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

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European Commission

September 2008

Abstract

This paper uses the EU KLEMS database to explore the industry specific determinants of the EU-US total factor productivity (TFP) growth gap which started to emerge in the mid-1990s. The bulk of this TFP gap is explained by the US's better performance in a handful of market service industries (most notably retail and wholesale trade) and ICT-producing manufacturing, whilst the EU exhibits a considerably stronger performance with respect to a number of network utilities. Our analysis of the determinants of TFP growth across countries and industries shows that, 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, our paper suggests 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. Industries with higher R&D expenditures and higher adoption rates for ICT-intensive technologies appear to exhibit higher TFP growth rates, other things being equal. R&D is a crucial determinant of TFP growth in ICT-producing manufacturing. With respect to the link between regulation and TFP, the paper suggests that product market regulations are related to reduced TFP growth but only in market services, most notably in the network utilities. Finally, in the retail & wholesale trade industry, cyclical consumption dynamics which permit a better exploitation of scale economies are a highly significant determinant of TFP growth.

Keywords : growth determinants, total factor productivity, European Union

JEL Classification : D24, O47, O52.

Acknowledgements : The authors would like to thank K. Havik for his very valuable contribution to an earlier draft of this paper. The opinions contained in this paper are those of the authors and should not be attributed to the European Commission.

1. Introduction

The present paper examines the EU's productivity performance relative to the US over recent decades. One of its key aims is to assess the role played by total factor productivity (TFP) in explaining the productivity patterns which have emerged, since TFP is the main driver of long run productivity growth and, hence, of living standards. An important feature of the analysis is the exploitation of the EU KLEMS industry level database to help identify those policy areas which could potentially have the greatest impact in narrowing the existing EU-US TFP gaps.

This issue of TFP divergences must also be seen in the wider context of Europe’s overall growth performance since the mid-1990’s which has been relatively disappointing. Whilst many EU countries managed to improve their labour market positions, this unfortunately was accompanied by a slowdown on the productivity side in a significant number of Member States, driven both by a deterioration in capital deepening as well as in TFP. This experience was in sharp contrast to many other developed economies around the world, in particular the US. For the US, the secular downward movement in productivity growth rates experienced since the 1970's was spectacularly reversed around the mid-1990's, aided by a strong performance in both the production and diffusion of information and communication technologies (ICT).

These growing divergences in the productivity performances of many developed world economies, and especially the size of the divergences presently being experienced between some of the EU's Member States, has provoked an ongoing debate in the EU regarding the implications of recent trends for future economic prospects.

In the absence of a change in policies, the prevailing view, largely supported by the Sapir report (Sapir et al., 2003) and van Ark analyses (see, e.g., van Ark, Inklaar and Mc Guckian, 2003), suggests that the EU may be unable to achieve a shift in its resources to industries with high productivity growth prospects and will continue with production in areas where it has traditionally held a global comparative advantage, namely the medium-technology manufacturing sector. This overall strategy appears increasingly threatened with firstly, the emergence of a number of strong competitors around the world in similar areas of the manufacturing sector (most notably from China and India) and secondly, the potentially negative impact on Europe's ability to compete in the, increasingly more tradeable, global services market.

However, more optimistically, the EU-US productivity gap could also be partly explained by measurement problems / adjustment lags, with perhaps the basis for a future pick-up already firmly established due to the labour, capital and product market reforms which have been progressively introduced since the early 1990's (see, e.g., Blanchard, 2004). Under this view the EU may now simply be in a transition phase whereby some of the negative effects of those reforms (e.g. a temporary decrease in productivity due to labour market changes) are visible, whilst the gains to be reaped in the future are not.

Existing analyses would agree that regulation-induced restrictions concerning labour and product markets (see, e.g., Soskice, 1997; Nickell et al.,1997; Eichengreen and Iversen, 1999; Nickell and Layard, 1999; Nicoletti et al., 2001; Scarpetta and Tressel, 2002; Scarpetta et al., 2002; Nicoletti and Scarpetta, 2003; and IMF, 2003); lack of openness to trade and/or foreign direct investments (see, e.g., Sachs and Warner, 1995; Alesina et al., 1997; Frankel and

Romer, 1999; and Ben-David and Kimhi, 2000); as well as barriers in terms of access to / generation of new technologies and the diffusion of existing innovations (see, e.g., Lucas, 1988; Romer, 1990; Grossman and Helpman, 1991; Coe and Helpman, 1995; and Aghion and Howitt, 1998) are amongst the key determinants of a country's productivity performance. In this respect, international comparisons reveal sizeable disparities in investments with regard to physical capital (especially in terms of ICT capital spending), human capital as well as R&D and other forms of intangible investments. The present paper will examine those countries and industries where the differences are most acute and will exploit a new database to analyse TFP determinants at the industry level for a panel of countries.

Whilst an analysis of productivity / TFP at the macro level has been possible for some time, a detailed cross-country examination at the industry level has been more problematic due to the fact that long time series of official industry level data were only available for a relatively small number of countries, industries and variables. This situation has significantly improved with the March 2007 release of the EU KLEMS datasets. The provision in EU KLEMS of detailed industry level series on economic growth, productivity, employment creation, capital formation and technological change for a large range of manufacturing and service industries is particularly noteworthy. Some degree of caution is warranted however since the datasets have yet to be thoroughly evaluated by the national statistical institutes (NSI's) and Eurostat. In addition, according to EU KLEMS, the EU-US productivity differences are heavily concentrated in the market services sector where the conceptual and empirical problems in accurately measuring output and price developments have been well documented. Despite these concerns, EU KLEMS nevertheless offers the research community an important additional source of information with which to deepen its existing analyses of productivity trends.[1]

The present paper shows that, 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, it suggests 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. Industries with higher R&D expenditures and higher adoption rates for ICT-intensive technologies appear to exhibit higher TFP growth rates, other things being equal. R&D is a crucial determinant of TFP growth in ICT-producing manufacturing. With respect to the link between regulation and TFP, the paper suggests that product market regulations are related to reduced TFP growth but only in market services, most notably in the network utilities. Finally, in the retail & wholesale trade industry, cyclical consumption dynamics which permit a better exploitation of scale economies are a highly significant determinant of TFP growth.

The remainder of the paper is organised as follows. Section 2 uses EU KLEMS to provide a descriptive analysis of the sources of EU-US industry level divergences in TFP performances. Section 3, uses panel regressions to assess the degree of statistical support which exists for the major hypotheses explaining TFP divergences over time– i.e. the role played by the regulatory environment (product, labour and financial markets); by the degree of openness of

[1] The potential of this new dataset has already been exploited for a detailed analysis of productivity in chapter 2 of "The EU Economy 2007 Review" which concluded that cross-country differences in labour productivity growth predominantly reflect differences in TFP performances, although ICT investment patterns also played a role, especially over the second half of the 1990's.

economies; by demographics; and finally by the efficiency of knowledge production (R&D, education and complementary, ICT-related, investments). The concluding remarks section looks at the implications of the analysis for the overall direction and industry focus of economic policy in the EU over the coming years.

2. EU KLEMS highlights the role of TFP in explaining post-1995 EU-US labour productivity divergences

The EU KLEMS project represents a unique collective effort on behalf of academics, statisticians and policy makers to provide fundamental policy insights into the changes which have occurred at the industry level in Europe, the US and Japan over recent decades. The value added of EU KLEMS is underlined by the provision of detailed industry level capital and labour accounts (and intermediate inputs in the case of gross output) which have been assembled at the national level by the EU KLEMS consortium partners :

- Firstly, industry level investment series have been collected for 7 different types of capital and for 31 industries (A31 level breakdown). These national accounts sourced series 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.

- Secondly, unlike standard measures of labour input, such as numbers employed or hours worked, the database provides, industry level, measures which take account of the wide differences in the productivity of various types of labour over time (i.e. labour services). Labour force heterogeneity is an integral part of these labour services calculations, with the overall growth contribution of labour being calculated on the basis of the services provided by different groups of high, medium and low-skilled workers.

Decomposing real GDP growth into its main determinants can be done using a wide variety of growth accounting methods, one variant of which is applied by the EU KLEMS research consortium. This variant essentially uses a production function which includes productive capital (a volume index of capital services); human capital (a skills based indicator of the average qualifications of the labour force); employment levels adjusted for hours worked; and a residual term which, amongst other things, includes an estimate of the level of efficiency associated with the use of the various factors of production. Due to the lack of capital stock data in EU KLEMS for some of the EU15 countries, a detailed growth accounting analysis at the industry level is only possible for 10 of the "old" EU15 member states, with these ten countries grouped together to form an EU15ex5 aggregate.[2] Fortunately, the EU15ex5 (henceforth EU) grouping includes all of the larger EU15 Member States and consequently the period average growth rates for the basic industry series are almost identical for both EU aggregates.

Table 1 gives the GDP (i.e. value added) growth accounting results for the EU and the US using the EU KLEMS approach, with GDP being decomposed into the contributions from labour services, capital services and TFP. The table shows that all of the 1.1% GDP gap between the EU and the US over the period since 1995 has been driven by TFP, with the

[2] EU15 excluding Greece, Ireland, Luxembourg, Portugal and Sweden.

small EU-US differences in the GDP contributions of capital services and labour services cancelling 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 dramatic turnaround compared with the 1981-1995 period, when the EU's total economy TFP growth rate was more than double that of the US, on an annual average basis.

Table 1 : EU15ex5 + US – Results of Growth Accounting Analysis – Gross Value Added Growth and Input Contributions (Annual Average Volume Growth Rates in %)

	EU15ex5		US	
	1981-1995	1996-2004	1981-1995	1996-2004
Total Industries				
Labour Services	0.2	0.7	0.9	0.4
Capital Services	1.1	1.2	1.7	1.4
TFP	0.7	0.1	0.3	1.2
Total Industries Value Added	2.0	2.0	2.8	3.1
Manufacturing				
Labour Services	-1.2	-0.4	-0.2	-1.5
Capital Services	0.8	0.7	1.0	1.0
TFP	1.9	0.9	2.2	3.4
Total Manufacturing Value Added	1.5	1.2	3.0	2.9
Private Services				
Labour Services	0.7	1.0	1.4	1.0
Capital Services	1.4	1.6	2.4	1.8
TFP	0.7	0.0	-0.5	1.1
Total Private Services Value Added	2.8	2.6	3.2	3.9
Rest of Economy				
Labour Services	0.5	0.9	1.5	1.4
Capital Services	0.7	0.6	0.7	0.9
TFP	-0.2	-0.1	-0.4	-0.5
Total "Rest of Economy" Value Added	1.0	1.4	1.8	1.8

Source : EU KLEMS and own calculations

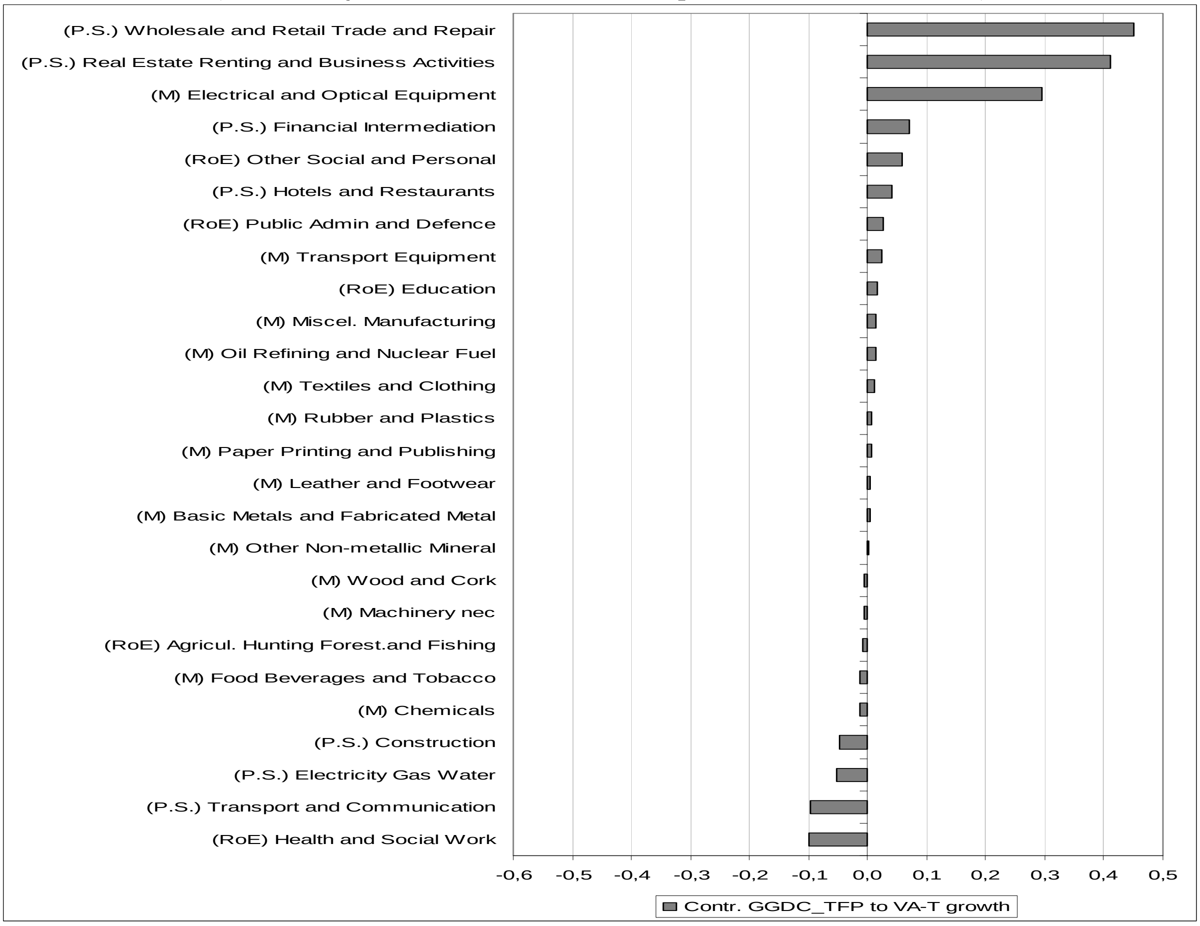
In addition to the sectoral analysis shown in Table 1, EU KLEMS can also be used to provide a more detailed breakdown for the manufacturing, private services and "rest of economy" sectors by examining those 26 industries in the databank (i.e. 14 manufacturing, 7 private services and 5 "other industries") where labour quality and capital stock data exists and which are therefore amenable to growth accounting analysis.[3] The results from this breakdown are shown in graph 1 which takes the TFP contributions of the 26 industries in the US and subtracts the equivalent EU contributions, with each of the industries in turn attributed to their respective sectors (i.e. M = manufacturing; P.S. = private services and O = "other industries"). This graph allows one to focus in on the specific industries within the 3 sectors which explain the EU-US TFP differences.

Graph 1 shows that over the 1996-2004 period that only a small number of industries drove the aggregate TFP growth gap of 1.1% points in favour of the US, with one manufacturing industry (electrical and optical equipment – which includes semiconductors, the main ICT producing industry) and two private services industries (wholesale and retail trade; real estate & other business activities) driving the EU-US TFP gap. On a more encouraging note for the EU, Graph 1 also indicates that the EU has done relatively well in "network utility" industries such as electricity, gas and water as well as transport and communications. With the exception of "real estate & other business activities" where measurement issues loom large, the regression analysis in section 3 will closely examine trends in the remaining TFP-driving industries (i.e. electrical & optical equipment; retail and wholesale trade; and the "network

[3] The analysis is only possible for 26 industries since 5 of the A31 level industries have been merged with other industries.

utilities"), with the objective of offering guidance to policy makers as to the most potent TFP-enhancing policies to pursue.

Graph 1 : Industry contributions to EU-US TFP gap : 1996-2004
(US industry TFP contributions minus equivalent EU contributions)



Source : EU KLEMS, Commission services

Overall, this descriptive analysis on the basis of the EU KLEMS datasets suggests that the EU may not be suffering from a generalised TFP slowdown across all industries but from industry-specific difficulties. The regression analysis in section 3 will try to decipher whether these difficulties are linked either to specific innovation drivers of TFP (i.e. frontier effects; human capital and R&D investments; the production and exploitation of ICT technologies; "creative destruction" mechanisms; role of complementary tangible and intangible investments in the technology transfer process in specific market services) or to factor efficiency drivers (e.g. cross country differences with respect to the intensity of competition; the scope to reap industry specific economies of scale; or inadequate incentives / market pressures to adopt new technologies or introduce better organisational structures / practices).[4]

[4] Whilst innovation is undoubtedly the key determinant of TFP growth over the long run (with ICT being the dominant technology over recent decades), this is not always the case over the short to medium term where factor efficiency considerations can be the dominant driver of TFP changes (as appears to be the case in the US since the year 2000). Awareness of this important time dimension underlines the fact that TFP is not just about technology – in fact the other determinants such as levels of competition, scale economies and organisational / managerial best practices can periodically be more important.

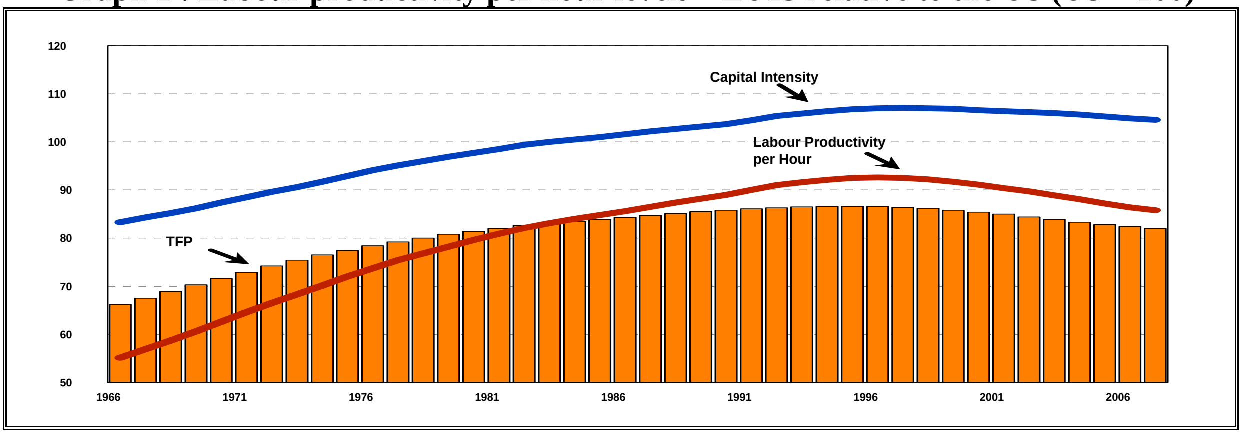
3. Understanding the determinants of TFP growth : What can we learn from EU KLEMS ?

3.1 Conceptual framework

A better 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. For a long period of time growth theory was not endowed with an appropriate paradigm to explain the determinants of TFP growth. In the standard neoclassical growth framework, TFP is exogenous and corresponds to the "Solow residual". In the early wave of endogenous growth models (the 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 that growth-friendly policies should be focussed on promoting savings and investment. The predictions of these models do not 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 (Graph 2), whilst TFP growth stagnated in the former group of countries and was sustained in the latter.

There is a growing consensus in the literature that recent growth theories, based on "Schumpeterian" creative destruction mechanisms, seem better equipped to interpret recent developments in the EU's growth performance (see, for example, Aghion and Howitt (2005)).[5] This theory focuses on innovation as the key driver of growth in economies at, or close to, the "technology frontier".[6] 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. At the aggregate level, the innovation rate depends on the resources devoted to the innovation effort (i.e. R&D and human capital) and on the stock of existing knowledge (knowledge spillovers). The growth rate of the economy will depend not only on the rate of innovation but also 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".

Graph 2 : Labour productivity per hour levels – EU15 relative to the US (US = 100)



Source : Commission services and own calculations

[5] For earlier analyses, see also Nelson and Phelps (1966), Abramowitz (1986) and Benhabib and Spiegel (1994).

[6] Hence, the focus is on TFP growth as the engine of growth.

In this "Schumpeterian" world, institutions and policies play a key role in determining the relative position of countries in the global innovation race. These framework conditions directly impact on the relative 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 in the literature have already analysed the determinants of TFP in a 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 sectoral / industry levels, with the datasets usually obtained from the OECD's STAN database.[7] 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 :

- 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); and

- an estimate of the growth rate of TFP at the frontier (i.e. the TFP growth rate of the most efficient country).

The first 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 here is simply 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 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 regulation and public ownership prevents 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 for innovation. This conclusion can be explained by the observation that being far from the frontier reduced the incentives to

[7] See, for example, Nicoletti and Scarpetta (2003); Griffith, Redding, and Van Reenen (2004), Conway et al. (2006).

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 (2005) 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 market 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 market services using the EU KLEMS database. Their analysis shows that although ICT investments were a main driver of labour productivity growth in the service sectors 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.

3.3. 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 market services. Additionally, there will be an attempt to identify the determinants of TFP growth in a number of specific industry groupings that contributed most to the EU-US TFP growth gap, namely the ICT- producing manufacturing (i.e. electrical & optical equipment) and wholesale & retail trade industries, 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 large number of policy and institutional variables.

The analysis concerns 9 EU countries plus the US over the 1980-2004 period and covers a total of 26 industries.[8] The baseline specification is similar to that found in existing analyses

[8] The 9 EU countries are Denmark, Germany, Spain, France, Italy, the Netherlands, Austria, Finland and the UK. The 26 industries are taken from the NACE A31 industry breakdown. Data is only available for a total of 26 industries since some of the smaller headings have been merged with other NACE codes.

(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).[9] 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.[10]

The baseline specification is subsequently augmented in such a way as to control for the impact of ICT and human capital, R&D, 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 presence of those economy-wide infrastructures which are most closely associated with the development of new technologies; demographic factors; barriers to entry; and competition, generally turned-out to be not significant.[11]

3.4. Regression results

3.4.1. Baseline specification : Table 2 presents the results for the baseline specification.[12]. Across the whole sample (column (1)), the results suggest that TFP growth is higher when there is stronger TFP growth in the frontier economy (reflecting the impact of innovation and technology spillovers) and when the technology gap is larger (which reflects TFP convergence via the adoption of existing superior technologies).

In comparison with previous similar analyses, whilst a significantly negative relationship between TFP growth and the gap in technology is generally found, the impact of TFP growth at the frontier is not always significant (e.g., Nicoletti and Scarpetta (2003)). Given that our results are strongly significant for "frontier" growth effects, as a robustness check, column (2)

[9] 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).

[10] 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.

[11] 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).

[12] Since the explanatory variables are likely to be exogenous, OLS estimation methods are used. Standard errors are robust with respect to heteroschedasticity and the possible autocorrelation of the residuals within countries.

in Table 2 also reports the same specification as in column (1) but using "ex-ante" calculated TFP growth rates. It is comforting to note that 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. labour across skill categories & 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 differentiate the marginal productivity of ICT capital, TFP growth taking place at the frontier does not appear to significantly affect TFP growth rates (column (3)). 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. On the basis of the more "sophisticated" TFP measures in EU KLEMS, TFP improvements appear to be more strongly affected by developments taking place at the frontier.

Table 2 : Basic specification

	All industries and years	All industries (“ex-ante” TFP)	All industries (“raw” TFP)	Only manufacturing sector	Only market services sector	Only ICT-related sector	Only years after 1995
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
TFP growth at the frontier	0.159**	0.113**	0.060	0.164**	0.135**	0.138***	0.158*
	(2.98)	(2.61)	(0.54)	(2.38)	(3.39)	(4.70)	(2.08)
Technological gap	-0.046***	-0.038***	-0.036***	-0.060***	-0.029***	-0.027***	-0.046
	(4.48)	(5.12)	(-4.96)	(3.81)	(4.14)	(4.85)	(1.20)
N. obs.	6619	6059	6677	3058	2133	2371	2796
R^2	0.13	0.12	0.10	0.16	0.10	0.50	0.12

Notes: Estimation method: panel OLS regressions; fixed effects included for countries, industries, and years; standard errors robust with respect to heteroschedasticity and possible correlation within countries. 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 –TFP level of the leader country).

Table 2 also reports results for the basic specification based on different sectoral breakdowns and time periods. Column (4) reports the results when the sample is restricted to the manufacturing sector, whilst columns (5) and (6) do the same for, respectively, private services and ICT-related sectors (the latter comprises both ICT producing manufacturing sectors and all sectors of the economy that use ICT goods intensively). Column (7) reports results for all sectors but in years after 1995 only. 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, regarding the technology gap term, TFP growth in the manufacturing sector is relatively more driven by the adoption of superior existing technologies, compared with the private services and ICT related sectors. Finally, in restricting the analysis to the last decade of the sample (i.e. 1995-2004), TFP growth appears to be mostly driven by growth at the frontier, with a non-significant impact from the technology gap variable. This finding is consistent with the view that across Europe, growth is increasingly being driven by innovation activity and less by the adoption of existing up-to date technologies. Given these emerging patterns, these results could be interpreted somewhat negatively given that they appear to indicate that the extent of catching-up across countries is weakening over time.

3.4.2. The role of human capital, ICT capital, and R&D : Table 3 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 role of human capital, R&D and ICT technologies. All variables vary across countries, industries and over time.[13]

These additional variables, when introduced in the baseline specification (whilst keeping country, industry, and year fixed effects) appear not to have significant explanatory power.[14] A possible explanation for this poor performance for factors commonly regarded as relevant for TFP dynamics 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. Moreover, with respect to the role of R&D, additional regression work suggests that it may be better to use the stock of R&D rather than R&D flows as an explanatory variable since a rise in TFP over time appears to be more strongly linked to changes in the stock, again due to the substantial lags in the manifestation of the effects.

The presence of country and industry fixed effects for the results shown in column (1) of table 3 imply that the impact of the explanatory variables on TFP growth is captured mostly along the time dimension. 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. In sum, 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 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 market services. Even if their ICT variable 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. Consequently, it is important to allow for a specific industry dimension.

A further check on the above results is provided in columns (4) and (5), where regression results without, respectively, country and industry effects are displayed when the TFP measure used is "raw" i.e. it does not take into account labour and capital composition 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 part of the explanation for the role of human capital is related to the fact that TFP growth also captures labour productivity improvements associated with the secular rise in the skill levels of the workforce in general,

[13] 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.

[14] An exception is the ICT variable when restricting the sample to manufacturing only (column (7)). In this case, the coefficient appears to be significantly negative. A possible explanation is that the introduction of ICT technologies require a re-adaptation of production methods and organization, which could have a temporary negative impact on TFP (see, for example, Basu and Fernald (2007)). The results suggest that such temporary negative TFP effects from ICT are mostly felt in manufacturing.

and that these improvements are stronger in the countries exhibiting higher skill levels on average over the sample period. These productivity improvements are excluded from the more "sophisticated" EU KLEMS TFP measure, instead forming part of the contribution from labour services.

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 capital and R&D with the “TFP growth at the frontier” variable. The idea in this latter case is that R&D and human capital could be factors facilitating innovation and the absorption of technological spillovers emanating from the technological frontier. To our knowledge this interaction was not performed in previous analyses. A reason could be the weak explanatory power of TFP growth at the frontier as a regressor when using TFP data which fails to appropriately take into account the change in the quality composition of labour and capital, which, as explained earlier, is not the case with the EU KLEMS data.

Furthermore, 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, market 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 technological gap variable and TFP growth at the frontier. Hence, consistent with Vandenbussche, Aghion and Méghir (2005), we also find that the positive impact of human capital is stronger the smaller is the technological 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 highly visible especially when restricting the analysis to market 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 market services.

Table 3 : The role of human capital, ICT capital, and R&D

	All industries	All industries	All industries	All industries ("raw" TFP)	All industries ("raw" TFP)	All industries	Only manufacturing sector	Only market 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	0.178**	0.175**	0.397***	0.161**
	(2.18)	(2.20)	(2.27)	(0.13)	(0.05)	(2.84)	(2.41)	(3.19)	(3.94)
Technological gap	0.091**	-0.092**	-0.085**	-0.075***	-0.062**	-0.088***	-0.106**	-0.031	-0.024***
	(3.15)	(3.25)	(3.25)	(-3.65)	(-3.10)	(3.24)	(2.85)	(1.10)	(3.50)
Human capital	-0.003	0.004	0.002	0.007***	0.000	0.003	-0.015	0.008	0.002
	(-0.65)	(1.08)	(0.50)	(3.92)	(0.19)	(0.31)	(0.68)	(1.88)	(0.36)
R&D flows	0.002	0.004	0.004***	0.006**	0.006**	0.004	0.005	0.037	0.004
	(0.67)	(1.25)	(4.98)	(2.23)	(3.18)	(0.36)	(0.38)	(1.57)	(0.73)
ICT/ non ICT real capital stock ratio	0.002	-0.000	0.006***	0.000	0.009***	0.002	-0.038**	0.001	-0.000
	(0.74)	(0.21)	(3.70)	(0.20)	(4.76)	(0.61)	(3.41)	(0.46)	(0.64)
Interaction TFP growth at the frontier with human capital						0.184	0.213	0.189***	0.133
						(1.46)	(1.42)	(5.59)	(1.43)
Interaction TFP growth at the frontier with R&D						0.011	0.028	0.349	0.048
						(0.31)	(0.76)	(1.17)	(0.99)
Interaction technological gap with human capital						0.028	0.017	0.011	0.009
						(1.48)	(0.48)	(1.38)	(0.59)
Interaction technological gap with R&D						0.010	0.016	0.006	-0.002
						(0.47)	(0.54)	(0.13)	(0.16)
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	0.23	0.21	0.32

Notes:
Estimation method: panel OLS regressions; standard errors robust with respect to heteroschedasticity and possible correlation within countries. 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). Source EU KLEMS.
Technological gap: lagged log (TFP level –log(TFP level of the leader country). Source: EU KLEMS.
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. Source: EU KLEMS.

In summary, ICT, 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 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 technological frontier, a result which confirms the findings of existing analyses.

3.4.3. The role of regulations : The next series of TFP determinants analysed are regulations in product and factor markets. Recent research carried out in international organisations has emphasised the role of regulations in driving efficiency gains (e.g., OECD (2003), IMF (2003)). In addition, the literature which is more closely focused on assessing TFP growth determinants also tends to find some impact of regulations on the growth of TFP (see section 3.2.). In our analysis we have considered 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 in each industry of the economy arising from anti-competitive regulations in non-manufacturing industries. Labour market and financial market regulations are summarised by the "freedom indicators" constructed by the Fraser institute. The indicators quantify the degree of absence of anti-competitive regulations in, respectively, the labour and financial markets. We consider the impact of these indicators taken with a minus sign, to capture instead the effect associated with regulations becoming heavier. All indicators vary across countries and industries and over time.

Table 4 displays the results. While regulations do not appear to play a significant role when directly added to the list of explanatory variables (and keeping all industries in the sample - column (1)), their impact is found to be significant when distinguishing sub-groups of industries but often with an unexpected positive sign. However, their interaction with TFP growth at the frontier and with the technology gap variable does reveal some significant effects, with more plausible negative coefficients.

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. Again however the coefficients are only marginally significant. 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 on TFP growth (see, e.g, Bassanini and Ernst -2002- for a discussion of the alternative channels highlighted in the theoretical literature). On the one hand, stricter labour market regulations, notably employment protection legislation, by limiting the room for re-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 protection of employment 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, appear to be largely insignificant.

Column (3) repeats the same specification as in column (2) but restricted to manufacturing. 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 market 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 4 : The role of regulations

	All Industries	All Industries	Only manufacturing sector	Only market services sector	Only ICT-related sector
	(1)	(2)	(3)	(4)	(5)
TFP growth at the frontier	0.171***	0.175***	0.398***	0.138***	0.153***
	(3.39)	(5.82)	(4.02)	(3.97)	(7.07)
Technological gap	-0.049***	-0.047***	-0.042*	-0.026***	-0.030***
	(5.09)	(5.20)	(2.26)	(5.13)	(6.95)
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.	6340	6340	2929	2043	2271
R^2	0.13	0.14	0.18	0.11	0.22

Notes: Estimation method: panel OLS regressions; fixed effects included for countries, industries, and years; standard errors robust with respect to heteroschedasticity and possible correlation within countries. 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). Source: EU KLEMS.
Technological gap: lagged log(TFP level)–log(TFP level of the leader country). Source: EU KLEMS.
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).

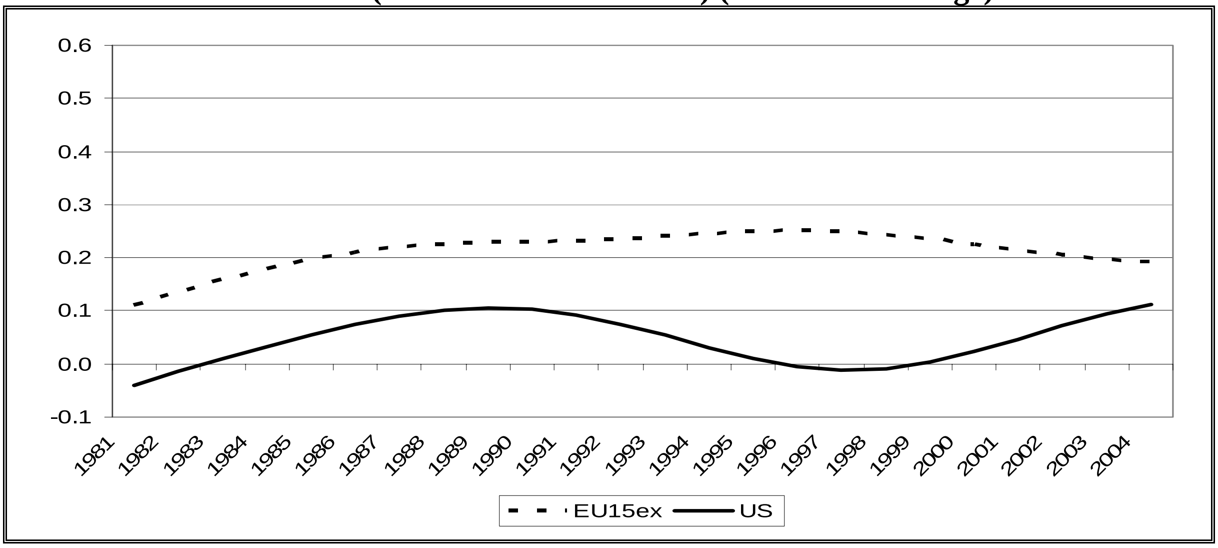
[15] This result is also corroborated in additional regression work which we carried out using firm level datasets. For this work, a number of relevant variables were tested including the average age of firms. One of the early conclusions from this work (complete results will appear in a subsequent draft of the paper) 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.

Overall, the role of regulations appears to be highly sector-specific. Results suffer from robustness checks with respect to the specification chosen and the sample definition. 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 market 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.

3.4.4. Industry-specific specifications : Part of the problems experienced with the regulatory regressions may be linked to the need to use a lower level of disaggregation than the broad sectoral aggregates which were used for the analysis in Table 4. This highlights the necessity of adapting the empirical model of TFP growth determinants to the specificities of different industries. 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 for those industries where the EU performance was comparatively satisfactory.

As shown earlier, the EU-US TFP gap is concentrated in the ICT producing manufacturing industry (i.e. electrical and optical equipment which includes semi-conductors) and a number of private service industries, most notably wholesale & retail trade. In addition, whilst the EU is underperforming in the latter industries, graph 3 also shows that there is a small group of industries where the EU has consistently outperformed the US over recent decades i.e. the "network" industries.

Graph 3 : Trend contributions to value added growth from TFP in the "network industries" (EU and US : 1981-2004) (Annual % Change)



Source : EU KLEMS, Commission services

Table 5 presents the results for those TFP determinants which have been selected for the ICT-manufacturing and wholesale & retail trade industries (which together account for over 2/3 of the EU-US TFP gap), and for utilities, as an example of an industry where the EU has achieved a relatively strong performance. 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.

Table 5 : Industry-specific models

	ICT producing manufacturing		Retail and affiliated industries		Utilities	
	Only ICT producing manufacturing	Only remaining industries	Only retail and affiliated industries	Only remaining industries	Only utilities	Only remaining industries
	(1)	(2)	(3)	(4)	(5)	(6)
TFP growth at the frontier	0.007	0.168**	0.152**	0.194**	0.086	0.190***
	(0.05)	(2.34)	(2.61)	(2.37)	(0.47)	(4.08)
Technological gap	0.010	-0.082**	-0.034***	-0.0544***	-0.022	-0.048***
	(0.67)	(3.28)	(4.26)	(4.03)	(0.84)	(4.92)
Interaction TFP growth at the frontier with R&D	0.130***	0.016				
	(3.50)	(0.38)				
Relative contribution of private consumption to GDP growth			0.004***	0.001		
			(5.08)	(1.80)		
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
Industry fixed effects	No	Yes	Yes	Yes	Yes	Yes
Year fixed effects	No	Yes	Yes	Yes	Yes	Yes
N. obs.	141	2497	836	5030	684	5656
R^2	0.56	0.18	0.17	0.14	0.22	0.13

Notes: Estimation method: panel OLS regressions; fixed effects included for countries, industries, and years; standard errors robust with respect to heteroschedasticity and possible correlation within countries. 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). Source: EU KLEMS.
Technological gap : lagged log (TFP level)–log(TFP level of the leader country). Source: EU KLEMS.
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 and affiliated industries : 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).
Utilities : energy (E)+transport and storage (60t63)+post and telecommunications (64).

Column (1) shows that for the ICT producing industry (i.e. electrical and optical equipment), the basic variables behave somewhat differently to prior expectations. The frontier and technology gap variables are non-significant, with the latter indicating that TFP growth rather than converging is diverging across countries in this particular 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)). Interestingly, the results change drastically when the same specification is tested on "total industries" excluding the ICT-producing manufacturing industry itself (column (2)). The key determinant for the ICT-producing manufacturing industry is clearly R&D, as indicated by the strongly positive coefficient for the interaction of R&D with the "TFP at the frontier" variable.

Regarding the retail and wholesale trade industry (column (3)), the results indicate a significant role for cyclical factors in providing a direct explanation for observed differences in TFP growth between the US and the EU's Member States (as suggested by the strongly significant positive coefficient for the relative contribution of private consumption to GDP growth).[16] 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 group of service industries. It is worth noting that a similar positive impact of cyclical factors is not observed in the remaining industries (column (4)).[17]

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 (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 communications. 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.

3.5. Summary of the main policy-relevant results : Whilst bearing in mind the need for caution in interpreting results that inevitably suffer, to some extent, from the imperfect measurement of TFP and from a number of robustness issues in the econometric specification, some potentially relevant findings stand out from our analysis.

- Firstly, compared with previous analogous studies, the use of the EU KLEMS database permits us to identify a statistically significant role of “TFP growth at the frontier” as an explanatory variable for TFP growth across the whole sample. Therefore, in addition to a significant TFP convergence phenomenon associated with the adoption of existing up-to-date technologies which is generally found in econometric work aimed at assessing TFP determinants with industry data, TFP growth also 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.

[16] In terms of its economic significance, consumption growth as a determinant accounts for about 20% of the TFP growth in retail & wholesale 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% of the EU-US TFP growth gap in retail & wholesale 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.

[17] In additional regression work using firm level datasets, preliminary results suggest that there is a positive interaction between the contribution of consumption to TFP 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 & wholesale trade industry. 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 sector. According to this paper, retailing in the US underwent a massive restructuring and reallocation of activity in the 1990's to adjust to the technological advances which were taking place. The authors found that virtually all of the productivity growth in the US retail trade industry 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 outperformance in retailing compared with Europe.

- Secondly, whilst there is a generalised tendency towards catching-up across countries in terms of TFP growth, such a tendency seems to be weakening over time, especially in the post-1995 period. Moreover, for the ICT-producing manufacturing sector this process of catching-up is particularly weak. TFP growth appears increasingly associated with innovation and technological spillovers from countries positioned "at the frontier".

- Thirdly, ICT, 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 growth rates of total factor productivity. 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. The implication for policy is that what matters for aggregate TFP growth is an expansion of the R&D and ICT-intensive industries rather than policies aimed at raising R&D and ICT technologies in all 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 technological frontier, a result that confirms the findings of existing analyses.

- Fourthly, the role of regulations appear to be highly sector-specific. Results suffer from robustness checks with respect to the specification chosen and the sample definition and from the limited time-variation of the sample. Notwithstanding 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 market services. Financial market regulations seem to play a negative role especially for what concerns the ability of countries to share in TFP improvements taking place at the frontier.

- Finally, the determinants of TFP growth appear to be largely industry-specific. Against this background, we attempted to identify the TFP growth determinants in those industries that explain the bulk of the EU-US TFP growth gap and in those where the EU's performance is relatively strong. 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. In the retail and wholesale trade industry, the evidence suggests a possible role for cyclical factors driving consumption dynamics : stronger consumption growth could be the source of TFP growth 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.

4. Conclusions

Whilst a growth accounting approach based on EU KLEMS is helpful in isolating those industries / sectors where the EU-US TFP differences lie, such an analytical approach has little to say concerning the underlying driving factors behind the divergences which emerged. Using a panel regression approach, the present paper statistically assessed the relative importance of those TFP determinants which have been consistently highlighted in the literature as playing a role. Given the sample of countries used in the analysis, it is clear that the focus was on assessing the drivers of TFP growth at the frontier rather than on analysing catching-up effects (e.g., learning-by-doing and imitation effects), with the role of R&D, ICT and human capital as well as a wide range of regulatory indicators being of specific interest.

One relatively clear finding, of a general nature, to emerge is that TFP growth is increasingly associated, especially over the post-1995 period, with innovation and technological spillovers from countries positioned "at the frontier". With regard to the role of R&D and ICT, a significant role is only found if the industry dimension is taken into account, implying that a more targeted policy approach is needed to maximise the benefits from the use of these knowledge-intensive resources. With respect to human capital, a direct benefit is not found using the more "sophisticated" TFP measure produced by EU KLEMS, with most of the gains from the secular rise in skill levels instead forming part of the contribution from labour services. However, human capital is found to indirectly facilitate innovation & spillovers at the frontier, especially in market services, with the impact being stronger the closer the economy is to the technological frontier. Regarding regulations, by limiting the sample to market services (most notably utilities), product market regulations appear to play a negative role for TFP growth, especially when the economy is further away from the frontier.

With respect to understanding the TFP trends in those specific industries where EU-US differences are concentrated, the regression analysis suggests that a relatively wide spectrum of factors are implicated. Whereas R&D intensity factors are linked with the relative under-performance of the EU's ICT producing manufacturing industry (mainly semiconductors), cyclical factors and the better exploitation of scale economies are a feature of the divergences in the retail and wholesale trade industries. Finally, with regard to the EU's out-performance in the network industries, there is evidence to suggest that these are mainly linked to one-off static efficiency gains associated with the sustained deregulation drive which occurred in these industries in many EU Member States over the last two decades.

Whilst the main policy-relevant conclusions from the regression analysis are undoubtedly tentative in nature, they are nevertheless in accordance with the emerging view in the literature that the TFP growth slowdown experienced by a large number of advanced European economies in recent years could be linked to a generalised failure in Europe to sufficiently adapt its policies and institutions from its post world war II phase of development.[18] Over the bulk of the post-war period, Europe drove its relatively successful

[18] While the regression results are thought provoking, it must be made clear that we are still far from a complete understanding of the determinants of TFP growth. Whilst a large number of explanatory variables were tested in the regressions, only a small number of them turned out to be significant, with the high number of insignificant variables suggesting that TFP is still very much a "black box". 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 an assessment of the implications of TFP trends for supply side policies. A degree of caution is also warranted given firstly that the EU KLEMS datasets are still in the "research" rather than the "official" statistics phase and secondly the need to be mindful of

catching-up process using an economic policy approach which in essence was focussed on imitating US technological advances. As convergence increasingly gave way to a phase in which EU countries joined, and in some cases extended, the global technology frontier, a large number of countries faced growing difficulties in replicating the TFP successes of earlier decades, with these successes in fact increasing their reluctance to acquiesce to the need for change.

The analysis in the present study supports the view that being at, or close to, the technology frontier, demands a re-focussing of policies and institutions more towards an innovation-based economic model, with less emphasis on the imitation of available, leading-edge, technologies and practices and more on sustained improvements in the EU's innovation capacity.[19] The hallmarks of an open-economy, innovation driven, developmental model are world class educational establishments; higher levels of, excellence driven and better targeted, R&D; more market based financing systems; and more flexible regulatory and institutional frameworks delivering a dynamic and competitive business environment. Whilst many aspects of this approach have been introduced in recent years in individual EU countries, the "mindset" shift needed to make an overall success of the process has unfortunately not yet occurred on a sufficiently large scale at the European level, despite the fact that "Lisbon" provides an effective vehicle for managing this essential transition process.

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the conceptual and empirical problems in accurately measuring output and price developments in some of the market service industries where EU KLEMS suggests the greatest EU-US TFP differences are to be found.

[19] The shift from an imitative (i.e. catching-up) to an innovation driven economic model has significant implications for EU institutions and policies with, for example, less emphasis to be placed on vocational education and more on third level; more stress on channelling resources to new start-ups rather than on large incumbent firms; more reallocation of scarce labour and capital resources across firms and innovation systems rather than within firms; and a movement away from an innovation system which was traditionally incremental in nature to one focussed on more fundamental breakthroughs.

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