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ABSTRACT

The EU-US total factor productivity gap: An industry-level perspective

The EU-US total factor productivity (TFP) growth gap since the mid-1990's is concentrated in a handful of market service industries (most notably retail trade) and in ICT-producing manufacturing, whilst the EU exhibits a stronger performance in a number of the network utilities. This paper explores the industry-specific determinants of the EU-US TFP growth gap using the EU KLEMS database. As found in previous analyses (e.g., Nicoletti and Scarpetta (2003); Griffith, Redding, and Van Reenen (2004); Inklaar, Timmer and Van Ark (2008)), TFP growth appears to be driven by catching-up phenomena associated with the gradual adoption of new-vintage technologies. Compared with previous analyses, TFP growth is also significantly driven by developments taking place at the "technological frontier," increasingly so since the mid-1990's. Industries with higher R&D expenditures and higher adoption rates for ICT-intensive technologies appear to exhibit higher TFP growth rates, whilst human capital has mostly a significant effect across countries. Regarding industry specific determinants, ICT producing industries appear to benefit from R&D in terms of stronger spillovers from TFP gains at the frontier; network utilities are strongly affected by improvements associated with reduced product market regulations; whilst the retail trade industry is significantly influenced by consumption dynamics which permit a better exploitation of scale economies.

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1. Introduction

Starting from the mid-1990's, the growth performance of the EU and the US economies diverged markedly. In many EU countries employment growth provided a positive contribution to growth but this was accompanied by a slowdown on the productivity side, notably in terms of total factor productivity (TFP). This experience was in sharp contrast to that of the US, where the secular downward movement in productivity growth rates since the 1970's was reversed around the mid-1990's.

These TFP growth developments have triggered a debate in the EU regarding the implications of recent trends for future economic prospects and required policy responses. Some observers consider the EU-US productivity gap as partly due to measurement problems and mostly temporary, in light of the lagged effects from the labour, capital and product market reforms progressively introduced in the EU since the early 1990's (e.g., Blanchard, 2004). However, according to the prevailing view (e.g., Sapir et al., 2003; van Ark, Inklaar and Mc Guckian, 2003), the EU-US TFP growth gap is structural and, in the absence of a fundamental policy turnaround, the EU could be condemned to a long period of low TFP growth. This pessimistic assessment reflects the fact that the EU's current institutions and policy frameworks underpin its comparative advantage in medium-technology manufacturing industries, where the room for further substantial TFP growth appears limited.

Understanding the determinants of TFP growth is consequently essential in devising effective policy responses. Existing analysis aimed at analysing the determinants of total factor productivity growth take either an aggregate perspective or make use of the overall available industry sample in panel data analysis. However, there is wide agreement that the EU-US TFP growth gap differs strongly across industries. While the US advantage is highly concentrated in information and communication technology (ICT), goods producing, industries and in a number of market service industries, notably retail tradeservices and business services, the EU has built up an advantage in network utilities, notably telecommunications. Since TFP determinants are likely to differ substantially across industries, this paper aims at identifying the TFP growth drivers in those industries that are key in explaining the divergent TFP performance of the EU relative to the US.

The analysis makes use of the EU KLEMS[1] database, an industry-level database funded by the European Commission and constructed by a consortium of European academic and government research institutes co-ordinated by the National Institute of Economic and Social Research (NIESR) in the UK and the Groningen Growth and Development Centre (GGDC) in the Netherlands. The database contains high-quality measures of factor inputs and has been conceived with the explicit purpose of carrying out growth analyses. In particular, it makes data available on different types of capital and, skills-differentiated, categories of labour. Compared with previous similar analyses using the EU KLEMS database (Inklaar, Timmer, and van Ark, 2008), our sectoral focus is broader since it does not restrict itself to private services but also includes manufacturing. In addition, there is also an attempt to explore the role of a larger set of potential TFP determinants : human capital, R&D, ICT capital, product and factor market regulations, macroeconomic developments, and industry-level indicators of changes in firm demography.

The approach which the paper adopts in assessing TFP determinants builds on "neo-Schumpeterian" growth theory (Aghion and Howitt, 2005) : TFP growth depends on the rate of innovation and on the rate at which "state-of-the-art" technologies are adopted / diffused throughout the wider economy. Countries that are close to the technology frontier will mainly grow thanks to the introduction of new technologies, whilst the "follower" grouping of countries will derive the largest share of their TFP growth from the adoption of better, but already existing, technologies which are available "at the frontier".

The empirical implementation is akin to that in, e.g., Nicoletti and Scarpetta (2003); Griffith, Redding, and Van Reenen (2004); Inklaar, Timmer and Van Ark (2008). A reduced form of an innovation-imitation model is estimated on a panel of 9 EU countries, the US and 28 manufacturing and services industries over the 1980 – 2004 period. TFP growth is assumed to depend on two basic explanatory factors, TFP growth at the frontier and a measure of the technology gap with the frontier economy, the former capturing innovation-related TFP improvements, whilst the latter captures imitation and later adoption of state-of-the-art technologies. On top of these basic explanatory factors, a series of other variables are utilised to represent the framework conditions affecting the production of human capital, R&D, the adoption of ICT technology, and market regulations. They are used either to directly explain

[1] K for capital, L for labour, E for energy, M for materials, S for services

TFP growth or to measure the extent to which they indirectly influence the role of TFP growth at the frontier or of the technology gap term in driving TFP growth.

As found in previous analyses, TFP growth appears to be driven by catching-up phenomena associated with the gradual adoption of new-vintage technologies. In addition, our analysis shows that TFP growth is also significantly driven by developments taking place at the “technological frontier”, and that these "frontier" effects are becoming stronger since the mid-1990's compared with the catching-up drivers of TFP. When country, sector and year fixed effects are kept in the empirical specification, human capital variables have no significant explanatory power on TFP growth. A role for human capital is restored by eliminating country effects from the specification and computing TFP growth without distinguishing the labour inputs of different skill groups. This result, broadly consistent with Inklaar, Timmer and van Ark (2008), suggests that the contribution of human capital improvements to TFP growth is mostly related to (unmeasured) improvements in the quality of labour inputs, and manifests itself across countries. R&D and the adoption of ICT capital appears to play a significant direct role in TFP growth provided that industry effects are not included. This suggests that individual industries with higher R&D expenditures and higher adoption rates for ICT-intensive technologies exhibit higher TFP growth rates, whilst an "across the board" increase in R&D and ICT does not significantly affect TFP growth. Regarding industry specific determinants, ICT producing industries appear to benefit from R&D in terms of stronger spillovers from TFP gains at the frontier; network utilities are strongly affected by improvements associated with reduced product market regulations; whilst the retail industry is significantly influenced by consumption dynamics which permit a better exploitation of scale economies.

The remainder of the paper is organised as follows. Section 2 describes the data and provides a descriptive analysis of TFP growth patterns in the EU and the US. Section 3 presents the conceptual background and an overview of existing empirical work on TFP determinants at the industry level. Section 4 presents the econometric analysis. The concluding remarks section summarises the results and discusses policy implications.

2. Data and stylised facts

The following analysis uses the EU KLEMS database, released in 2007 and constructed by a consortium of EU academic and government research institutes. The purpose of EU KLEMS is to analyse growth at the industry-level in European countries, the US and a number of other OECD economies over recent decades. The value added of EU KLEMS is the improved quality and availability of information on the various inputs used in production. Gross output is decomposed into the contributions of intermediate inputs (i.e. energy, materials and services) as well as value added. Value added in turn is decomposed into the contributions from different types of capital and labour. Data has been collected on 7 different types of capital which are aggregated on the basis of the user cost of capital (i.e. the rental price of employing each asset type for a particular period of time) to produce capital service flows which take into account the widely different marginal productivities of the different components of a country's capital stock. In addition to aggregate measures of capital services, separate sub-totals for ICT and non-ICT capital are also available. Regarding labour inputs, these are differentiated with respect to skill levels (as measured by educational attainment), age and gender. Data is available at the industry level, on a comparable cross-country basis, for three different skill levels, with the labour inputs aggregated on the basis of their marginal productivities. Overall, compared with previous databases, EU KLEMS allows researchers to assess TFP developments excluding the impact of changes in the composition / quality of both capital and labour inputs.

The EU KLEMS database provides a decomposition of GDP growth into its main determinants on the basis of a Cobb-Douglas production function approach which includes productive capital (i.e. a volume index of capital services); human capital (i.e. a skills based indicator of the average qualifications of the labour force); employment levels adjusted for hours worked; and TFP obtained as a residual term. [2]

Due to the lack of capital stock data, a complete and detailed growth accounting analysis at the industry level is only possible for 9 EU countries (Denmark, Germany, Spain, France, Italy, the Netherlands, Austria, Finland and the UK) over the 1980 – 2004 period. Henceforth

[2] Since TFP is a residual measure, it includes a mix of both important policy relevant information (such as innovation and technological change; the overall efficiency with which the different factors of production are used) as well as spurious information linked with a number of measurement problems (for example, unmeasured or badly measured factor inputs). These ongoing measurement issues undoubtedly complicate the analysis of TFP determinants and the assessment of the implications of TFP trends for supply side policies. A degree of caution is also warranted due to the conceptual and empirical problems in accurately measuring output and price developments in some of the market service industries.

we will refer to the aggregate formed by these 9 EU countries as EU-9. Regarding the industry breakdown, growth accounting variables are available at the NACE A31 level.

Table 1 summarises the GDP growth accounting results for the EU-9 and the US using the EU KLEMS approach[3]. The table shows that virtually all of the 1.2 percentage points GDP gap between the EU-9 and the US over the period since 1995 has been driven by TFP, with the small EU-US differences in the GDP contributions of capital services and labour services tending to cancel each other out. At the level of individual sectors, Table 1 also shows large EU-US TFP growth rate differentials for both the manufacturing and private services sectors over the period 1996-2004. These figures constitute a substantial turnaround compared with the 1981-1995 period, when the EU's total economy TFP growth rate was more than double that of the US.

[Table 1]

Graph 1 provides a breakdown of the TFP gap between the US and EU-9 at the A31 industry level[4]. It emerges, over the 1996-2004 period, that only a small number of industries drove the bulk of the aggregate TFP growth rate gap in favour of the US : one manufacturing industry (electrical and optical equipment – ISIC 30t33 which includes semiconductors, the main ICT producing industry) and a number of private service industries (retail trade – ISIC 50 & 52;

[3] The basic data source for table 1 and graph 1 is the EU KLEMS growth accounts which are based on the growth accounting methodology as laid out in the seminal contribution of Jorgenson and Griliches (1967) and put in a more general input-output framework by Jorgenson, Gollop and Fraumeni (1987) and Jorgenson, Ho and Stiroh (2005). Using the standard assumptions of constant returns to scale and competitive markets, industry value added growth is defined as follows :

$$\Delta \ln V_{jt} = \overline{w}_{jt}^{K} \Delta \ln K_{jt} + \overline{w}_{jt}^{L} \Delta \ln L_{jt} + \Delta \ln A_{jt}^{V}$$

with the growth of value added (V) being a function of the growth of capital (K), labour (L) and technology (A), where $\overline{w}_{jt}$ is the two period average share of the input in nominal value added. The contribution of each input to value added is therefore equal to the product of the input's growth rate and its two period average value added share. All aggregations of outputs and inputs over industries use the Tornqvist quantity index, which is a discrete time approximation to a Divisia index. This aggregation approach uses the relevant annual moving weights (e.g. value added) based on averages of adjacent points in time. To aggregate across countries, use is made of Purchasing Power Parities (PPPs), with the PPPs used being industry-specific and reflecting differences in price levels across countries at a detailed industry level. For a more detailed description of the EU KLEMS methodology, see "EU KLEMS Growth & Productivity Accounts, Part 1 Methodology" (March 2007 – www.euklems.net).

[4] TFP growth is defined as follows :

$$\Delta \ln A_{jt}^{V} = \Delta \ln V_{jt} - \overline{w}_{jt}^{K} \Delta \ln K_{jt} - \overline{w}_{jt}^{L} \Delta \ln L_{jt}$$

i.e. the growth of TFP is derived as the real growth of value added minus a weighted growth of labour and capital inputs (see footnote 3 for further details) real estate renting and other business activities – ISIC 71t74). Graph 1 also indicates that the EU has done relatively well in "network utility" industries such as electricity, gas and water (ISIC E) and especially transport, storage and telecommunications (ISIC 60t64). The regression analysis in section 4 will closely examine trends in these main TFP-driving industries, with the objective of offering guidance to policy makers as to the most potent TFP-enhancing policies to pursue.

[Graph 1]

3. Conceptual framework and existing literature

3.1. Conceptual framework

An understanding of the key determinants of TFP growth has been high on the research agenda of international organisations and the academic community over the past decade. In the standard neoclassical growth framework, TFP is exogenous and corresponds to the "Solow residual". In the early wave of endogenous growth models (so-called "AK models"), TFP growth is often the result of capital accumulation, which is assumed not to be subject to decreasing returns to scale, with the implication being that growth-friendly policies should be focussed on promoting savings and investment. The predictions of these models do not however appear to be consistent with recent stylised facts regarding the EU's growth performance with, for example, capital intensity levels in the second half of the 1990s being higher in Europe than in the US, whilst TFP growth stagnated in the former group of countries and was sustained in the latter.

There is a growing consensus that recent growth theories, based on "neo-Schumpeterian" creative destruction mechanisms, seem better equipped to interpret recent developments in the growth performance of advanced economies (e.g., Aghion and Howitt, 2005).

Innovators, by introducing superior product varieties and technologies, have the effect of both displacing existing firms and of inducing the adoption of new products and techniques at the wider industry level. The growth rate of the economy will thus depend both on the rate of innovation and on the rate at which "state-of-the-art" technologies are adopted and diffused throughout the economy. In turn, the innovation rate depends on the resources devoted to the innovation effort (notably, R&D and human capital) and on the rate at which innovations are introduced in the frontier economies (due to knowledge spillovers), whilst imitation and adoption of state-of-the art technologies are expected to be faster, the greater the distance from the frontier. Countries that are close to the technological frontier will mainly grow thanks to the introduction of new technologies, whilst "follower" countries will derive the largest share of their TFP growth from the adoption of new-vintage, existing, technologies.

According to this view, institutions and policies play a key role in determining the relative position of countries in the global innovation race and consequently strongly influence relative growth patterns. These framework conditions directly affect the ability of countries to innovate at the frontier or to adopt existing, leading-edge, technologies. Whilst follower countries would gain from institutions and policies favouring the cost efficient adoption of existing technologies, countries operating at the frontier would profit more from policies that promote excellence in higher education and R&D; financial markets that reward risky projects; and regulations that do not put an excessively heavy burden on either incumbent firms nor on potential entrants (see, e.g., Sapir et al., 2003).

3.2. Existing empirical work

A number of papers have already analysed the determinants of TFP in a neo-Schumpeterian framework. Most of the existing analyses use panel data information, pooling together data on TFP levels and growth rates over several years and countries. Some papers also use information at the industry level, with the datasets usually obtained from the OECD STAN database (e.g., Nicoletti and Scarpetta, 2003; Griffith, Redding, and Van Reenen, 2004).

The available empirical specifications normally reflect a reduced form of the basic innovation-imitation model, with most of them regressing TFP growth on two key explanatory variables. First, a measure of the technology gap (i.e. the distance between the TFP of the country analysed and that of the country with the highest level of efficiency). This variable captures the extent to which TFP growth in a specific country can be explained by the adoption of more efficient existing technologies. The assumption is that the larger the technology gap, the higher the potential gains from adopting more efficient, internationally available, technologies and consequently the faster the rate of TFP growth. The second key variable is an estimate of the growth rate of TFP at the frontier (i.e. the TFP growth rate of the most efficient country). This second variable aims at capturing the link between TFP growth in the "catching-up" country with the extent of innovation and knowledge spillovers which are taking place in the technologically most advanced country.

In addition to the above basic explanatory variables, most papers also control for a series of policy and institutional factors that may affect the rate of TFP growth independently or may interact with the "technology gap" and "technology spillovers" variables to have an impact on TFP.

Nicoletti and Scarpetta (2003) analyse industry TFP growth in a panel of OECD countries and find some support for the view that entry liberalisation and privatisation have a positive impact on TFP. Moreover, this impact appears to be stronger the further away are countries from the technology frontier. The interpretation is that entry regulations and public ownership prevent the adoption of existing up-to-date technologies, so that the impact is greater away from the frontier, where TFP growth is more strongly based on adoption rather than on innovation. This result can be contrasted with the findings in Aghion, Bloom, Blundell, Griffith and Howitt (2003) who analyse the patenting activity of UK firms at the US patenting office. They find that when firms are close to the national technological frontier that product market competition has a stronger positive impact on innovation. This conclusion can be explained by the observation that being far from the frontier reduced the incentives to innovate by reducing innovators' rents more strongly. A similar result is obtained in Aghion, Blundell, Griffith, Howitt and Prantl (2006) who analyse patenting activity and TFP growth at the firm and establishment levels in the UK.

Regarding the role of human capital, Nicoletti and Scarpetta (2003) find that higher skill levels have a positive impact on TFP growth, although the effect is not always significant. Vandenbussche, Aghion and Méghir (2006) analyse aggregate TFP determinants in a panel of OECD countries and show that high-skilled human capital has a positive effect on TFP growth, an effect which is stronger the closer a country is to the technology frontier.

Griffith, Redding and Van Reenen (2004) study TFP determinants across industries in a panel of OECD countries and show that R&D has both a direct impact on TFP growth and a role in facilitating the cross-country convergence of TFP levels. The result is interpreted as providing support for the two "faces" of R&D in promoting productivity growth : on the one hand, R&D enhances a firm's innovative potential (thus increasing directly the rate of TFP growth); on the other hand, it improves the absorptive capacity of firms and industries, thus facilitating the adoption of existing technologies and spurring TFP convergence.

Most of the existing analyses at the industry level are limited to manufacturing industries. However, we learned earlier that TFP growth rates in Europe and the US have been diverging, in recent times, especially in private services. Hence, a better understanding of the TFP growth determinants in these industries is crucial in assessing the factors which are driving the EU's widening productivity gap with the US. With a view to addressing such questions, Inklaar, Timmer and Van Ark (2008) analyse the determinants of TFP growth in private services using the EU KLEMS database. Their analysis shows that although ICT investments were a main driver of labour productivity growth in the service industries of both the EU and the US, the adoption of ICT-intensive technologies does not appear to be associated with higher growth rates of TFP. Additionally, human capital intensity has no significant explanatory power for TFP growth and entry regulations mattered only in telecommunications, but not in other market service industries.

4. Empirical analysis

4.1. Empirical strategy

The aim of the following analysis is to take a step forward compared with existing work by capitalising on the recent release of the EU KLEMS datasets and specifically on the increased availability of TFP data series and of substantially enhanced industry level detail. Compared with Inklaar, Timmer, and Van Ark (2008), we will not limit the analysis to private services. Additionally, there will be an attempt to identify the determinants of TFP growth in those specific industry groupings that contributed most to the EU-US TFP growth gap, namely ICT- producing manufacturing (i.e. electrical & optical equipment), retail trade and business services, and for those industries where EU countries exhibited a stronger performance, i.e. public utilities. Compared with existing analyses, there will also be an attempt to control for a potentially larger number of policy and institutional variables.

Our sample is made up of a panel of 10 countries (9 EU countries plus the US) and 28 industries over the 1980-2004 period.[5] The baseline specification is similar to that found in existing analyses (e.g., Nicoletti and Scarpetta, 2003). TFP growth rates are regressed over a measure of innovation / technology spillovers (i.e. the TFP growth rate of the leader country) and of a technology gap term (i.e. the lagged logarithm of the difference between TFP in a specific country and TFP at the frontier, with the frontier being determined by the country exhibiting the highest TFP level in that particular industry, in that particular year). Country, industry and year fixed effects control for factors that independently may affect TFP growth rates.

The TFP growth rates used in the analysis are those computed using the established "ex-post" capital services method in the EU KLEMS database. With regard to the measurement of the technology gap variable, we make use of the PPP-adjusted TFP levels dataset provided for the 10 countries in Inklaar, Timmer and Van Ark (2007).[6] As a countercheck, TFP data obtained using an "ex-ante" approach, and "raw" TFP measures that do not distinguish between labour with different skill levels and between the widely different marginal productivities of ICT and non-ICT capital, are also used.[7]

The baseline specification is subsequently augmented in such a way as to control for the impact of human capital, R&D, ICT capital, regulations, and other framework conditions. In the following section, only the specifications exhibiting the strongest explanatory power are displayed. A long list of country-level variables, capturing overall macroeconomic conditions; the availability of economy-wide infrastructures which are most closely associated with the

[5] Food products, beverages and tobacco (15t16); Textiles, textile products, leather and footwear (17t19); Wood and products of wood and cork (20); Pulp, paper, paper products, printing and publishing (21t22); Coke, refined petroleum products and nuclear fuel (23); Chemicals and chemical products (24); Rubber and plastics products (25); Other non-metallic mineral products (26); Basic metals and fabricated metal products (27t28); Machinery, nec (29); Electrical and optical equipment (30t33); Transport equipment (34t35); Manufacturing nec; recycling (36t37); Electricity, gas, and water supply (E); Construction (F); Sale, maintenance and repair of motor vehicles and motorcycles, retail sale of fuel (50); Wholesale trade and commission trade, except of motor vehicles and motorcycles (51); Retail trade except of motor vehicles and motorcycles; repair of household goods (52); Hotels and restaurants (H); Transport and storage (60t63); Post and telecommunications (64); Financial intermediation (J); Real estate activities (70); Renting of machinery and equipment and other business activities (71t74); Public administration and defence; compulsory social security (L); Education (M); Health and social work (N); Other community, social and personal services (O).

[6] The TFP levels data in Inklaar, Timmer and Van Ark (2007) refer to the year 1997. TFP levels for other years are derived from TFP growth rates computed ex-ante. R. Inklaar is gratefully acknowledged for providing the TFP levels data produced in Inklaar, Timmer and Van Ark (2007).

[7] The difference between the ex-post and the ex-ante method for computing TFP is that the latter is based on an exogenous value for the rate of return whereas the ex-post approach estimates the internal rate of return as a residual given the value of capital compensation from the national accounts and estimates for depreciation and capital gains.

development of new technologies; demographic factors; barriers to entry and competition; generally turned-out to be not significant.[8]

4.2. Regression results

4.2.1. Baseline specification

Table 2 presents the results for the baseline specification. Since there is, a-priori, no strong suspicion of explanatory variable endogeneity and reverse causation issues, Least Square Dummy Variables estimation methods are used. Standard errors are robust with respect to heteroschedasticity and the possible lack of independence of the residuals within countries. Fixed effects are included for countries, industries, and years.

The results suggest that, across the whole sample, TFP growth is significantly higher when there is stronger TFP growth in the frontier economy (reflecting cross-border innovation dynamics and technology spillovers) and when the technology gap is large (which reflects TFP convergence via the adoption of existing superior technologies). The contribution of the latter to explaining TFP dynamics appears to be dominant. This is easily understood by noting that the simple average of TFP growth at the frontier is 1.7 per cent, whilst the technological gap is on average 36 per cent. Multiplying these averages times the regression coefficients in column (1) yields a contribution of the technology gap which is about 6 times larger.

[Table 2]

Wald tests suggest keeping fixed effects for countries, industries and years in the specification. However, the results do not appear to be very significantly affected by the removal of fixed effects (columns (2)-(4)). Furthermore, the baseline specification in (1) does not seem to suffer from a major problem of mis-specified dynamics. [9] In particular, the lagged

[8] The data sources for these variables are as follows : European Commission DG ECFIN's AMECO database for macroeconomic conditions (output gap, relative contribution of consumption to GDP growth, relative contribution of investment to GDP growth); Barro and Lee data on economy-wide education indicators; World Bank Development Indicators for infrastructure (number of internet users, computer diffusion, share of population with tertiary degree, public spending on education, public spending on R&D, number of patent applications) and for the age structure of the population; OECD for economy-wide indicators of product market regulation and barriers to competition (public ownership of firms, public involvement in business operations, regulatory and administrative opacity, administrative burden on start ups, barriers to competition, explicit barriers to foreign trade and investment, other barriers to foreign trade and investment).

[9] Note that specification (1) in Table 2 can be interpreted as the Error Correction Mechanism specification of a model where TFP levels in country *i*, industry *j*, at year *t*, are assumed to depend on TFP in industry *j*, at year *t*, in the "frontier economy".

dependent variable when added to specification (1) does not yield a significant regression coefficient.

[Table 3]

Column (6) in Table 2 also reports the same specification as in column (1) but using "ex-ante" calculated TFP growth rates. The results are broadly similar in terms of the coefficient estimate and its significance level. What appears to matter instead for the result is the allowance made in EU KLEMS, when constructing the TFP variable, for shifts in the quality of factor inputs (i.e. different skill categories for labour and ICT vs. non-ICT capital) over time. Indeed, by repeating the baseline regressions using a "raw" measure of TFP that does not distinguish between labour with different skills and that does not specifically differentiate the marginal productivity of ICT capital, TFP growth at the frontier does not appear to significantly affect TFP growth rates (column (7)). It is notable that in previous similar analyses using databases other than EU KLEMS, a significantly negative relationship between TFP growth and the gap in technology is generally found, but the impact of TFP growth at the frontier is not always significant (e.g., Nicoletti and Scarpetta, 2003). This result suggests that the possibility of taking into account labour and capital inputs of different quality permits one to get closer to a measure of TFP growth which reflects both innovation dynamics and factor efficiency gains from the introduction of new technologies to a greater extent than "cruder" TFP measures.

Table 3 also reports results for the basic specification based on different sectoral breakdowns, geographical aggregates, and time periods. Column (2) reports the results when the sample is restricted to the manufacturing sector, whilst columns (3) and (4) do the same for, respectively, private services and ICT-related sectors (the latter is comprised of both the ICT producing manufacturing sector and all industries in the economy that use ICT goods intensively). Column (5) reports results for all sectors but for EU countries only, column (6) only includes the sample years after 1995, while column (7) displays results when the sample is restricted to EU countries after 1995. A number of results stand out. Firstly, innovation and knowledge spillovers have a broadly similar effect on the TFP growth performance of the manufacturing, private services and ICT-related sectors, as indicated by a similar value for the coefficient of TFP growth at the frontier. Secondly, looking at the technology gap variable, it appears that TFP growth in the manufacturing sector is relatively more driven by the adoption of superior existing technologies as compared with private services and ICT related sectors.

Thirdly, limiting the sample to EU countries gives results which are qualitatively similar to those obtained with a sample including the US. Finally, when the sample is restricted to the latest decade (i.e. 1995-2004), TFP growth appears to be still significantly driven by growth at the frontier, whilst the technology gap variable becomes non-significant. This finding is consistent with the view that growth is increasingly being driven by innovation activity, with catching-up associated with the adoption of existing up-to date technologies having a less robust impact.

4.2.2. The role of human capital, ICT capital and R&D.

Table 4 reports the results for the basic specification augmented to take into account the role of human capital, ICT capital and R&D in affecting TFP growth. On top of the determinants included in the basic specification, the share of skilled labour compensation, the share of R&D expenditure, and the share of ICT capital and non-ICT capital are added to control for, respectively, the roles of human capital, R&D and ICT technologies. All these variables vary across countries, industries and over time. [10]

These additional variables, when introduced in the baseline specification (whilst keeping country, industry and year fixed effects) appear not to have significant explanatory power. A possible explanation could be that the sample period is not sufficiently long for the impact of these variables to become manifest, or that such effects unfold only gradually and with long delays.

In order to allow the cross-country dimension to play a role, in column (2) we repeat the same regression as in column (1) but eliminating the country fixed effects. Even allowing for a cross-country dimension, human capital, R&D flows and ICT still do not play a statistically significant role. Column (3) repeats the regression excluding the industry fixed effects. It appears that it is the variation across industries that permits one to identify a largely significant role for R&D and ICT intensity. Hence, while it seems, other things being equal, that industries characterised by higher R&D and ICT intensity tend to exhibit higher growth rates of TFP, an across the board increase in R&D and ICT intensity does not appear to

[10] More traditional measures of human capital, like educational attainment levels in the whole economy (Barro and Lee source), were tested but produced only small and insignificant effects.

translate into higher TFP growth. This result helps to qualify those previously obtained in Inklaar, Timmer, and van Ark (2008) regarding the role of ICT in private services.[11]

A further check on the above results is provided in columns (4) and (5) which show the results using a "raw" TFP measure that does not take into account labour and capital composition effects. The regression results are displayed without, respectively, country and industry effects. With this measure of TFP, a role for human capital is found for the specification excluding country fixed effects. Countries where the skill intensity of production technologies is higher tend to exhibit higher TFP growth rates, other things being equal. The fact that this result holds only with a "raw" TFP measure suggests that the role of human capital in explaining productivity growth is largely related to labour productivity improvements associated with the secular rise in the skill levels of the workforce, and that these improvements are stronger in the countries exhibiting higher skill levels over the sample period. Whilst these productivity improvements are excluded from the EU KLEMS TFP measure, they form part of the "raw" TFP measures.

As shown in previous analyses, the impact of human capital and R&D may depend on the degree of technological advancement of countries, as captured by distance from the frontier. In order to capture this effect, we add as an explanatory variable our human capital and R&D measures interacted with the "technological gap" variable. In addition, we also interact human and ICT capital and R&D with the "TFP growth at the frontier" variable.[12] The idea in this latter case is that these variables could affect the extent to which TFP is driven by innovation and by the absorption of technological spillovers emanating from the technology frontier. To our knowledge this interaction was not considered in previous analyses.

[Table 4]

[11] Although the variable used in Inklaar, Timmer, and van Ark (2008) differs from ours (being defined as the share of ICT capital returns on total costs), their regressions also include fixed effects for countries, industries, and years.

[12] Since the human capital and R&D variables are standardised in such a way as to have zero mean and unit standard deviation, and since both variables (subject to interaction) are included independently in the empirical specification, the interpretation of the interacted variables is as follows. The value of the coefficient of, say, human capital interacted with the technological gap term, represents the change in the technological gap variable associated with a one-standard-deviation increase in the share of skilled labour compensation in total labour compensation. Thus, a positive (negative) coefficient could be interpreted as meaning that more human capital is associated with faster (slower) TFP convergence. The regression coefficient of the non-interacted "technology at the frontier" and technological gap variables represent their impact keeping the value of human capital at zero, i.e., at sample mean. An alternative interpretation is that the change in the coefficient of the human capital variable is associated with a one per cent reduction in the technological gap (i.e. the percentage distance between the TFP in a given country, industry and year and the highest TFP value found across countries in the same industry in that year). Thus, a positive (negative) coefficient could mean that being closer to (further away from) the frontier raises (reduces) the impact of human capital. Analogous interpretations are given for the remaining interacted variables.

Column (6) reports the results across the whole sample of industries. Columns (7), (8), and (9) repeat the same regression limiting the sample to the manufacturing, private services, and ICT-related sectors respectively. It appears that, across all industries, human capital has a positive and almost statistically significant coefficient when interacted with both the technology gap and TFP growth at the frontier variables. Hence, in line with Vandenbussche, Aghion and Méghir (2006), we also find that the positive impact of human capital is stronger the smaller is the technology gap. Moreover, human capital also permits one to share in the TFP improvements taking place at the frontier, either because analogous innovations to those put in place at the frontier become more likely also "at the periphery", or because the capacity to absorb technological spillovers increases with human capital. This role of human capital as facilitator of frontier-type innovation and technological spillovers is very visible especially when restricting the analysis to private services. In this case, the coefficient of the human capital variable interacted with TFP growth at the frontier is highly significant.

R&D also appears to have a positive, but only marginally significant, effect on the ability of a country to share in the TFP improvements taking place at the frontier, as revealed by the positive coefficient of the R&D variable interacted with TFP growth at the frontier, with this effect being stronger in private services. As for ICT capital, its impact appears to be stronger the closer is the economy to the technological frontier (as revealed by the positive and significant interaction with the technology gap variable), while a more intense use of ICT capital seems to be associated with lower spillovers from TFP growth taking place at the frontier, but significantly so only in manufacturing industries.

In summary, ICT, human capital and R&D appear to play a role in TFP growth. However, results seem sensitive to the inclusion of industry and country effects and to the approach for measuring TFP. R&D and ICT intensive technologies have a positive impact on TFP only if industry effects are not included, which implies that the relationship is mostly found across industries. Human capital plays a role in facilitating innovation and spillovers, as indicated by its positive interaction with the "TFP growth at the frontier" variable, which is highly significant especially when the analysis is limited to market services. The impact of human capital also appears stronger the closer is the economy to the technology frontier, a result which confirms the findings of existing analyses.

4.2.3. The role of regulations

The next series of TFP determinants which are analysed are regulations in product and factor markets. In the policy debate, the role of regulations are often emphasized in the context of the efficiency gains associated with the entry of high-productivity firms and the exit of inefficient competitors (e.g., IMF, 2003; OECD, 2003). Columns (1) and (2) in Table 5 display regression results for our baseline specification augmented with, respectively, the number of firms entering and exiting the industry.[13] In line with expectations, both variables have a positive and broadly significant effect. Entry and exit dynamics are affected, inter-alia, by regulations in product and factor markets.

To assess the impact of regulations on TFP we have collected data on the degree of regulations in product, labour and financial markets separately. Product market regulations are captured by the "Regimpact" indicator developed by the OECD (Conway and Nicoletti, 2006), which measures the "knock-on" effect on each industry arising from anti-competitive regulations in non-manufacturing industries. Labour market and financial market regulations are summarised by the "freedom" indexes constructed by the Fraser institute. These indexes quantify the degree to which anti-competitive regulations play a role in, respectively, the labour and financial markets. We consider the impact of these indexes taken with a minus sign, to capture instead the effect associated with regulations becoming heavier. The Fraser indexes vary across countries and over time.

Table 5 displays the results. Regulations do not appear to play a significant role when directly added to the list of explanatory variables (column (1)). The results displayed in column (2) suggest that, across all industries, anti-competitive financial market regulations appear to reduce TFP growth directly as well as indirectly by inhibiting the extent to which the economy can share in TFP improvements taking place at the frontier. However, the regression coefficient fails to reach statistical significance at the 10 per cent level. The same regression shows that more regulated labour markets, although reducing TFP growth directly, have a significant, but positive, impact on the extent to which TFP growth benefits from developments at the frontier. This evidence highlights the ambiguous role that may be played by labour market regulations in influencing TFP growth.[14] On the one hand, stricter labour market regulations, notably employment protection legislation, by limiting the room for re-

[13] This variable, EU KLEMS source, is available only for a subset of countries, industries and years. This explains the lower number of observations for the regressions in columns (1) and (2) of Table 5.
[14] See, e.g, Bassanini and Ernst (2002) for a discussion of the alternative channels highlighted in the theoretical literature.

adjusting the labour force in the case of redundancies, may hinder the incentives of firms to engage in risky innovation projects, thus reducing TFP growth at the frontier. On the other hand, stronger employment protection may increase job-tenure and investment in job-specific skills, which may be complementary to TFP growth (Acemoglu and Shimer, 2000). Finally, the impact of product market regulations, at the level of total industries, appears to be largely insignificant.

Column (3) repeats the same specification as in column (2) but restricted to the manufacturing sector. Unexpectedly, product market regulations appear to have a positive impact on TFP growth both directly and via increased benefits from developments at the frontier. The role of financial market regulations in limiting such benefits is strengthened compared with the case in which the analysis comprises all industries. By limiting the sample to private services, the impact of product market regulations turns negative, and appears to have an influence both directly and indirectly. In particular, product market regulations appear to reduce TFP growth more strongly when the economy is further away from the frontier.[15]

[Table 5]

Overall, the role of regulations appears to be highly sector-specific. Additionally, the limited time-variation of the sample used in the regressions makes it difficult to disentangle the short term transitional effects of labour market reforms, introduced by many EU countries since the early 1990's, from the long run impact of those reforms on TFP growth rates. In spite of these caveats and limitations, some results of interest stand up. As expected product market regulations appear to play a negative role for TFP growth in private services. Financial market regulations seem to play a negative role, especially concerning the ability of countries to share in TFP improvements taking place at the frontier.

[15] This result is also corroborated in additional regression work which we carried out using firm level datasets. For this work, a number of relevant variables were tested including the average age of firms. One of the conclusions is that the age of firms contributes negatively to TFP growth across industries (i.e. when the industry fixed effects are eliminated). These results should be interpreted as suggesting that market dynamics (i.e. entry & exit rules) could be playing a relatively significant role in explaining the TFP performances across industries, with industries where the entry of new firms and the exit of incumbents is more easily achieved being characterised by higher TFP growth. This result is in keeping with Nicoletti and Scarpetta (2003) who showed that inappropriate labour and product market regulations can be damaging for productivity not only by increasing barriers to entry but also by inhibiting the uptake of ICT and reducing the net returns to investment and innovation. In addition, with respect to the potential negative effects on innovation, regulatory barriers which decrease the intensity of competition may be more costly the closer an industry is to the technology frontier since, as we have seen earlier, growth at the frontier appears to be driven more by innovation rather than imitation.

4.2.4. Industry-specific specifications

As shown earlier (Graph 1), the EU-US TFP gap is concentrated in a handful of industries : the ICT producing manufacturing industry (i.e. for the industry aggregation employed in our analysis, “electrical and optical equipment”, which includes semi-conductors) and a number of private service industries, most notably retail trade and business services. Conversely, there is a small group of industries where the EU has outperformed the US over recent decades, i.e., the "network" utilities, in particular telecommunications, transport and energy. In the following, our aim is to identify empirical models specific to those industries which contributed strongly to the EU-US TFP growth gap as well as those industries where the EU performance was comparatively strong.

Table 6 presents the results for those TFP determinants which have been selected separately for ICT-manufacturing, retail trade and business services, which together account for the bulk of the EU-US TFP gap, and for utilities where the EU was strongest (see footnotes to Table 6 for the detailed description of the industry breakdown). Since the aim is to identify TFP determinants that are distinctive for the industries under analysis, the table also reports results when the selected variables are used to explain TFP growth in all of the remaining industries.[16]

[Table 6]

Column (1) shows the results for the ICT producing industry. The chosen specification augments the baseline model with R&D interacted with the TFP growth at the frontier variable. The basic variables behave somewhat differently to prior expectations. The non-interacted frontier variable is non-significant, indicating that, keeping R&D at sample mean, no significant spillovers are present in this industry. The technology gap variable is also non-significant, indicating that TFP growth rather than converging is diverging across countries in this ICT producing industry. This result is consistent with the existing evidence which suggests that labour productivity in "high tech" industries is not converging across countries, in contrast with what is observed for most other industries (see, for example, Scarpetta and Tressel, 2002). The interaction of R&D with the "TFP at the frontier" variable is instead strongly significant, indicating that R&D is crucial for benefitting from innovation spillovers

[16] Note that whenever a single industry is kept in the sample, in addition to industry fixed effects, also time effects need to be kept out of the specification since they become collinear with the TFP growth at the frontier variable, that only varies over time.

taking place in the frontier economy. Interestingly, the results change drastically when the same specification is tested on a sample including all industries except ICT-producing manufacturing (column (2)).

Regarding the retail trade industry (column (3)), the results indicate a significant role for macroeconomic factors, of a possibly cyclical nature, in providing a direct explanation for observed differences in TFP growth between EU countries and the US, as suggested by the strongly significant positive coefficient for the relative contribution of private consumption to GDP growth.[17] Our interpretation is that, due to its construction as a residual term, TFP growth also captures productivity improvements associated with the better exploitation of scale economies, which are likely to be a relevant factor in explaining productivity dynamics in this specific group of service industries. This result is in keeping with that of Foster, Haltiwanger and Krizan (2006) which regard economies of scale as being a key determinant of the strong TFP performance of the US retail trade industry.[18] It is worth noting that a similar positive impact of cyclical factors is not observed in the remaining industries (column (4)).[19]

Columns (5) and (6) display results relating to business services only. It turns out that, whilst catching-up is significant, spillovers from TFP dynamics at the frontier are only significant provided that the capital stock is sufficiently ICT-intensive, as suggested by the non-significant frontier variable and by its significant interaction with the ratio of ICT capital to the total capital stock. This result is not really surprising since part of the activities included in the industry aggregate are ICT-related consulting services.

Finally, regarding the "network" industries, product market regulations are shown to have a significant negative impact on this grouping of industries but not on the rest of the economy

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[17] In terms of its economic significance, consumption growth as a determinant accounts for about 20 per cent of the TFP growth in retail trade. The different consumption growth performances over the period 1996-2004 in the US and the 9 EU countries included in the analysis suggests that about 11 per cent of the EU-US TFP growth gap in retail trade may be explained by this factor. In addition, a role for cyclical factors is suggested also by the positive and significant coefficient of the output gap as an alternative explanatory variable.

[18] The authors find that virtually all of the productivity growth in the US retail trade industry in the 1990s was accounted for by the entry of large, national, retail chains into the marketplace. This suggests that scale effects (most notably the emergence of "mega" chains such as Wal Mart) may be an important part of the explanation for the US's productivity performance in retailing compared with Europe.

[19] Unreported regression results suggest that there is a positive interaction between the relative contribution of consumption to growth and average firm size. Although the coefficient of the interacted term is not significant, it supports the interpretation that the industry level findings can be rationalised on the basis of different degrees of exploitation of scale economies in the retail trade industry.

(for which the coefficient has instead an unexpected positive sign - see column (6)). This regulatory impact appears to reflect the "knock-on" effects of regulations in this specific industry grouping on all other industries of the economy. Its influence is likely to be particularly high, given the amount of regulations which have tended, in the past at least, to be imposed on a number of individual network industries, including electricity, gas and water, as well as on transport and telecommunications. The direct impact exercised should however be interpreted mostly in terms of the better exploitation of scale economies and reduced "X inefficiencies" rather than to any dynamic TFP gains.

5. Concluding remarks

Over the past decade, the TFP performance of the EU and the US economies started to diverge significantly, with the US staging a strong recovery from the productivity slowdown of the 1980s and with the EU lagging behind. Understanding the determinants of TFP growth is consequently high on the EU's policy agenda. This paper makes a step forward in deciphering the TFP dynamics in those industries that account for most of the EU-US TFP growth gap. Despite the need for caution in interpreting results that inevitably suffer, to some extent, from the imperfect measurement of TFP, especially in a number of service industries, some potentially relevant findings stand out from our analysis.

Compared with previous analogous studies, the use of the EU KLEMS database permits us to identify a statistically significant role for TFP advances taking place at the “frontier” - namely TFP advances in those economies exhibiting the strongest performance in terms of TFP levels - as an explanatory variable for TFP growth. Growth in TFP appears to be determined significantly by the capacity of countries to share in developments taking place at the frontier, either because of independently participating in the same innovation trajectories or because of technological spillovers. This result could be related to the fact that the EU KLEMS TFP measures control for the impact of changes in the skill composition of the workforce and for differences in the productivity of ICT and non-ICT capital investments. Our analysis also shows that the catching-up process taking place across countries in terms of TFP levels seems to be weakening over time, as revealed by a reduction in the statistical significance of this explanatory variable after 1995.

The adoption of ICT-intensive technologies, human capital and R&D appear to play some role in TFP growth. However, results seem sensitive to the specification and in particular to the inclusion of industry and country effects and to the approach for measuring TFP. R&D

and ICT intensive technologies have a significantly positive impact on TFP only if industry effects are not included. The relationship therefore holds mostly across industries : industries spending more on R&D and using more ICT-intensive technologies tend to exhibit higher TFP growth rates. However, there is no significant evidence that an across-the-board increase in R&D expenditures or in the use of ICT-intensive technologies translates into higher TFP growth. Human capital plays a role in facilitating innovation and spillovers, as indicated by its positive interaction with the "TFP growth at the frontier" variable, which is highly significant especially when the analysis is limited to private services. The impact of human capital also appears stronger the closer is the economy to the technology frontier, a result that confirms the findings of existing analyses. Additionally, the role of human capital in explaining TFP growth turns out to be stronger when TFP is measured without taking into account the changing composition of the workforce (as is done in EU KLEMS). This suggests that part of the human capital effect found with "raw" TFP measures simply reflects labour productivity improvements associated with changes in the quality of the workforce.

The results indicate that high entry and exit rates for firms have a positive impact on TFP growth - this is possibly due to less stringent product and factor market regulations allowing stronger productivity gains to be reaped from the entry of more efficient competitors and the exit of inefficient incumbents. However, despite these "entry & exit" results, the performance of indexes of regulations in product, labour and financial markets exhibit a relatively fragile performance in explaining TFP growth. The results depend on the specific regulation considered and are highly sector-specific. Notwithstanding these limitations, some results of interest stand up. As expected, product market regulations appear to play a negative role for TFP growth in private services. Financial market regulations seem to play a negative role especially for the ability of countries to share in the TFP improvements taking place at the frontier.

The EU KLEMS data shows that the advantage of the US in terms of TFP growth since the mid 1990s is concentrated in a handful of industries : ICT-producing manufacturing and a few private service activities, notably retail trade and business services. Conversely, over the same period, the EU exhibited a stronger performance in the network utility industries : telecommunications, transport and energy. Consistently, we attempted to identify the specific TFP growth determinants in these industries. Differences in the ICT-producing manufacturing industry appear to be firmly related to the role played by R&D in allowing countries to share in the TFP growth improvements taking place at the frontier. A similar role is played by ICT capital in the business services industry, with this result influenced by the fact that an important part of the overall industry is focussed on ICT-related consulting services. Moreover, for ICT-producing manufacturing, the process of catching-up in TFP levels does not appear to be statistically significant, indicating that TFP growth rates in this specific industry are diverging rather than converging across countries. In the retail trade industry, the evidence suggests a possible role for cyclical factors driving consumption dynamics : stronger consumption growth could be the source of that part of TFP growth which is associated with a better exploitation of scale economies. Finally, TFP growth in the network industries appears to be driven in a comparatively strong fashion by product market regulations. In this respect, the satisfactory TFP growth performance in the EU in this set of industries could be related to the deregulation drive which characterised the behaviour of most EU countries towards these industries over the last two decades, and to the resultant more pro-competitive environment.

Overall, our results broadly support the view that the TFP growth slowdown experienced by several EU countries since the mid-1990s could be linked to difficulties encountered in adapting policies and institutions to changing sources of TFP growth. As more European countries converge to the technology frontier, TFP growth becomes less and less driven by a catching-up process related to imitation and adoption of existing new-vintage technologies and increasingly by innovation. This shift in TFP growth drivers requires a re-focussing of policies and institutions towards an innovation-based economic model, with greater emphasis, inter-alia, on excellence in tertiary education, better financing and targeting of R&D, and regulatory frameworks which encourage the entry of more efficient and innovative competitors and which permit the reallocation of production factors across firms and sectors. Our analysis also shows that the way in which the above factors contribute to TFP growth is highly industry-specific. The main implication for EU policies aimed at facilitating a recovery in TFP growth, including within the framework of the Lisbon agenda, is that more efficient results could be achieved by more targeted policy initiatives aimed at those industries where the gains in TFP growth are potentially greatest.

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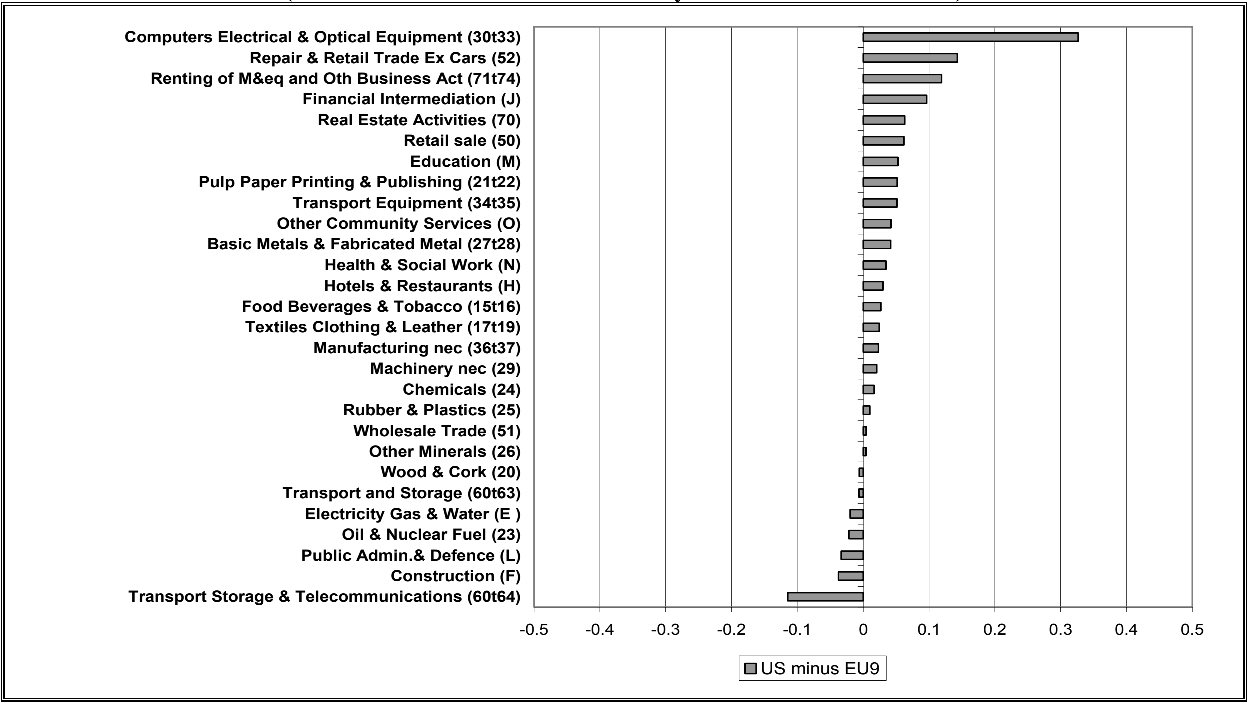
Graph 1 : Industry contributions to EU-US TFP gap: 1996-2004

(contribution of TFP to value-added growth, %, US-EU-9 difference)

(Source for US data is SIC industry accounts from the BLS)



Source : EU KLEMS and own calculations

Table 1 : Growth accounting results : Gross value added growth and input contributions (annual average volume growth rates in %)

	EU-9		US*	
	1981-1995	**1996-2004**	**1981-1995**	**1996-2004**
	Total Industries			
Labour Services	0.3	0.8	1.1	0.7
Capital Services	1.0	1.2	1.2	1.4
TFP	0.9	0.2	0.4	1.2
Total Industries Value Added	2.2	2.1	2.7	3.3
	Manufacturing			
Labour Services	-1.2	-0.3	0.1	-1.1
Capital Services	0.7	0.7	0.7	0.9
TFP	1.8	0.9	2.1	4.3
Total Manufacturing Value Added	1.3	1.2	2.9	4.0
	Private services			
Labour Services	0.7	1.0	1.4	1.0
Capital Services	1.4	1.6	1.6	1.8
TFP	0.6	0.1	0.0	0.8
Total Private Services Value Added	2.8	2.8	3.0	3.6
	Rest of Economy			
Labour Services	0.6	1.0	1.4	1.1
Capital Services	0.7	0.6	0.8	0.8
TFP	0.5	-0.2	-0.2	0.3
Total "Rest of Economy" Value Added	1.8	1.5	2.0	2.2

*** SIC (Standard Industrial Classification) industry accounts from the BLS (Bureau of Labor Statistics)**

Source : EU KLEMS and own calculations

Table 2. TFP growth determinants : Basic specification

Dependent variable: TFP growth	Baseline	No country effects	No industry effects	No year effects	Lagged dependent variable included	"Ex-ante" TFP	"Raw" TFP
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
TFP growth at the frontier	0.159**	0.159**	0.196***	0.162**	0.157**	0.113**	0.060
	(2.98)	(3.00)	(03.78)	(3.03)	(3.03)	(2.61)	(0.54)
Technological gap	-0.046***	-0.047***	-0.046***	-0.045***	-0.049***	-0.038***	-0.036***
	(4.48)	(5.00)	(-4.79)	(4.60)	(4.25)	(5.12)	(-4.96)
Lagged dependent variable					0.094		
					(1.58)		
Country fixed effects	Yes	No	Yes	Yes	Yes	Yes	Yes
Sector fixed effects	Yes	Yes	No	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	No	Yes	Yes	Yes
N. obs.	6619	6619	6619	6619	6339	6059	6677
Wald test for country fixed effects (P value)	0.000	0.000	0.000	0.000			
Wald test for industry fixed effects (P value)	0.000	0.000	0.000	0.000			
Wald test for year fixed effects (P value)	0.000	0.000	0.000	0.000			
R^2	0.13	0.13	0.11	0.12	0.14	0.12	0.10

Notes: Estimation method: Least Square Dummy Variables regressions; standard errors robust with respect to residual heteroschedasticity and possible within-country dependence. Absolute value of t tests reported in parenthesis. ***, **, * denote, respectively, statistical significance at 1, 5, and 10 per cent level. Wald tests refer to the hypothesis of fixed effects being jointly equal to zero. The tests are run on the equation estimated with standard errors robust with respect to heteroschedasticity.

TFP growth at the frontier: TFP growth of the country with the highest TFP level in industry *s*, year *t* (leader country).

Technological gap: lagged log(TFP level) –log(TFP level of the leader country).

Table 3. TFP growth determinants : Basic specification; alternative industry, country and period breakdowns

Dependent variable: TFP growth	All industries and years	Only manu-facturing sector	Only private services sector	Only ICT-related sector	Only EU countries	Only years after 1995	Only years after 1995, EU countries
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
TFP growth at the frontier	0.159**	0.164**	0.135**	0.138***	0.169**	0.158*	0.153
	(2.98)	(2.38)	(3.39)	(4.70)	(2.89)	(2.08)	(1.79)
Technological gap	-0.046***	-0.060***	-0.029***	-0.027***	-0.048***	-0.046	-0.053
	(4.48)	(3.81)	(4.14)	(4.85)	(4.13)	(1.20)	(1.26)
N. obs.	6619	3058	2133	2371	5950	2796	2516
R^2	0.13	0.16	0.10	0.50	013	0.12	0.12

Notes: Estimation method: Least Square Dummy Variables regressions; fixed effects included for countries, industries, and years; standard errors robust with respect to residual heteroschedasticity and possible within-country dependence. Absolute value of t tests reported in parenthesis. ***, **, * denote, respectively, statistical significance at 1, 5, and 10 per cent level.
TFP growth at the frontier: TFP growth of the country with the highest TFP level in industry *s*, year *t* (leader country).
Technological gap: lagged log(TFP level) –log(TFP level of the leader country).

Table 4. TFP growth determinants : The role of human capital, ICT capital and R&D

Dependent variable: TFP growth	All industries	All industries	All industries	All industries ("raw" TFP)	All industries ("raw" TFP)	All industries	Only manufacturing sector	Only private services sector	Only ICT-related sector
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
TFP growth at the frontier	0.186*	0.186*	0.192*	0.025	0.008	0.180**	0.144**	0.427***	0.168***
	(2.18)	(2.20)	(2.27)	(0.13)	(0.05)	(2.91)	(2.38)	(3.80)	(4.46)
Technological gap	-0.091**	-0.092**	-0.085**	-0.075***	-0.062**	-0.086**	-0.118	-0.035	-0.031***
	(3.15)	(3.25)	(3.25)	(-3.65)	(-3.10)	(3.17)	(1.83)	(1.23)	(4.74)
Human capital	-0.003	0.004	0.002	0.007***	0.000	0.001	-0.015	0.008	-0.001
	(-0.65)	(1.08)	(0.50)	(3.92)	(0.19)	(0.13)	(-0.61)	(1.79)	(0.19)
R&D flows	0.002	0.004	0.004***	0.006**	0.006**	0.002	0.002	0.027	0.004
	(0.67)	(1.25)	(4.98)	(2.23)	(3.18)	(0.19)	(0.16)	(1.27)	(0.68)
ICT/ non ICT real capital stock ratio	0.002	-0.000	0.006***	0.000	0.009***	0.006	-0.028	0.010	0.000
	(0.74)	(0.21)	(3.70)	(0.20)	(4.76)	(1.21)	(-0.48)	(1.68)	(0.12)
Interaction TFP growth at the frontier with human capital						0.189	0.228	0.186***	0.139
						(1.53)	(1.73)	(5.11)	(1.51)
Interaction TFP growth at the frontier with R&D						0.024	0.085	0.412	0.050
						(0.57)	(1.68)	(1.40)	(1.02)
Interaction TFP growth at the frontier with ICT capital ratio						-0.063	-0.395**	-0.079	-0.013
						(0.59)	(2.75)	(0.69)	(0.14)
Interaction technological gap with human capital						0.024	0.018	0.014*	0.000
						(1.21)	(0.46)	(1.90)	(0.03)
Interaction technological gap with R&D						0.007	0.016	-0.005	-0.001
						(0.34)	(0.41)	(0.11)	(0.12)
Interaction technological gap with ICT capital ratio						0.026**	-0.041	0.023	0.014*
						(3.28)	(0.36)	(1.54)	(2.29)
Country fixed effects	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N. obs.	2251	2251	2251	2242	2242	2251	1535	574	786
R^2	0.20	0.19	0.19	0.12	0.12	0.22	0.24	0.22	0.32

Notes: Estimation method: Least Square Dummy Variables regressions; standard errors robust with respect to residual heteroschedasticity and possible within-country dependence. Absolute value of t tests reported in parenthesis. ***, **, * denote, respectively, statistical significance at 1, 5, and 10 per cent level.
TFP growth at the frontier: TFP growth of the country with the highest TFP level in industry *s*, year *t* (leader country).
Technological gap: lagged log(TFP level) –log(TFP level of the leader country).
Human capital: share of high skill labour compensation in total labour compensation. Standardised variable. Source: EU KLEMS.
R&D: R&D expenditure/gross output. Standardized variable. Source: OECD STAN.
ICT/non ICT real capital stock ratio. Standardized variable. Source: EU KLEMS.

Table 5. TFP growth determinants : The role of regulations

Dependent variable: TFP growth	All industries	All industries	All industries	All industries	Only manufacturing sector	Only private services sector	Only ICT-related sector
	(6)	(7)	(1)	(2)	(3)	(4)	(5)
TFP growth at the frontier	0.188**	0.159**	0.171***	0.175***	0.398***	0.138***	0.153***
	(3.94)	(4.77)	(3.39)	(5.82)	(4.02)	(3.97)	(7.07)
Technological gap	-0.093**	-0.095**	-0.049***	-0.047***	-0.042*	-0.026***	-0.030***
	(2.79)	(2.72)	(5.09)	(5.20)	(2.26)	(5.13)	(6.95)
Number of firms entering the industry (thousands)	0.051						
	(1.54)						
Number of firms exiting the industry (thousands)		0.067*					
		(2.13)					
Product market regulation			-0.002	-0.000	0.126***	-0.008	0.008**
			(0.96)	(0.01)	(3.41)	(1.65)	(2.81)
Labour market regulation			0.008	-0.004	-0.009	0.002	0.006
			(1.45)	(0.79)	(1.46)	(0.36)	(0.95)
Financial market regulation			0.005	-0.007	-0.004	0.009	0.009*
			(1.31)	(1.43)	(0.36)	(1.73)	(2.01)
Interaction TFP growth at the frontier with product market regulation				0.016	0.416**	-0.005	-0.040
				(0.41)	(2.73)	(0.23)	(0.98)
Interaction TFP growth at the frontier with labour market regulation				0.090**	0.080**	0.069*	0.014
				(2.43)	(2.12)	(1.85)	(0.35)
Interaction TFP growth at the frontier with financial market regulation				-0.078	-0.127**	-0.063**	-0.081**
				(1.62)	(2.80)	(2.55)	(2.57)
Interaction technological gap with product market regulation				-0.007	0.064	-0.013*	0.002
				(0.90)	(1.17)	(2.07)	(0.38)
Interaction technological gap with labour market regulation				-0.004	-0.007	-0.005	0.001
				(0.48)	(0.47)	(0.81)	(0.16)
Interaction technological gap with financial market regulation				-0.003	-0.014	0.016**	0.007*
				(0.34)	(0.97)	(2.34)	(1.89)
N. obs.	1056	989	6340	6340	2929	2043	2271
R^2	0.26	0.27	0.13	0.14	0.18	0.11	0.22

Notes: Estimation method: Least Square Dummy Variables regressions; fixed effects included for countries, industries, and years; standard errors robust with respect to residual heteroschedasticity and possible within-country dependence. Absolute value of t tests reported in parenthesis. ***, **, * denote, respectively, statistical significance at 1, 5, and 10 per cent level.
TFP growth at the frontier: TFP growth of the country with the highest TFP level in industry *s*, year *t* (leader country).
Technological gap: lagged log(TFP level) –log(TFP level of the leader country).
Product market regulation: indicator of the "knock on" industry impact of regulations in non-manufacturing industries. Standardised variable. Source: OECD "Regimpact" indicator.
Labour market regulation: indicator of anti-competitive regulations in the labour market. Standardised variable. Source: Fraser institute freedom indicators (taken with negative sign).
Financial market regulation: indicator of anti-competitive regulations in the labour market. Standardised variable. Source: Fraser institute freedom indicators (taken with negative sign).
Number of firms entering and exiting the industry. Source: EU KLEMS.

Table 6. TFP growth determinants: Industry-specific models

Dependent variable: TFP growth	ICT producing manufacturing		Retail trade		Renting of machinery and equipment and other business activities		Network utilities	
	Only this industry	Only remaining industries	Only this industry	Only remaining industries	Only this industry	Only remaining industries	Only this industry	Only remaining industries
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TFP growth at the frontier	0.113	0.138**	0.152**	0.194**	0.103	0.163**	0.086	0.190***
	(1.06)	(2.24)	(2.61)	(2.37)	(0.89)	(3.09)	(0.47)	(4.08)
Technological gap	0.026	-0.069**	-0.034***	-0.0544***	-0.087***	-0.051***	-0.022	-0.048***
	(0.61)	(5.28)	(4.26)	(4.03)	(2.09)	(4.18)	(0.84)	(4.92)
Interaction TFP growth at the frontier with R&D	0.089**	0.062						
	(1.99)	(1.45)						
Interaction of technological gap with R&D	-0.005	-0.004						
	(0.35)	(0.61)						
Relative contribution of private consumption to GDP growth			0.004***	0.001				
			(5.08)	(1.80)				
ICT/ non ICT real capital stock ratio					-0.003	0.003*		
					(1.14)	(1.84)		
Interaction TFP growth at the frontier with ICT capital ratio					0.129*	-0.032		
					(1.70)	(0.96)		
Interaction technological gap with ICT capital ratio					-0.000	0.006*		
					(-0.03)	(1.98)		
Product market regulation							-0.010*	0.004
							(2.00)	(0.063)
Interaction TFP growth at the frontier with product market regulation							0.032	0.043
							(0.33)	(1.32)
Interaction technological gap with product market regulation							-0.115	0.005
							(1.06)	(0.90)
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Year fixed effects	No	Yes	Yes	Yes	No	Yes	Yes	Yes
N. obs.	132	2335	836	5030	204	5850	684	5656
R^2	0.57	0.18	0.17	0.14	0.23	0.14	0.22	0.13

Notes: Estimation method: Least Square Dummy Variables regressions; fixed effects included for countries, industries, and years; standard errors robust with respect to residual heteroschedasticity and possible within-country dependence. Absolute value of t tests reported in parenthesis. ***, **, * denote, respectively, statistical significance at 1, 5, and 10 per cent level.

TFP growth at the frontier : TFP growth of the country with the highest TFP level in industry *s*, year *t* (leader country).

Technological gap: lagged log(TFP level) –log(TFP level of the leader country).

R&D : R&D expenditure/gross output. Standardized variable. Source: OECD STAN.

Human capital: share of high skill labour compensation in total labour compensation. Standardised variable. Source: EU KLEMS.

Relative contribution of private consumption to GDP growth: GDP growth due to private consumption/GDP growth. Source AMECO.

Product market regulation: indicator of the "knock on" industry impact of regulations in non-manufacturing industries. Standardised variable. Source: OECD "Regimpact" indicator.

Financial market regulation: indicator of anti-competitive regulations in the labour market. Standardised variable. Source: Fraser institute freedom indicators (taken with negative sign).

ICT-producing manufacturing : electrical and optical equipment (30t33).

Retail trade: Retail sale, maintenance and repair of motor vehicles and motor cycles (50) + wholesale trade and commission trade except motor vehicles and motor cycles (51) + Repair of household goods and retail trade except of motor vehicles and motor cycles (52) + hotels and restaurants (H).

Renting of machinery and equipment and other business activities (71t74): The industry aggregate includes: renting of machinery and equipment (71), computer and related activities (72), research and development (73), other business activities (74).

Utilities : energy (E)+transport and storage (60t63)+post and telecommunications (64).