CHAPTER

5

European productivity in the digital age: evidence from EU KLEMS

Robert Inklaar[1], *Kirsten Jäger*[2], *Mary O'Mahony*[3], *Bart van Ark*[4,5]

[1]Faculty of Economics and Business, University of Groningen, Groningen, The Netherlands; [2]The Vienna Institute for International Economic Studies, Vienna, Austria; [3]King's Business School, King's College London, London, United Kingdom; [4]The Conference Board, New York, NY, United States; [5]Faculty of Economics and Business, University of Groningen, Groningen, The Netherlands

5.1 Introduction

Over the past three decades productivity growth in European countries has gradually weakened despite some recovery after recessions and crises. Productivity growth has therefore become a central cause for concern about prospects for future growth in living standards across Europe. Especially when US productivity growth accelerated in the mid-1990s, the lack of a similar development across most of Europe stood out (Timmer et al., 2010). Between 1995 and 2005, GDP per hour worked increased at an average annual rate of 2.5% in the United States compared with 1.4% in the EU-15, the countries that were members of the European Union before 2004.[1]

Since the mid-2000s, US labor productivity growth has been similarly stuck in lower gear. Between 2006 and 2015, US labor productivity grew at an average annual rate of 1.1%, while labor productivity growth in the EU-15 was only 0.7%. The Global Financial Crisis (GFC) depressed productivity growth in part for cyclical reasons. However, as the productivity slowdown started well before the GFC, around 2005, there are good reasons to assume there have been other structural factors at work, including a long-term shortfall of investment (Cette et al., 2016; Fernald et al., 2017) and major business and societal challenges translating digital technology into productivity growth (van Ark and O'Mahony, 2016).

One strand of literature has focused on the declining effectiveness of the overall innovation process, which shows signs of having become both more difficult and more expensive, so that a slowdown in productivity may be unavoidable even in the medium term (Bloom et al., 2018). Others have argued that the productivity effects

[1] The Conference Board Total Economy Database, November 2018, https://www.conference-board.org/data/economydatabase/.

Measuring Economic Growth and Productivity
https://doi.org/10.1016/B978-0-12-817596-5.00005-6

of new technology have so far primarily benefited global frontier firms, while other firms have lagged increasingly behind (Andrews et al., 2016; Riley and Bondibene, 2018). However, much of the recent uneven effects of technology on growth may just be temporary as suggested, for example, by Harberger (1998) who distinguishes between a random "mushroom-type" and a broad-based "yeast-like" phase of productivity improvements across industries. Such ideas are not out of line with the more systemic thinking from the evolutionary school of economics about sociotechnological paradigm changes. For example, Perez (2002) distinguishes between the installment and the deployment phases of new technologies with distinctly different growth and productivity effects.

So far, most of the analysis of the recent changes in productivity dynamics has been conducted at the aggregate level. This chapter employs the latest available 2017-version of the EU KLEMS database to examine these trends more closely by focusing on the characteristics of industries and their relative productivity growth performance. A more detailed analysis at industry level can help to detect some of the causes of the slowdown, as well as possible signals of a recovery in specific industries of the economy. We distinguish industries by their intensity of usage of information and communication technology (ICT), intangible capital, degree of offshoring, skill levels, and the average age of their workforces. We consider industry productivity measures until 2015 for an aggregate of 12 European countries, that cover both the largest economies and different regions of Europe, and we provide a more detailed analysis for 9 of these countries. The United States is also included in this analysis as a comparator.

First we include a brief overview of the EU KLEMS database, its history and methodology, and explanations of the sector groupings. This is followed by an overview of output and productivity growth performance at the aggregate economy level, followed by a more detailed analysis of the performance in the goods versus market services sectors of the economy. We then look at the performance of industries that have been characterized as intensive users on the basis of our taxonomies to detect differences in productivity growth across the European countries and the United States as well as between the first period (1995–2005) and the second period (2006–15) in our analysis. We conclude this chapter with a brief summary of what we know so far, and what next steps the research on the productivity slowdown needs to take, including the issues around improved measurement of productivity in the digital age.

5.2 The EU KLEMS database

5.2.1 A brief history of EU KLEMS

If one was to go back over two decades to the mid-1990s, both the policy concerns regarding economic growth and the evidence base were primarily concerned with unemployment and low labor force participation. The defining feature of the decade starting from 1995—the significant impact of ICT on growth—was only hinted at in a handful of firm-based studies (e.g., Brynjolfsson and Hitt, 1996). The aggregate growth implications of ICT were not understood at the time. Evidence on the key role of high-level skills acquisition was only beginning to emerge in the academic literature and therefore higher education was not high on the policy agenda. Intangible investments were hardly mentioned and were seen as too difficult to measure, while again the focus in the literature was on firm-specific intangibles such as brand development rather than on their macroeconomic importance.

Going forward 5 years to the end of the century, in the context of accelerating productivity growth in the United States, some key papers emerged that argued for a significant impact of ICT on growth (Jorgenson and Stiroh, 2000; Oliner and Sichel, 2000) and that ICT had radically altered the demand for different types of labor in favor of those with university-level education (Autor et al., 1998). Policy makers began to focus much more on productivity and growth in the light of these findings. However, these earlier papers were based on data for the United States and it soon became apparent that the information base required to investigate sources of growth in Europe was not up to the task. There then followed a concerted research effort, mostly financed by the European Commission Framework Programmes, to redress this information deficiency. Using the framework developed by Dale Jorgenson and co-authors, summarized in Jorgenson et al. (1987), EU KLEMS was born.

The EU KLEMS project[2] aimed to produce long time series by sector on outputs, inputs, and productivity for all EU countries using a harmonized methodology, at the (NACE revision 1) industry level. It produced some data series for all EU-25 countries, covering the time period 1970–2007 for up to 70 industries, although the time period, industry detail, and input measures varied by country. It brought together data from national accounts and other official sources such as firm- and individual-level surveys to produce long time series on outputs, inputs, and productivity by country and industry. The database enabled a decomposition of sources of growth into volumes and types of labor (skills), quantities and types of capital (ICT and non-ICT), and total factor productivity (TFP). Details of the methodology and main results were summarized in O'Mahony and Timmer (2009). The database subsequently went through a number of revisions, in particular changing the industrial classification to NACE revision 2, and updates to 2015 for some larger economies.

The economic context in which the database was developed was that, for the macro economy, there was a catching-up process in labor productivity in the EU relative to the United States during the postwar period from the 1950s to the mid-1990s, after which the United States forged ahead. The EU KLEMS database was designed to facilitate research behind these aggregate figures, focusing especially on the industry location of these trends, the sources of differences between the United States and EU (input use or productivity), and cross-country variation. The highlights of the original EU KLEMS work were the findings that the EU productivity gap with the United States was concentrated in market service sectors and that ICT was key to explaining the labor productivity growth gap (see van Ark et al., 2008; Timmer et al., 2010).

Over time national statisticians and academics in other countries expressed interest in developing similar approaches to that in EU KLEMS. This led to the setup of the World KLEMS consortium, which includes all participants in EU KLEMS and partners from China, India, Russia, and countries in Asia, Africa, and Latin America—40 partners in total (Jorgenson et al., 2016).

Since 2008, the EU KLEMS database has been updated a few times. The most comprehensive revision was done in 2016 and 2017, switching to data based on the new European System of National Accounts (ESA10), with data covering the period until 2015. The new data, also available from www.euklems.net, provide a unique opportunity to analyze productivity growth for the total economy and two major sectors in the economy (goods-producing and market services) and cover 12 European economies. Taken together those 12 economies, which include Austria, Belgium, Czech Republic, Denmark, Germany, Finland, France, Italy, the Netherlands, Spain, Sweden, and the United Kingdom and will be named the EU-12, accounted for 90% of the European Union's nominal GDP in 2015.

A preliminary analysis of the data showed that the slow productivity growth, which had been visible in most market services in the decade before, had broadened to the goods-producing

[2] www.euklems.net coordinated by the University of Groningen, the Netherlands.

sector for most European economies since the crisis. The manufacturing sector was particularly hard hit by the GFC and had only partially recovered by 2015. The slowing growth trend is driven by a triple combination of modest recovery in employment growth, stagnant growth in capital input, and a further weakening in the TFP growth trend (van Ark and Jäger, 2017). In this chapter we extend the analysis by looking at various industry taxonomies to improve on our preliminary diagnosis of the productivity slowdown, and to use the EU KLEMS data set to pinpoint the main factors accounting for the slowdown.

5.2.2 Growth accounting and methodology

To assess productivity growth at the industry level, we rely on the method of growth accounting. This method has a long history, with a first systematic exposition in Jorgenson et al. (1987) and discussed in more detail in the setting of EU KLEMS in Timmer et al. (2010). Hulten (2010) provides a survey of the growth accounting literature, which includes a discussion of industry growth accounting and a broader discussion on what is and what is not measured in growth accounting.

We proceed here with a brief exposition. We assume an industry in a country at a particular point in time can be characterized by a production function exhibiting constant returns to scale (suppressing country and industry subscripts for brevity):

$$Y_t = A_t F(K_t, L_t, M_t). \tag{5.1}$$

Output Y is produced using (Hicks-neutral) technology A and the inputs are capital K, labor L, and inputs of energy, materials, and services M_t. Assuming Eq. (5.1) takes a translog form and assuming that inputs are paid their marginal products, we can compute productivity growth as the change in output that is not accounted for by changes in inputs using the following productivity growth index:

$$\Delta\log A_t = \Delta\log Y_t - \overline{w}_t^K \Delta\log K_t - \overline{w}_t^L \Delta\log L_t - \overline{w}_t^M \Delta\log M_t. \tag{5.2}$$

Here $\Delta logA_t \equiv logA_t - \log A_{t-1}$ is the change operator, $w^X \equiv \frac{p^X X}{p^Y Y}$ is the costs of using input X, $p^X X$, relative to total revenues $p^Y Y$, and the upper bar denotes the two-period average input share, $\overline{w}_t^X = \frac{1}{2}\left(w_t^X + w_{t-1}^X\right)$.

Especially when the aim is to assess the contribution of industries to aggregate growth or, as below, to growth of a group of industries, it is more convenient to work with a value-added measure of productivity growth. We take the value-added volumes V_t from the National Accounts and compute value-added based productivity as:

$$\Delta\log A_t^V = \Delta\log V_t - \bar{s}_t^K \Delta\log K_t - s_t^L \Delta\log L_t. \tag{5.3}$$

The growth of capital input and of labor input is now weighted using the share of input costs in value added, $s_t^X \equiv \frac{p^X X}{p^V V}$. This, in effect, means we move to the value-added production function, rather than the gross output production function from Eq. (5.1), assuming that this production function is separable between intermediate and other inputs.

A key feature of the EU KLEMS database is that inputs of capital and labor are not homogenous, but instead represent a variety of different types of capital and labor, such as buildings and computers for capital and low-skilled and high-skilled workers for labor.[3] To reflect the different types of capital and labor input requires a straightforward extension from Eq. (5.3), where there are $m = 1, \ldots, M$ types of capital input

[3] See Jäger (2018) for more details.

and $n = 1, \ldots, N$ types of labor input that each earn their marginal products:

$$\Delta \log A_t^V = \Delta \log V_t - \sum_m \bar{s}_{mt}^K \Delta \log K_{mt} - \sum_n s_{nt}^L \Delta \log L_{nt}. \quad (5.4)$$

The industry productivity growth rates as computed based on Eq. (5.4) can be aggregated using the share of each industry i in aggregate value added, $v_i = p_i^V V_i / \sum_i p_i^V V_i$:

$$\Delta \log A_t^V = \sum_i \bar{v}_{it} \Delta \log A_{it}^V. \quad (5.5)$$

Note that Eq. (5.5) can be applied for any combination of industries, a key feature in our analysis, below.

While the methodology underlying the EU KLEMS database is, by now, standard, the implementation is far from standardized. National statistical offices in many European countries do not routinely publish productivity accounts. In addition, there are a variety of methods employed to estimate real inputs, especially capital that requires assumptions on the rates and patterns of depreciation. This leads to difficulties in international comparisons of sources of growth. The EU KLEMS project set out to produce productivity accounts using internationally comparable methods and data sources.

In the most recent version of the EU KLEMS database, concepts and methodologies to calculate the various growth and productivity variables were adjusted to the new European System of National Accounts (ESA10) in which the asset boundary was expanded by including research and development as intellectual property assets (Jäger, 2018). Capital stock figures are mostly obtained from Eurostat and are thus consistent with national accounts assumptions on the measurement of capital stock, rather than being fully harmonized. These, plus other adjustments, imply that the latest release is not directly comparable to earlier versions of EU KLEMS. Therefore, in this chapter we only report results from 1995 to 2015.[4]

5.3 Industry taxonomies

Based on our preliminary observations about the possible causes of the productivity slowdown in the past 2 decades, we summarize the industry productivity results using a series of taxonomies, whereby the growth calculations are carried out for groups of industries that share common characteristics. These taxonomies are based largely on the intensity of use of various types of inputs. The taxonomies are as follows.

ICT intensity: In previous studies during the 1990s and early 2000s, the performance of industry productivity has often been compared on the basis of the level of intensity of investment or capital services in information and communication−based hardware and software. This research showed that ICT-intensive industries typically tended to show significantly faster labor productivity growth. However, in contrast to US industries, European industries tended to reveal lower impact from greater ICT intensity on TFP growth (Stiroh, 2002; van Ark et al., 2003). Recently the nature of digital technology has shifted from relying primarily on ICT assets, such as hardware and telecommunication equipment, toward spending on ICT services. The latter refers to data storage and information processing services (including cloud computing), computer systems design, other information

[4] For some countries, the start date of the new measures are a few years after 1995—this is indicated in the tables.

services (including Internet publishing), and the usage of data, storage, and communication.[5] The data are obtained from supply—use tables published as part of the World Input-Output Database (www.wiod.org), described in Timmer et al. (2016). Comparing ICT intensity, including those services, to the original ICT assets-only classification reveals a distinctly different taxonomy because ICT hardware has diminished as a share of value added in the past decade while the use of data services has increased, especially in service sectors of the economy (van Ark, 2016).

Intangibles intensity: This industry taxonomy comprises the aggregate of intangibles assets and distinguishes innovative property intensive and economic competency intensive, as explained below. Organizational changes and other forms of intangible investments, such as workforce training and other economic competencies, have long been seen as necessary to benefit from the adoption of new technology (Bresnahan et al., 2002; Bertschek and Kaiser, 2004). The pioneering work of Corrado et al. (2005, 2009) allows the measurement of these assets divided into three categories: computerized information, innovative property, and economic competencies. Computerized information coincides with computer software, which is already included in ICT capital. Innovative property refers to the innovative activity built on a scientific base of knowledge as measured not only by conventional R&D statistics but also by innovation and new products and processes more broadly defined, including new architectural and engineering design, mineral exploration, and new products development costs in the financial industry. Economic competencies include spending on strategic planning, worker training, redesigning or reconfiguring existing products in existing markets, investment to retain or gain market share, and investment in brand development. The industry divisions are based on the data available from the INTAN Invest platform.[6] Recent work has highlighted the importance of intangible capital in explaining productivity growth in advanced economies (Corrado et al., 2017).

Skill intensity: Industries can also be classified on the basis of the proportion of workers with a university degree. The skill-biased technical change literature shows that the wage of the highly skilled is positively associated with technological changes (Autor et al., 1998). High skills have been widely regarded as complementary to ICT in generating productivity improvements. However, as the technology has become more mature, there is some evidence that high skills are less in demand than previously—firms investing in innovation create opportunities for improving conditions of a wider group of workers. For example, Aghion et al. (2017) argue that low-skilled workers employed in high-tech UK companies enjoy a higher wage premium compared not only to other low-skilled workers but also to the highly skilled.

Age profile of workers: This taxonomy is based on the proportion of workers aged 50 and over. The relationship between age and creative performance has been found to follow a hump-shaped profile in many studies using individual-level data. However, this finding needs to be treated with some caution as this type of analysis may be subject to many endogeneity and selection biases (Frosch, 2011). For example, educational attainment tends to be lower for older workers which may result in a spurious negative correlation between

[5] More precisely, computer services refer to the following detailed industries in the North American Industry Classification System (NAICS): data processing, hosting, and related information services (NAICS 51820 and 51913) and computer systems design services and related computer services (NAICS 54152, 54153, and 54159).

[6] See www.intaninvest.net.

innovative performance and age. Also, more mature and less innovative firms tend to attract fewer younger workers. Correcting for these biases using firm-level data tends to shift the age-productivity curve toward older workers (Göbel and Zwick, 2012). Nevertheless, there remains a negative link beyond a certain age (Jones, 2010).

Both the skill taxonomy and the age taxonomy are based on tabulations from the European Labour Force Survey. The skill taxonomy relies on proportions of the workforce who have university degrees or equivalents and the age taxonomy on proportions of the workforce who are aged 50 or over. These data are consistent with the divisions of the workforce by gender, age, and skill that underlie the EU KLEMS labor composition measures.

Offshore intensity: The final classification of industries concentrates on the usage of intermediate inputs and is based on the share of industry intermediate inputs sourced from abroad. Buying inputs from abroad can be an important source of productivity growth, for instance, because they embody new technologies (Keller, 2004) and are thus of higher quality or because new, imported varieties of inputs suit different needs than domestically produced versions. For individual firms, the evidence seems clear that importing more of its inputs improves productivity (e.g., Goldberg et al., 2010; Halpern et al., 2015). The degree of "offshoring intensity" is based on the World Input-Output Database, as described in Timmer et al. (2016). It measures how much an industry relies on foreign intermediate inputs in its production. This can be approached in different ways, since the inputs of industry's suppliers may also be partly sourced abroad. For example, Timmer et al. (2013, 2014) use share of value added created domestically versus abroad. We adopt a simpler approach, focusing only on the first-stage of the value chain, that is, the degree to which an industry directly sources its inputs from abroad. Choosing this measure over measures that also capture upstream foreign sourcing is unlikely to have a substantial impact on the results: all manufacturing industries score high on our measure, as well as agriculture, mining, transport and storage, and motor vehicle and fuel distribution.

To employ the taxonomies for an analysis of productivity, we need to make a delineation between more and less intensive industries in terms of input usage, offshoring, and other taxonomies. For this purpose, industries were identified as 0 or 1 depending on whether they belonged to the bottom or top half, respectively, of the industries in terms of their intensities. For example, the most intensive ICT-using industries are those with the highest share of value of ICT investment plus purchases of ICT services as a percentage of "synthetic output" (which is value added at industry level plus the intermediate use of those ICT services) in at least four of seven countries for which data were readily available (Finland, France, Germany, Italy, the Netherlands, Sweden, and the United Kingdom). The intangible, skill, age, and offshoring intensities were also based on being above the median of industries for a minimum of four countries out of nine countries (the countries above as well as Austria and Spain).[7]

Table 5.1 summarizes the different taxonomies that we use for the 1-digit market economy industries. The taxonomies on intangibles, skills, and age are not readily available at a greater level of detail than this 1-digit level, while the ICT and offshoring taxonomies are available at the 2-digit level in most cases. For 1-digit industries with more detailed taxonomies, we show the fraction of the 1-digit

[7] In the cases of ICT and offshore intensities, there was more information available for subindustries, so that the average of 0 and 1 for all subindustries was used.

TABLE 5.1 Taxonomies of industries: Market Economy.

	ICT	Intan	InProp	EcComp	Offshore	Skill	Age
Agriculture, forestry, and fishing	0	0	0	0	1	0	1
Mining	0	0	1	0	1	0	1
Manufacturing	0.73	1	1	1	1	0	0
Electricity, gas, and water	1	0	1	0	1	1	1
Construction	0	0	0	0	1	0	0
Wholesale and retail trade	0.67	1	0	1	0.33	0	0
Transportation and storage	0.50	0	0	0	0.50	0	1
Hotels and restaurants	0	0	0	0	0	0	0
Information and communication	1	1	1	1	0	1	0
Finance and insurance	1	1	1	1	0	1	0
Business services	1	1	1	1	0	1	0
Arts, entertainment, and recreation	1	0	0	1	0	1	0
Other services	0	0	0	1	0	0	1
Household services	0	0	0	1	0	0	1

Notes: Industries were identified as 0 or 1 depending on whether they belonged to the bottom or top half, respectively, of the industries in terms of their intensities. In the cases of ICT and offshore intensities, there was more information available for subindustries, so that the average of 0 and 1 for all subindustries was used. The market economy excludes industries mostly in the public sector (education, health, and public administration) and real estate, due to well-known issues in measuring output in these sectors. The table shows whether an industry is classified as intensive according to each criterion. Intan: intangible capital; InProp: innovative properties; EcComp: economic competencies. Fractions indicate that more detailed industries are divided between intensive and nonintensive. Information on intangibles, skill, and age are not available below the level of detail shown in the table.
Sources: see text.

industry that is classified as "intensive" according to this criterion based on the number of underlying 2-digit industries.

The table shows that the intensive industries included in the taxonomies show some overlap, but there are substantial differences too. For example, the ICT taxonomy corresponds closely to the skills and the intangibles taxonomies, though there are notable differences between these. The age taxonomy, which is based on the share of workers aged 50 and over, tends to highlight those industries that are not highlighted in the other taxonomies, such as agriculture and transportation and storage. This is to be expected as age is picking up a factor that is likely to lead to lower performance, whereas the other taxonomies focus on higher-performing industries. Most taxonomies point at the aggregate manufacturing sector as an intensive sector, except for skill and age. The more detailed ICT intensity classification signals that more than a quarter of manufacturing industries are not ICT-intensive. The information and communication sector, finance and insurance, and business services are intensive on ICT usage, intangibles, and skills but not for offshoring or age. For intangibles, we find that some sectors that did not score on innovation properties did show up for economic competencies: these include wholesale and retail trade, arts/entertainment/creation, and other personal and household services. In contrast, mining and utilities which scored as intensive sectors on the basis of innovative properties dropped out on the basis of economic competencies. The one industry that stands as being not intensive across all taxonomies is hotels and restaurants: it is the only industry that is not ICT-intensive, not intangibles-intensive, not skills-intensive, not prone to offshoring and not employing a relatively old workforce.

In sum, the differences between the taxonomies should provide enough scope for differences in average growth for each classification. Yet the similarities also make clear that any (mono-)causal discussion is not warranted, as there are multiple factors that influence productivity growth and there is no silver bullet that impacts productivity growth beyond all else.

5.4 Aggregate growth accounting

Before turning to the productivity results by industry taxonomy, we consider trends in outputs and inputs for aggregate economic activity. Table 5.2 summarizes value added growth and labor productivity (value added per hour worked) growth for an EU aggregate based on 12 countries,[8] compared to the United States. Between 1998 and 2005, average growth in real value added for both the total economy and the market economy in the United States was about 40% faster than in the EU-12. In the decade since 2005, both regions have witnessed a significant drop in aggregate output growth. The slowdown was partly due to the GFC, but when excluding the most critical years of the crisis (2008–10) and examining the period since 2011, output growth in both the United States and EU-12 was about half of that achieved from 1995 to 2005. Similar trends are observable for labor productivity growth. Both regions experienced a large drop in productivity growth during the second period, and the average labor productivity growth for the United States dropped almost to the EU-12 level for both the aggregate and the market economy. Strikingly, the slowdown in productivity for the United States shows no sign of any significant recovery in the most recent years, to 2017.[9]

Fig. 5.1A and B shows contributions from hours worked and labor productivity to output

TABLE 5.2 Aggregate growth in real value added and labor productivity, average % per annum.

	Total economy		**Market economy**	
	1998–2005	**2006–15**	**1998–2005**	**2006–15**
Value Added				
EU-12	2.1	0.9	2.3	0.8
United States	2.9	1.3	3.1	1.2
Labor Productivity (value added per hour)				
EU-12	1.4	0.7	1.7	0.8
United States	2.5	0.8	3.1	1.0

Notes: The 12 EU economies include Austria, Belgium, Czech Republic, Denmark, Germany, Finland, France, Italy, the Netherlands, Spain, Sweden, and the United Kingdom. The EU KLEMS-based growth rates for the total economy results can be slightly different from official estimates as reported in the National Accounts of individual countries or in data sets such as Penn World Tables or the Total Economy Database, as the EU KLEMS growth rates are aggregated up from a sector level, and can therefore be affected by slightly different weighting.
Source: EUKLEMS, 2017, euklems.net.

[8] Taken together those 12 economies, which include Austria, Belgium, Czech Republic, Denmark, Germany, Finland, France, Italy, the Netherlands, Spain, Sweden, and the United Kingdom, named EU-12, account for 90% of the European Union's nominal GDP in 2015.

[9] See https://www.conference-board.org/data/economydatabase/.

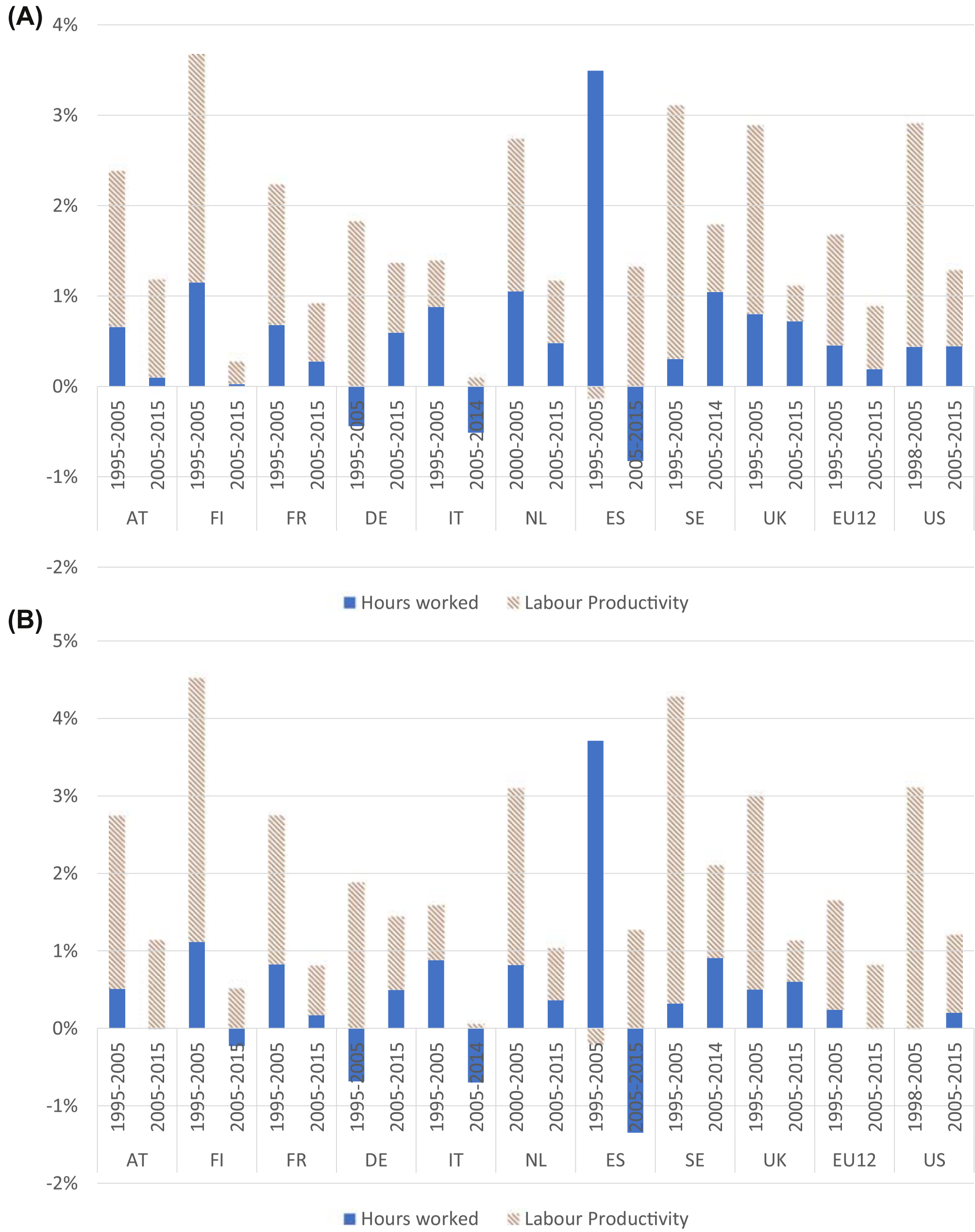

FIGURE 5.1 (A) Hours Worked and Labor Productivity growth rates, Total Economy, % per annum. (B) Hours Worked and Labor Productivity growth rates, Market Economy, % per annum.

growth for the nine largest EU economies separately for the aggregate and market economy, respectively.[10] For the EU-12, hours worked growth rates were slower in the 2006–15 period than during the 1998–2005 period, whereas in the US, hours for the total economy increased at about the same rate during both periods and even slightly improved for the market economy. However, the slump in labor productivity growth, which occurred in both regions, was much more pronounced for the United States than for Europe even though US productivity growth remained marginally higher than in the EU-12 during the 2006–15 period. Similar patterns emerge for most of the individual European countries shown in the diagram with weakening hours and productivity growth rates during the latest period. In Germany and Sweden, the growth in hours worked was higher in the later period and hours worked growth also held up well for the United Kingdom, but for all three economies there was a slowdown in labor productivity growth. The main exception is Spain, where labor productivity growth declined in the earlier period but rose in the later period and vice versa for hours worked which is largely due to the greater exposure of the Spanish economy to boom-and-bust cycles, especially in construction and tourism.

The slowdown in labor productivity growth can partly be explained by reductions in the extent of capital deepening, defined as the growth in capital services per hour worked. Fig. 5.2A and B illustrates the significant slump in this measure, for the EU-12 group, individual EU countries, and the United States. The slowdown in capital deepening was most pronounced in the United Kingdom and the United States which had seen the fastest increases in capital intensity during the earlier period. Overall the period since the financial crisis is one of widespread reduced investment in capital per worker hour.

Finally, we consider growth rates of TFP. Fig. 5.3A and B shows TFP growth rates for the same time periods and country/region groups as in the previous charts. These figures show a much weaker TFP growth than was evident for labor productivity. In many countries TFP growth was either negative or almost zero in the second period. Countries that experienced the highest growth rates in the earlier period, Finland, the United Kingdom, and the United States, have shown the greatest drop since. Only Germany experienced a slight improvement in TFP growth across the two time periods for both the total and the market economy although at relatively low values. Also Spain, which already had experienced negative TFP growth during the 1996–2005 period, saw that deterioration somewhat lessening during the later period.

In summary the review of the labor productivity, capital deepening, and TFP metrics for the aggregate and market economy highlights that Europe and the United States entered a period of much slower productivity growth from the mid-2000s and that there is little evidence of a recovery after the crisis. Before examining growth according to the industry taxonomies, we first consider TFP growth rates dividing the market economy into goods production and market services. Timmer et al. (2010) highlighted the importance of market services as drivers of growth (in the United States) and slowdown (in most European economies) during the decade from 1995 to 2005, when ICT had its greatest impact on output and labor productivity growth, and arguably also on TFP growth through the use of this technology.

[10] For the remainder of the analysis in this chapter, we have excluded separate analysis of three of the smaller European economies (Belgium, Czech Republic, and Denmark) for which up-to-date estimates are available, which are included with the EU-12 aggregate.

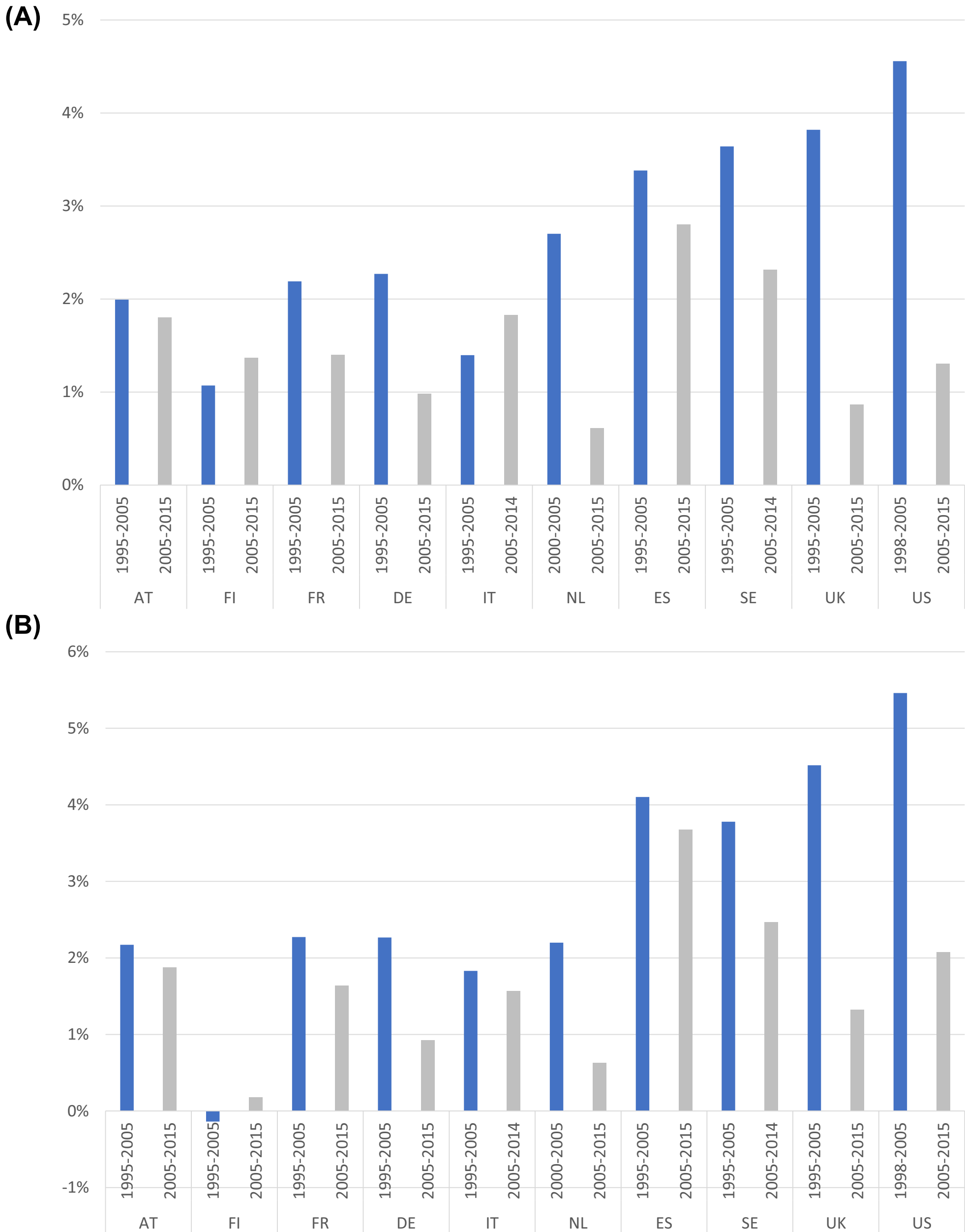

FIGURE 5.2 (A) Growth in Capital per Hour Worked, Total Economy, % per annum. (B) Growth in Capital per Hour Worked, Market Economy, % per annum.

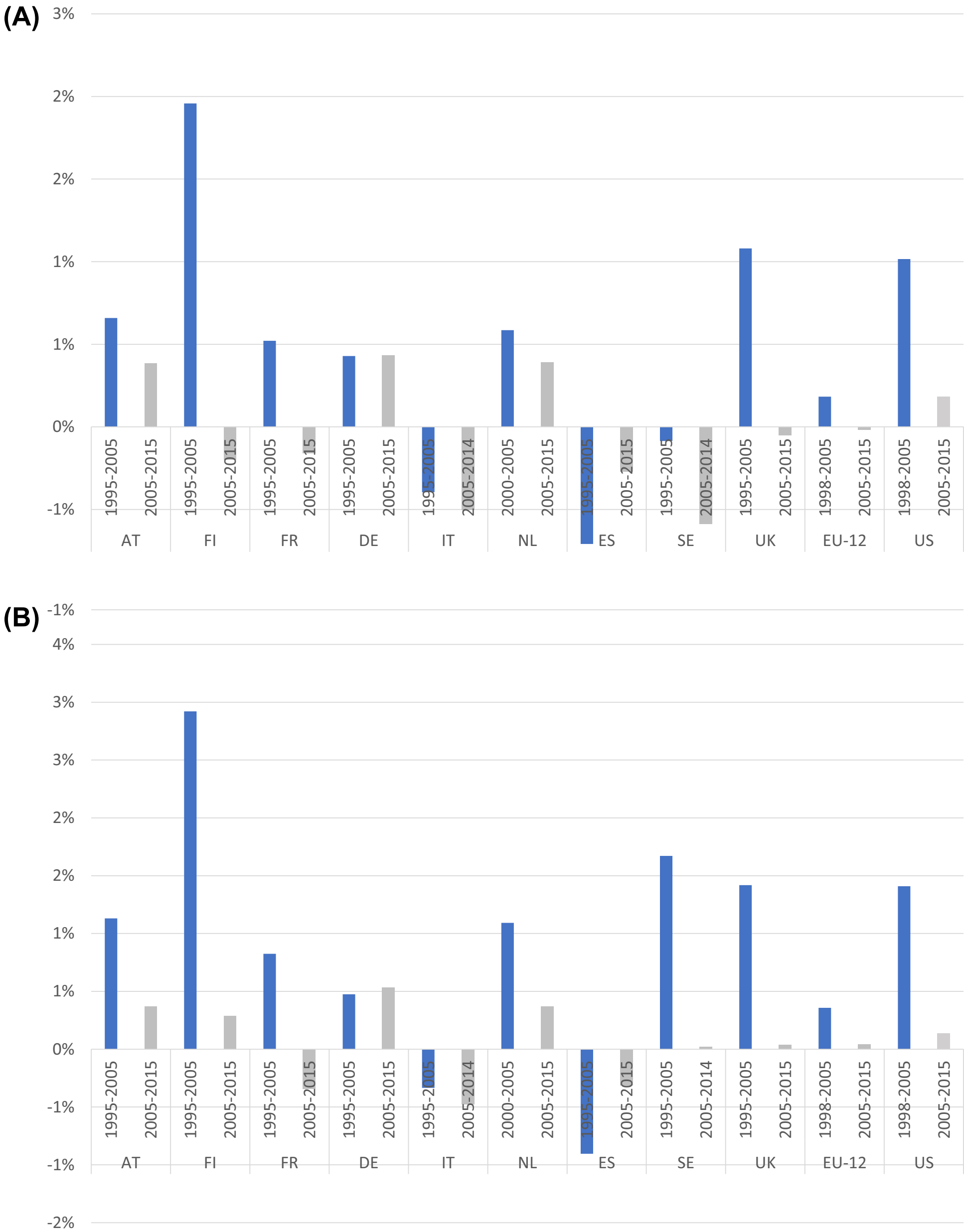

FIGURE 5.3 (A) Growth in Total Factor Productivity, Total Economy, % per annum. (B) Growth in Total Factor Productivity, Market Economy, % per annum.

Table 5.3 shows TFP growth by these major sectors. From 1995 to 2005, TFP growth in the market services sector was much slower than in the goods sector. However, the slowdown during the second period was less dramatic for market services than for manufacturing. In market services, the growth in TFP was moderately positive in the earlier period in most countries, with the exception of Germany, Italy, and Spain. Market services productivity was especially strong in Finland and the United Kingdom. In the later period TFP growth in market services fell to very low numbers or became negative, with the exception of the Netherlands.

TFP growth fell much faster in goods production, but the rates remained largely positive, although in this case the Netherlands and the United Kingdom were showing negative rates. In the United States the TFP decline in the goods sector was also surprisingly strong from 3.5% from 1995 to 2005 to 0.9% from 2006 to 15. However, these observations hide the significant swings in goods-sector productivity over the past decade. For example, van Ark and O'Mahony (2016) showed that manufacturing TFP growth in the EU-12 dropped from 2.4% between 2002 and 2007 to −1% during the most critical recession years from 2008 to 2010 and recovered modestly to 0.9% from 2011 to 2015. In market services, signs of recovery have been limited so far. Therefore the later period cannot be characterized as one in which the market services sector helped to offset the productivity collapse in the goods sector of the economy.

TABLE 5.3 Total factor productivity growth in Market Services and Goods Production, % per annum.

	Market services		Goods	
	1995–2005	**2006–15**	**1995–2005**	**2006–15**
Austria	0.9	0.0	1.9	1.4
Finland	2.1	0.3	4.3	0.3
France	0.2	−0.7	2.4	0.9
Germany	−0.3	0.3	2.1	1.1
Italy*	−0.4	−0.7	0.0	0.1
Netherlands*	1.1	0.7	1.3	−0.5
Spain	−1.9	−0.7	1.3	1.2
Sweden*	1.0	−0.1	3.2	0.4
United Kingdom	1.6	0.2	1.4	−0.2
EU-12*	0.2	−0.1	1.3	0.7
United States*	0.8	0.0	3.5	0.9

***Note:** Netherlands 2000–05; EU-12 and United States 1998–2005 instead of 1995–2005; Italy and Sweden 2005–14 instead of 2005–15.
Source: EUKLEMS (2017), euklems.net.

5.5 Growth by sector characteristics

In order to get to a better diagnosis of what have been the key reasons behind the recent productivity dynamics and how to understand differences across countries and sectors, we have introduced a range of taxonomies to classify and distinguish industries in EU KLEMS. As a starting point, it is helpful to first analyze the growth experience of the United States between 1998 and 2005 using these taxonomies.[11] As discussed in the previous section, productivity growth in the United States stood out relative to the EU in this first period, as growth was substantially faster than before—or since (Byrne et al., 2016).

Table 5.4 shows the TFP growth rates for the overall market economy and the breakdown in groups of industries according to the different characteristics. Market economy TPF in the United States grew at a rate of 1.4% on average over the 1998–2005 period. Industries producing

[11] For most countries, the latest EU KLEMS release provides data since 1995 (or earlier), but for the United States 1998 is the starting year.

TABLE 5.4 Average annual total factor productivity growth in the United States, 1998–2005 (%).

Market economy	1.4
ICT producers	6.0
ICT users	1.6
Total intangibles	2.0
Innovative properties	1.9
Economic competencies	1.8
Offshoring	2.0
Skill	0.9
Age	−0.1

Note: Productivity growth for various taxonomies indicate productivity growth rates of industries that were characterized as above median for all industries for that specific group. *ICT*, Information and communication technology.
Source: EUKLEMS, 2017, euklems.net.

ICT goods and services, which include production of semiconductors, computers, and telecommunication equipment on the goods side and the information and communication industries on the services side, show the fastest TFP growth compared to other groups at 6.0%, substantially higher than the average TFP growth for the market economy as a whole.

ICT-using industries cover the industries that make the most intensive use of ICTs. Unlike earlier ICT classifications, which identified ICT intensity based only on the use of ICT hardware and software capital, the new taxonomy also incorporates information on use of ICT services as intermediate inputs. This aims to capture that firms are increasingly outsourcing ICT activities: rather than maintaining servers and building dedicated software, they purchase access to data centers and cloud-based software services. As Table 5.4 shows, the group of ICT-using industries contributed positively to high productivity growth in the United States until 2005, slightly above the market sector average.[12]

The three intangible assets taxonomies also show that the most intangible-intensive industries exhibited faster productivity growth than industries that invested less in intangible assets. As shown in Table 5.1, industries scoring high on "intellectual properties" are different from those with high scores on "economic competencies," yet growth of either grouping exceeds market economy growth. This highlights that industries that are in neither grouping—agriculture, construction, transportation and storage, and hotels and restaurants—showed particularly low productivity growth in the United States between 1998 and 2005.

The offshoring taxonomy highlights the productivity performance of industries which have intensively offshored parts of their production process. The relatively high growth in this grouping illustrates that market services were not the only factor in strong US productivity growth during the 1998–2005 period but that globalization played an important role as well.

The two labor-taxonomies highlight that industries that were intensive in usage of high skill levels, and especially of experienced workers over the age of 50 years, were not showing a productivity advantages over industries that did not. One common feature is that these taxonomies both omit manufacturing and wholesale and retail trade. The age-based taxonomy shows a particularly stark result in that TFP growth for industries with relatively many older workers in the United States was below zero.

The discussion so far shows that intensive ICT usages, intangibles. and offshoring were key contributors to the relatively strong TFP growth performance of the market sector in the United States between 1998 and 2005. Yet the more

[12] Most industries that are classified as ICT-intensive according to the new "assets + services" framework were also ICT-intensive according to the old asset-based framework.

TABLE 5.5 Average annual total factor productivity growth in Europe and the United States, 1995–2015 (%).

	Market	ICT	Intangibles	InProp	EcComp	Offshore	Skill	Age
Spain	−0.6	−0.2	0.2	0.1	0.2	−0.2	−0.6	−0.6
Italy	−0.4	−0.3	−0.2	−0.4	−0.3	−0.4	−0.7	−0.6
France	0.2	0.1	0.4	0.3	0.4	0.6	−0.3	0.5
Germany	0.5	0.4	0.6	0.4	0.5	1.2	−0.7	0.6
Netherlands	0.6	0.5	1.0	0.4	0.9	0.0	0.6	−0.3
United States	0.7	0.8	1.1	1.1	0.9	0.8	0.6	0.1
United Kingdom	0.7	0.9	1.3	1.1	1.2	0.3	1.3	−0.8
Austria	0.8	0.9	1.0	1.0	0.9	0.6	0.6	0.9
Sweden	0.9	1.2	1.7	1.3	1.5	0.6	0.3	−0.8
Finland	1.6	1.6	2.2	2.0	2.1	1.0	1.3	0.8
Correlation with market economy	1.0	0.96	0.93	0.91	0.93	0.73	0.79	0.44

Notes: The table shows average annual total productivity growth for the group of industries identified in the column heading; see Table 1 for the composition of the industry groups. *Market*, Market economy; *ICT*, Information and communication technology; *InProp*, Innovative properties; *EcComp*, Economic competencies. The period covered is shorter in Italy (1995–2014), the Netherlands (2000–15), Sweden (1995–2014), and the United States (1998–2015).
Source: EUKLEMS, 2017, euklems.net.

pressing questions that motivate this chapter are whether we can use these taxonomies to find a common thread in the productivity performance across European countries and the United States and what factors explain the slowdown after 2005.

Table 5.5 aims to answer the first question, comparing the performance of TFP growth across countries and taxonomies over the full period for the European countries and the United States, sorted by average growth in the market economy (first column) and subsequently for the different taxonomies. Over the full period, most of the countries show average annual TFP growth between 0 and 1%, and with the United States not in an exceptional position relative to the European economies. However, the variation in productivity growth between European countries is substantial, especially when considering the decline in productivity in Spain and Italy for most groups on the one hand, and the average TFP growth of 1.6% in Finland, as well as strong TFP growth numbers across the groups, on the other hand.[13]

However, there are some common features in terms of the performance of different groups between the countries. In all countries, the industries that are investing more in intangibles, and particularly in intangibles related to economic competencies, show faster productivity growth than the aggregate for the market economy. In most countries, the ICT-intensive industries also show faster productivity growth than the market economy as a whole, whereas the differences are less pronounced for intangible-intensive industries. Conversely, the skill-intensive

[13] Much of the strong productivity growth in Finland during the 1995–2005 period was because of a strong "Nokia effect" in this relatively small economy.

TABLE 5.6 Change in average annual total factor productivity growth: 2005–15 versus 1995–2005.

	Market	ICT	Intangibles	InProp	EcComp	Offshore	Skill	Age
Finland	−2.6	−3.1	−3.2	−3.7	−3.1	−3.1	−2.2	−1.4
Sweden	−1.7	−1.3	−1.3	−1.4	−1.2	−3.0	0.1	−1.9
United Kingdom	−1.4	−1.3	−1.1	−1.8	−1.0	−1.5	−2.2	−3.0
United States	−1.3	−1.4	−1.6	−1.3	−1.4	−2.0	−0.4	0.3
France	−1.2	−1.0	−0.9	−1.2	−1.0	−1.8	−0.8	−1.6
Austria	−0.8	−1.0	−0.5	−0.9	−0.5	−1.2	−1.0	−1.6
Netherlands	−0.7	−0.9	−0.5	−1.3	−0.6	−1.4	−1.0	−2.2
Italy	−0.1	−0.3	0.2	0.0	0.2	−0.7	−0.1	−1.2
Germany	0.1	0.6	0.3	0.6	0.3	−1.0	1.9	−1.5
Spain	0.6	−0.8	0.3	−0.9	0.3	−0.2	−1.3	−0.9
Correlation with market economy	1.00	0.84	0.96	0.84	0.96	0.92	0.47	0.17

Notes: The table shows the change in average annual productivity growth before and after 2005 for the group of industries identified in the column heading; see Table 1 for the composition of the industry groups. *Market*: Market economy; *ICT*, Information and communication technology; *InProp*, Innovative properties; *EcComp*, Economic competencies. The period covered is shorter in Italy (1995–2014), the Netherlands (2000–15), Sweden (1995–2014), and the United States (1998–2015).
Source: EUKLEMS, 2017, euklems.net.

industries and those that employ relatively older workers tend to grow more slowly, or even show declining productivity such as for older-worker–intensive industries in Italy, Spain, the Netherlands, the United Kingdom, and Sweden. Finally, as indicated by the correlations in the bottom row of the table, the cross-country patterns of productivity growth in ICT-intensive and in intangible-intensive industries correspond most closely to the overall growth pattern, suggesting that these industries are most important for characterizing the growth differences across countries.

Table 5.6 addresses the second question, namely the slowdown in productivity growth in most countries after 2005. The first column highlights that TFP growth slowed down between the first and second period in all countries, except Germany and Spain. In most countries the slowdown was in the order of 1 percentage point or more. The degree to which the change in growth for the individual taxonomies corresponds to the change in aggregate growth is smaller than the correspondence of growth rates in Table 5.5. For example, in approximately half the countries (Sweden, France, the United Kingdom, the United States, and Germany), the slowdown was smaller or the same in ICT-intensive industries compared to the aggregate, while in the other half of countries (Finland, Austria, the Netherlands, Italy, and Spain), the slowdown was larger. The clearest pattern can be seen in industries that invest most intensively in economic competencies and in industries that are offshoring more intensively. The productivity slowdown in industries that invest most intensively in economic competencies is less severe than for the aggregate in nearly all countries, while the slowdown in offshoring-intensive industries is larger than for the aggregate in all countries. The more severe slowdown in offshoring-intensive industries could point to the importance of the broad slowdown in global trade in recent years and the possible impact of a defragmentation of global value chains on productivity growth (Timmer et al., 2016). This would be another sign that firms are exploiting fewer cost reductions from foreign sourcing and specialization.

5.6 Summary and conclusions

Productivity research since the GFC has shown that the productivity slowdown of the past decade or so started well before the crisis—around 2005. However, the recession has exacerbated the productivity crisis which most economies have experienced because of slowing demand, weak investment, and structural rigidities in product, labor, and capital markets (van Ark and Jäger, 2017). In addition, while creating new business models and applications, the complex characteristics of the New Digital Economy, characterized by the combined shifts to mobile technology, cloud computing and storage, and ubiquitous access to broadband, have created important challenges in how to leverage these new technologies to drive productivity growth (van Ark, 2016).

In this chapter we adopted a series of industry taxonomies to detect more precisely the possible causes of differences in productivity growth between European countries and the United States, and the slowdown in productivity growth since 2005. Our findings confirm insights from the literature that the degree of investment in ICT and intangibles assets, and in particularly economic competencies, has accounted for a fair part of the difference between sectors that have shown productivity performance above the average for the market economy vis-à-vis those who performed below that. In contrast, we do not find much evidence that industries which are relatively intensive on the usage of high skills show above average performance and there appears to be signs of a negative impact from the aging workforce.

We also find that the productivity slowdown since 2005 has hit the United States even more than for the average of the European economies together, especially in manufacturing, even though the average US productivity growth rates are still slightly higher than in the EU. Industries that are strong on the intensity of ICT usage and intangibles have generally experienced smaller slowdowns than those that are characterized as less intensive on those characteristics. This implies that the prominent productivity issues in the digital economy have become more visible on a global scale and are less important in distinguishing between US and European productivity performance. While the United States remains a clear technology leader in the digital economy, compared to Europe, the productivity effects from the use of that technology are not superior.

Finally, we find that industries that benefited most from offshoring trends during the period 1995–2005 experienced bigger slowdowns in productivity growth since then. This implies that the slowdown in global trade and possible impact of a defragmentation of global value chains on productivity may have been in play over the past decade.

We emphasize that it is still early days to fully establish the reasons for the productivity slowdown, and that more detailed analysis over time should help to deepen our understanding of the phenomenon. First, we are still in the midst of the transition from the Old Digital Economy (which was characterized by the introduction of the PC in people's lives and business processes, the rise of the Internet, and the beginnings of e-commerce) to the New Digital Economy (which is characterized by the change toward mobile, ubiquitous access to the Internet, the storage and usage of data, and advances in artificial intelligence and robotics). The past decade of slow productivity growth may be characteristic of an adjustment process between two technologies, and a productivity recovery could therefore be around the corner.

Second, even if it is just a matter of time for the effects of the New Digital Economy to show, it is questionable whether the currently agreed measurement framework for productivity will be able to pick up the effects of the New Digital Economy. Most recent studies have argued that increased mismeasurement of output and productivity is unlikely to account for the entire productivity slowdown. However, that does not mean we may not be missing something. Except for well-known measurement issues related to price declines of digital assets and services, which still may account for some underestimation of growth (Byrne et al., 2016), the bigger measurement issues revolve around how to handle the impact of free digital content on the economy. The New Digital Economy may provide benefits that are not being identified in GDP or in the productivity accounts. For example, the user utility of free digital content is not easily captured in a production cost or resources-saving framework, including national and growth accounts. Similarly, output-saving technical change from consumer technologies may change the growth effects from digital technologies (Hulten and Nakamura, 2018). These measurement issues are currently being debated by national accounts statisticians and economists, but their resolution is still some way off.

References

Aghion P, Bergeaud A, Blundell R, Griffith R: *Innovation, firms and wage inequality*, Harvard University.

Andrews D, Criscuolo C, Gal P: *The best versus the rest: the global productivity slowdown, divergence across firms and the role of public policy*, OECD Productivity Working Papers. 5, 2016.

Autor D, Katz LF, Krueger A: Computing inequality: have computers changed the labor market? *Quarterly Journal of Economics* 113(4):1169–1213, 1998.

Bertschek I, Kaiser U: Productivity effects of organizational change: microeconometric evidence, *Management Science* 50(3):394–404, 2004.

Bloom N, Jones CI, Van Reenen J, Webb M: *Are ideas getting harder to find*, March 2018. Version 2.0.

Bresnahan TF, Brynjolfsson E, Hitt LM: Information technology, workplace organization, and the demand for skilled labor: firm-level evidence, *Quarterly Journal of Economics* 117(1):339–376, 2002.

Brynjolfsson E, Hitt LM: Paradox Lost? Firm-level evidence on the returns to information systems, *Management Science* 42(4):541–558, 1996.

Byrne DM, Fernald JG, Reinsdorf MB: Does the United States have a productivity slowdown or a measurement problem? *Brookings Papers on Economic Activity Spring* 109–182, 2016.

Cette G, Fernald J, Mojon B: The pre-great recession slowdown in productivity, *European Economic Review* 88: 3–20, 2016.

Corrado C, Haskel J, Jona-Lasinio C: Knowledge spillovers, ICT and productivity growth, *Oxford Bulletin of Economics & Statistics* 79(4):592–618, 2017.

Corrado C, Hulten C, Sichel DE: Measuring capital and technology: an expanded framework. In Corrado C, Haltiwanger J, Sichel DE, editors: *Measuring capital in the new economy*, University of Chicago Press, pp 11–46.

Corrado C, Hulten C, Sichel DE: Intangible capital and U.S. economic growth, *Review of Income and Wealth* 55: 661–685, 2009.

Fernald JG, Hall RE, Stock JH, Watson MW: The disappointing recovery of output after 2009, *Brookings Papers on Economic Activity* 1–58, 2017.

Frosch KH: Workforce age and innovation: a literature survey, *International Journal of Management Reviews* 13(4): 414–430, 2011.

Göbel C, Zwick T: Age and productivity – sector differences, *De Economist* 160(1):35–57, 2012.

Goldberg PK, Khandelwal AK, Pavcnik N, Topalova P: Imported intermediate inputs and domestic product growth: evidence from India, *Quarterly Journal of Economics* 125(4): 1727–1767, 2010.

Halpern L, Koren M, Szeidl A: Imported inputs and productivity, *The American Economic Review* 105(12): 3660–3703, 2015.

Harberger A: A vision of the growth process, *The American Economic Review* 88(1):1–32, 1998.

Hulten C: Growth accounting. In Hall B, Rosenberg N, editors: *Handbook of the Economics of Innovation*, vol. 2. Elsevier, pp 987–1031.

Hulten C, Nakamura L: *Accounting for growth in the age of the internet: the importance of output-saving technical change*, 2018. NBER Working Paper No. 23315.

Jäger K: *EU KLEMS Growth and productivity accounts, 2017 release, statistical module: description of methodology and country notes*. www.euklems.net.

Jones BF: Age and great inventions, *The Review of Economics and Statistics* 92(1):1–14, 2010.

Jorgenson DW, Fukao K, Timmer MP, editors: *The world economy. growth or stagnation?* Cambridge University Press.

Jorgenson DW, Gollop F, Fraumeni B: *Productivity and U.S. economic growth*, Cambridge and London, 1987, Harvard University Press.

Jorgenson DW, Stiroh K: Raising the speed limit: U.S. economic growth in the information age, *Brookings Papers on Economic Activity* 1:125–211, 2000.

Keller K: International technology diffusion, *Journal of Economic Literature* 42(3):752–782, 2004.

Oliner SD, Sichel DE: The resurgence of growth in the late 1990s: is information technology the story? *The Journal of Economic Perspectives* 14:3–22, 2000.

O'Mahony M, Timmer MP: Output, input and productivity measures at the industry level: the EU KLEMS database, *Economic Journal* 119:F374–F403, 2009.

Perez C: *Technological revolutions and financial capita: the dynamics of bubbles and golden ages*, Edward Elgar.

Riley R, Bondibene CR: *Winners and losers in the knowledge economy: the role of Intangible capital*, NIESR.

Stiroh KJ: Information technology and the US productivity revival: what do the industry data say? *The American Economic Review* 92(5):1559–1576, 2002.

Timmer MP, Inklaar R, O'Mahony M, van Ark B: *Economic growth in Europe*, Cambridge University Press.

Timmer MP, Erumban AA, Los B, Stehrer R, de Vries GJ: Slicing up global value chains, *The Journal of Economic Perspectives* 28:99–118, 2014.

Timmer MP, Los B, Stehrer R, de Vries GJ: An anatomy of the global trade slowdown based on the WIOD 2016 release, *GGDC Research Memorandum* 162, 2016.

Timmer MP, Los B, Stehrer R, de Vries GJ: Fragmentation, incomes and jobs: an analysis of European competitiveness, *Economic Policy* 28:613–661, 2013.

van Ark B: The productivity paradox of the new digital economy, *International Productivity Monitor* 31:1–15, 2016.

van Ark B, Inklaar RC, McGuckin RH: ICT and productivity in Europe and the United States. Where do the differences come from? *CESifo Economic Studies* 49(3):295–318, 2003.

van Ark B, Jäger K: Recent trends in Europe's output and productivity growth performance at the sector level, *International Productivity Monitor* 33:8–23, 2017.

van Ark B, O'Mahony M: Productivity growth in Europe before and since the 2008/2009 economic and financial crisis. In Jorgenson DW, Fukao K, Timmer MP, editors: *The world economy. Growth or stagnation?* Cambridge University Press, pp 111–152.

van Ark B, O'Mahony M, Timmer MP: The productivity gap between Europe and the U.S.: trends and causes, *The Journal of Economic Perspectives* 22(1):25–44, 2008.