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Mid-Tech Europe? A Sectoral Account on Total Factor Productivity Growth from the Latest Vintage of the EU-KLEMs Database

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Mid-Tech Europe?

A Sectoral Account on Total Factor Productivity Growth from the Latest Vintage of the EU-KLEMs Database

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Abstract

This paper uncovers patterns of TFP growth in the EU compared with the US using the latest vintage of the EU-KLEMS database which accounts better for intangible capital in production. Both in the EU and the US the growth contribution of TFP has been declining over the past two decades, while that of intangible capital and labour composition has been growing since the Global Financial Crisis (GFC) recovery. Most TFP growth can be attributed to a relatively few industries. The TFP growth advantage of the US over the EU is linked both to higher TFP growth rates in the sectors generating large TFP gains and to larger shares in value added for these sectors. Over the 2013-2019 period, in both the EU and the US, TFP growth is mostly due to TFP growth in services. While in the EU several so-called mid-tech manufacturing sectors, provided a positive contribution to overall TFP growth, in the US the only manufacturing sector that did so is not mid-tech: manufacturing of computers and electronics. Despite an acceleration of intangible capital investment in the EU, dynamics remain slower as compared with those observed in the US. Econometric estimations show that the elasticity of TFP to intangible capital has dropped considerably since the post GFC recovery, suggesting a possible slowdown of technological diffusion. Overall, even though sectors which are expanding their share in value added in the EU are generally those exhibiting higher and accelerating TFP growth, it appears that in the EU the transition towards the services sectors, where TFP is growing the fastest, is slower compared with the US.

JEL Classification: D24, E22, O40, O52.

Keywords: Productivity growth, Total Factor Productivity, sectoral patterns of Total Factor Productivity growth, intangible capital and Total Factor Productivity growth.

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1. INTRODUCTION

Productivity is key for long-term growth, but its measurement is subject to several difficulties. Over sufficiently long time periods, productivity growth, and most notably the so-called Total Factor Productivity (TFP), is the most important driver of economic growth among advanced economies. Assessing TFP dynamics is however problematic, as witnessed by the debate surrounding the reasons underlying the productivity slowdown in the EU and the US since the 2000s (e.g., OECD, 2017; Syverson, 2017).

This paper analyses productivity across the EU based on the latest vintage of the EU-KLEMS database, focusing on TFP. EU-KLEMS originated as an industry level, growth, and productivity research project, initially financed under EU research framework programmes. The key objective is to allow a more refined breakdown of the sources of productivity growth, capturing the contributions of the changing compositions of labour and capital types, and allowing a more precise estimation of TFP obtained as a residual. The last vintage of the database, dubbed EU-KLEMS & INTANProd (henceforth simply referred to as EU-KLEMS), compared with previous versions, provides a better disentangling of intangible capital as a contributor of productivity growth. Intangible capital includes research and databases (R&D), intellectual property, human capital, organisational capital. Examples of intangible capital include patents, trademarks, copyrights, software, employee training programs, corporate culture, brand recognition, customer loyalty, and supplier relationships. Intangible capital is important for economic growth because it fosters innovation by encouraging research and development, which leads to new products, services, and production processes. The EU-KLEMS & INTANProd database was developed by the Luiss Lab of European Economics at Luiss University in Rome, Italy. [1]

The paper analyses patterns of productivity growth across countries, industries, and time periods, with a comparatively fine disaggregation of different sources of productivity growth. The growth accounting uses data for 10 different capital assets (both tangible such as buildings and machinery and intangible such as software and R&D) and eight labour force types (based on age, gender, and educational attainment). The disaggregation by industry allows considering up to 42 different industries. As a substantial share of TFP growth originates from relatively narrowly defined sectors, a sufficiently fine disaggregation is required for a satisfactory analysis of sectoral patterns of productivity growth. Cross-country comparisons are carried out across EU countries and within the EU and the US.

More specifically, the analysis in the paper deals with the following aspects:

- Analysis of aggregate (total economy) labour productivity and TFP growth cross-country patterns, including to shed light on convergence dynamics.
- Description of productivity growth patterns by source, industry, time periods for the EU on aggregate (for 10 EU Member States, which have consistent data), the US and selected major EU economies.
- Assessment of the contribution of each industry on overall TFP growth by sub-periods. This allows in particular to disentangle the extent to which TFP growth differences between the EU and the US were associated with differences in within-industry TFP growth rates or rather linked to different composition of value added across sectors.

[1] The database is available here: EUKLEMS & INTANProd - Luiss Lab of European Economics.

- EU-KLEMS are particularly suited to analyse sectoral patterns of intangible capital investment. The paper hence aims also to shed light on how intangible capital investments have evolved and what this has implied for TFP growth by means of panel econometric estimations. Compared with previous analogous work (e.g., Corrado et al., 2017; Ma et al., 2022), estimates are carried out also using the sectoral dimension of the panel at a higher degree of industry disaggregation.

The remainder of the paper is structured as follows. The next section gives a brief overview of the productivity measures obtained by growth accounting and presents the updated EU-KLEMS database. Section 3 presents productivity and TFP growth patterns at the total economy level, including looking into convergence dynamics. Section 4 gives labour productivity decomposition at the industry level. Section 5 then presents a breakdown of total economy Total Factor Productivity (TFP) into contributions from the various industries and a productivity growth comparison between the EU and the US. Section 6 focuses on sectoral patterns of intangible capital investments and the implications for TFP growth. Section 7 concludes.

2. TFP ESTIMATION AND THE UPDATED EU-KLEMS DATABASE

2.1. WHAT IS TFP, HOW IT IS CALCULATED AND WHAT ARE RELEVANT ESTIMATION ISSUES?

TFP summarises how effective are all production factors taken together in producing value added. TFP is usually seen as an embodiment of technological and organisational innovation (thus it could overlap with some forms of capital, creating additional difficulties in its measurement), that allows for a better production efficiency. It also reflects the state of the regulatory and business environment. TFP growth is estimated residually (the so-called Solow residual) after taking account of the contribution of production factors to value added growth. The higher is TFP, the more efficiently employed are all factors of production. Details on how TFP is measured in EU-KLEMS can be found in Annex 2.

A key difficulty in estimating TFP is the need to have very good estimates of the contribution of the various types of capital, including intangible capital, and labour used in production. Moreover, precise estimates of income shares that are paid to each distinct labour or capital type used in production are needed to estimate the parameters of the production function. Under the assumption of perfect competition, the shares equal the output elasticities of the production factors and permit to aggregate production factors in a Cobb-Douglas constant returns technology. Any violation of the perfect competition assumption implies that the Solow residual contains not only a pure estimate of TFP, and thus of production efficiency, but also a measure of the growth of the capital-to-labour ratio weighted by the mark-up of prices over marginal costs, see presentation in Hall (1989). Thus, any cyclicality that raises the capital-to-labour ratio, e.g., related to capacity utilisation, will be reflected in the Solow residual. [2] Likewise any violation of the constant returns to scale assumption will contaminate the Solow residual-based TFP estimates with a measure of the more than proportionate change in the factors.

[2] For correcting TFP figures for capacity utilisation see e.g., Burnside, Eichenbaum and Rebelo (1996),

2.2. MAIN OBJECTIVES AND FEATURES OF THE EU-KLEMS DATABASE

The most recent vintage – the 2023 EU-KLEMS & INTANProd[3] - updates previous editions of EU-KLEMS incorporating additional measures of intangible investment from INTAN Invest, thus going beyond the scope of the definition of capital assets according to the System of National Accounts, particularly in terms of what is considered to be an intangible asset. [4] In fact, EU-KLEMS & INTANProd is the first cross-country productivity database that includes a comprehensive account of intangible assets, following the definition proposed in the seminal work by Corrado et al. (2005) - categorised as 'computerised information', 'innovative property' and 'economic competences'. Such account of intangible assets is carried out in a harmonised framework coherent with the national accounts, which represents a significant advancement for productivity analysis and evidence-based policymaking. The new database, altogether, provides data for the 27 EU Member States, the United Kingdom, the United States and Japan across 42 industries and 15 industry aggregates over the timespan 1995 – 2020.[5] More information on EU-KLEMS is available in Box 2.1. below.

Box 2.1. **HOW DOES THE LATEST INTANPROD UPDATE DIFFER FROM THE PREVIOUS VINTAGES?**

The EU-KLEMS & INTANProd database is – in accordance with earlier editions – organised in two modules: (1) a *statistical module*, which represents a repository of all key variables for industry-level productivity analysis sourced directly from the national accounts of individual countries; and (2) an *analytical module* that complements these data with information on investment and capital stocks for intangible assets that are not included as gross fixed capital formation in official national accounts. Conceptually, the main changes compared to previous vintages concern the analytical module and thus in particular the capturing of intangible assets beyond the corresponding definitions for such assets according to the National Accounts and the reporting of TFP levels, calculated based on the methodology proposed by Inklaar and Timmer (2008).

Some of the most recent developments include the following:

- The 2023 release extends the time coverage to 2020 based on the latest national accounts.
- All EU-KLEMS-INTANProd variables are now available separately for Professional, Scientific, and Technical Services (section M of the NACE rev. 2 classification) and Administrative and Support Services (section N of the NACE rev. 2 classification), depending on data availability.

[3] EU-KLEMS has become over time the go-to reference when it comes to harmonised, industry-level data to analyse productivity growth across EU, the US, and other high-income economies. The name EU-KLEMS stands for European Union (EU) levels of capital (K), labour (L), energy (E), Material (M) and service (S) inputs. The original project started in 2003 and ended in 2008 and involved 18 European research institutes in a joint effort to gather and harmonise the necessary data, under the coordination of the Groningen Growth and Development Centre (GGDC). Subsequently, DG ECFIN has promoted and financed the evolvement of the database, which has been updated accordingly several times in 2009, 2011, 2012, 2016/17, 2018/19/20 and 2021/23, thus involving a wide network of researchers and institutions.

[4] The procurement procedure ECFIN/2020/OP/0001 – Provision of Industry level growth and productivity data with special focus on intangible assets – 2020/S 114-275561 provided funds for the new (current) database. For information about past releases of EU-KLEMS see www.euklems.net, van Ark et al. (2008), and Timmer et al. (2010) and https://euklems.eu/ by the Vienna Institute for International Economic Studies (WiiW). For more information about INTAN Invest see www.intaninvest.net.

[5] Industry detail and coverage vary over time and across countries. Detailed information for each country is available on the website: https://euklems-intanprod-llee.luiss.it/. The Japanese data are kindly supplied by RIETI institute and Hitotsubashi University (for details check: https://www.rieti.go.jp/en/database/JIP2021/index.html) and the data for Belgium are generated with the support from the Federal Planning Bureau. The Instituto Valenciano de Investigaciones Económicas (IVIE) has provided gross fixed capital formation (GFCF) and capital stocks data for Spain since the first EU-KLEMS release to supplement the lack of official data and kindly contributed to both releases of EU-KLEMS & INTANProd.

Box 2.1. continuation

- New harmonised estimates of investments and capital stocks in intangible assets, that are not included in national accounts (including new estimates of Industrial Design, Organisational Capital, Brand and Training). Intangible investment by asset thus covers purchased and own-account components for all asset types.

- The harmonised estimates for intangible assets are now generated for 38 NACE industries versus 19 industries of the INTAN-Invest database. Measures of intangible assets are available for 12 manufacturing industries as well as for selected service sectors (wholesale and retail trade, transport, professional services, and health) now expanded to provide larger industry detail.

- Real intangible investment incorporates price deflators based on closely aligned services output. For instance, a deflator for investment in brand and marketing research was developed from input price indexes for content development and production costs, internet advertising, and traditional media advertising. Information and communication technology (ICT) assets in volume terms reflect price deflators whose product quality change component is harmonised across countries.

- The analytical module provides harmonised capital stocks for all tangible and intangible assets based on geometric depreciation. The analytical growth accounting is based on these harmonised capital stocks and provided for a selection of countries. It also incorporates bottom-up aggregations for the market sector (excluding agriculture) and for the total economy for a selected number of countries. Most importantly, to complement the statistical module of EU KLEMS, it also provides information on capital services corresponding to intangible assets that are not included as such in the European System of Accounts [SNA].

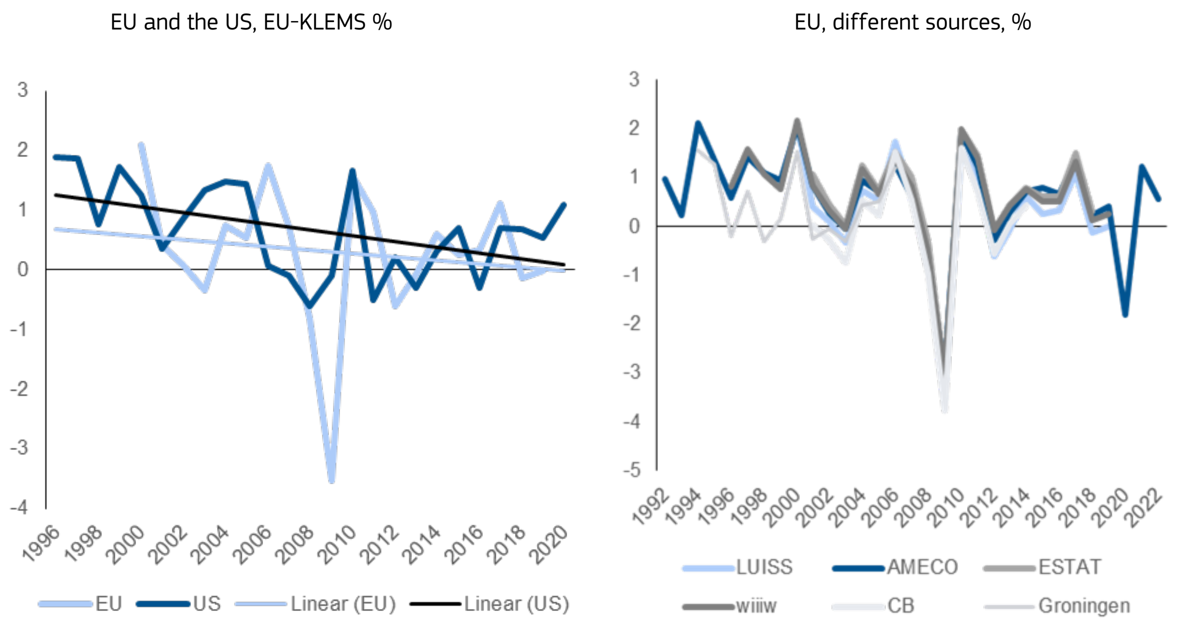
Productivity levels by industry are produced using VA, capital and labour PPPs and is consistent with the statistical module. For further details please refer to the corresponding methodological report (available as Deliverable D2.3.1 of the corresponding project at the EU-KLEMS website: https://euklems-intanprod-llee.luiss.it/wp-content/uploads/2023/02/EUKLEMS_INTANProd_D2.3.1.pdf.

3. TOTAL ECONOMY TFP EVOLUTION

The TFP estimate available from EU-KLEMS confirms a phenomenon of TFP growth slowdown. This is visible for both the EU and the US since the last 30 years (Graph 1). Some degree of TFP cyclicality is also visible, notably over the period of the Global Financial Crisis (GFC). TFP growth in the EU-KLEMS vintages, as compared with the one computed by ECFIN and available in AMECO, accounts better for contributions of the changing labour and capital compositions. Thus, it is slightly lower (although exhibiting qualitatively a similar trend) than the one computed by ECFIN and available in AMECO (right panel of Graph 1), which does not account for labour and capital composition, does not distinguish tangible from intangible assets and does not include intangible assets different than those present in national account statistics.[6] As previous EU-KLEMS vintages did not take into account intangible capital not included in national accounts TFP growth estimated from the latest vintage of the EU-KLEMS is also below that estimated from older EU-KLEMS vintages. In line with the findings in Corrado et al. (2009) for the US, accounting for a wide set of intangible assets results into a reduction in TFP growth estimates.

[6] Note that ECFIN computes actual TFP and, using it, it computes a trend TFP, where the cyclicality is removed, the latter is used by the EU-CAM (Commonly Agreed Method) for the output gap calculation, while the former is calculated as the Solow residual similar to the approach in EU-KLEMS. The actual TFP calculated by DG ECFIN, and not the trend TFP, is presented here.

Graph 1. **Total economy TFP growth over 30 years**



Notes: TFP growth calculated as the Solow residual. EU is the GDP weighted average of AT, BE, DE, DK, ES, FI, FR, IT, NL, SE. "LUISS", "wiiw", "CB" and "Groningen", refer to the 2023, the 2019, the 2018 and the 2012 vintages of the EU-KLEMS database.

Source: EU-KLEMS vintage by LUISS Lab of European Economics (LUISS), European Commission (AMECO, Spring 2023 forecast), Eurostat Experimental Statistics (ESTAT), EU-KLEMS vintage by Vienna Institute of International Economic Studies (wiiw), EU-KLEMS vintage by Conference Board (CB), EU-KLEMS vintage by Groningen Growth and Development Centre (Groningen).

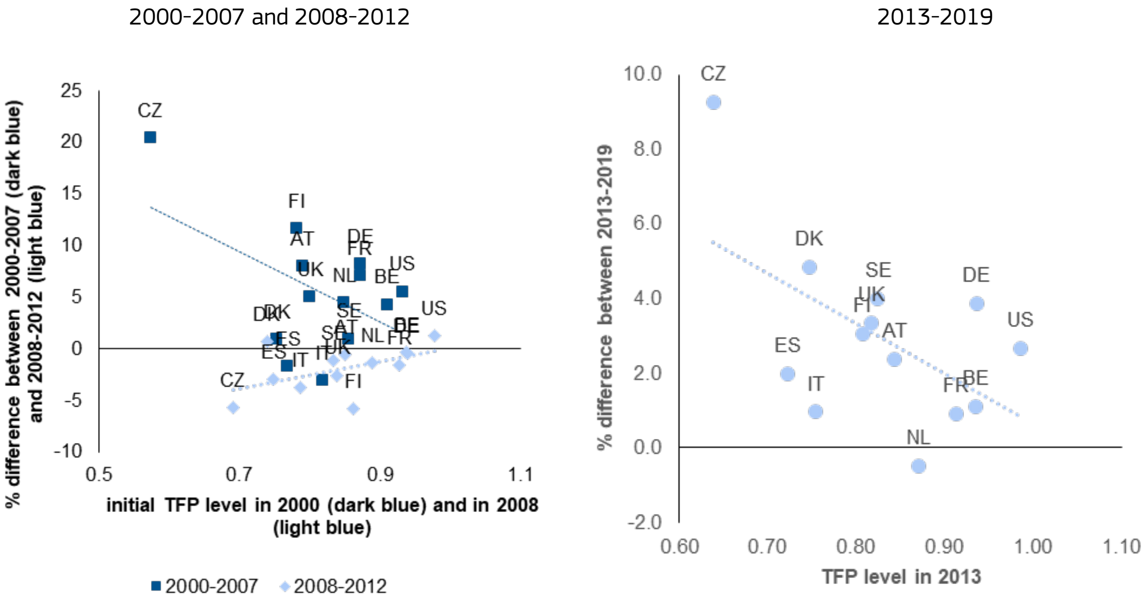
Aggregate EU TFP growth figures mask considerable differences among EU countries.

- TFP growth in Germany has been on average slightly higher than in France, Italy and Spain (see Annex 1).
- France shows a major deceleration of TFP growth since the Global Financial Crisis (Graph A2), while in Italy and Spain TFP growth has mostly been negative except during short periods preceding the financial crisis (Graphs A3-A4).

TFP growth in Central and Eastern Europe has been higher than in the West (Graphs A5 and A6), including considering transition dynamics.

TFP data from EU-KLEMS supports the hypothesis of productivity convergence (Graph 2). Countries with a lower starting level of TFP in PPP terms generally displayed faster TFP growth, as it would be expected because of intersectoral reallocation taking place during transition and following the "neo-Schumpeterian" growth models where laggard countries benefit from a higher rate of adoption of new technologies (e.g., Aghion and Howitt, 2008). This is confirmed both over the pre-crisis period (Graph 2, left panel) and over the post GFC recovery (i.e., after 2013, Graph 2 right panel), but not during the Global Financial Crisis (Graph 2, left panel), when it is likely that large cyclical developments masked the convergence dynamics.

Graph 2. **TFP change (vertical axis) vs TFP level (horizontal axis) in the total economy**



Notes: TFP change calculated as the percentage change in the TFP level using the Solow residual to populate the time series. TFP levels calculated in terms of PPPs with US in 2017=1.

Source: EU-KLEMS.

4. DISSECTING THE CONTRIBUTIONS TO LABOUR PRODUCTIVITY GROWTH – AN INDUSTRY PERSPECTIVE

This section presents a sectoral breakdown of labour productivity growth distinguishing by sources and time periods.

- As detailed in eq. (A11) in Annex 2 the growth of labour productivity, measured as gross value added per hour worked, is decomposed into the contributions of several items: (i) the growth of capital-per hour worked ratios for the different types of capital considered (tangible non-ICT, such as buildings, machines and equipment; tangible ICT, such as computer hardware and communications equipment, and intangibles such as computer software and databases and R&D); (ii) the change in labour composition, which is calculated as any change in labour services that does not come purely from a change in hours worked;[7] (iii) TFP growth. In sum, labour

[7] For example, if a more skilled and productive worker, who is also paid more since by assumption she is remunerated her marginal product, spends X more hours working, the labour productivity per hour worked is augmented even if total hours worked remain the same (because another worker works X hours less). In this case total employment remains constant but labour productivity per hour increases because hours worked by a more productive worker replace hours worked by a less productive one. Of course, this restriction is not strictly necessary, so labour services can be augmented by an increase in hours and an increase in labour composition both happening at the same time, or an increase in the labour composition may offset a decrease in total hours, still resulting in an increase in labour services. The labour types in EU-KLEMS are distinguished by age, gender, or educational attainment of the employed workforce, each paid her marginal product, so information about pay reveals information about labour quality and change in the composition of labour.

productivity increases with the increase in capital-per hour (capital deepening), change in labour composition towards more skilled labour and better production efficiency (increase in TFP).

- Regarding the industry breakdown, labour productivity growth and its main sources is reported for the total economy, and the main sectoral aggregates (manufacturing, agriculture, mining, and the main service categories). In addition, to capture productivity dynamics taking place at finer level of disaggregation, values are reported at the level of the NACE Rev.2 nomenclature and, for manufacturing and information and communication services, also at the two-digit level of the NACE Rev.2. Hence, the breakdown needs to be interpreted with caution in view of overlaps. For example, the overall manufacturing sector, denoted by C, is reported together with manufacturing of transport equipment, denoted by C29_C30, which is contained in C.

- Regarding the geographical breakdown, figures are reported for the EU as a whole (across available countries, thus largely excluding countries in Southern and Central and Eastern Europe for which data are not available), the largest five EU Member States, and the US. Note that labour productivity decomposition is unavailable for certain industries in the US so the industry sample in the US is slightly smaller. [8] Moreover, different sub-periods are considered, for the years available in the database: the years preceding monetary unification (1996-1998), the period between the start of EMU and the GFC (1999-2007), the GFC years and its aftermath (2008-2012), and the years of the recovery (2013-2019).[9]

The main insights from the labour productivity growth breakdown are provided in Graphs 3-10. A number of observations stand out.

The main source of labour productivity growth over the period analysed is TFP, although its role has been falling while the contribution of intangible capital has been on the rise. [10]

- For the total economy, *both for the EU and the US, the main contributor to productivity growth generally appears to be TFP, followed by tangible and intangible capital deepening* (Graphs 3 to 10). [11] *TFP growth also explains the bulk of productivity growth dispersion across sectors*.

- *The contribution of TFP growth has, however, declined over time*, with negative rates over GFC years in light of cyclical effects associated with reduced capacity utilisation. This holds especially for the EU. *After the GFC, intangible capital provides a stronger contribution, especially in manufacturing*, and notably in sectors linked to the production of transport equipment, while previously tangible capital played a bigger role than intangible capital.

- For both the EU and the US, *since the GFC, labour composition has become a relatively more important productivity growth contributor* (as with depressed demand skilled workers were engaged relatively more than unskilled ones who were the first to lose their jobs).[12]

[8] The following industries are not available in the US growth accounting data: Manufacturing of chemicals & pharma (C20_C21), Manufacturing of machinery (C28), Electricity & gas (D), Water supply & sewerage (E), Telecommunications (J61) and Public administration (O).

[9] The period since the start of the COVID-19 pandemic is excluded due to inconsistent data across countries.

[10] Note that here we abstract from the neoclassical notion that TFP growth in developed countries (where labour force is less dynamic) is the only source of GDP growth. Here we are interested in the short-term dynamics and the growth of labour composition as well.

[11] Note that the start of the time period in the EU is 1996 and in the US it is 1995, due to different data availability in EU-KLEMS.

EU TFP growth over the whole period appears particularly strong in a handful of manufacturing and services industries with growth rates that differ, however, quite considerably, between the EU and the US. The manufacturing sectors generally displaying higher TFP are manufacturing of computers and electronics, manufacturing of transport equipment, chemicals, while services displaying strong TFP dynamics comprise public utilities, IT, professional and administrative services as well as wholesale and retail trade. US growth rates have been in general much higher than those recorded in the EU for what concerns IT-related activities while the EU has a comparatively stronger performance in other manufacturing activities. Differences in sectoral TFP growth rates are also observed across major EU economies. Sectoral TFP dynamics were driven partly by structural transformations, partly by cyclical effects linked to varying capacity utilisation, which played a particularly strong role over the financial crisis. Moreover, the timing of TFP dynamics appears quite different, with strong TFP spurts in the US followed by accelerations in the same sector in the EU with some lags.

- *In the EU, over the years preceding the GFC, the highest rates of TFP growth are observed in telecommunication services*, notably because of the liberalisation of that sector and pro-competitive reforms (Graphs 4 and 5). High TFP growth rates in this period are observed also for *IT services* in general (IT services contain telecommunication services). In addition to telecommunication, other *network industries* such as transport and energy and gas display relatively high TFP growth. TFP growth is also relatively strong in *wholesale and retail trade*, partly due to changing average scale of retail firms and better exploitation of scale economies, partly because of cyclical effects related to capacity utilisation.[13] Regarding manufacturing the highest rates of TFP growth are observed in the *manufacturing of computer and electrical equipment* (including because of dynamic scale economies in line with "Moore's law"), *chemicals, transport equipment and machinery*.

- *Over the GFC years*, TFP dynamics were affected by reduced capacity utilisation. High TFP growth rates are still observed in telecommunications and IT related services (Graph 6). Instead, other *services such as transport, energy, trade, professional and administrative services* display *negative TFP growth rates*. [14] Strongly negative growth rates are displayed by a cyclical sector such as construction. Manufacturing as a whole displays negative growth in TFP, which is confirmed in most manufacturing industries, except textiles.

- *The post GFC recovery* had been characterised by *milder labour productivity and TFP growth* rates compared with pre-GFC years (Graph 7). The *deceleration* is visible where TFP growth was typically stronger, notably *in telecommunications and the manufacture of computers and electrical equipment.* Negative growth rates are recorded in services such as transport, energy, and finance. A strong *rebound* in TFP growth is instead recorded in *wholesale and retail*. Over this period, *intangible capital* starts playing a *stronger role* in driving productivity growth, mainly *in manufacturing* (with a remarkable growth especially in transport equipment manufacturing).

- Looking at the largest five EU Members States (see Annex 1), *Germany, France, Spain, and the Netherlands we can see that the aggregate TFP dynamics mask some differences at the country level*. Germany exhibits a particularly strong TFP performance in telecommunications and IT services, and a broad-based positive TFP growth in manufacturing industries, except in the

[12] See some evidence on employment composition effects over the business cycle with impact on labour productivity during the COVID-19 pandemic as well in Anderton et al. (2021), Christodoulopoulou and Kouvavas (2022) and Howard et al. (2022).

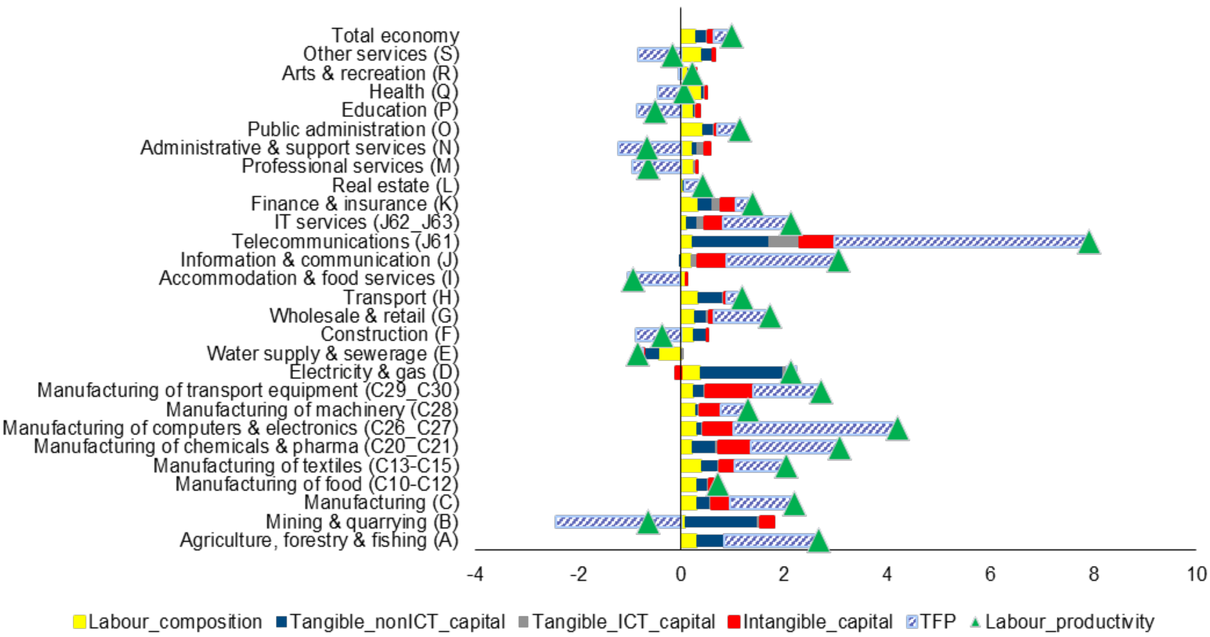
[13] See Planas et al. (2013).

[14] Note that relaxation of the assumptions of the Solow model result in capacity utilisation contaminating the Solow residual, thus resulting in measuring negative TFP growth.

production of machines. In France a relatively strong TFP growth rate is observed in the chemical industry while machine manufacturing displays negative TFP growth. TFP growth in the chemical sector in instead negative in Spain, which records also relatively small TFP growth in IT services. *Italy, instead, shows quite different patterns compared with that of the EU:* TFP is negative in telecommunication and IT services, as well as in the manufacturing of computers and electrical equipment and in that of machines. Within manufacturing, relatively large positive TFP growth is observed in transport equipment and chemicals as well as traditional manufactures such as textiles and food.

- The *US exhibits sectoral TFP patterns which differ to some extent from those observed for the EU* (Graphs 8, 9 and 10). The most remarkable difference is the *much stronger TFP growth recorded in manufacturing of computers and electronic equipment*. This is not surprising as most innovation in this sector originated in the US over the recent decades. *Network industries*, notably IT services, have instead *recorded slower TFP growth* as compared with the EU, especially before the GFC, while very strong TFP dynamics took place in wholesale and retail trade in the 1990s and early 2000s with a subsequent deceleration (see, e.g., Mc Morrow et al. 2010).[15] It is also noticeable that *in the most recent years, TFP growth in computer manufacturing and manufacturing overall in the US has been slowing* (although remaining above rates recorded in the EU*)*, while an acceleration is recorded in IT services. The evidence suggests that TFP growth spurts which started in the US in view of innovations (e.g., manufacturing of computers, software development) were followed by accelerations in the EU in view of adoption. Productivity improvements linked to a better exploitation of scale economies (wholesale and retail), or erosion of market power (telecommunications) followed country-specific processes and different timing across the Atlantic.

Graph 3. **Labour productivity growth and its contributors in the EU total economy and sectors, 1996-2019, in p.p.**

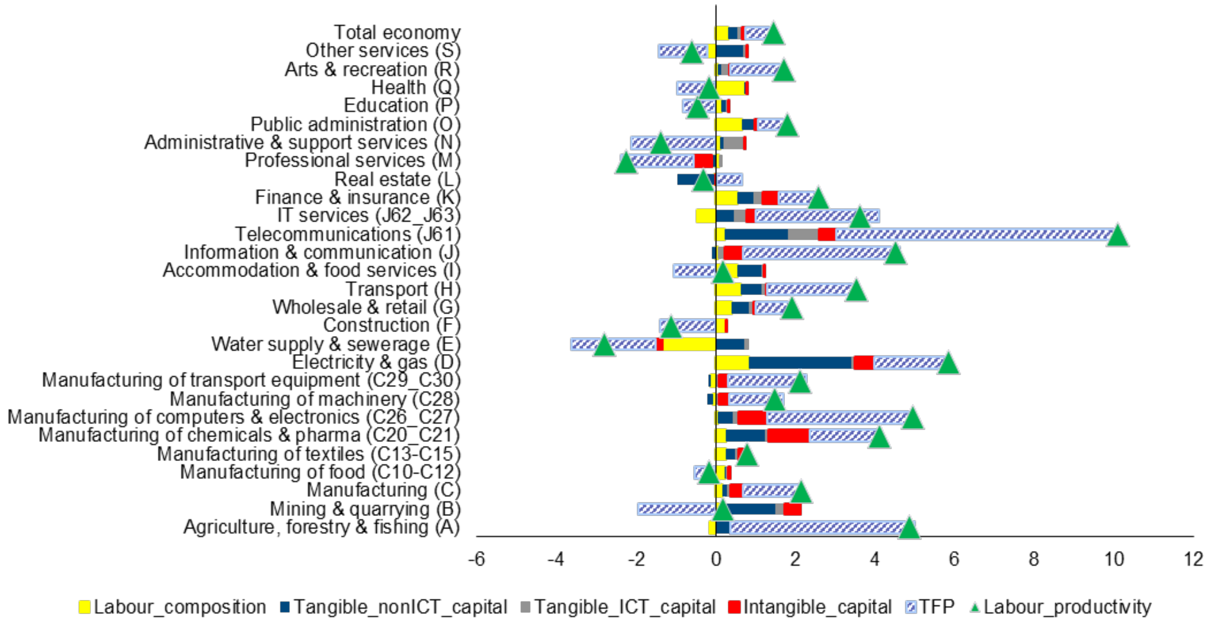


Notes: Average for 1996-2019. EU is the GDP weighted average of AT, BE, DE, DK, ES, FI, FR, IT, NL, SE.

Source: EU-KLEMS.

[15] A comparison complementing EU-KLEMS with data from US source is not possible, as data for most US network utilities are missing in EU-KLEMS.

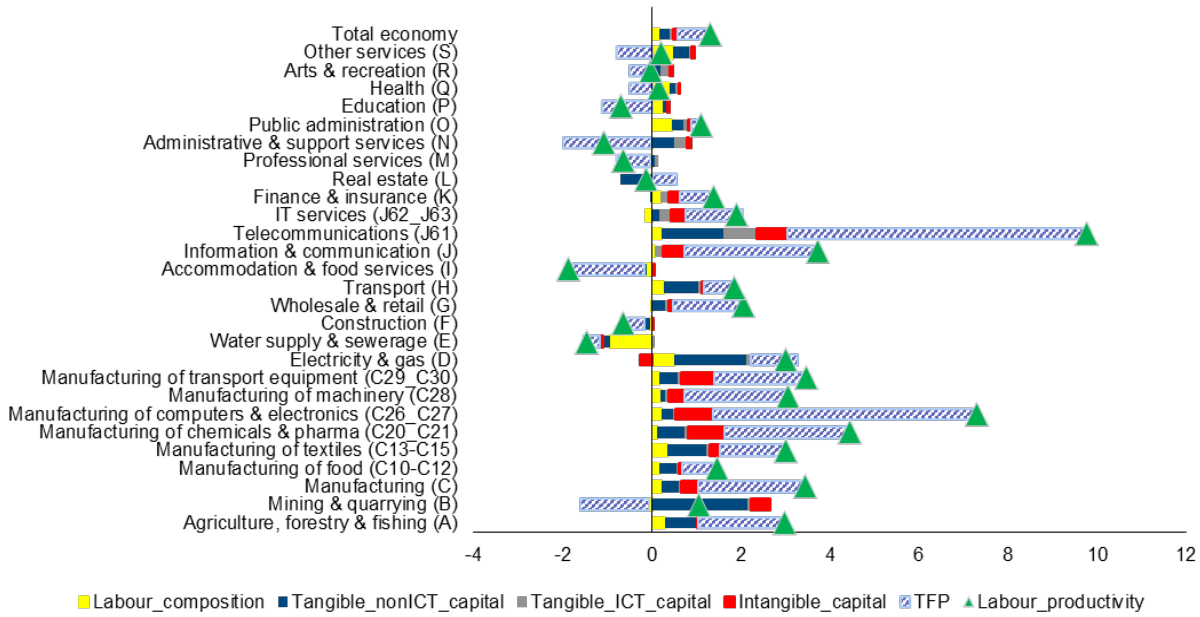
Graph 4. **Labour productivity growth and its contributors in the EU total economy and sectors, 1996-1998, in p.p.**



Notes: Average for 1996-1998. EU is the GDP weighted average of AT, BE, DE, DK, ES, FI, FR, IT, NL, SE.

Source: EU-KLEMS.

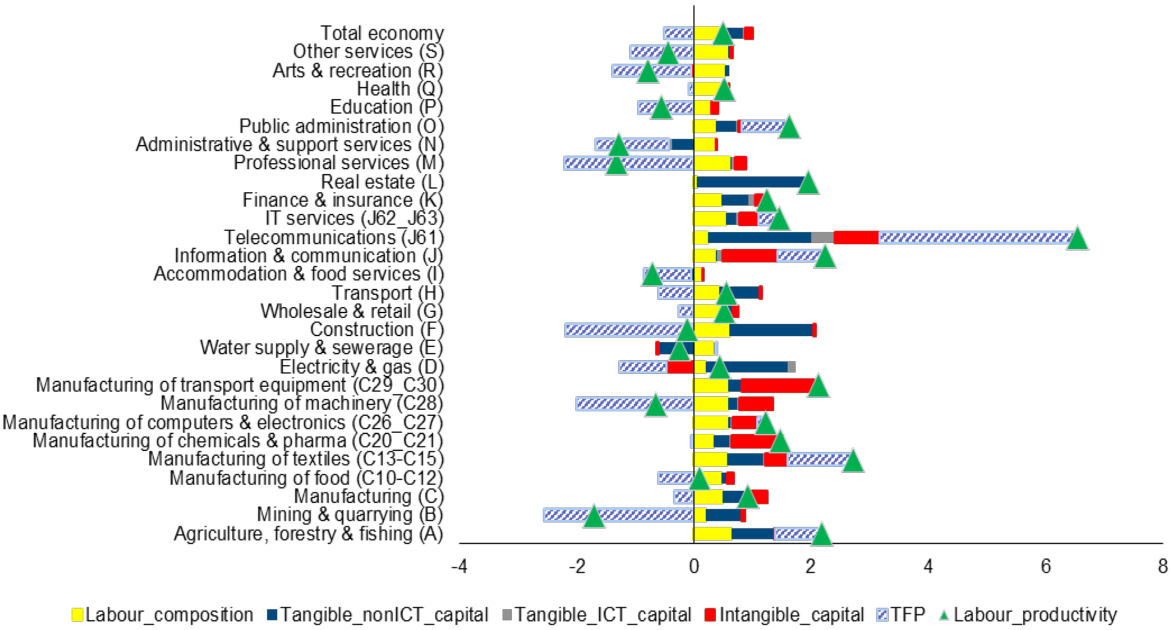
Graph 5. **Labour productivity growth and its contributors in the EU total economy and sectors, 1999-2007, in p.p.**



Notes: Average for 1999-2007. EU is the GDP weighted average of AT, BE, DE, DK, ES, FI, FR, IT, NL, SE.

Source: EU-KLEMS.

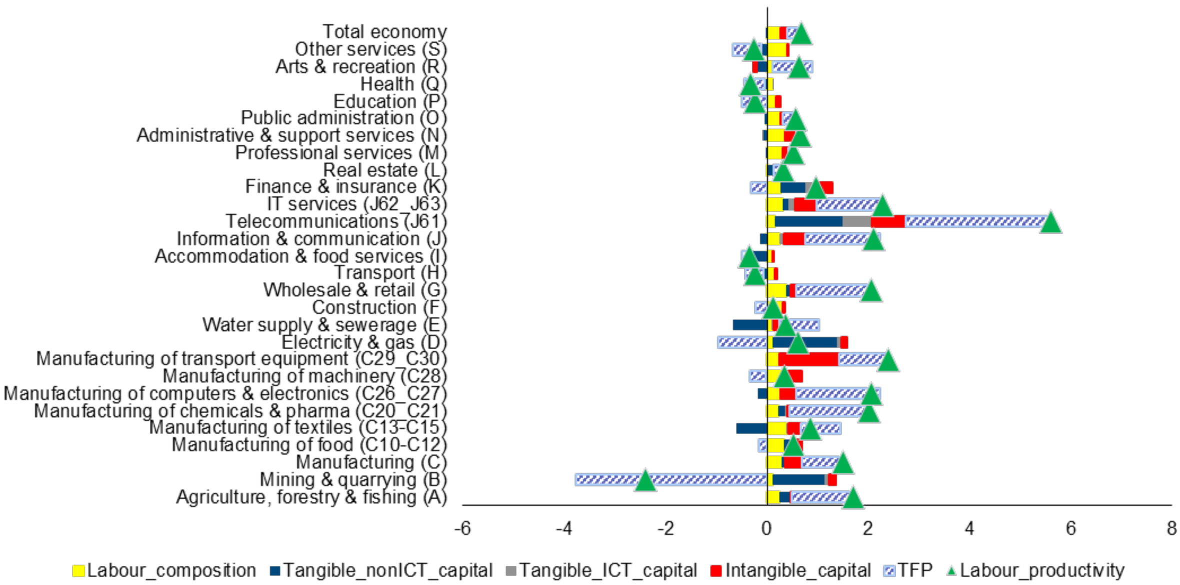
Graph 6. **Labour productivity growth and its contributors in the EU total economy and sectors, 2008-2012, in p.p.**



Notes: Average for 2008-2012. EU is the GDP weighted average of AT, BE, DE, DK, ES, FI, FR, IT, NL, SE.

Source: EU-KLEMS.

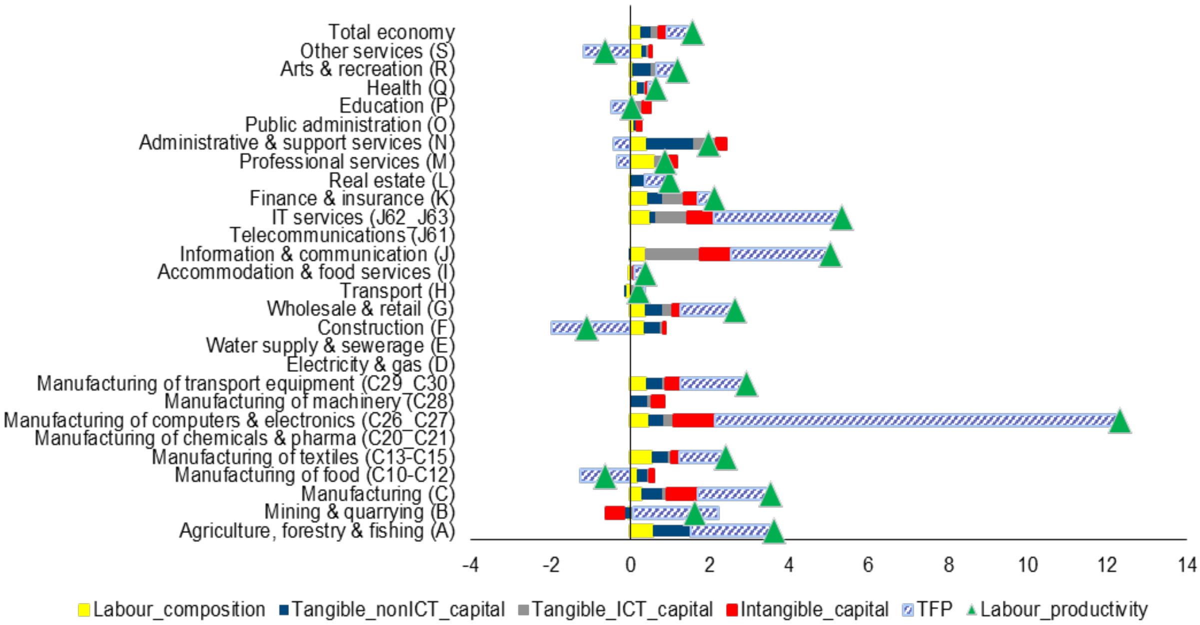
Graph 7. **Labour productivity growth and its contributors in the EU total economy and sectors, 2013-2019, in p.p.**



Notes: Average for 2013-2019. EU is the GDP weighted average of AT, BE, DE, DK, ES, FI, FR, IT, NL, SE.

Source: EU-KLEMS.

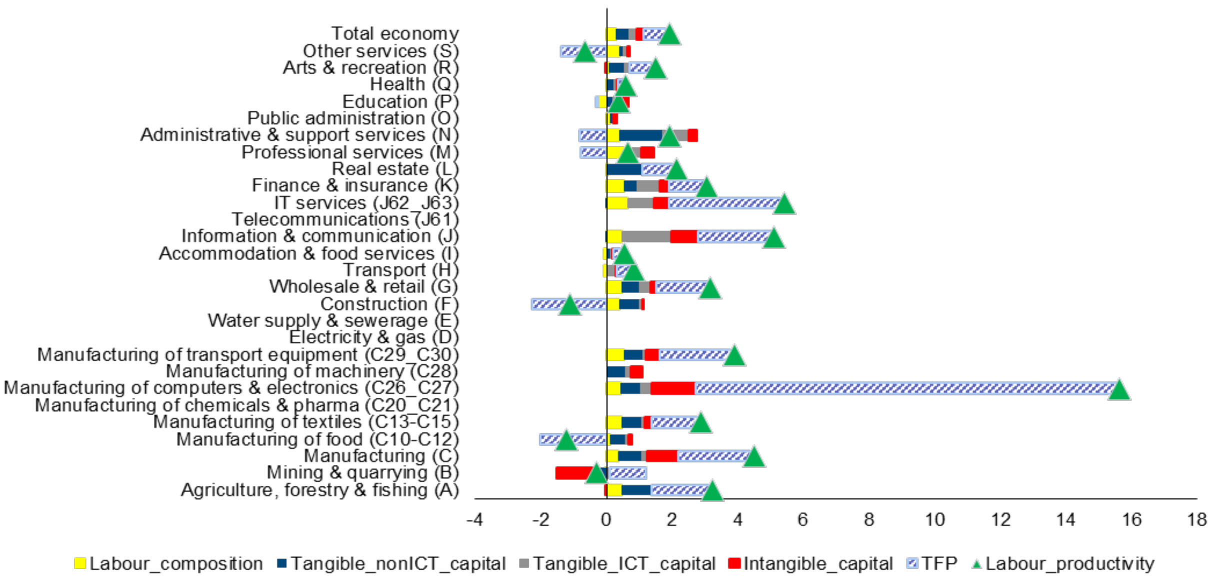
Graph 8. **Labour productivity growth and its contributors in the US total economy and sectors, 1995-2019, in p.p.**



Notes: Average for 1995-2019.

Source: EU-KLEMS.

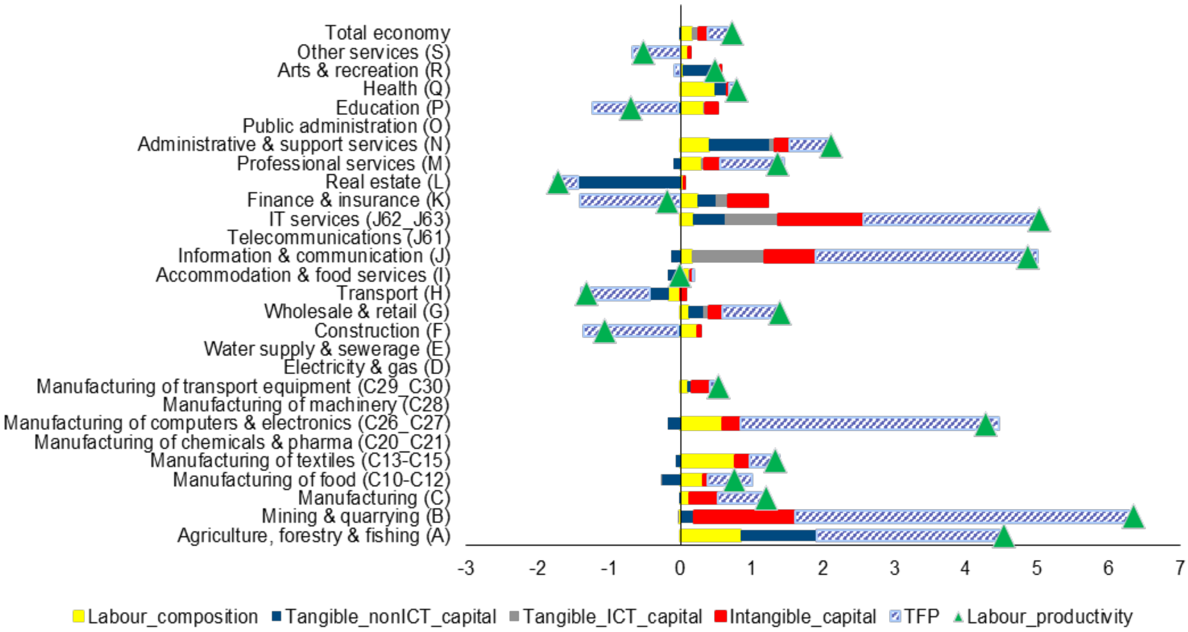
Graph 9. **Labour productivity growth and its contributors in the US total economy and sectors, 1995-2012, in p.p.**



Notes: Average for 1995-2012.

Source: EU-KLEMS.

Graph 10. **Labour productivity growth and its contributors in the US total economy and sectors, 2013-2019, in p.p.**



Notes: Average for 2013-2019.

Source: EU-KLEMS.

5. DISENTANGLING THE INDUSTRY CONTRIBUTION TO OVERALL TFP GROWTH

The present section aims at disentangling the contribution of each different industry to aggregate TFP growth. To that purpose what needs to be compared is not only the change in TFP across the industries, but also how important the contribution of each of the industries' TFP change is for the TFP change of the total economy (a weighting factor).

The analysis that follows uses an industry disaggregation that differs from the one used in the previous section and does not present overlaps. While the labour productivity growth decomposition in the previous section relies on presenting the change in *labour productivity* and its contributors in each industry with possible overlaps due to different levels of aggregation reported in the same graph, this section decomposes change in the total economy *TFP* into the contributions driven by different industries with the contribution of all industries summing up to the change in the TFP of the total economy. As data for some industries are missing, all those for which data are not presented are included in a residual labelled "Rest". To ease the reading, industry contributions to total economy TFP are ordered according to the values recorded over the 2000-2019 period (transparent bars in graphs 11 and 12), while also showing each industry's contribution between 2007 and 2013 (dark blue diamond), 2013 and 2019 (light blue bar) and 2000 and 2007 (grey triangle). Due to data availability the time coverage starts in 2000. The industry names and the corresponding NACE Rev.2 codes are on the vertical axis.[16]

Sectoral TFP drivers since 2013 differ between the EU and the US, with manufacturing still playing a role in the former, while in the US the bulk of overall TFP contribution comes from IT and professional services. Both in the EU and the US aggregate TFP figures in both the EU and the US appear to increasingly be driven by services. However, while in the US the strongest role is played by IT and professional services and finance, in the EU the strongest contributor is wholesale and retail sector. Moreover, while in the EU a few manufacturing sectors, including transport equipment, chemicals, computers, and electronic equipment, provided a positive contribution to overall TFP growth, in the US the only manufacturing sector with a non-negligible and positive contribution to aggregate TFP growth is manufacturing of computers and electronics. Results are reported in Graphs 11-15. The following observations stand out.

- In general, *rankings of industry contributions may differ quite a lot from TFP growth rankings* as industry size is very heterogeneous.

- The contributions of some industries are strongly affected by *cyclical factors*, evident for example of a strong reversal of sign during the GFC in *retail, construction, professional and administrative services. The reduction of the EU TFP growth gap with respect to the US in the post GFC period is partly linked to* those *temporary factors.*

- *In both the EU and the US there is a general increase over time in the contribution coming from services (*especially *IT, administrative and professional services*, for the latter two also perhaps cyclically driven in the recovery) as compared with that coming from manufacturing. *In the EU there is a big reduction in the role of telecommunications*, while the increase in the role of wholesale and retail trade is likely partly driven by cyclical effects and partly by structural transformations in the industry allowing more room for exploiting scale economies in analogy with what previously happened to a large extent in the US. In the US, retail services exhibit a falling contribution, mainly due to its the falling share in the total economy.

- *In the US, the manufacturing of computers and electronics accounted for a big part of the TFP growth between 2000 and 2007 while it has been contributing less after 2013.* Nonetheless, the role of this sector in the US for total TFP growth remains larger than in the EU. The finding is due both to the higher rate of TFP growth in this sector in the US, and the fact that the share of this sector on total value added is higher in the US that in the EU. Chemical and pharmaceutical manufacturing in the EU has also a strong role in overall economy TFP.

- The cumulative contribution of the key sectors to overall TFP growth, since 2000, looks quite different between the EU and the US over the available period (Graph 13). *In a nutshell, while in the US (Graph 13 right panel) the largest contribution was provided by sectors linked to ICT and electronics and computer manufacturing with almost all other industries not showing a cumulated contribution to total economy TFP growth, in the EU (Graph 13 left panel) strong contributions came not only from IT services but also from retail and manufacturing industries like transport equipment and chemicals (mid-tech manufacturing, see Fuest et al, 2024.).* The manufacturing of computers and electronics was insufficient in size to account for a large contribution, while a contribution that is becoming increasingly significant is the one by IT services signalling that the EU is a follower of the US in these technologies.

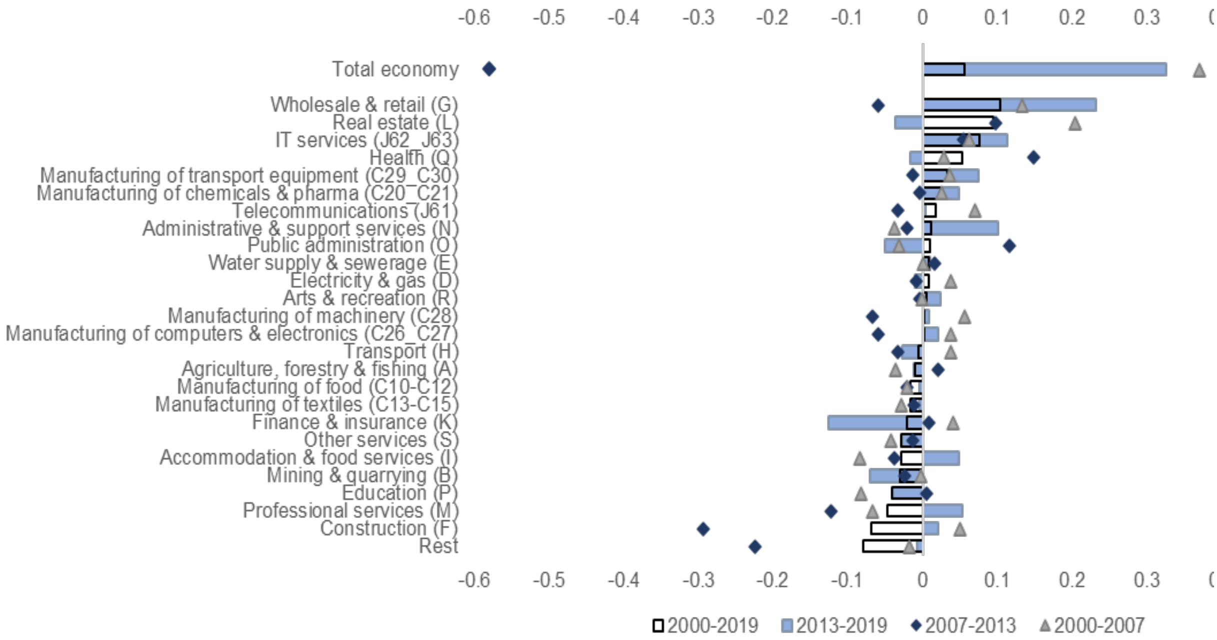
[16] In addition, industry coverage for the EU and the US is not completely identical, as data for certain industries (Manufacturing of chemicals & pharma (C20_C21), Manufacturing of machinery (C28) Electricity & gas (D), Water supply & sewerage (E), Telecommunications (J61) and Public administration (O).) for the US are not available.

- Graph 14 helps visualising sectoral TFP growth differences between the EU and the US in the most recent period, i.e., 2013-2019. Restricting the comparison to industries where TFP growth has been positive both in the EU and in the US, it is apparent that *the EU's TFP growth performance has recently been stronger in manufacturing of transport equipment among manufacturing industries, and in a number of services* including wholesale and retail trade, arts and recreation. *The US has mainly a higher TFP growth in computer manufacturing, agriculture, IT services, professional services, administrative and support services*.

- For what concerns sectoral contributions to overall TFP growth since 2013 (Graph 15) the stronger role played in the US as compared with the EU of IT and professional services is evident, as well as that of manufacturing of computers and electronic equipment. The industries that contributed negatively to EU aggregate TFP growth since 2013 were mainly services, including finance, public administration, education, real estate.

- Looking at the individual Member States (see Annex 1) there are noteworthy differences for what concerns the industry contribution to overall TFP growth. In Germany auto manufacturing is still contributing positively to productivity growth but its contribution has fallen compared to the 2000-2007 period. In France trade, administrative and support services, agriculture, and auto manufacturing have added to productivity growth since 2013. Trade, car and food manufacturing and accommodation and food services became positive growth contributors in Italy in 2013-2019, while contributing negatively in the pre-crisis period. Some country-specific developments appear to be mainly linked to swings in industry output and therefore capacity utilisation linked to the cycle. Spanish construction showed a substantial negative TFP growth contribution in the period 2007-2013, mainly linked to a substantial drop in its share in the total economy during that period.

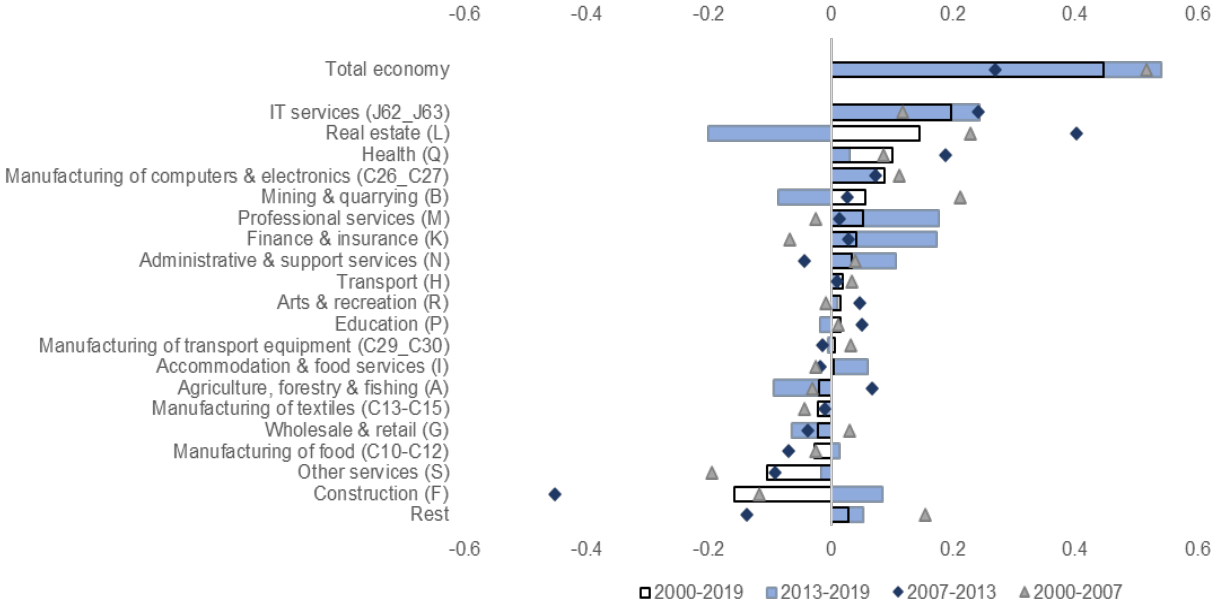
Graph 11. **Contribution to the annualised growth (%) in total economy TFP in the EU between 2000 and 2019 by industry**



Notes: EU is the GDP weighted average of AT, BE, DE, DK, ES, FI, FR, IT, NL, SE.

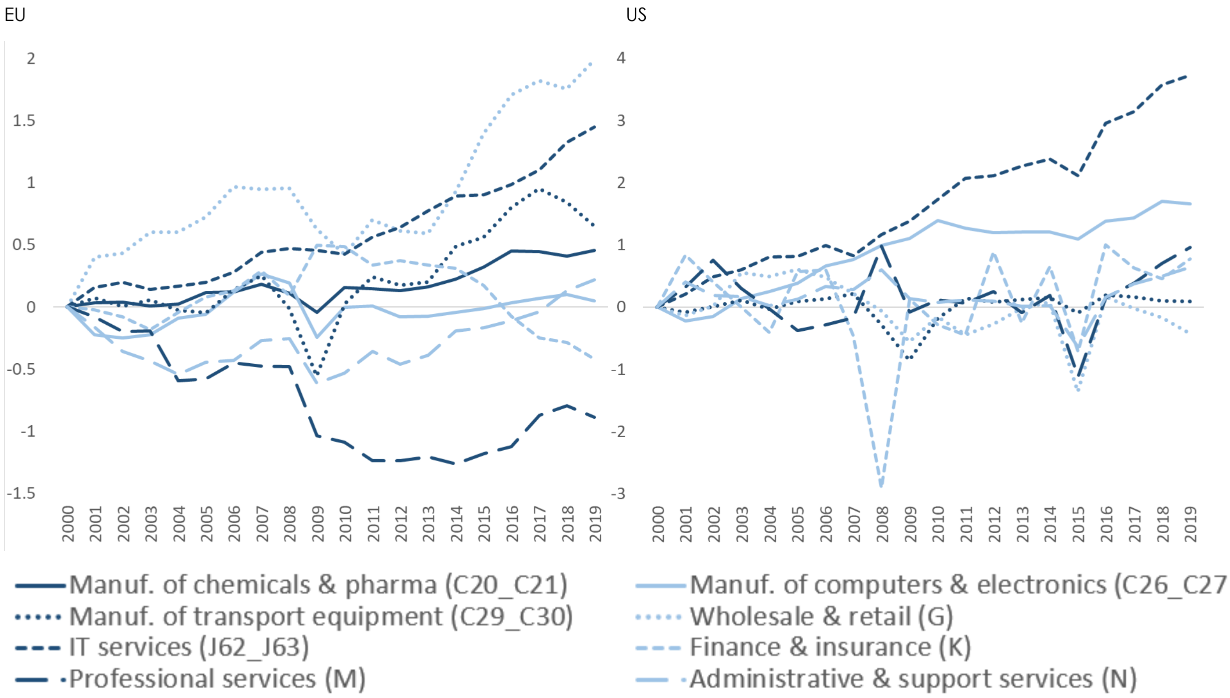
Source: EU-KLEMS.

Graph 12. **Contribution to the annualised growth (%) in total economy TFP in the US between 2000 and 2019 by industry**



Source: EU-KLEMS.

Graph 13. **Cumulative contribution to total economy TFP growth between 2000 and 2019, selected industries**



Notes: Manufacturing of chemicals & pharma (C20_C21) missing for the US.

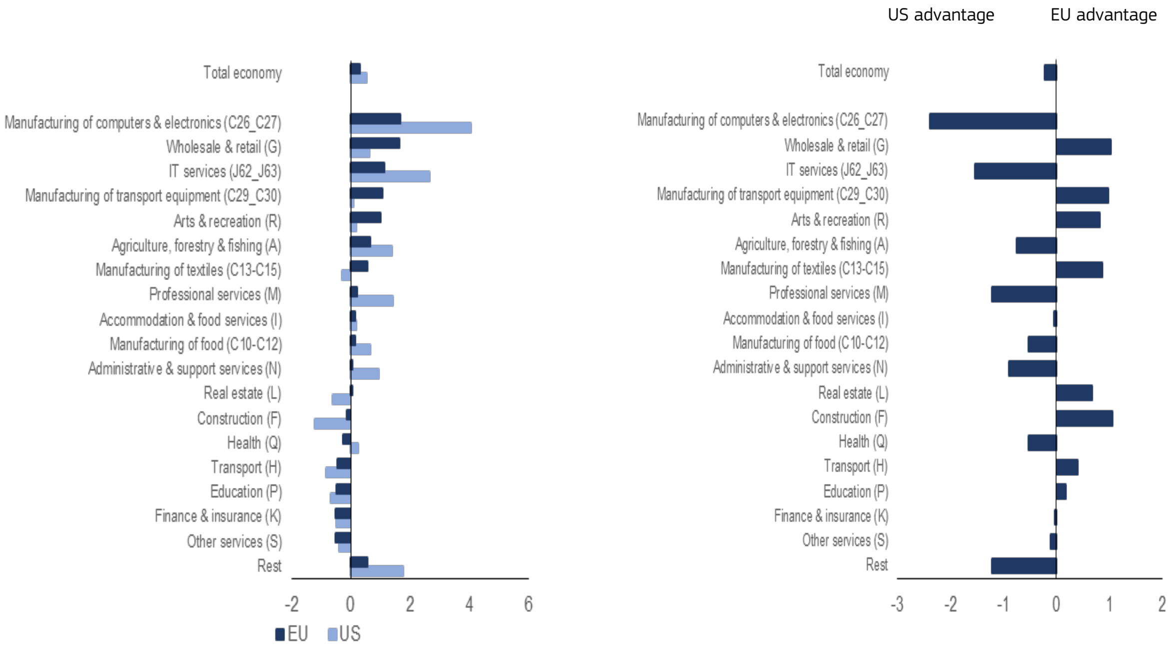
Source: EU-KLEMS.

Graphs 16 and 17 help understanding which factors account for the contribution of the different industries to total TFP growth, whether it is the rate of TFP growth, the relative size of the industry, or the change in the industry size. In particular, the graphs permit to assess whether the sectors that grew in relative terms are the same as those that displayed stronger TFP growth (Graph 16), or a stronger TFP growth acceleration (Graph 17). A number of findings stand out as follows:

- The EU and the US have roughly the same number of industries where TFP is growing between 2013 and 2019 (bubbles above the horizontal axis, Graph 16). However, *unlike in the US, in the EU industries that have become relatively bigger have also generally shown a relatively stronger TFP growth* (positively sloping fitting line in Graph 16). In particular, in the EU the manufacturing of IT equipment, computer and electronics (C26_C27) has been growing in relative terms, while the same industries have been narrowing in the US. The manufacturing of transport equipment has been growing in the EU and broadly stagnant in the US. IT services haven been one of the fastest growing sectors in relative terms both in the EU and in the US. However, in light of the sheer size of TFP growth gap and of the strongest growth rate recorded in the US the contribution of IT services to the overall TFP growth gap between the EU and the US has further grown of the post GFC period.

- Graph 17 shows the relationship between the increase in the relative share of industries between 2013 and 2019 and TFP growth acceleration between two separate 6-year periods – 2007-2013 and 2013-2019. *EU industries appear clearly to be growing especially in sectors with stronger TFP accelerations, while this is not the case for the US*. Overall, the evidence suggests that *inter-sectoral reallocations have recently been playing in favour of TFP growth in the EU, while no such evidence is there for the US.*

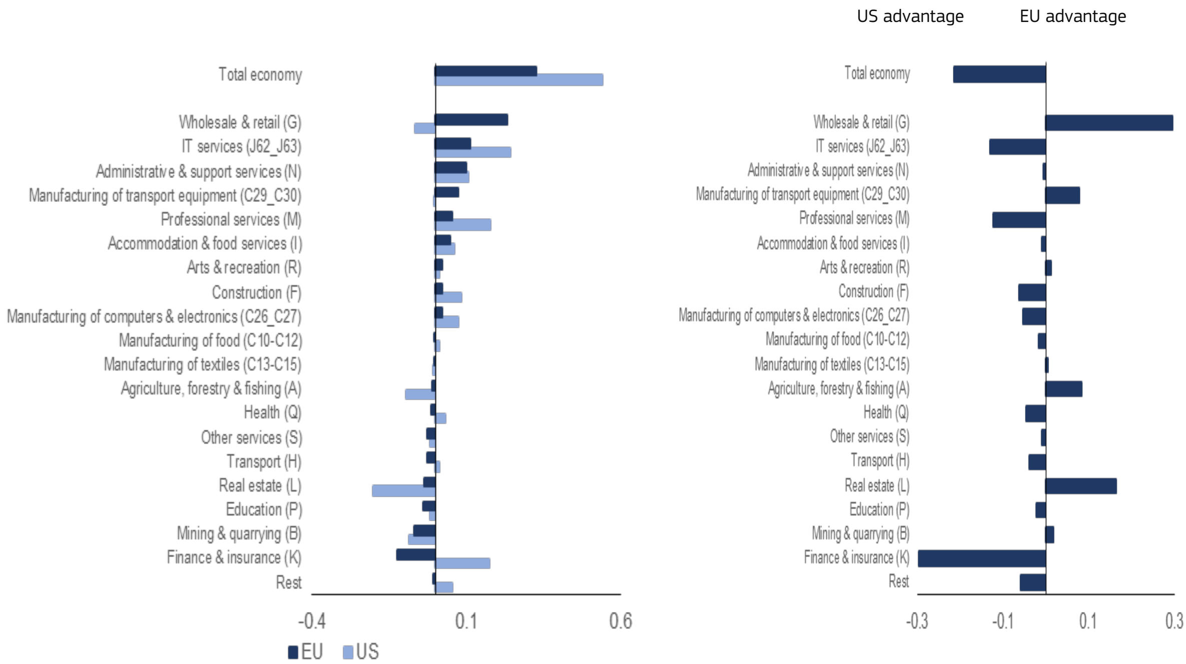
Graph 14. **Sectoral annualised TFP growth (%): EU, US, and difference EU-US 2013-2019**



Notes: EU is the GDP weighted average of AT, BE, DE, DK, ES, FI, FR, IT, NL, SE.

Source: EU-KLEMS.

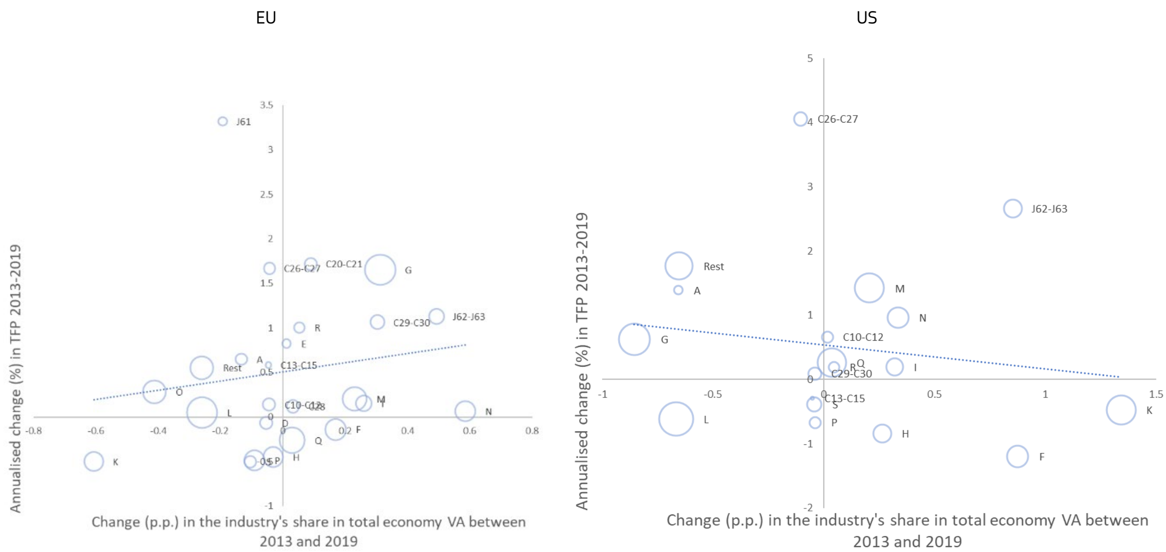
Graph 15. **Industry contribution to annualised total-economy TFP growth (%): EU, US, and difference EU-US, 2013-2019**



Notes: EU is the GDP weighted average of AT, BE, DE, DK, ES, FI, FR, IT, NL, SE.

Source: EU-KLEMS.

Graph 16. **Change in industry's share in total economy VA vs. change in industry's TFP between 2013 and 2019**



Notes: EU is the GDP weighted average of AT, BE, DE, DK, ES, FI, FR, IT, NL, SE. Bubble size represents industry's share in in total economy VA in 2019,

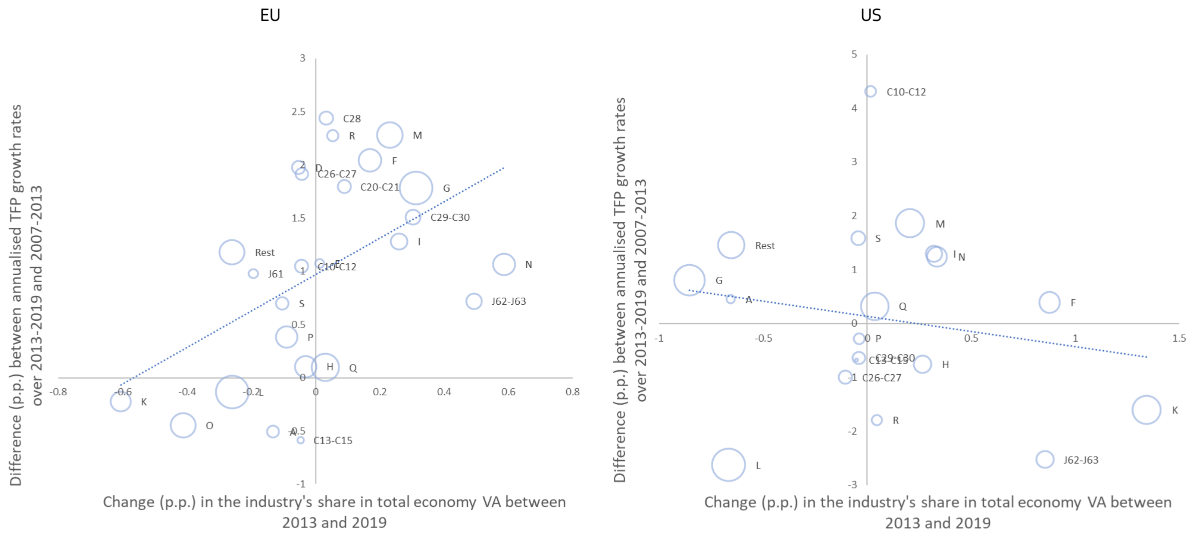
Legend: Agriculture, forestry & fishing (A), Mining & quarrying (B), Manufacturing of food (C10-C12), Manufacturing of textiles (C13-C15), Manufacturing of chemicals & pharma (C20_C21), Manufacturing of computers & electronics (C26_C27), Manufacturing of machinery (C28), Manufacturing of transport equipment (C29_C30), Electricity & gas (D), Water supply & sewerage (E), Construction (F),

Wholesale & retail (G), Transport (H), Accommodation & food services (I), Telecommunications (J61),

IT services (J62_J63), Finance & insurance (K), Real estate (L), Professional services (M), Administrative & support services (N), Public administration (O), Education (P), Health (Q), Arts & recreation (R), Other services (S), Rest – all the rest.

Source: EU-KLEMS.

Graph 17. **Change in industry's share in total economy VA vs. difference between industry's TFP changes over 2013-2019 and 2007-2013**



Notes: EU is the GDP weighted average of AT, BE, DE, DK, ES, FI, FR, IT, NL, SE. Bubble size represents industry's share in in total economy VA in 2019,

Legend: Agriculture, forestry & fishing (A), Mining & quarrying (B), Manufacturing of food (C10-C12), Manufacturing of textiles (C13-C15), Manufacturing of chemicals & pharma (C20_C21), Manufacturing of computers & electronics (C26_C27), Manufacturing of machinery (C28), Manufacturing of transport equipment (C29_C30), Electricity & gas (D), Water supply & sewerage (E), Construction (F),

Wholesale & retail (G), Transport (H), Accommodation & food services (I), Telecommunications (J61),

IT services (J62_J63), Finance & insurance (K), Real estate (L), Professional services (M), Administrative & support services (N), Public administration (O), Education (P), Health (Q), Arts & recreation (R), Other services (S), Rest – all the rest.

Source: EU-KLEMS.

6. THE ROLE OF INTANGIBLE INVESTMENT FOR TFP GROWTH

In this section we exploit the granular information on intangible capital of the EU-KLEMS database to shed light on the interplay between intangible capital investments and TFP growth. Section 2 of the present paper, discussed how accounting for a broad definition of intangible capital, as provided in the EU-KLEMS database, in addition to physical capital, would lead mechanically to a reduction in the estimated TFP growth derived from growth accounting. As long as the stock of intangible capital grows over time, this would be deducted from value added growth when performing growth accounting computations, resulting in a more muted dynamics of TFP, when obtained as a residual.

This section focuses rather on the economic effects of intangible capital on productivity growth. In line with endogenous growth models (e.g., Lucas, 1988; Romer, 1990), TFP growth cannot be assumed exogenous as in the neoclassical growth theory, depending itself on investments allowing to raise the stock of knowledge, and hence the capacity of extracting larger amount of output from a given stock of production factors. Accounting for intangible capital allows considering for the type of investments that generate knowledge spillovers, i.e., that, due to improved techniques, permit to enhance the productivity of all production factors not only where these investments take place, but potentially also in the rest of the economy, thanks to the non-rival and imperfectly appropriable nature of ideas. Such investments have a clear connection with enhanced knowledge in the case of R&D investments. However, also non-R&D intangible investments can contribute to improve production processes by expanding the stock of information available and improving organisation and management activities.

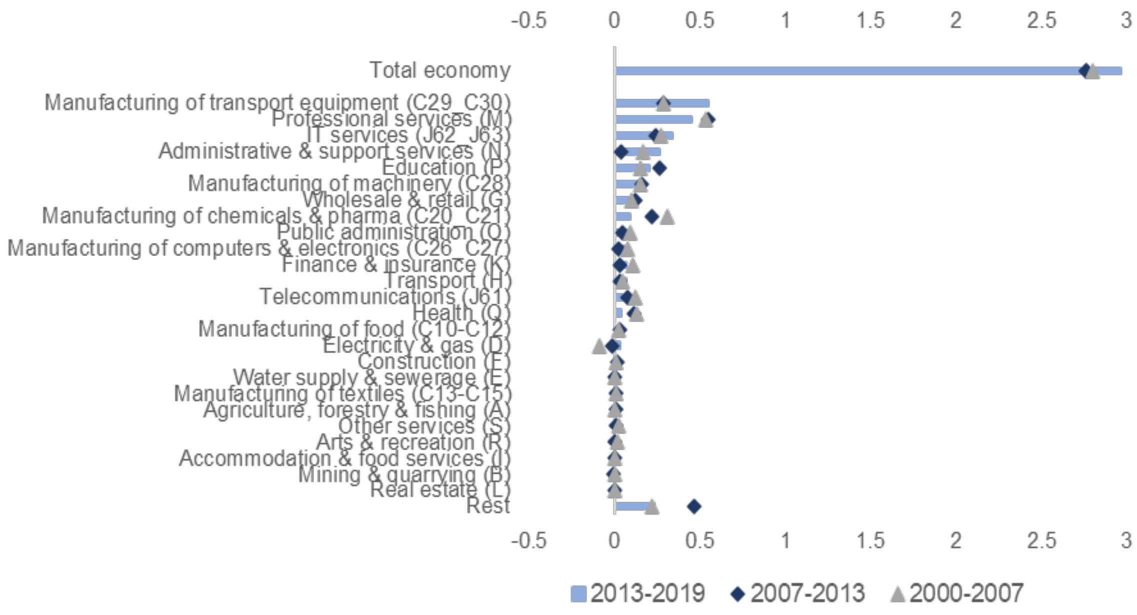
As discussed in recent papers (e.g., Corrado et al., 2022), the deceleration in intangible capital accumulation has been identified among the causes responsible for the productivity growth slowdown in the second half of the 2000s. In particular, the strong deceleration of intangible capital in the EU after the 2008 financial crisis has been estimated to account for about ¼ of a percentage point reduction in TFP growth. This result is based on EU-KLEMS data and the often used rule-of-thumb relation between TFP and intangible capital growth of about 1/5, namely, for any additional percentage point of additional intangible capital growth, TFP would increase by 0.2 percentage points, based on economy-wide estimations for R&D capital from Griliches (1992, 1994) and Corrado, Haskel and Jona-Lasinio (2017) for non-R&D capital.

In the sections below we analyse first the sectoral breakdown of changes in intangible capital, comparing the EU and the US experience, subsequently, we estimate the relationship between intangible capital and TFP growth. In carrying out the analysis, compared with previous studies (Corrado et al., 2017; and Ma et al.; 2022), we better exploit the sector variability offered by the data on intangible capital and productivity in EU-KLEMS, working with a dataset with a finer sectoral disaggregation. We also check whether the estimated relation between intangible capital growth and TFP growth has been changing over time, by restricting the time sample and whether it is affected by the extent to which sectors use intangible capital, by running regressions limiting the sample to sectors where intangible capital is used more intensively.

6.1. DISENTANGLING THE INDUSTRY CONTRIBUTION TO OVERALL INTANGIBLE CAPITAL GROWTH

Graph 18 reports the contribution of each economic sector to the percentage change of intangible capital of the total economy (hence broadly corresponding to overall intangible investment) and how it has changed over time. Intangible capital is defined according to national accounts. Analysing the industry-level contribution to overall intangible capital growth is of interest in a number of respects. First, it helps identifying which sectors of the economy account for the bulk of intangible capital growth: an expansion of these sectors will likely also imply a stronger growth of overall intangible capital other things being kept equal. Second, the breakdown helps identifying the sectors where TFP is more likely to benefit from intangible capital dynamics. Third, it helps assessing whether the contribution of different industries to overall intangible capital has been changing over time according to specific patterns.

Graph 18. **Industry contribution to annualised total-economy change (%) in intangible capital: EU, 2013-2019**



Notes: EU is the GDP weighted average of AT, BE, DE, DK, ES, FI, FR, IT, NL, SE. Intangible capital is Research and Development and Software and Databases.

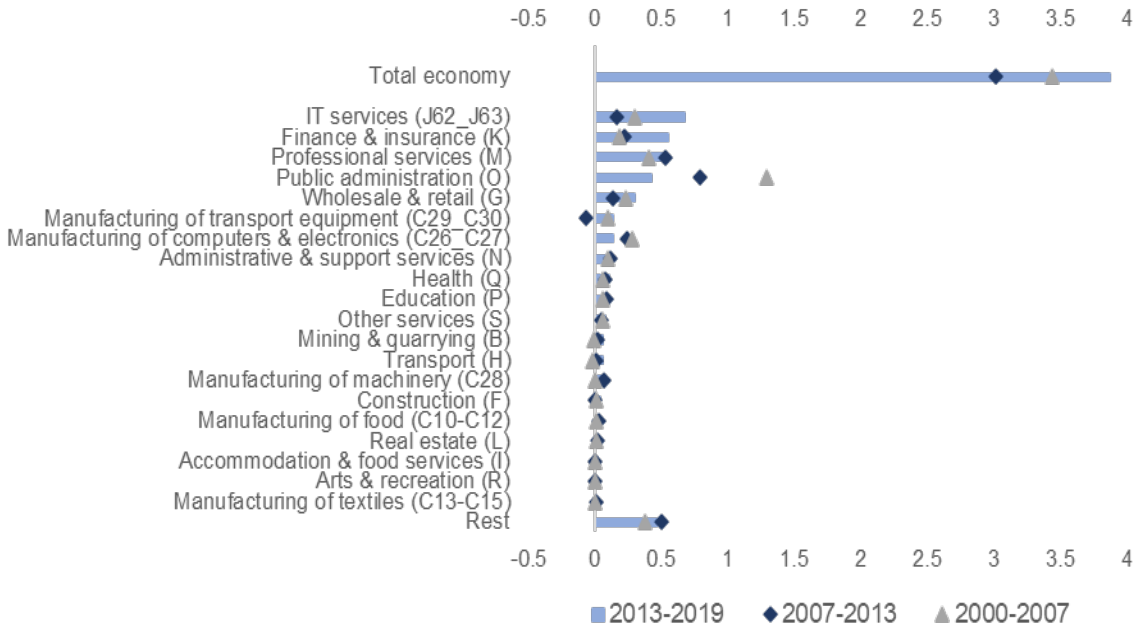
Source: EU-KLEMS.

Intangible capital growth in the EU proved quite resilient over the GFC period, and in the post-GFC recovery resumed above pre-crisis levels, remaining however well below the growth rates observed in the US. As shown in Graph 18, intangible capital remained resilient over the period of the financial crisis, as it kept growing broadly at the same rate as in the pre-GFC period while tangible capital fell considerably, a phenomenon already documented (e.g., Thum-Thyssen et al., 2017). In the post-GFC period intangible capital growth outpaced that prevailing over pre-GFC years. However, what stands out when comparing intangible capital for the EU and US total economy (Graphs 18 and 19) is the considerably slower growth in intangible capital in the EU as compared with the US.

In recent years, the industries that have been providing a strong contribution to overall EU intangible capital investment, are manufacturing of transport equipment, professional services and IT services, followed by administrative services and education. Manufacturing of chemicals and pharmaceuticals, finance and telecommunications played instead a bigger role in intangible investment between 2000 and 2007 compared with more recent years.

Sectoral patterns of US intangible capital growth differ from those observed for the EU, with a much smaller role for industry and a prevalence of services in driving intangible capital accumulation for the overall economy (Graph 19). In particular, sectors like IT services, Finance, Professional services, and Public administration are among the major contributors.

Graph 19. **Industry contribution to annualised total-economy change (%) in intangible capital: US, 2013-2019**



Notes: Intangible capital is Research and Development and Software and Databases.

Source: EU-KLEMS.

6.2. INTANGIBLE CAPITAL AND TFP GROWTH: AN EMPIRICAL ASSESSMENT

The role of intangible investment in driving productivity growth is analysed by means of multivariate econometrics. The econometric approach follows Corrado et al. (2017) and Ma et al. (2022). While Corrado et al. (2017) uses aggregate economy-wide data to account for possible externalities arising from intangible capital to TFP, Ma et al. (2022) use data disaggregated in 8 sectors and explicitly account for spillovers by including a separate variable reflecting intangible investment taking place in other sectors.

The approach followed in our analysis is akin to that in Ma et al. (2022) but it allows a much higher degree of sectoral disaggregation. Allowing for a finer disaggregation seems needed in light of the remarkable cross-sector differences in TFP growth. Our dataset includes 10 EU countries: Austria, Belgium, Germany, Denmark, Spain, Finland, France, Italy, the Netherlands and Sweden, between 1995 and 2020 and covers the 26 economic sectors (industries) used in the preceding sections. [17]

The dependent variable is the annual change in the natural log TFP index (TFP growth) from EU-KLEMS. The intangible capital explanatory variable is obtained as the annual difference in the natural log of intangible capital evaluated net of depreciation and at real terms (2015 chain linked volumes). Intangible capital consists of the sum of two intangible capital items of the statistical module in EU-KLEMS: Research and Development (R&D) and Computer Software and Databases.[18] The sum of Research and Development and Software and Database comprise the vast majority of the total intangible capital available in EU-KLEMS (close to 94% of total intangible capital in the statistical module in EU-KLEMS) and these are the two intangible capital items with the clearest potential impact on production efficiency, by easing the creation of new goods, enhancing the efficiency of production processes, improving marketing and organisational activities. The rationale for using an intangible capital variable consisting of the sum of these two items is their relatively comprehensive data coverage across countries and sectors in EU-KLEMS which allows reducing considerably the number of missing observations in the econometric analysis.

The basic specification is as follows:

$$\Delta \ln y_{c,s,t} = \alpha + \beta_1 \Delta \ln y_{c,s,t-1} + \beta_2 \Delta \ln K^{intan}_{c,s,t} + \beta_3 \Delta \ln y_{US,s,t} + \gamma_1 D_{cs} + \gamma_2 D_t + \varepsilon_{c,s,t} \qquad (1)$$

Where $\Delta \ln y_{c,s,t}$ is change in the natural log TFP index for country *c*, sector *s* and time *t*. This is regressed on a constant (α), the lag value of the change in the natural log TFP index ($\Delta \ln y_{c,s,t-1}$), in order to allow for dynamic effects and the change in the natural log intangible capital ($\Delta \ln K^{intan}_{c,s,t}$), defined as the sum of Research and Development and Software and Databases from the EU-KLEMS database. The baseline regression also includes the natural log TFP index in the US ($\Delta \ln y_{US,s,t}$), in order to capture TFP growth in production taking place at the technological frontier. In light of technological spillovers (e.g., adoption of superior, new-vintage technologies, imitation) higher TFP growth taking place at the technological frontier is expected to translate into a TFP acceleration also elsewhere. Following Ma et al. (2022) the US is assumed to be the technological leader, i.e., where the technological frontier is located. The regression includes a set of country-sector (D_{cs}) and time fixed effects (D_t). Country-sector fixed effects are chosen to capture unobserved factors specific to each country-sector pair, therefore allowing a wider variation than a set of independent sector and country fixed effects. This allows properly correcting standard errors for within-panel heteroscedasticity and autocorrelation. [19]

[17] Lack of data on cross-country comparable TFP levels at the necessary industry level (26 economic sectors) prevents us from using a variable that represents gap to the technological frontier for each country-sector pair, a variable, which is used in Ma et al. (2022). Ma et al. (2022) also uses a human capital variable, but it does not vary by industry. We used a country-level human capital variable in a model variant as a robustness check.

[18] The statistical module collects existing official national accounts data, consistently with previous EU-KLEMS releases, and organises them for developing productivity analysis, see Bontadini et al. (2023).

[19] In particular, this allows a more powerful correction of standard errors for within panel autocorrelation and heteroscedasticity compared with the alternative of identifying panels only along the country dimension.

In a second specification we add a variable to measure the cyclical position of the economy. Following Corrado et al. (2017), the cycle is captured by a variable measuring hours worked per employee in each country and sector ($\Delta Hr_{c,s,t}$), also calculated from the data in the EU-KLEMS database.

$$\Delta \ln y_{c,s,t} = \alpha + \beta_1 \Delta \ln y_{c,s,t-1} + \beta_2 \Delta \ln K_{c,s,t}^{intan} + \beta_3 \Delta y_{US,s,t} + \beta_4 \Delta Hr_{c,s,t} + \gamma_1 D_{cs} + \gamma_2 D_t + \varepsilon_{c,s,t} \quad (2)$$

In addition, in specification (3) we augment the model with a measure of intangible capital spillovers from other upstream sectors. [20] Specifically, this variable for sector *s* is calculated as the change in aggregate intangible capital in all other sectors using as weights, for each other sector the inputs received by sector *s* from this particular sector, divided by the sum of all inputs sector *s* receives from all other sectors combined. This way the variable intangible capital growth in upstream sectors ($\Delta \ln K_{c,s,t}^{oth.sec.intan}$) captures possible spillovers by giving more weight to intangible investment in sectors that are more closely connected along the upstream value chain.
The specification, called ***baseline specification***, is therefore modified as follows:

$$\Delta \ln y_{c,s,t} = \alpha + \beta_1 \Delta \ln y_{c,s,t-1} + \beta_2 \Delta \ln K_{c,s,t}^{intan} + \beta_3 \Delta \ln y_{US,s,t} + \beta_4 \Delta Hr_{c,s,t} \beta_3 + \\ + \beta_5 \Delta \ln K_{c,s,t}^{oth.sec.intan} + \gamma_1 D_{cs} + \gamma_2 D_t + \varepsilon_{c,s,t} \quad (3)$$

All estimations contain the lagged dependent variable among the regressors, and the estimation method needs to take into account the inconsistency arising in panel data. The presence of the lagged dependent variable among the regressors results in fixed effects being correlated with the error terms when the time sample is short, the so-called Nickell (1981) bias. Moreover, correlation between errors and the explanatory variables may arise from endogeneity, i.e., not only investment affecting productivity but higher productivity also causing more investment. In such cases OLS estimates tend to be biased and the bias does not go away as the sample size increases, i.e., they are also inconsistent. Instrumental variable estimators are usually employed in order to produce unbiased and consistent estimates. The Arellano-Bover/Blundell-Bond estimator, which we use, differences the instruments, on the ground that the first difference of the instruments are uncorrelated with the fixed effects, and estimates the model in a stacked system of original and transformed data by generalised method of moments (GMM) (for more details see, e.g., Roodman, 2009).[21]

Sample splits are operated to assess the robustness of results over time and across industries. The three model specifications (1) to (3) are estimated for the complete time sample between 1995 and 2020. In order to capture any slowdown in technology diffusion in more recent years the model (3) is also estimated for the period 2007-2020, specification (4). Finally, in specification (5), in order to account for the possibility that intangible investment affects productivity more actively in sectors that use intangible capital more intensively, specification (3) is estimated only for the country-sector pairs that are at the top 1/3 of the distribution of the share of intangible capital in total capital.

[20] This measure was computed based on the OECD (2021) Inter-Country Input-Output Database.

[21] This estimator is designed for dataset with a relatively short time dimension, 25 years from 1995 to 2020 in our case, and a large panel dimension, 260 country-sector pairs in our case. Even though the GMM estimator is consistent and unbiased in comparison to the OLS, standard errors are larger and there is a loss in efficiency. The same estimations were therefore also carried out by means of OLS, yielding results that were downward-biased. Similar downward bias of OLS vs. GMM estimates of intangible elasticity to TFP was documented in Table B.21 in the Online Appendix of Niebel et al. (2017).

Table 1: Regression results for intangible investment impact on TFP in the EU

Dependent variable: TFP growth	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
	Basic specification	Inclusion of a cyclical variable	Spec. (2) and intangible capital spillover (baseline specification)	Baseline (3), years>2007	Baseline (3), only sectors in the top 1/3 in terms of intangible capital intensity
Lag TFP growth	0.036	0.037	0.038	0.066	0.069
	(0.030)	(0.030)	(0.030)	(0.043)	(0.046)
Intangible capital growth	0.144	0.157*	0.126	0.061	0.176
	(0.089)	(0.092)	(0.084)	(0.140)	(0.132)
TFP growth in US	0.170***	0.173***	0.173***	0.176***	0.255***
	(0.038)	(0.038)	(0.038)	(0.054)	(0.046)
Hours/employee		0.000	0.002	0.085	0.183
		(0.077)	(0.077)	(0.097)	(0.145)
Intangible capital growth in upstream sectors			0.006	0.005	0.039
			(0.020)	(0.025)	(0.037)
Intercept	-0.007*	-0.003	-0.003	-0.001	-0.008
	(0.004)	(0.005)	(0.005)	(0.005)	(0.008)
Country-sector & time FE	Yes	Yes	Yes	Yes	Yes
Ar(1)	0.000	0.000	0.000	0.000	0.000
Ar(2)	0.315	0.350	0.323	0.153	0.644
Sargan	0.002	0.001	0.001	0.313	0.004
Hansen	0.407	0.346	0.394	0.437	0.464
# Of instr.	38	40	42	25	51
Obs.	4087	4087	4087	2258	1171

The definitions of the variables are detailed in section 6.2.

Estimation method: system and difference GMM following Arellano-Bover/Blundell-Bond, see Roodman (2009).

Instruments used: lags of the dependent and independent variables.

The Sargan and Hansen tests check whether the model's choice of overidentifying restrictions (moment conditions exceeding dimensions) fits the data well. The Sargan's null hypothesis is: "Not robust, but not weakened by many instruments", the Hansen's is "Robust, but weakened by many instruments". In general, a positive outcome is the rejection of the former and not rejection of the latter.

Specifications (1) to (4) are estimated for the following countries: Austria, Belgium, Germany, Denmark, Spain, Finland, France, Italy, the Netherlands and Sweden and the following sectors: Agriculture, forestry & fishing (A), Mining & quarrying (B), Manufacturing of food (C10-C12), Manufacturing of textiles (C13-C15), Manufacturing of chemicals & pharma (C20_C21), Manufacturing of computers & electronics (C26_C27), Manufacturing of machinery (C28), Manufacturing of transport equipment (C29_C30), Electricity & gas (D), Water supply & sewerage I, Construction (F), Wholesale & retail (G), Transport (H), Accommodation & food services (I), Telecommunications (J61), IT services (J62_J63), Finance & insurance (K), Real estate (L), Professional services (M), Administrative & support services (N), Public administration (O), Education (P), Health (Q), Arts & recreation(R), Other services (S).

Model (5) includes only sectors where the intangible capital share to total capital is in the top 1/3 of its distribution. These are the following sectors: Manufacturing of textiles (C13-C15), Manufacturing of chemicals & pharma (C20_C21), Manufacturing of computers & electronics (C26_C27), Manufacturing of machinery (C28), Manufacturing of transport equipment (C29_C30), Electricity & gas (D), Wholesale & retail (G), Telecommunications (J61), IT services (J62_J63), Finance & insurance (K), Professional services (M), Administrative & support services (N), Education (P), Arts & recreation (R), Other services (S).

Robust standard errors in parenthesis, * p<0.1 ** p<0.05 *** p<0.01.

Source: own calculations based on the EU-KLEMS database.

Table 1 provides the results. They are in line with what is found in Ma et al. (2022) for what concerns the relation between intangible capital and TFP and in several other studies that seek to find the elasticity of productivity with respect to intangible investment, such as Roth and Thum (2013) and Chen et al. (2016). In the basic specification (column 1), the elasticity of intangible capital is estimated to be 0.144, i.e., an increase of 10 pp. in the growth of intangible capital is associated with an increase of slightly less than 1.5 pp. in TFP growth. The statistical significance of the variable however does not reach 90%. The higher statistical significance found in previous analogous analyses is likely associated with the fact that in those analyses within-panel heteroscedasticity and autocorrelation was corrected at coarser level, resulting in underestimated standard errors. In addition, the statistical significance is affected by the necessary choice of instruments. However, when controlling for cyclical developments (column 2), the estimated impact of a 10 pp. increase in intangible capital rises somehow and becomes statistically significant. Accounting for intangible investment in upstream sectors (column 3) reveals a possible role for spillovers. The growth of intangible capital in upstream sectors has the expected positive sign, although not being significant. At the same time, the elasticity of intangible capital growth taking place within sectors is somehow reduced and loses significance with respect to specification (2). In specification (3) there is also a more positive coefficient for the cyclical variable, in line with expectations. With a view to include a role for possible intangible capital spillovers specification (3) is kept as baseline to operate sample splits.

The elasticity of TFP to intangible capital appears to have dropped in recent years. The first sample split restricts the estimation of the baseline to the post-GFC period. As discussed previously, over the GFC a drop in intangible investment took place both across the EU and in the US, and investment to previous levels was restored also following the post-GFC recovery, see Graphs 18 and 19. The question arises whether recent decades were associated not only with a drop in intangible investment but also with a modification in the relation between intangible capital and TFP growth. It turns out that by restricting the sample to years after 2007 the elasticity of intangible investment on productivity drops considerably, becoming roughly half that estimated over the full sample (column 4). This is corroborative to the hypothesis that the process of technology diffusion may have become less effective in recent years (Andrews et al., 2016; Corrado et al., 2022): the same investments in R&D, software, etc. may have resulted in a lower growth in TFP because the associated innovations took longer to be adopted and diffused within the same sector. Further analysis is needed to assess whether such drop is only temporary or whether it reflects permanent structural changes. [22]

Sectors that are more intensive in intangible capital tend to exhibit a higher elasticity of TFP to intangible capital. The second sample split restricts the data sample only to the sectors that are in the top third of the intangible capital-to-total capital distribution (column 5). It turns out that restricting the analysis to those sectors increases the estimated elasticity of intangible capital close to 0.18 (column 5). It also appears that restricting to sectors that are intensive in intangible capital use allows for an overall increase in the magnitude of the expected relations, with a stronger role for TFP growth at the frontier, the economic cycle, and spillovers from upward industries, a result similar to the one in Chen et al. (2016). These results suggest that the link between intangible capital and TFP could be subject to threshold effects, with superior knowledge translating into higher productivity growth especially when sufficiently large investments are carried out.

All in all, the empirical assessment presented above broadly confirms previous findings that intangible capital is potentially a relevant TFP driver. To convey the potential relevance of intangible capital for TFP growth one could consider the thought experiment of raising intangible capital investments in the EU in line with values recorded in the US. Over the 2013-2019 period, the EU annual growth rate in intangible capital was about 1 pp. below that of the US, compare Graphs 18 and 19. Applying the elasticity in specification reported in column (3) in Table 1 (baseline specification) it is obtained that by increasing intangible capital growth by 1 pp. TFP growth in the EU would rise by about almost 0.13 pp. This means that raising on a permanent basis intangible capital investment growth to match US intangible capital investment growth would permit the EU to roughly fill about 2/3 of the TFP growth gap recorded with the US since the early 2000s.[23]

7. SUMMARY AND POLICY CONCLUSIONS

This paper analyses TFP growth across the EU on the basis of the new vintage of the EU-KLEMS database. The database is particularly suited for productivity analysis thanks to a comparatively accurate measurement of capital inputs distinguished by typologies and for the possibility of taking into account changes in the composition of labour inputs. The latest EU-KLEMS vintage allows taking into account the contribution of intangible capital items not included in National Account Statistics. EU-KLEMS data also allow for disaggregating up to 42 industries, thus allowing the identification of TFP dynamics also in relatively narrowly defined sectors which however provide comparatively strong contribution to overall TFP growth.

The analyses sheds light on patterns of productivity growth with a comparatively fine disaggregation of different sources of productivity growth and a fine sectoral breakdown. Such patterns are analysed across different time periods between 1996 and 2019 to capture how sources of productivity growth have been changing over time and to understand how the different

[22] As the sample consists of 10 EU countries, the evidence can be attributed as being EU-specific. Having a US only estimation would not permit to maintain sufficient variation in the data to run comparable estimations.

[23] The TFP growth recorded on average between 2000 and 2023 in the US, euro area and EU have been respectively, 0.88%, 0.51%, 0.69%; source DG ECFIN AMECO database.

industries have been playing a different role over time. Cross-country comparisons are carried out across EU countries and within the EU and the US.

The analysis permits to distil a number of key messages as follows.

- **Aggregate TFP growth**. The last vintage EU-KLEMS data confirm a *TFP growth slowdown in the last two decades* that characterises both the EU and the US, a *TFP growth gap of the EU vis-a-vis the US*, with however a *remarkable deal of within-EU heterogeneity*. *The data broadly support TFP convergence across the EU* except over the years of the Global Financial Crisis (GFC) where TFP developments were strongly affected by cyclical effects linked to reduced capacity utilisation. Compared with data from other sources, TFP growth rates from the last EU-KLEMS vintage are slightly below those obtained form other data sources in light of a most complete account of intangible capital.

Sources of productivity growth. *TFP is in general the component that accounts for the biggest share of productivity growth in most countries and sectors, followed by tangible and intangible capital deepening.* TFP growth also accounts for the bulk of labour productivity growth dispersion across industries. Both in the EU and the US *the contribution of TFP growth has been declining over time, while that of intangible capital and labour composition has been growing since after the post GFC recovery.*

Industry patterns.

- *The bulk of aggregate TFP growth rates are recorded in relatively few industries*. Over the 2013-2019 period, TFP growth across the EU is accounted mostly by TFP growth in services such as *wholesale and trade, IT services, administrative, support and professional services*. Among manufacturing, large contributions come from *manufacturing of transport equipment, chemical, computer and electronics*. TFP growth rates in network industries have strongly reduced compared with values recorded in previous decades and linked to one-off improvements in scale economy exploitation linked to liberalisation processes.

Sectoral TFP patterns differ to some extent between the EU and the US, with the US displaying in particular much higher productivity growth in IT services and the manufacturing of computers and electronics (linked notably to the origination of innovations benefiting from Moore's law). Strong TFP spurts in the US are followed with some lags from TFP acceleration in the same sector in the EU. Differences in sectoral TFP growth rates are also observed across major EU economies.

The TFP growth advantage of the US over the EU is linked both to higher TFP growth rates in the sectors generating large TFP gains and to larger shares in value added for these sectors.

Overall, *even though sectors that are expanding their share on value added in the EU are generally those exhibiting higher and accelerating TFP growth rates,* it appears that *the transition towards the services sectors where TFP is growing the fastest in the EU is taking place at slower pace* as compared with what happened in the US. In this respect, despite some sectoral reallocation taking place, industries exhibiting TFP gains from radical innovations are under-represented in the EU as compared with the US, with TFP gains being to a greater extent associated with dynamics pertaining to mid-tech manufacturing (e.g., Fuest et al., 2024). Sectors that belong to mid-tech manufacturing are for example manufacturing of transport equipment, manufacture of chemicals and manufacture of basic metals. Fuest et al. (2024) show that most of the business R&D spending in the EU occurs in firms that belong to mid-tech sectors, unlike in the US – where firms in high-tech services such as ICT, and manufacture of electronics are the largest innovation spenders. These digital technology sectors are the sectors which benefited from rapid productivity growth and have produced many new products and services in recent years.

- **The role of intangible capital in driving TFP growth**. Over the long-term TFP growth is linked to products and production processes incorporating superior knowledge. The accumulation of intangible capital (R&D, software and databases) is therefore impacting output growth both directly, and indirectly, via its contribution to higher TFP growth. Analysis of EU-KLEMS data uncovers several findings as follows.

    - *Intangible capital growth has been resilient since the post GFC recovery* (2013), *but remaining substantially below rates recorded in the U.S*. This is partly linked to a much more limited presence of intangible investments in high-tech services in the EU and a relatively stronger role of manufacturing, notably transport equipment.

    Econometric estimates confirm findings from previous work that any percentage point of *additional growth of intangible capital tends to be associated with about 0.15-0.2 percentage points of additional TFP growth*. Such relation seems however not constant over time, with the *elasticity* of TFP to intangible capital having *dropped by about half since the post GFC recovery, suggesting a possible slowdown of technological diffusion* (e.g., Andrews et al., 2016; Corrado et al., 2022).

The results from the analysis have a number of implications for policy. The analysis indicates that TFP growth is the most relevant source of productivity growth over the long term but also that TFP outturns may strongly be affected by cyclical factors, which underscores on the one hand the need of high-quality data for such an analysis and the major challenges in interpreting TFP data over short time periods. The fact that TFP growth rates differ so substantially across industries has implications for policies that can help removing bottlenecks to resources reallocation. In this respect, supportive regulatory frameworks for labour and capital markets can make a difference. The fact that TFP growth rates within the same sector can differ so considerably across countries reveals that differences in the potential for innovation matter greatly for long-term productivity growth. The analysis suggests that accelerating intangible capital growth by means of policies helping to remove bottlenecks to investments are key to innovation that could revive TFP growth across the EU.

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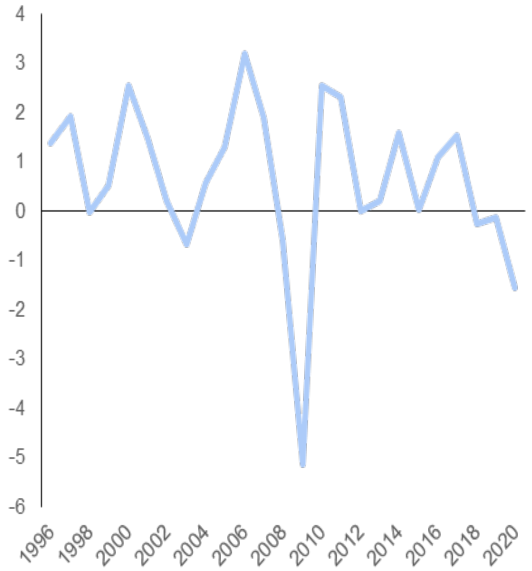
ANNEX I

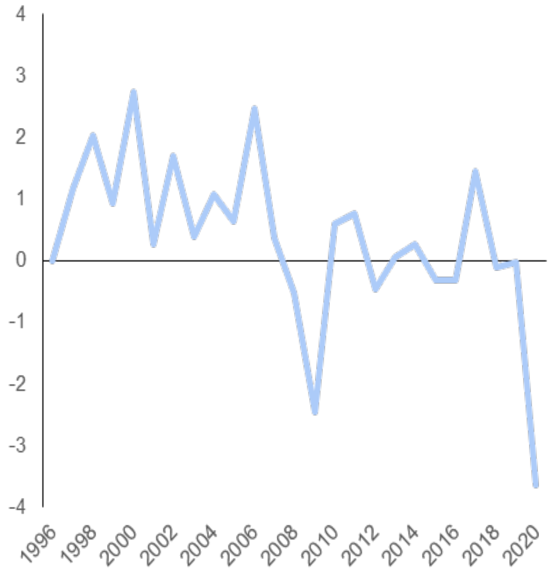
Additional graphs

Graph A1: **TFP growth in Germany, in %**



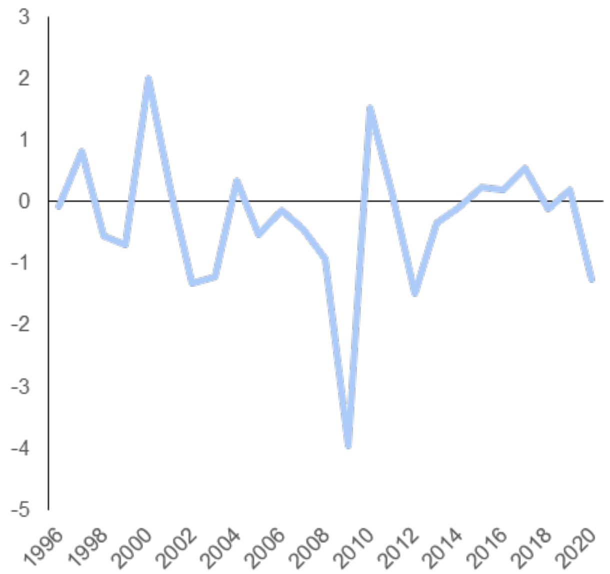
Source: EU-KLEMS.

Graph A2: **TFP growth in France, in %**



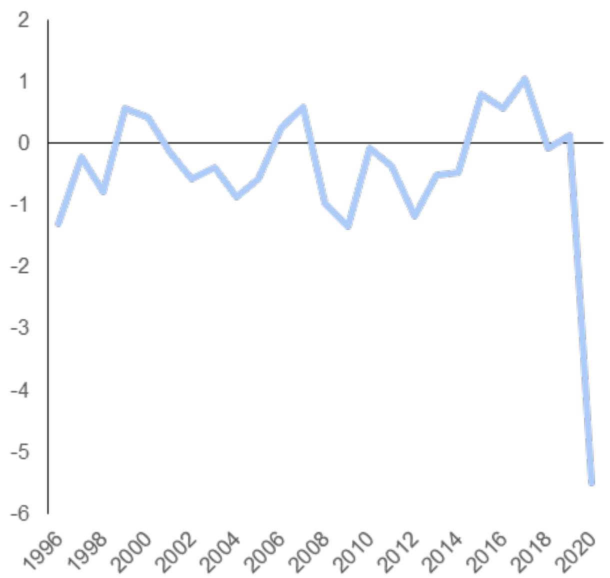
Source: EU-KLEMS.

Graph A3: **TFP growth in Italy, in %**



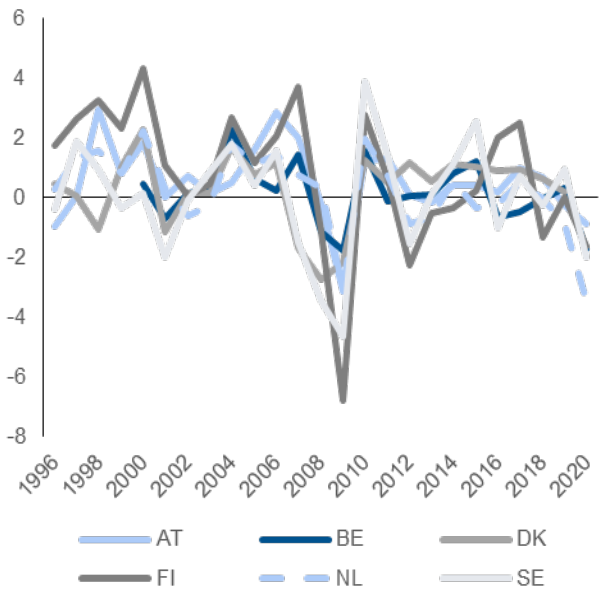
Source: EU-KLEMS.

Graph A4: **TFP growth in Spain, in %**



Source: EU-KLEMS.

Graph A5: **TFP growth in Western Europe , in %**

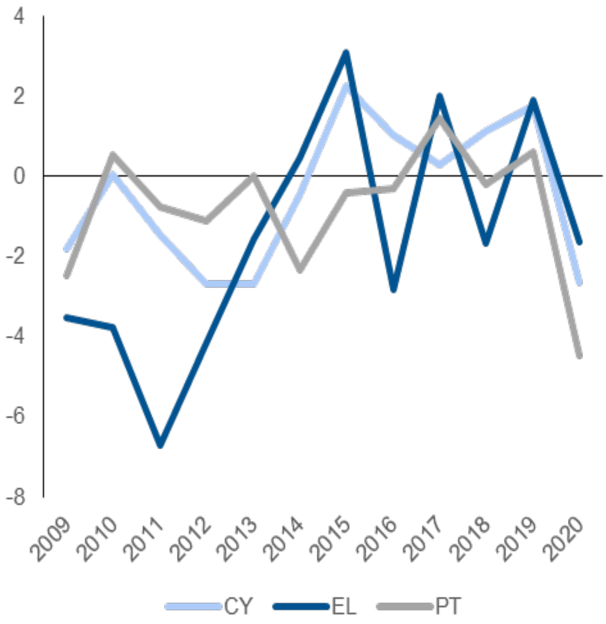


Source: EU-KLEMS.

Graph A6: **TFP growth in Eastern Europe, in %**

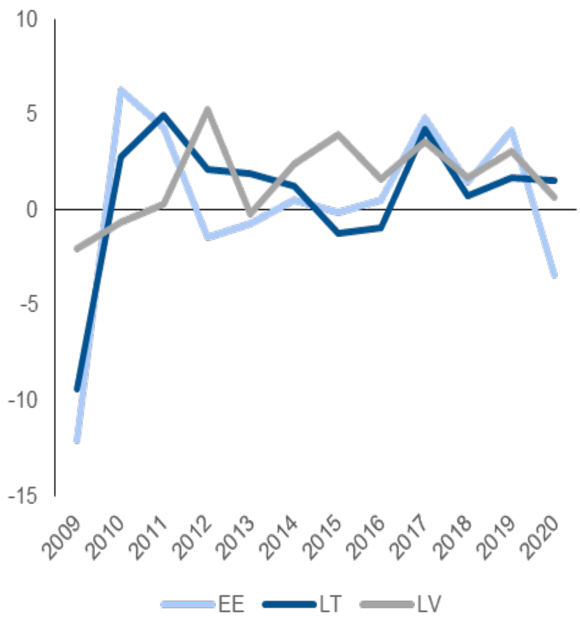
Source: EU-KLEMS.

Graph A7: **TFP growth in Southern Europe, in %**



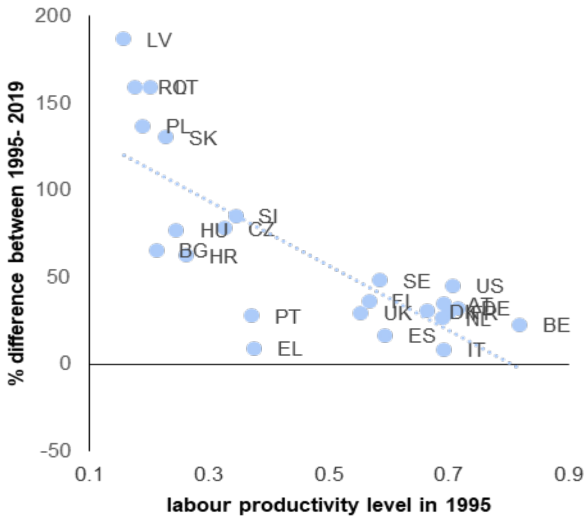
Source: EU-KLEMS.

Graph A8: **TFP growth in the Baltics, in %**



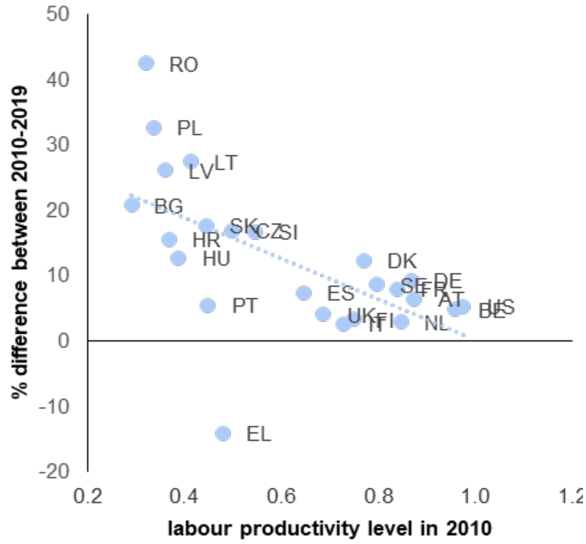
Source: EU-KLEMS.

Graph A9: **Labour productivity change 1995-2019 (vertical axis) vs. labour productivity level in 1995** (horizontal axis)



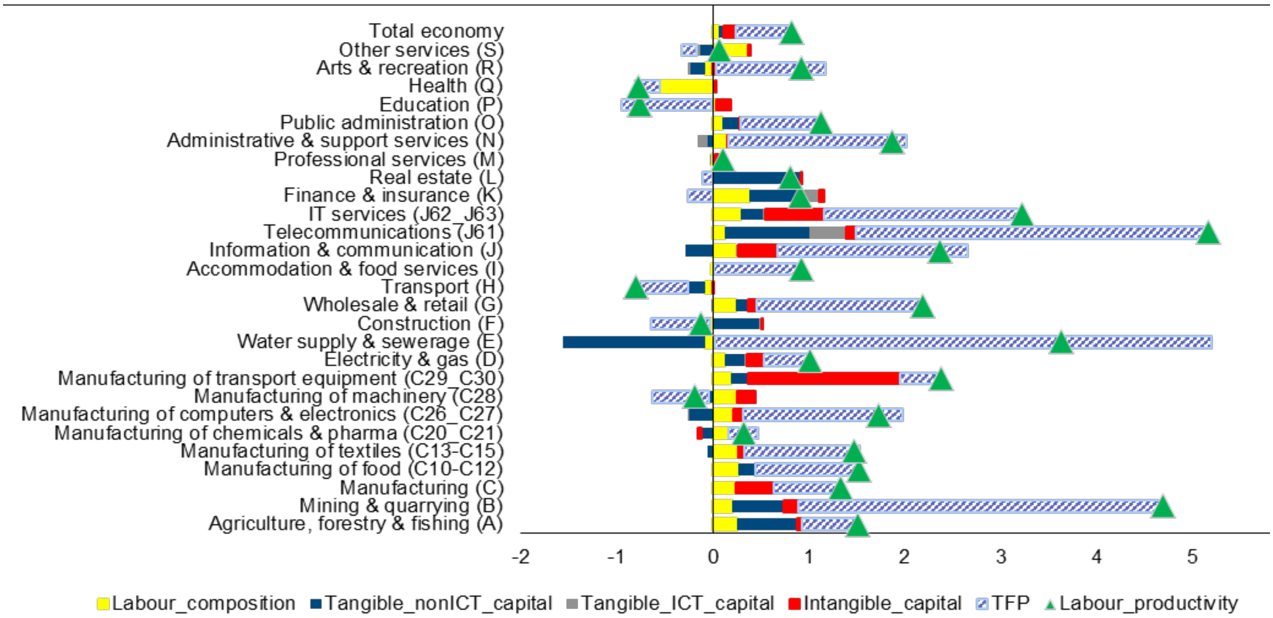
(1) Labour productivity change calculated as the percentage change in the labour productivity level between 1995 and 2019 using the growth of GVA per hour worked to populate the time series. Labour productivity levels calculated in terms of PPPs with US in 2017=1.
Source: EU-KLEMS.

Graph A10: **Labour productivity change 2010-2019 (vertical axis) vs. labour productivity level in 2010** (horizontal axis)



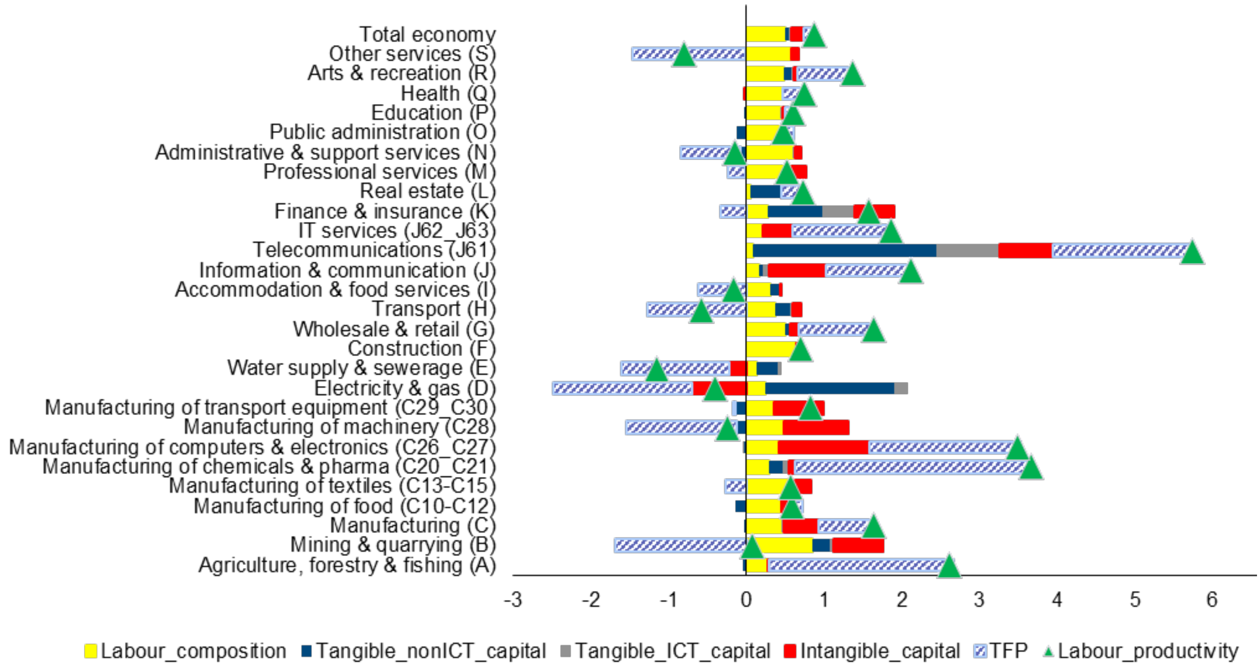
(1) Labour productivity change calculated as the percentage change in the labour productivity level between 2010 and 2019 using the growth of GVA per hour worked to populate the time series. Labour productivity levels calculated in terms of PPPs with US in 2017=1.
Source: EU-KLEMS.

Graph A11: **Labour productivity growth and its contributors in Germany, 2013-2019, in p.p.**



(1) Average for 2013-19.
Source: EU-KLEMS.

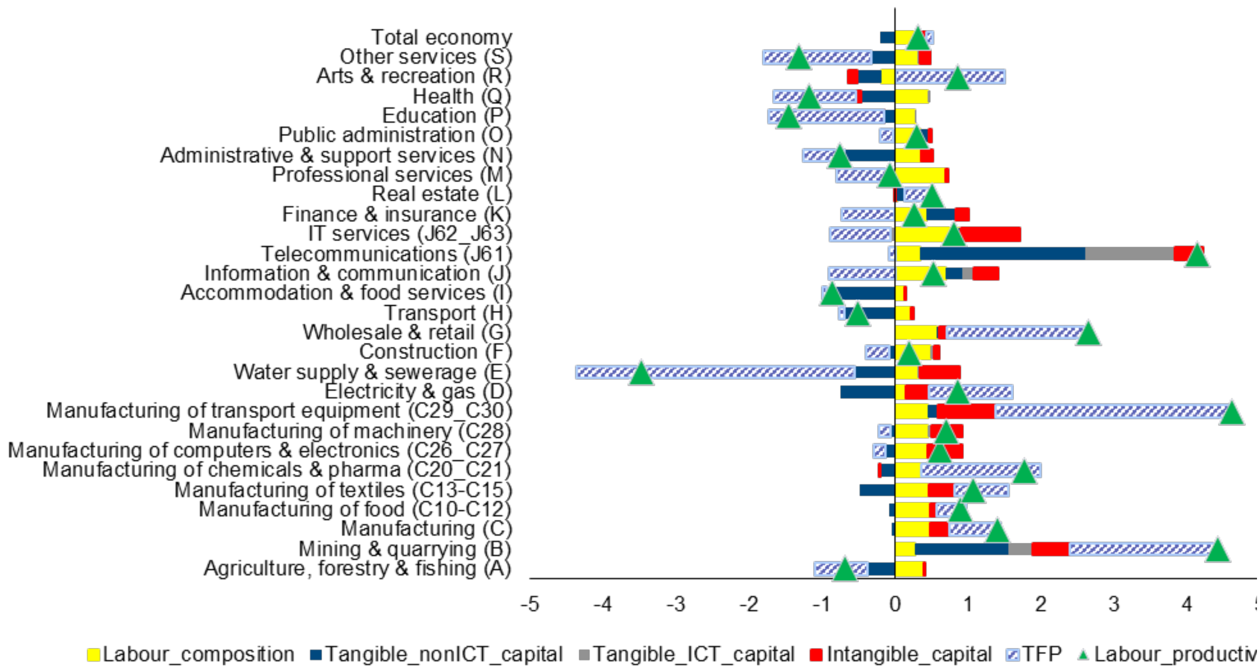
Graph A12: **Labour productivity growth and its contributors in France, 2013-2019, in p.p.**



(1) Average for 2013-19.

Source: EU-KLEMS.

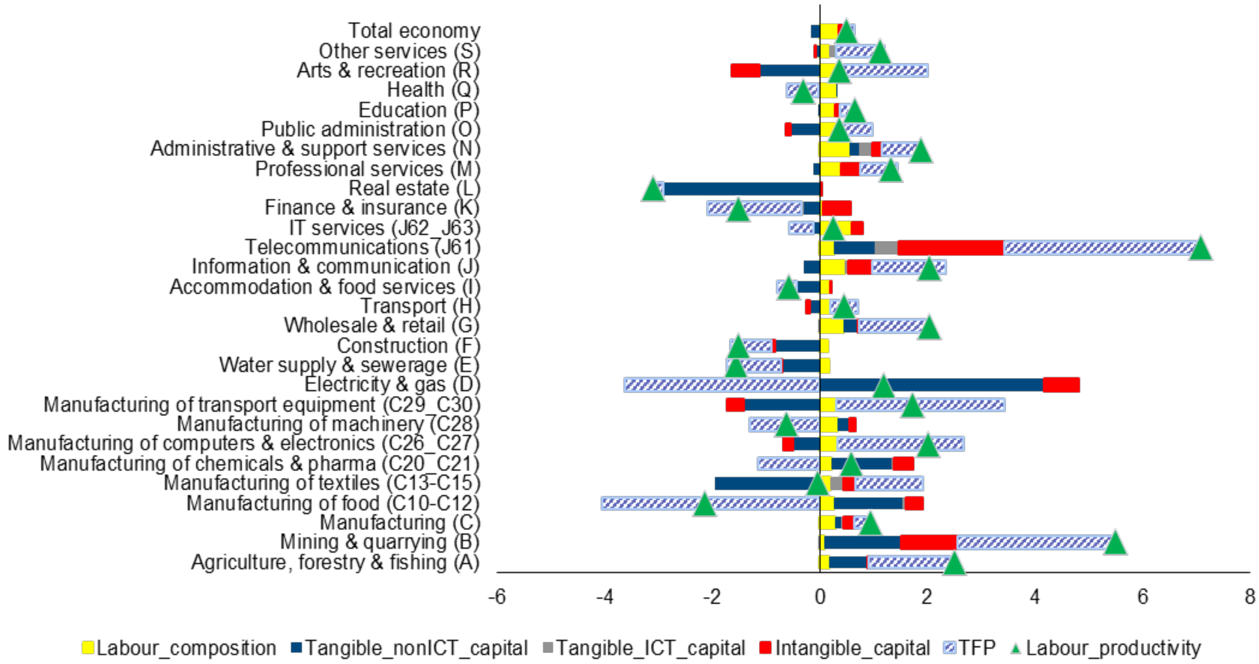
Graph A13: **Labour productivity growth and its contributors in Italy, 2013-2019, in p.p.**



(1) Average for 2013-19.

Source: EU-KLEMS.

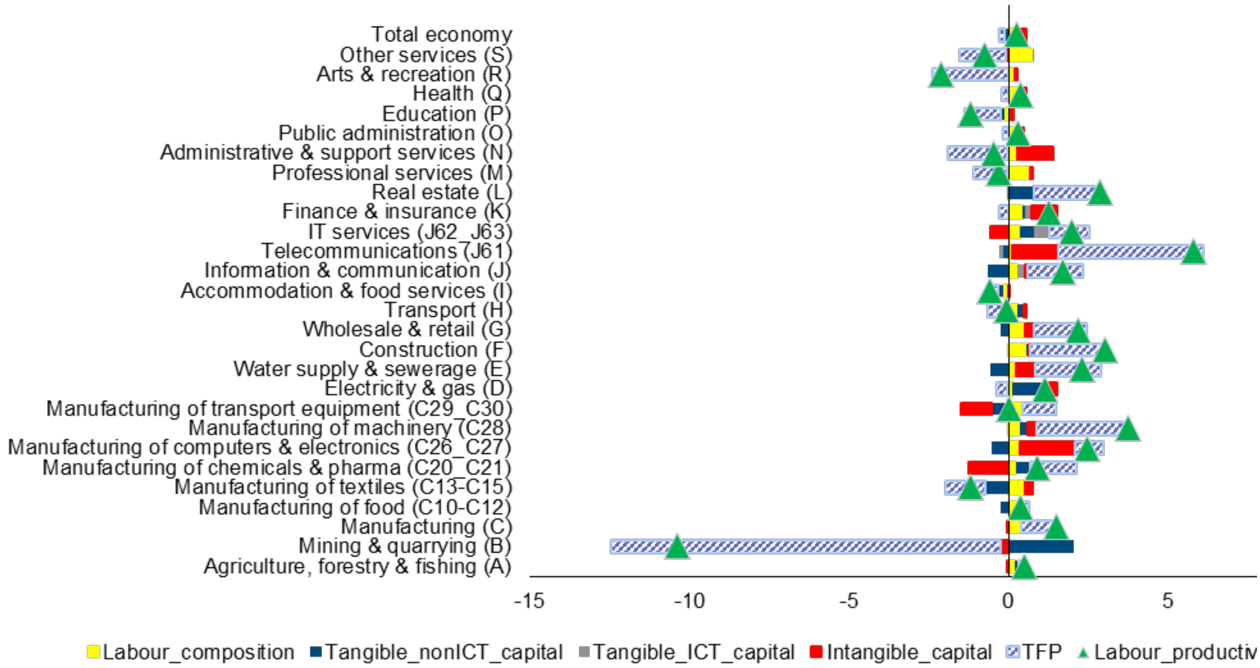
Graph A14: **Labour productivity growth and its contributors in Spain, 2013-2019, in p.p.**



(1) Average for 2013-19.

Source: EU-KLEMS.

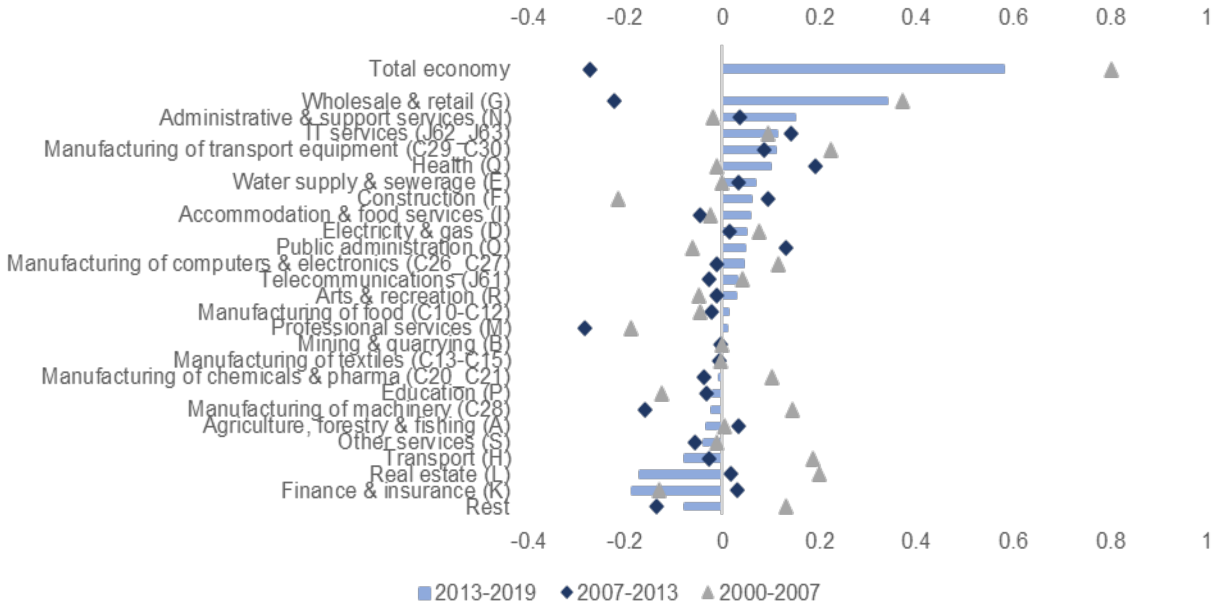
Graph A15: **Labour productivity growth and its contributors in the Netherlands, 2013-2019, in p.p.**



(1) Average for 2013-19.

Source: EU-KLEMS.

Graph A16: **Contribution to the change in total economy TFP in Germany between 2000 and 2019 by change in industry TFP**

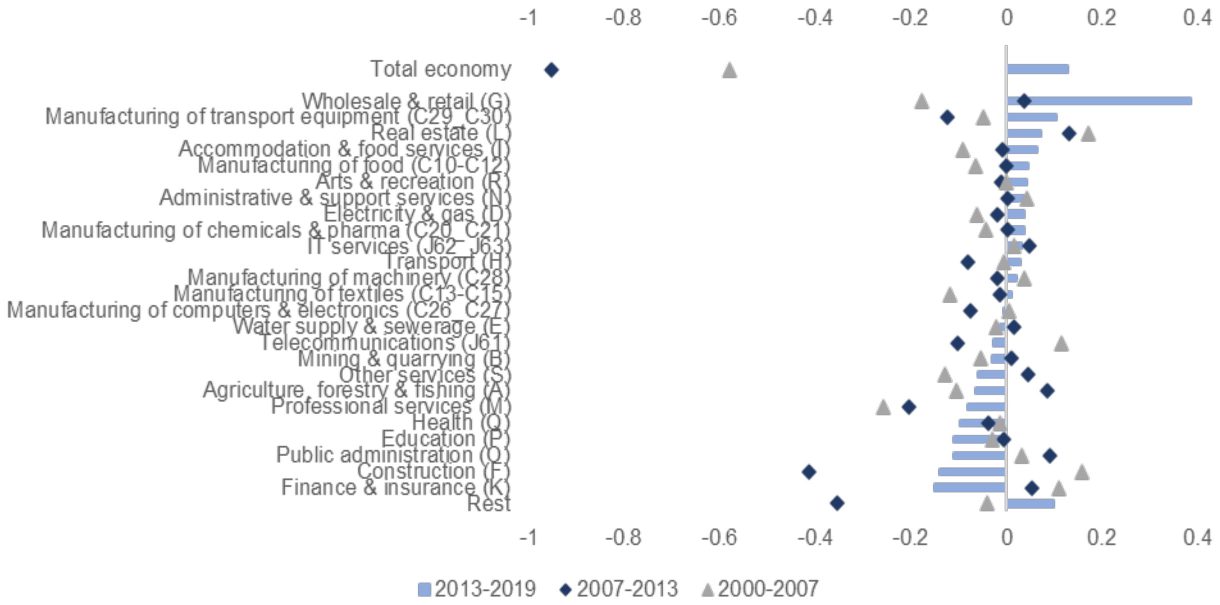


Source: EU-KLEMS.

Graph A17: **Contribution to the change in total economy TFP in France between 2000 and 2019 by change in industry TFP**

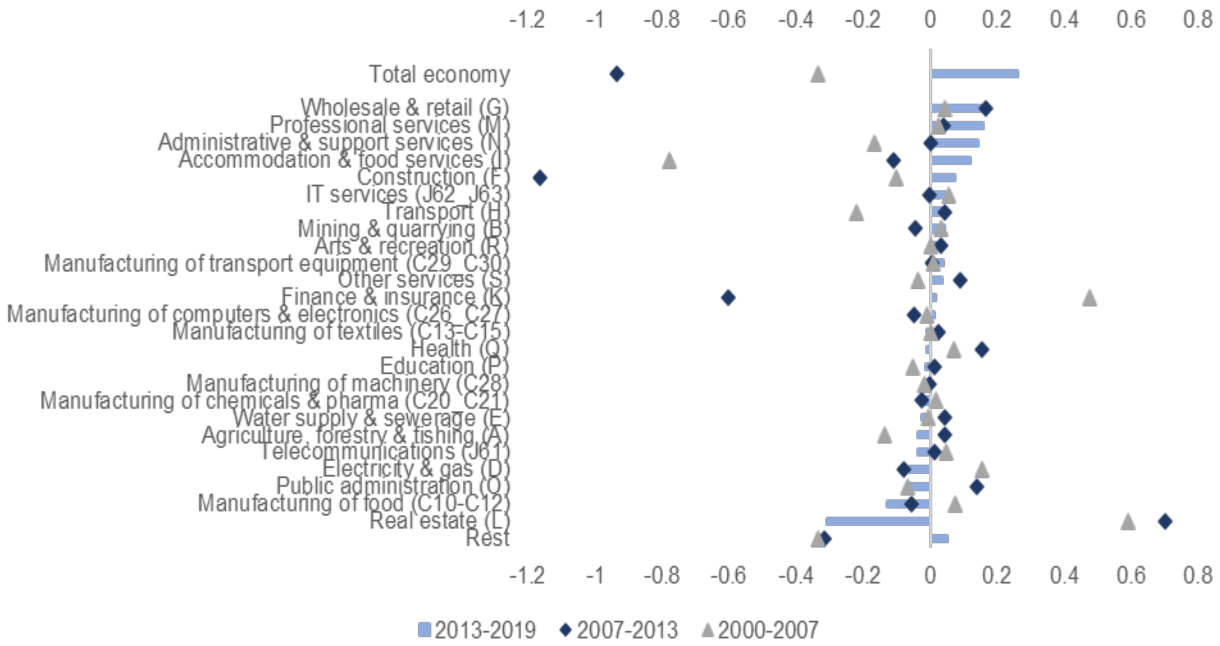
Source: EU-KLEMS.

Graph A18: **Contribution to the change in total economy TFP in Italy between 2000 and 2019 by change in industry TFP**



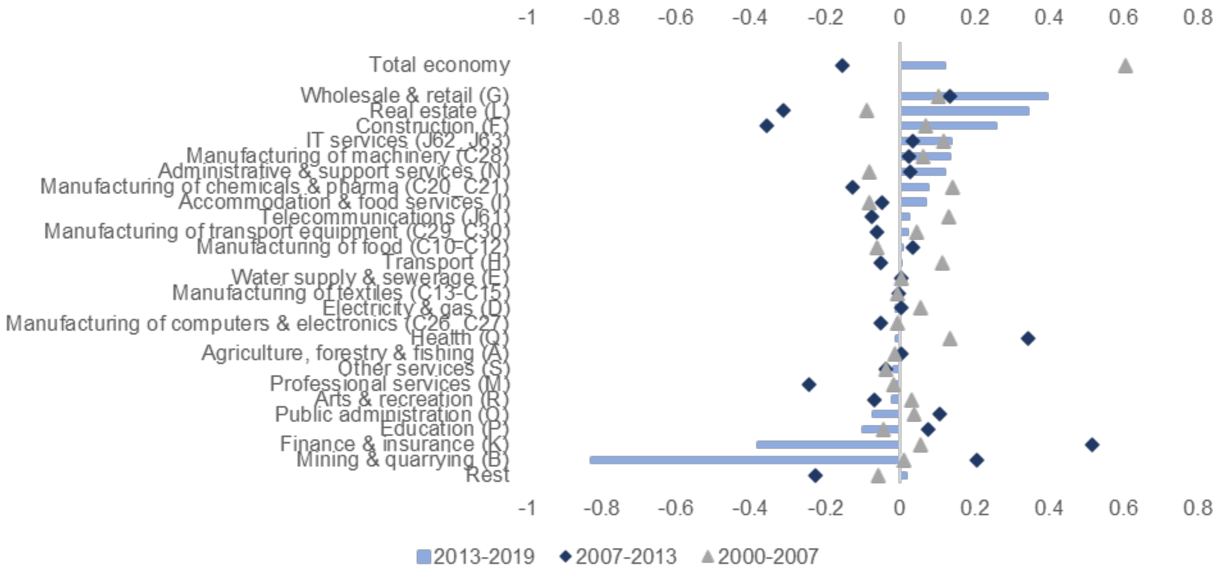
Source: EU-KLEMS.

Graph A 19: **Contribution to the change in total economy TFP in Spain between 2000 and 2019 by change in industry TFP**



Source: EU-KLEMS.

Graph A20: **Contribution to the change in total economy TFP in the Netherlands between 2000 and 2019 by change in industry TFP**



Source: EU-KLEMS.

ANNEX II

Detailed description of the EU-KLEMS approach to growth accounting and productivity measurement

The first step in computing TFP growth is the estimation of a production function in a neoclassical growth framework:

$$V_j = A_j K_j^{\alpha} L_j^{\beta} \tag{A1}$$

where gross value added in an industry j is denoted by V_j, K_j are capital services (buildings, machines, but also intangible capital, such as software), L_j stands for labour services (which is measured either as number of employees, or hours spent working and can be distinguished by type of worker, age, gender, educational attainment and skills of the workforce) and A_j is Total Factor Productivity. The parameters α and β are the output elasticities of capital and labour. Assuming constant returns to scale and perfect competition in the capital and labour markets allows to express natural log TFP changes as follows:

$$\Delta lnA_j = \Delta lnV_j - \upsilon_{K,j}\Delta lnK_j - \upsilon_{L,j}\Delta lnL_j \tag{A2}$$

where $\upsilon_{K,j}$ and $\upsilon_{L,j}$ are the capital and labour shares of income respectively corresponding to parameters α and β and summing up to 1.

EU-KLEMS data permit to further decompose the contribution of production factors to gross value added by means of a further disaggregation of capital types and changes not only in labour inputs but also in labour composition as follows:

$$\Delta lnA_j = \Delta lnV_j - VAConH_j - VAConLC_j - VAConTICT_j - VAConTNICT_j - VAConINTAN_j \tag{A3}$$

where $VAConH$ denotes the contribution of hours worked, while the contribution of labour composition $is\, VAConLC$. The latter reflects mainly changes in skills as proxied by compensation per hour, which under the assumption of perfectly competitive labour markets equals the labour's marginal product. The contribution of tangible ICT capital is denoted by $VAConTICT$, that of tangible non-ICT capital is $VAConTNICT$ and that of the contribution of intangible capital is $VAConINTAN$.

All these different contributions are calculated as a product of the natural log change of the factor in question multiplied by its respective share in income, which under the perfectly competitive factor market assumptions equals the output elasticity of the factor (an expansion of eq. (2)). So:

$$VAConH_j = \upsilon_{L,j}\Delta lnH\_EMP_j \tag{A4}$$

$$VAConLC_j = \upsilon_{L,j}\Delta lnLC_j \tag{A5}$$

$$VAConTICT_j = \upsilon_{ktict,j}\Delta lnCAPTICT_j \tag{A6}$$

$$VAConTNICT_j = \upsilon_{ktnict,j}\Delta lnCAPTNICT_j \tag{A7}$$

$$VAConINTAN_j = \upsilon_{kint,j}\Delta lnCAPIntang_j \tag{A8}$$

, where labour composition is defined as the difference between total labour services and pure hours worked:

$$\Delta lnLC_j = \Delta lnL_j - \Delta lnH\_EMP_j \tag{A9}$$

Labour services are calculated by aggregating volume indexes of individual labour types with a Tornqvist index and weighting them with the average shares of each type in labour compensation. The labour types are classified by gender categories (male, female), age categories (15-29 years; 30-49 years; 50 years and higher), and educational qualifications levels (high, medium, and low) as well as by eighteen worker types.

Capital services asset breakdown includes computer hardware and telecommunications equipment (tangible ICT capital); dwellings, other buildings and structures, transport equipment, other machinery and equipment, cultivated biological resources (tangible non-ICT capital), research and development, computer software and databases and entertainment and artistic originals (intangible capital). Capital services are computed in two steps. First, the volume of the services provided by each type of asset (i.e., its productive capital stock) and the corresponding asset price (i.e., its user cost) are calculated; then, the second step entails the calculation of an aggregate measure of the productive contribution of the different types of assets (i.e., of the aggregate flow of capital services).

Total Factor Productivity is closely related to another productivity indicator – labour productivity. Using the growth accounting approach, labour productivity growth in sector *j*, $LP1\_G_j$ can be decomposed as follows:

$$LP1\_G_j = \Delta lnA_j + LP1ConLC_j + LP1ConTICT_j + LP1ConTNICT_j + LP1ConINTAN_j \tag{A10}$$

which states that the growth of labour productivity (growth of value added per hour worked) is obtained as the sum of TFP growth and a series of capital-to-labour growth contributions. The growth contributions are calculated in an analogous way as above – a product of the natural log change of the production factor per hour multiplied by its respective share in income.

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