) Mean Group estimator (MG), which does not account for cross-section dependence and basically consists in estimating country by country regressions and averaging the coefficients across countries to obtain average effects.

The main results are presented in Table 1. The first column shows the estimates obtained using the MG estimator. The second column uses also the MG but standard errors are robust to autocorrelation and heteroscedasticity and the third column shows the results obtained using the AMG estimator with robust standard errors. Results in column 3 of Table 1 indicate that the common dynamic process has a positive effect on TFP and therefore the use of the AMG is justified. Also in terms of root mean squared error, AMG is preferred to MG estimator.

Table 1. Determinants of estimated TFP

	Mean Group (MG)	MG Robust	AMG Robust
Ln EU-25 Exports	.111**	.139***	.122***
	(.051)	(.0318)	(.0378)
Ln FDI	.00941**	.00593**	.0101***
	(.00431)	(.00286)	(.00303)
Ln ITC	.00707	.00908***	.00817**
	(.00516)	(.00306)	(.00414)
LN Unitary Wages	.191*	.168**	.225***
	(.108)	(.0675)	(.0797)
Human Capital	.0055	.00321	.00354
	(.00401)	(.00229)	(.00249)
Trend	.0217***	.0147***	.0045
	(.00624)	(.00448)	(.00633)
Common Dynamic Process			.629***
			(.227)
Constant	5.39***	5.55***	5.49***
	(.389)	(.31)	(.366)
N	1322	1322	1106
RMSE		0.0266	0.0221
N trends		21	10

Note: Share of group-specific trends significant at 5% level: 0.098 (= 10 trends). Variable trend refers to the group-specific linear trend terms.

Focusing on the specific average effect of the explanatory variables, unit wages is the most influential variable, the corresponding estimated coefficient is statistically significant at the 1 percent level and its magnitude indicates that an increase in unit wages of 10 percent leads to an increase in TFP in about 2.25 percent. It could be interpreted in two ways. First, assuming that more efficient workers are paid higher salaries, it could indicate that industries employing workers with a higher labour productivity are also more productive (in terms of TFP). Second, if we interpret this positive coefficient as correlation, it could be that industries with higher TFP pay higher salaries. The two variables proxying for globalization, namely exports and FDI as a percentage of GDP, both present a positive and statistically significant coefficient indicating therefore a positive correlation between globalization and TFP. In particular, an increase in inward FDI (export share) share of 10 percent increases TFP by around 1 percent (1.22 percent). Also the use of information and communication technologies is positively correlated to TFP, although the effect is small in economic terms. Finally, our proxy for human capital is not statistically significant, but shows also a positive coefficient, which cannot be precisely estimated perhaps due to our sample size.

Accounting for common dynamic processes is important in our estimation for two reasons. First, the corresponding coefficient indicates that part of the growth in TFP is explained by these processes. Second, modeling these factors also influences other variables' coefficients, especially those of the FDI and unitary wage variables that would have been underestimated without considering these common factors.

Table 2 presents the first step results of the pooled model estimated in first differences. We compare the results for calculated TFP (according to the standard accounting method) and estimated TFP (as in Section 2) in columns 1 and 2, respectively. The estimates could provide an approximation to the short run effects of the considered variables in TFP as well as show the time evolution of the "dynamic common process", which is represented by the time dummies. We can observe that the year dummy coefficients are all positive when TFP is estimated but not when it is calculated using accounting methods. Also, as regards the statistically significance of the common time effect, we observe in column 2 of Table 2 that it is in year 2000 and also after 2004 when most of the coefficients are statistically significant at conventional levels. This could be indicating that it has been in those two years, but also in the following years after 2004, when some common effects (Euro introduction, EU enlargement) have been influencing TFP.

Table 2. First step estimation of AMG for TFP and estimated TFP

	Model in first differences	
First step APMG	**TFP**	**TFP estimated**
Variables:	b/se	b/se
D.ln EU-25 Exports to non-EU	.108***	.0815**
	(.0298)	(.0376)
D.ln intra-EU-25 Exports	.0589**	.0828**
	(.0295)	(.0371)
D.ln FDI	.00162	.00383**
	(.0013)	(.00164)
D.ln ITC	.00194	.00386**
	(.00129)	(.00163)
D.ln Unitary Wages	.0923***	.204***

	(.0198)	(.0249)
D.ln Human Capital	.00289***	.00272**
	(.000983)	(.00124)
year_1998	-.00505	.00815
	(.00725)	(.00914)
year_1999	-.00617	.0132
	(.00689)	(.00867)
year_2000	.000324	.0176*
	(.00716)	(.00905)
year_2001	-.0122*	.00504
	(.00653)	(.00823)
year_2002	-.0204***	.00613
	(.00712)	(.00897)
year_2003	-.0148**	.0121
	(.00675)	(.00848)
year_2004	.00669	.0222***
	(.00628)	(.00791)
year_2005	-.0254***	.000808
	(.0062)	(.00781)
year_2006	.0174***	.0268***
	(.0061)	(.00768)
year_2007	.00569	.0171**
	(.00621)	(.00782)
R-squared	0.222	0.148
N	1158	1158

Note: robust standard errors in brackets. D. denotes first differences.

5. Economic policy lessons and conclusions

Differences in the TFP performance are perceived not only across countries but also between sectors. In this paper, we have presented new estimates of TFP using a value added approach and sectoral data for 17 EU countries over recent years. In an econometric estimation setting, we have also searched for indicators affecting our estimated TFP. In both cases – when estimating TFP and when searching for its determinants - we have used a recently proposed estimation technique, namely the augmented mean group estimatore, which considers common dynamic factors and specific time-varying factors as important components of value added and TFP.

The main results show that TFP varies across sectors and countries and over time and that these variations are mainly explained by factors common to all countries: globalization in terms of trade openess, use of information and communication technologies and human capital.

The main policy recommendation is that countries aiming at improving TFP and therefore, their economic performance in the global economy, should favor specific sectoral policies that promote exports, widen the use of ITCs and create support for highly specialized and highly efficient work force. Consequently, given such human capital efficiency improvements, it is justified to reward with higher salaries. This should, indeed, be as a factor contributing to higher TFP.

We leave for further research the study of the fail or success of related policies, namely EU regional policies and also the study of other, until now unexploited, determinants of TFP in the EU. In particular, the potential impact on TFP levels of reallocation - as a factor permitting to transfer productive resources where the expectation over the returns is higher – as well as specific measures of sectoral competitiveness could be expected to exercise an important impact on TFP.

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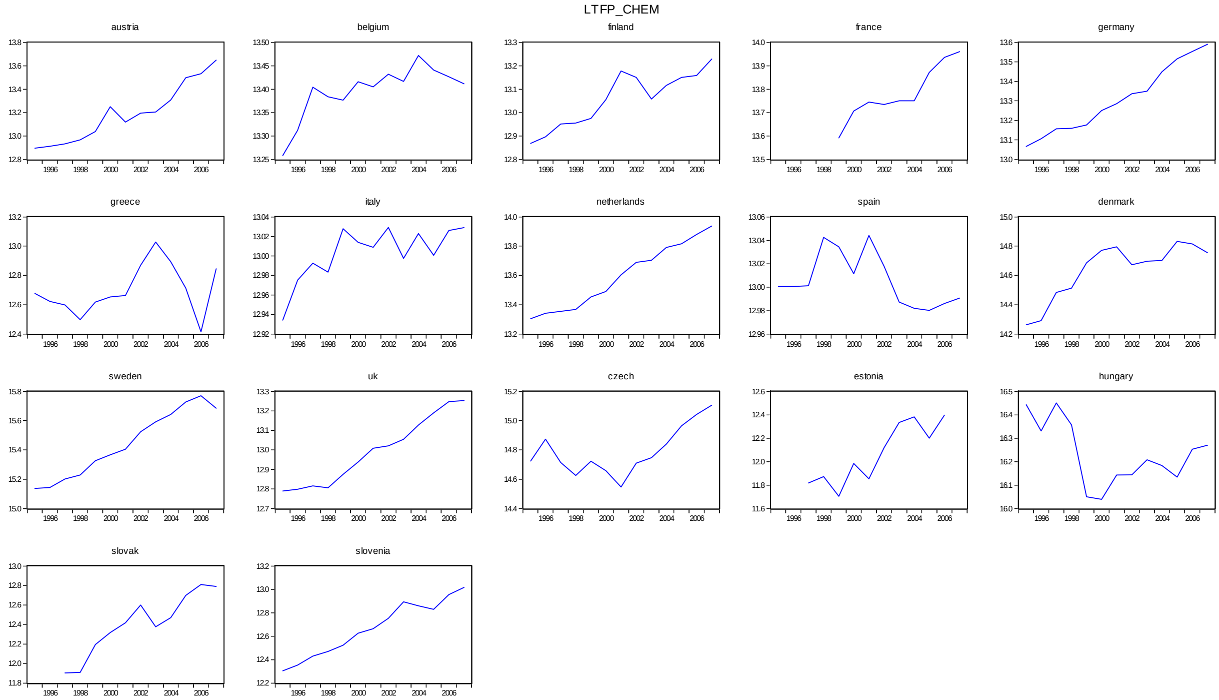
Appendix A.1:

Sectoral TFP (1995-2007)

Figure A.1: TFP development in the chemicals sector



Note: The country codes valid also for figures A.1 to A.13 : 1_Austria; 2_Belgium; 3_Finland; 4_France; 5_Germany; 6_Greece; 7_Italy; 8_Netherlands; 9_Spain; 10_Denmark; 11_Sweden; 12_UK.

Figure A.2: TFP development in the coke sector

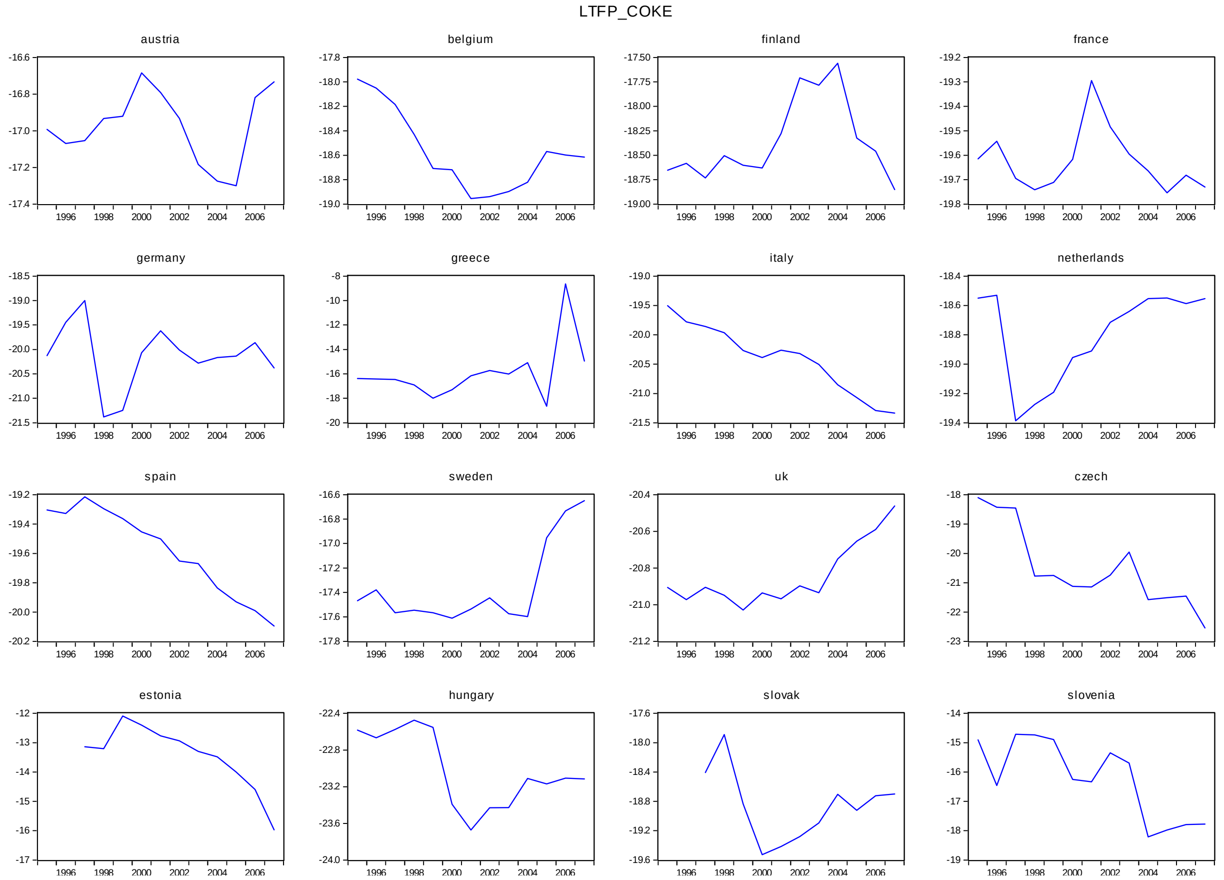


Figure A.3: TFP development in the electrical equipment sector

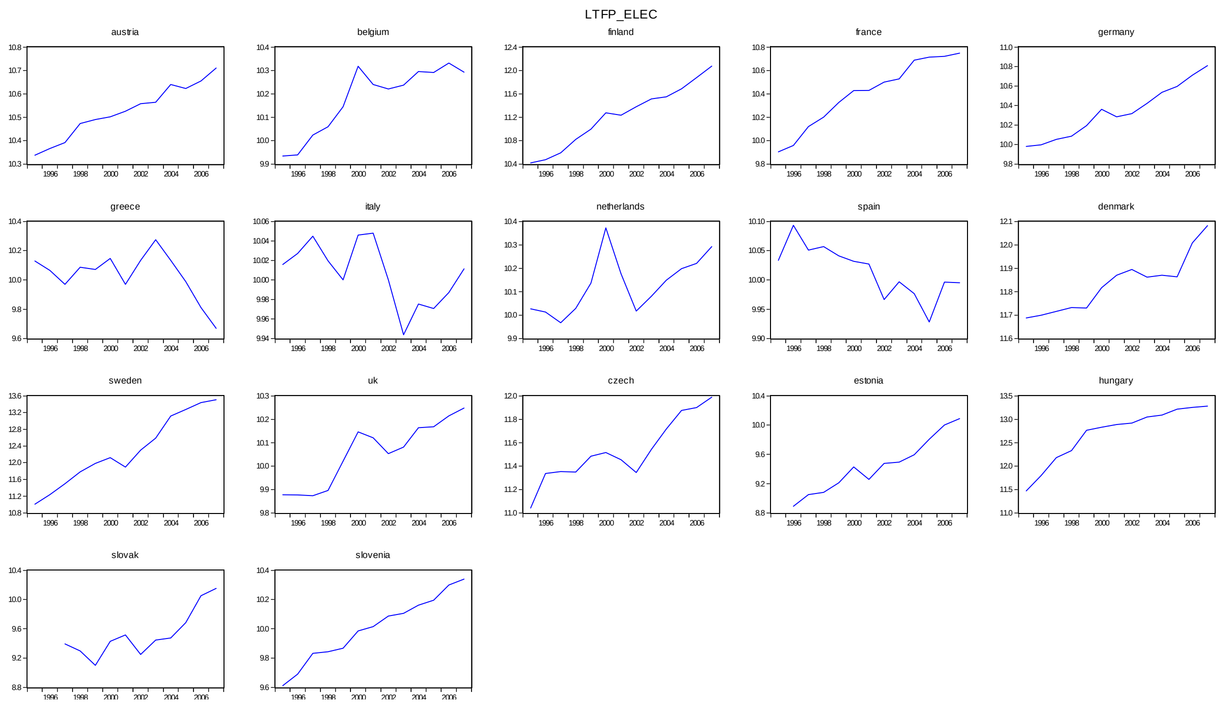


Figure A.4: TFP development in the food sector

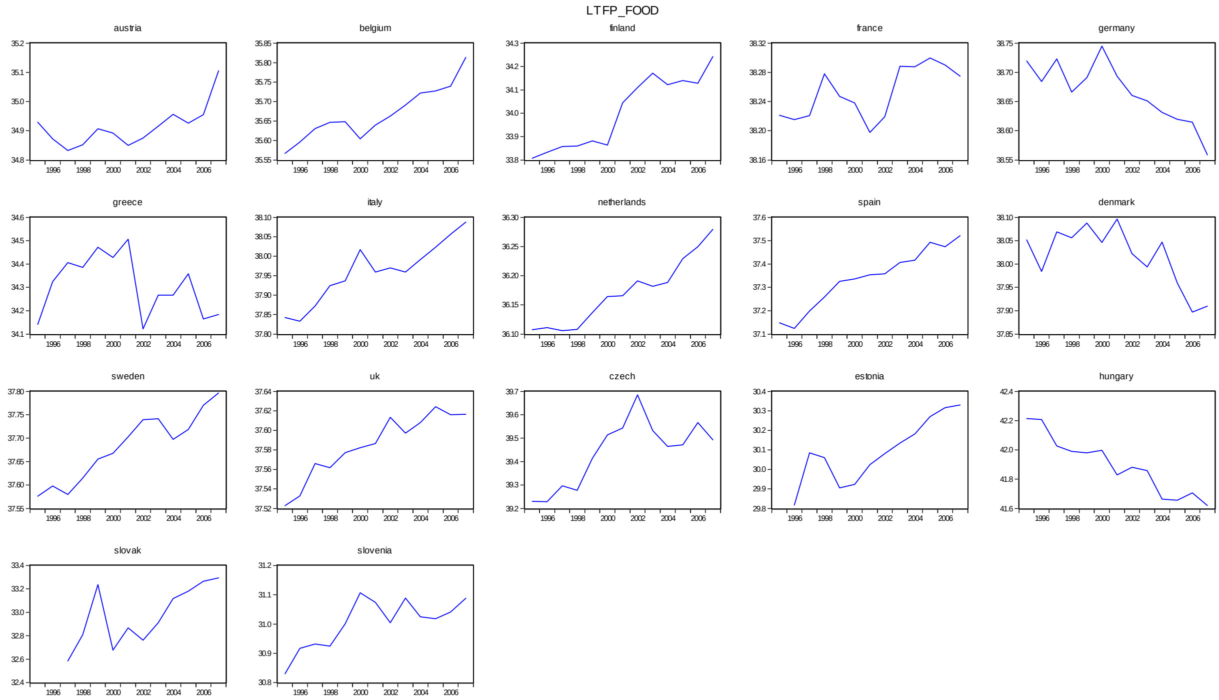


Figure A.5: TFP development in the machinery sector

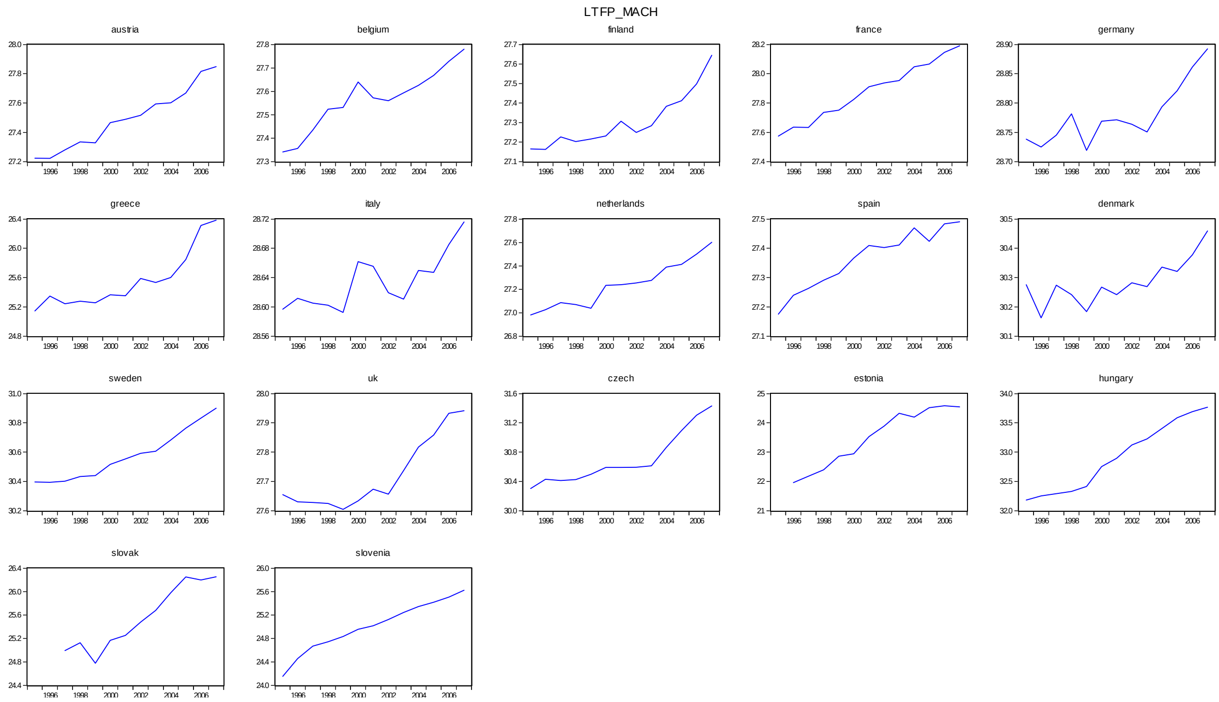


Figure A.6: TFP development in the manufacturing n.e.c. sector

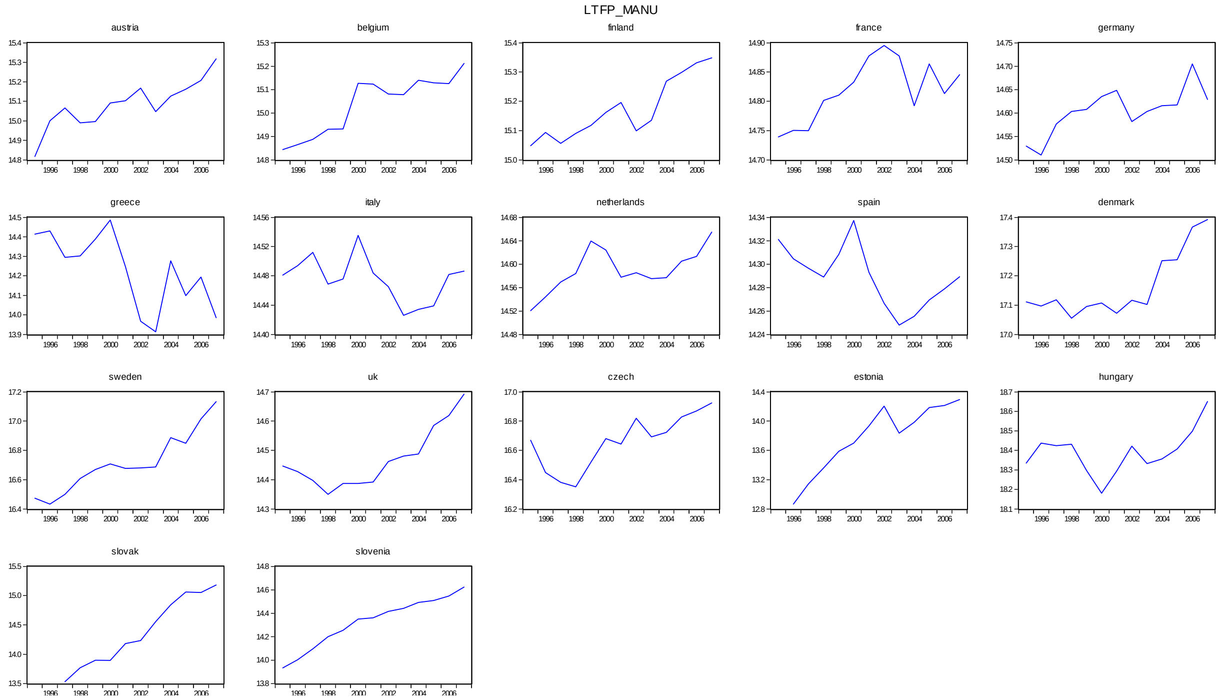


Figure A.7: TFP development in the metal sector

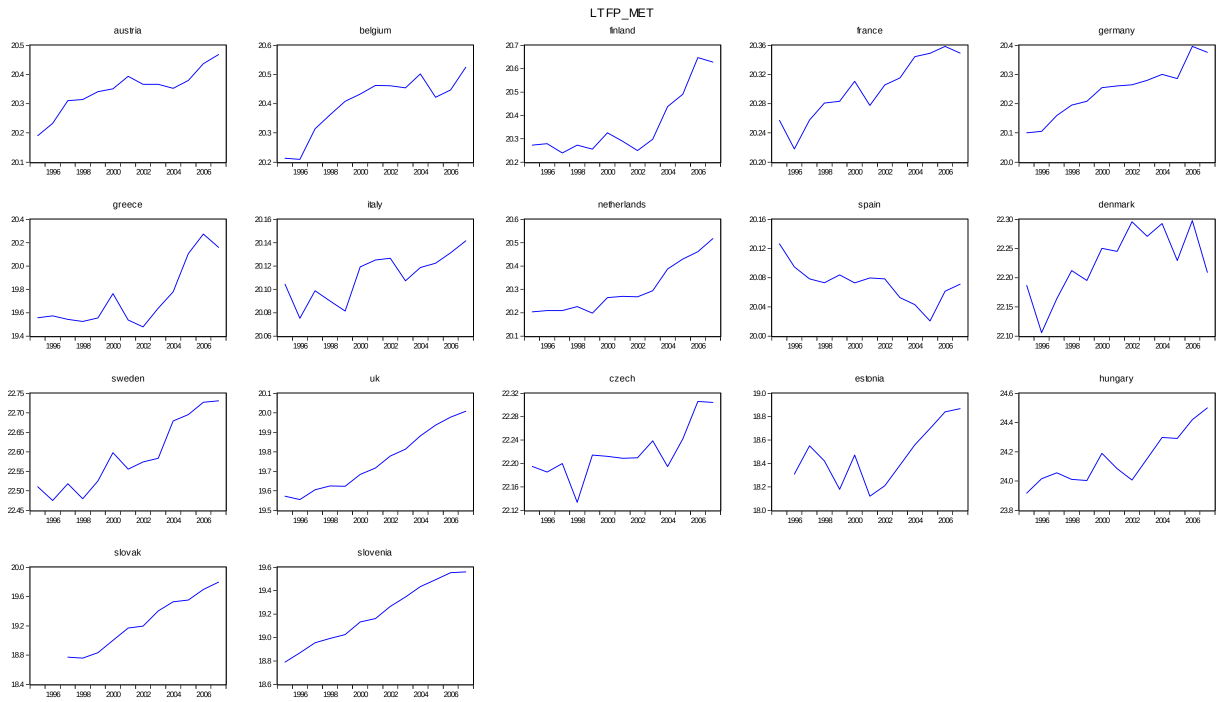


Figure A.8: TFP development in the other non-metallic minerals sector

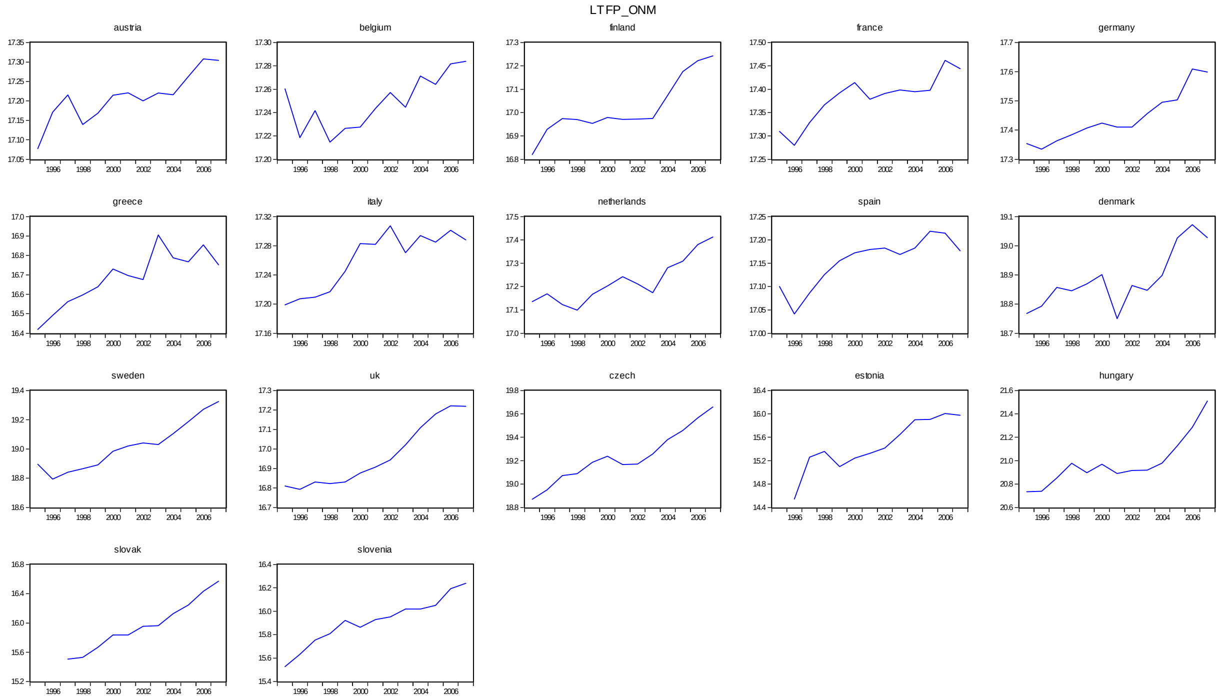


Figure A.9: TFP development in the paper & pulp sector

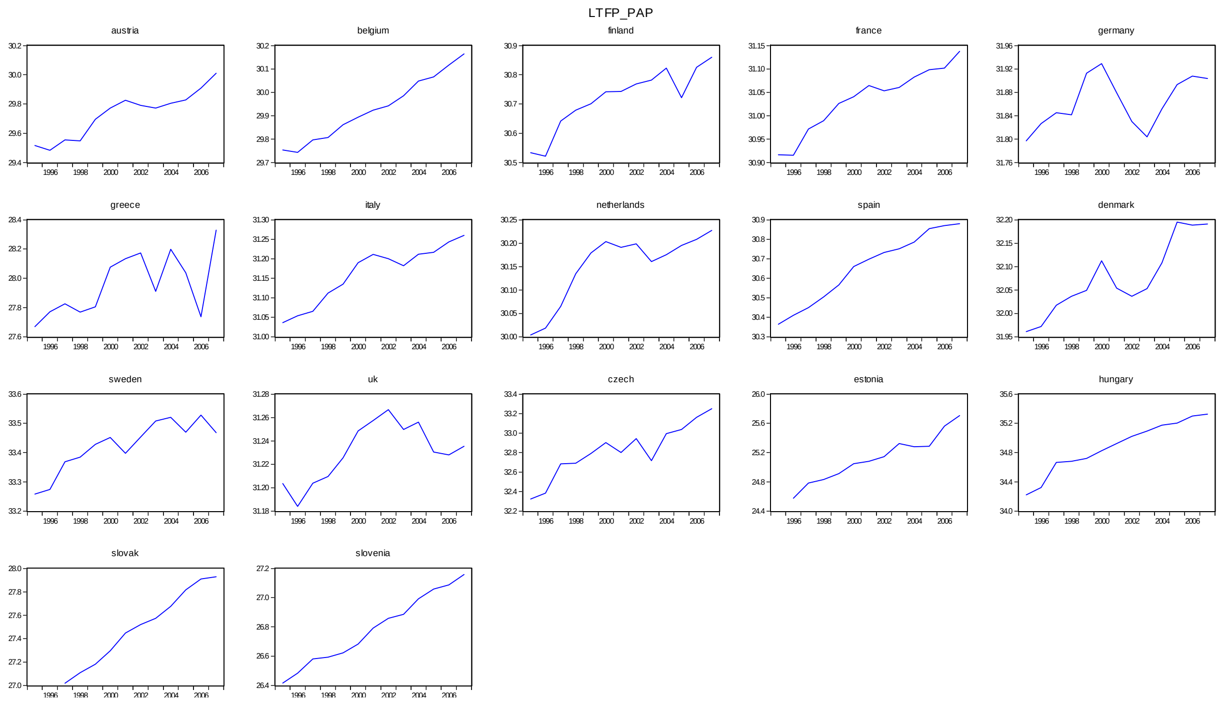


Figure A.10: TFP development of the rubber sector

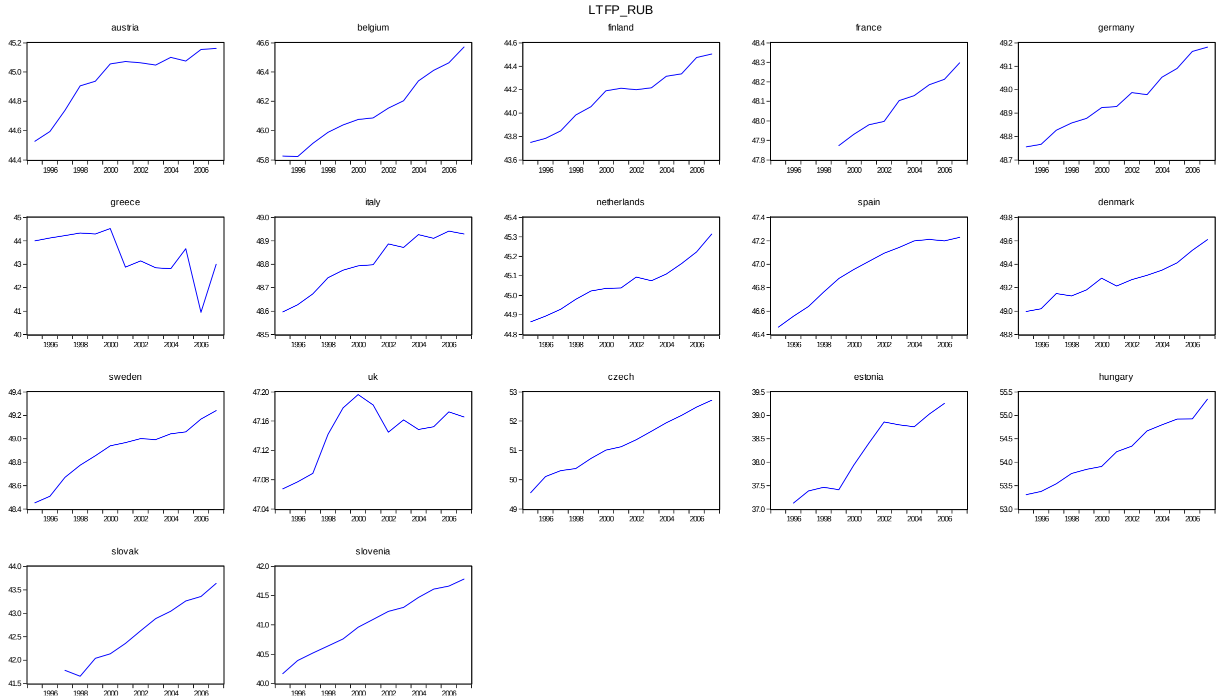


Figure A.11: TFP development in the textiles sector

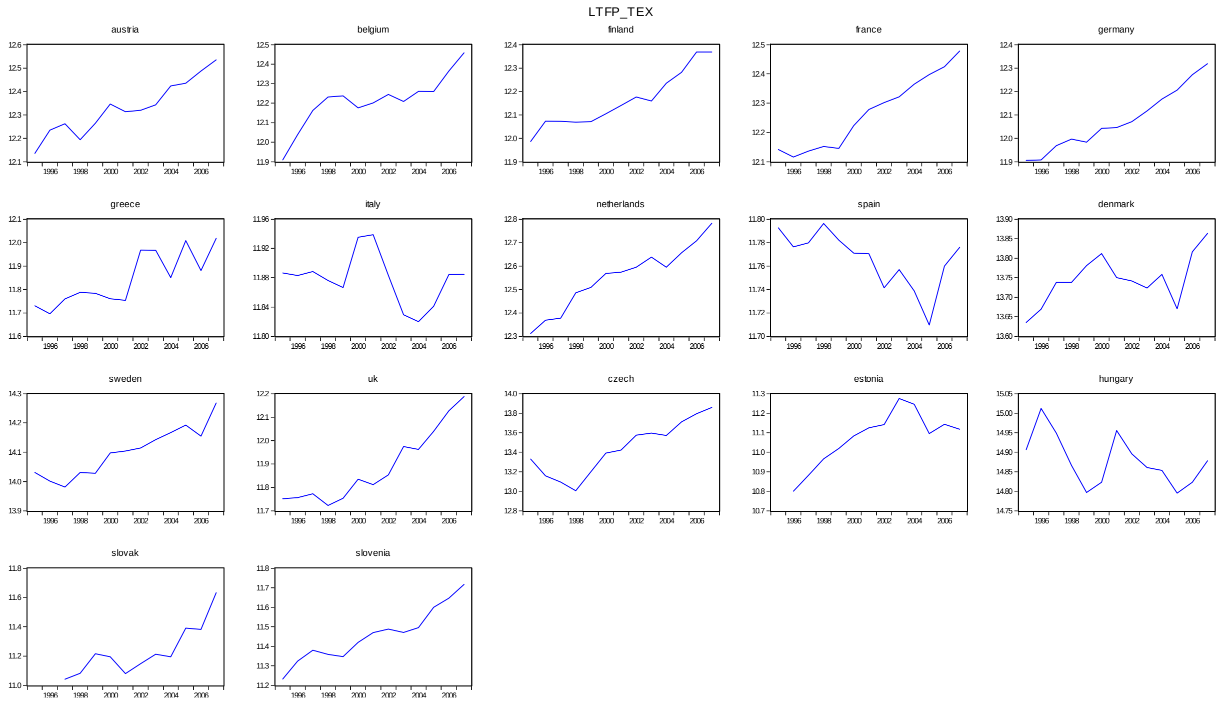


Figure A.12: TFP development in the transport equipment sector

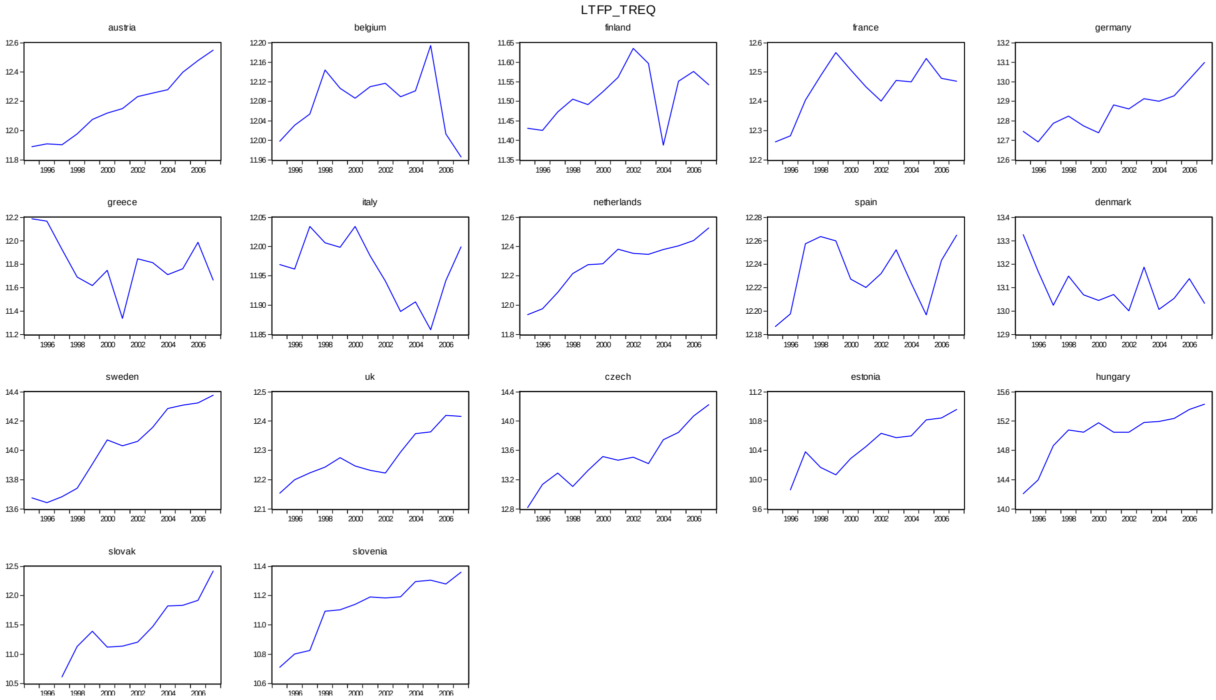
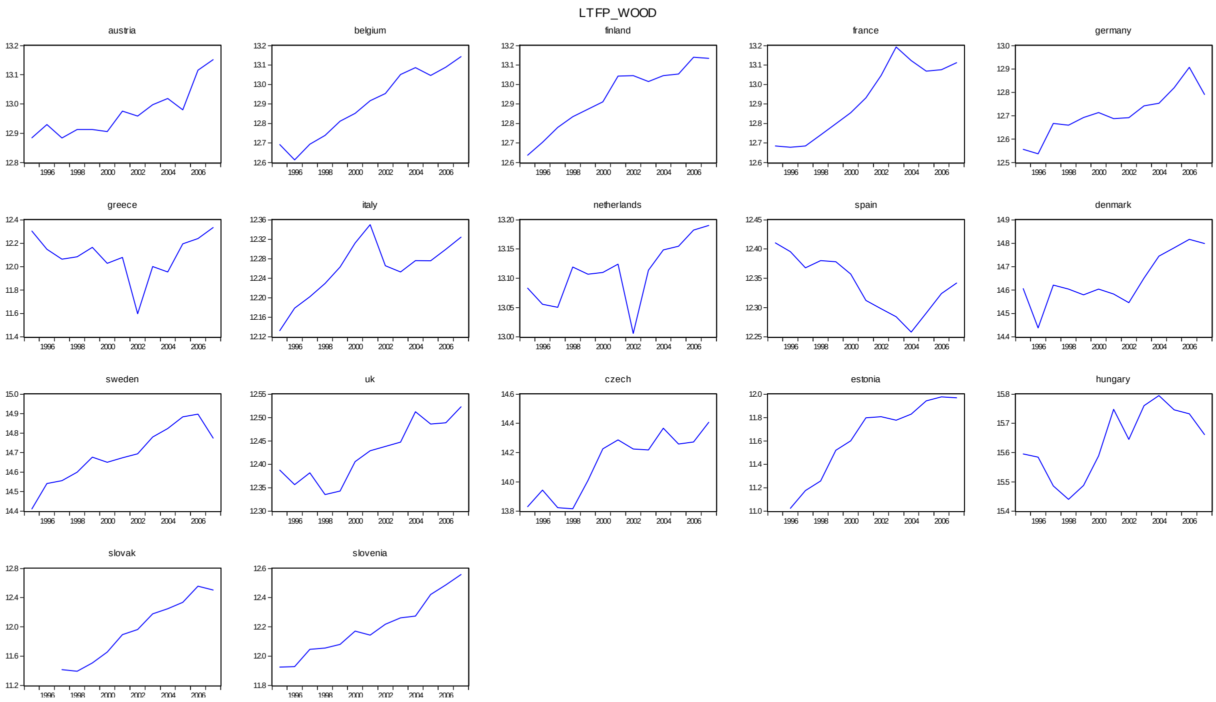


Figure A.13: TFP development in the wood sector



Appendix A.2

Sector's short name	NACE code	Full name of the sector
Food		Food product, beverages and tobacco
Textiles		Textiles, textile products, leather and footwear
Wood		Wood and products of wood and cork
Paper		Pulp, paper, paper products, printing and publishing
Chemicals		Chemicals and chemical products
Coke		Coke, refined petroleum products and nuclear fuel
Rubber		Rubber and plastic products
Non-metallic products		Other non-metallic mineral products
Metal products		Basic metals and fabricated metal products
Machinery		Machinery and equipment
Electrical equipment		Electrical equipment
Transport equipment		Transport equipment
Manufacturing n.e.c.		Manufacturing (non otherwise classified)