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Co-leads of the work stream

Wolfgang Modery
European Central Bank

Maria Teresa Valderrama
Oesterreichische Nationalbank

Coordinator and pen-holder

Paloma Lopez-Garcia
European Central Bank
email: paloma.lopez-garcia@ecb.europa.eu)

Additional contributing authors

Maria Albani (co-author of Section 3)
Bank of Greece

Paloma Lopez-Garcia (co-author of Sections 1, 2, 4, 5 and 6)
European Central Bank

Sofia Anyfantaki (co-author of Sections 3 and 5)
Bank of Greece

Philipp Meinen (co-author of Section 5)
Deutsche Bundesbank

Claudio Baccianti (co-author of Section 1)
European Central Bank

Isabella Moder (co-author of Section 5)
European Central Bank

Rodrigo Barrela (co-author of Section 4)
European Central Bank

Kaspar Oja (co-author of Section 2)
Eesti Pank

Katalin Bodnar (co-author of Section 5)
European Central Bank

Christian Ragacs (co-author of Section 2)
Oesterreichische Nationalbank

Maurice Bun (co-author of Section 4)
De Nederlandsche Bank

Roehe Oke (co-author of Section 2)
Deutsche Bundesbank

Jan De Mulder (co-author of Section 3)
Nationale Bank van België/Banque Nationale de Belgique

Patrick Schulte (co-author of Section 3)
Deutsche Bundesbank

Elisabeth Falck (co-author of Section 2)
Deutsche Bundesbank

Ana Seco Justo (co-author of Section 3)
European Central Bank

Gerhard Fenz (co-author of Section 2)
Oesterreichische Nationalbank

Roberta Serafini (co-author of Section 5)
European Central Bank

Beatriz Gonzalez Lopez (co-author of Section 5)
Banco de España

Ralph Setzer (co-author of Sections 4 and 5)
European Central Bank

Vincent Labhard (co-author of Section 5)
European Central Bank

Irune Solera Lopez (co-author of Section 2)
Banco de España

Julien Le Roux (co-author of Section 2)
European Central Bank

Maria Teresa Valderrama (co-author of Section 5)
Oesterreichische Nationalbank

Andrea Linarello (co-author of Section 2)
Banca d'Italia

Juuso Vanhala (co-author of Section 4)
Suomen Pankki – FInlands Bank

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No 263, "The implications of globalisation for the ECB monetary policy strategy".
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Abstract

The aim of this report is to foster a better understanding of past trends in, and drivers of, productivity growth in the countries of the European Union (EU) and of the interplay between productivity and monetary policy. To this end, a group of experts from 15 national central banks and the European Central Bank (ECB) joined forces and pooled data and expertise for more than 18 months to produce the report. Group members drew on the extensive research already conducted on productivity growth, including within the European System of Central Banks and in the context of the review of the ECB's monetary policy strategy, and worked together to conduct new analyses.

After recalling the key facts and figures, the report looks into the predominant drivers of productivity growth in firms, with a focus on technology as a key determinant of aggregate productivity dynamics. It then discusses the main factors behind resource reallocation both across incumbent firms and as a result of the entry and exit of firms. Although productivity is a real-economy phenomenon and its evolution predominantly hinges on the structural features of the economy and national policies, the report also raises the question of the extent to which, and under what circumstances, monetary policy may affect productivity. In addition, it places productivity in a broader perspective by taking into account other important structural trends that are expected to have an impact on productivity in the medium-to-long run, such as globalisation, population ageing, climate change and digitalisation. Finally, the report considers the possible impacts of the coronavirus (COVID-19) pandemic on productivity in EU countries. It concludes that the long-term slowdown in productivity growth in Europe and other advanced economies results from the interaction of a variety of factors – at the global, country and sector levels, and both structural and temporary – including shocks with potential scarring effects on productivity and potential growth, such as the global financial crisis or the COVID-19 pandemic.

Regarding the possible implications for monetary policy, productivity growth can play a significant role in boosting the current low rates of potential economic growth, with implications for the natural rate of interest and for the monetary policy space needed to deliver price stability over the medium term.

JEL Codes: D22, D24, D61, O33, O47, O52.

Keywords: Productivity growth, European Union, drivers and policy implications.

Executive summary

The objective of this report is to foster a better understanding of past trends in, and drivers of, productivity growth in the European Union (EU) countries and of the interplay between productivity and monetary policy. To this end, a group of experts from 15 national central banks (NCBs) and the European Central Bank (ECB) joined forces and pooled data and expertise for more than 18 months to produce the report. Group members drew on the extensive research already conducted on productivity growth, also including within the European System of Central Banks (ESCB) and in the context of the review of the ECB's monetary policy strategy, and worked together to conduct new analyses.

The key findings of the report can be summarised as follows:

1. **Labour productivity growth has been declining for decades in EU countries.** Labour productivity growth is a key driver of a country's living standards, particularly in a situation where hours worked per employee and demographics limit the growth of hours worked per capita. Until the global financial crisis, the main factor behind the decline in aggregate labour productivity growth was the diminishing contribution of total factor productivity (TFP) growth. In the post-crisis period, the recovery of employment levels and weak investment resulted in muted capital deepening, which also contributed to sluggish labour productivity growth.

2. **Intra-sector productivity growth plays a key role in explaining aggregate productivity trends.** Aggregate productivity dynamics depend primarily on the capacity of firms to increase their efficiency (within-firm productivity growth) and on resource reallocation across firms operating in the same sector of activity. The reallocation of resources across sectors plays a smaller role in explaining aggregate productivity patterns.

3. **Technology is a key factor driving within-firm productivity growth.** However, this factor plays a less prominent role in productivity growth in EU countries than in the United States and may be slowing down in EU countries. Three findings support this statement.

   (a) Productivity growth in the information and communication technology (ICT) sectors of EU countries is much lower than in the United States. More broadly, technology-intensive sectors drive aggregate productivity growth to a larger extent in the United States than in Europe.

   (b) There is some evidence, both macro-based and micro-based, that innovation in the manufacturing sector has been slowing in both the United States and the EU. The macro evidence shows that patenting activity has been flat since the global financial crisis in both regions. In addition, the United States and the EU's market share of high-technology manufacturing exports has declined sharply over time, to the benefit of

China. This finding is supported by evidence based on firm-level data, showing a slowdown in technology creation by EU manufacturing firms at the frontier. This slowdown is concentrated in high-technology sectors.

(c) Technology creation in services has accelerated over time in the EU. However, the productivity gains from this development seem to be benefiting relatively few services firms at the frontier. Laggards in services continue to show low levels of productivity growth. This evidence points to a slowdown in technology diffusion in the services sector.

4. **The contribution to aggregate productivity growth of resource reallocation across incumbent firms operating in the same sector is productivity-enhancing but declining over time.** The report estimates that resource misallocation could be reducing aggregate productivity growth in the EU by about 0.2 percentage points annually. The regulatory frameworks and structural characteristics behind these dynamics vary across countries and sectors and over time.

5. **The entry and exit of firms contribute positively to aggregate productivity growth, notwithstanding the low productivity of new firms in their early years.** There are, however, stark country differences. Whereas new firms are between 80% and 90% as productive as incumbent firms in the same sector in Belgium and France, they are only about half as productive in Italy. After entry there is an intense selection process, whereby about one-third of new firms exit the market before completing three years of activity. Surviving firms grow fast thereafter to catch up with average sector productivity levels. However, the report finds that the high productivity growth rates of young surviving firms are driven by very few firms. By contrast, most young surviving firms linger at relatively low productivity growth rates. Lastly, as in the United States, firm entry rates seem to have been declining since at least the early 2000s.

6. **The proportion of distressed firms, often referred to as "zombie" firms in the literature, increased from 2007 to 2014 and declined thereafter in the EU countries analysed, to around 7% of all firms in the market.** The report shows that zombie dynamics have mainly been driven by the rate of entry into distress, which is very cyclical. By contrast, the speed at which weak firms exit financial distress, either because they recover or because they exit the market altogether, has been relatively stable over the period from 2003 to 2018. According to the interest coverage ratio (ICR) criterion, firms identified as zombies are not necessarily non-viable, as almost one-third of them are expanding in terms of employment. Moreover, the analysis suggests that about half of firms exiting the "zombie status" recover their financial health. The other half, accounting for about 2% of all firms in the market, end up leaving the market. Finally, zombies are found to crowd out resources for healthy firms (congestion effects), with an indirect negative impact on productivity growth.

7. *Although productivity is a real-economy phenomenon and its evolution hinges on national fiscal, structural, and financial sector policies, an accommodative monetary policy stance has under certain circumstances*

the potential to stimulate investment and productivity. However, in recent years it has increasingly been argued that very low interest rates over a long period of time could have negative effects on resource allocation and productivity through their interaction with financial frictions, weak banks or weak banking supervision, among other things. There are several channels through which monetary policy can affect productivity, and they might interact with institutional arrangements and other policies. Therefore, the aggregate effect of monetary policy on productivity is ambiguous and needs to be determined empirically. Overall, the Work stream's own (partial) empirical analyses do not find pervasive negative side effects of monetary policy on productivity.

Going forward, the impact on aggregate productivity growth of the COVID-19 shock and its interaction with the dynamics of technological progress and productivity-enhancing resource reallocation is uncertain. First, the possible restructuring of global value chains after the pandemic and a further rise in trade barriers could have a negative influence on the trade outlook and productivity growth as a result of reduced technology transfers, a deterioration in input quality and reduced scope for productive firms to expand. Second, the massive policy support for the corporate sector in response to the pandemic crisis has been crucial to mitigate the initial impact of the shock. However, once the economic recovery takes hold on a sustainable basis, policy support needs to be lifted gradually to avoid impairing the efficient reallocation of resources by setting wrong incentives. Hence the design and timing of the exit strategy is expected to determine further (lagged) effects of the pandemic crisis on aggregate productivity growth. And third, financial distress, together with high uncertainty, might increase the financing cost and reduce the expected benefits of new productivity-enhancing projects and delay investment, with impacts on productivity growth. Further, the uptake of new debt by corporates to cover liquidity gaps could result in debt overhang and further reduce investment.

Investment in green technology and an acceleration in digital uptake could be silver linings. Large-scale investment in the development and adoption of green technologies, as a result of both demand and supply factors, could push the technological frontier significantly outwards. This would also be an important factor in offsetting the foreseeable short-term negative impacts of stringent environmental regulations as a result of the diversion of resources from productivity-enhancing activities to regulatory compliance. Last, the acceleration in digital uptake already taking place could play a vital role in reaping the benefits of new technologies and improving technology adoption by laggards, particularly small and medium-sized enterprises (SMEs).

The ageing of the euro area (hereinafter also EA) population means that productivity growth has a significant role to play in boosting the current low rates of economic potential growth and thus of the natural rate of interest. Available estimates suggest that the natural rate of interest has declined considerably in recent years. If productivity growth, and implied potential growth, remain low, the natural rate of interest will remain subdued in the future, with implications for the room for manoeuvre of stability-oriented monetary policy. Productivity hinges predominantly on fiscal and structural policy decisions by elected

national governments. However, monetary policy has the potential to support productivity growth in the recovery phase of the economy by monitoring and maintaining favourable financing conditions for as long as is needed to safeguard price stability in the euro area.

1   Introduction

"If it persists, this slowdown in productivity growth will matter greatly for our future prosperity, and will have direct consequences for the conduct of monetary and fiscal policy and the cohesion of the euro area" (Mario Draghi 2016)[1]

"The Federal Reserve's objectives of maximum employment and price stability do not, by themselves, ensure a strong pace of economic growth or an improvement in living standards. The most important factor determining living standards is productivity growth" (Janet Yellen 2015)[2]

"There are risks and costs to action. But they are far less than the long range risks of comfortable inaction." John F. Kennedy

1.1   Why is productivity important for a central bank?

Productivity growth is a key determinant of potential output growth and the natural rate of interest.[3] It is therefore an important factor that shapes the environment in which monetary policy operates, with the potential to affect the effectiveness of monetary policy, its room for manoeuvre and its transmission to the economy. In this sense, central bankers have a vested interest in higher productivity growth, especially at times of low equilibrium rates of interest. Indeed, productivity growth plays a significant role in boosting the current low rates of potential economic growth, with implications for the natural rate of interest and therefore for the monetary policy space needed to deliver price stability over the medium term. At the same time, while acknowledging that productivity is a real-economy phenomenon and its evolution predominantly hinges on the structural features of the economy and the design of national policies, an accommodative monetary policy stance has, under certain circumstances, the potential to stimulate investment and productivity.[4]

Besides its impact on the natural rate of interest, long-run productivity growth is the principal source of improvements in living standards. Rising living standards, approximated by income per capita growth, depend on the growth of hours worked per capita and on of labour productivity growth. In a situation where hours worked per employee and demographics limit the growth of per capita hours worked, labour productivity growth is a key driver of a country's living standards

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[1]   "The productivity challenge for Europe", Lectio magistralis by Mario Draghi, President of the ECB, marking the 100th anniversary of the Deusto Business School, Madrid, 30 November 2016.

[2]   "The Outlook for the Economy", Speech at the Providence Chamber of Commerce, Providence, Rhode Island, 22 May 2015.

[3]   The natural rate of interest is the rate at which factors of production are fully used, and inflation is not subject to inflationary nor disinflationary forces.

[4]   At least since Hume (1752), macroeconomics has largely operated under the assumption that money is neutral in the long run. However, a new wave of endogenous growth models has challenged this canon. See for example Bachmann and Sims (2012) and, more recently, Benigno and Fornaro (2018) and Jordà et al. (2020).

[5]   See Blinder (1997) and Krugman (1997) for a discussion of the usefulness of this relationship.

(Chart 1, left panel).[5] But even in the short and medium run, the rate of productivity growth influences the economy in important ways, affecting key variables such as output, employment and wages.

Productivity growth has come to occupy a central position in the policy debate because of its long-standing declining trend in the EU and other advanced economies. Productivity growth has a large cyclical component, declining and even entering negative territory during crises and increasing during the early phases of expansion as a result of time-varying capacity utilisation. Once this cyclicality is smoothed out, a long-term declining trend in labour productivity growth, starting at least in the 1970s, emerges. Over the past five decades, average annual labour productivity growth in those EU countries with sufficiently long time series has declined from 3.9% in the 1970s to 2.5% in the 1980s to 1.5% in the 1990s to 1% since the early 2000s, excluding the period of the global financial crisis (2009-12) (Chart 1, right panel).

Chart 1

Correlation between labour productivity growth and income per capita growth, 1970-2019 (left panel) and labour productivity growth trends in the EA10 and the United States (right panel)

Correlation between labour productivity growth and income per capita growth, 1970-2019	Labour productivity growth trends in the EA10 and the United States
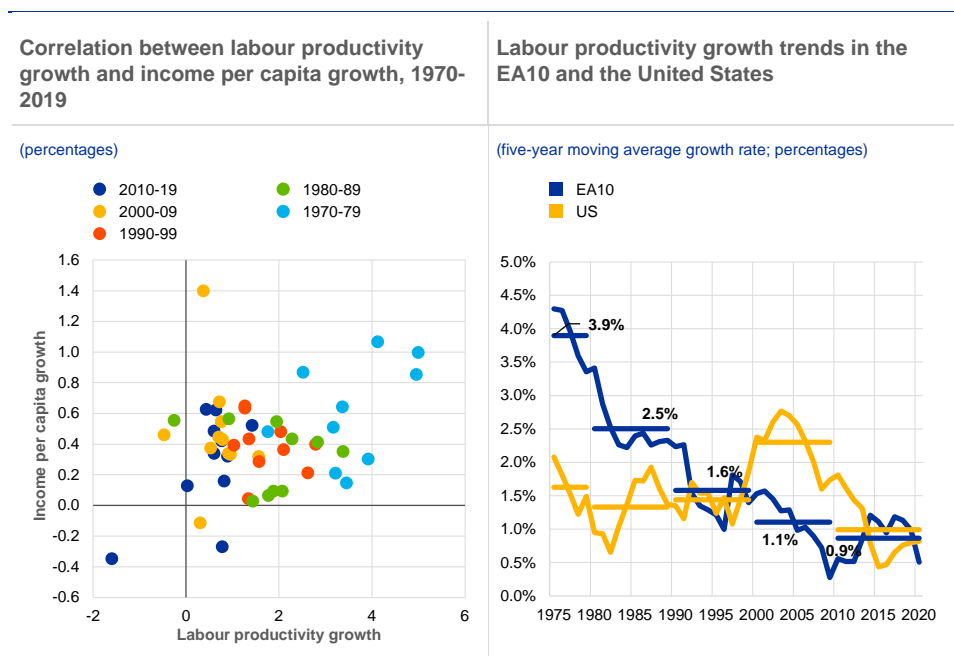
Source: Own calculations using AMECO data.
Notes: Left panel: Each point represents country-average annual growth of labour productivity and income per capita in each decade since 1995. The chart includes only countries that entered the EU before 2004. Right panel: Labour productivity measured as GDP at constant 2010 prices per hour worked. Weighted average across countries with available data, including Belgium, Germany, Ireland, Spain, France, Italy, Lithuania, Netherlands, Portugal and Finland.

The aim of this report is to foster a better understanding of past trend developments in, and the dominant drivers of, productivity growth, with a particular focus on its relevance from a monetary policy perspective. To this end, a group of experts from 15 NCBs and the ECB joined forces and pooled data and expertise for 18 months. Group members drew on the extensive existing

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[5] See Blinder (1997) and Krugman (1997) for a discussion of the usefulness of this relationship.

research already conducted on productivity growth, including within the ESCB and in the context of the review of the ECB's monetary policy strategy 2020-21, and worked together to conduct new analyses.

"Simply put, productivity is efficiency in production: how much output is obtained from a given set of inputs" (Syverson 2011, page 329). The most commonly used measure of productivity, in this report too, is labour productivity defined as units of output produced per unit of labour input. However, the level of such single-factor productivity depends on the intensity of use of the other production factors. For this reason, researchers also use a multi-factor productivity measure, Total Factor Productivity (TFP), which is invariant to the intensity of use of inputs, unobservable and computed as a residual. Box 1 below discusses conceptual details and possible TFP measurement issues.

Different datasets and measures of productivity are used in the different sections of this report, depending on the specific questions addressed. For example, the long-term and international view requires macroeconomic indicators of productivity, defined both as labour productivity and TFP growth, whereas the analysis of resource reallocation across firms requires firm-level data. For this reason, productivity is defined differently across sections. The use of different datasets also means that country and period coverage are not uniform throughout the report. In general terms, sections using macro data rely on AMECO data[6], covering the 27 EU and 12 euro area country aggregates and the United States, and measure productivity as real gross domestic product (GDP) per hour worked or as the Solow Residual.[7] Sections using sector data draw on EUROSTAT or EUKLEMS[8], have a similar regional coverage as the macro sections and define productivity at the sector level as sector real value added per hour or per employee. Sections exploring firm-level data define productivity as the firm's real value added per employee or as TFP and draw on ORBIS-iBACH datasets[9] or on firms' balance sheets as available to the NCBs. Details of the data used will be clearly stated in the introduction and Annex of each section.

1.2   A conceptual framework for the analysis of productivity growth

There is a vast body of research on productivity growth drivers, based on a wide variety of growth theories, modelling techniques and types of data. These range from theoretical models using a macroeconomic perspective to microeconomic

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[6]   AMECO is the annual macro-economic database of the European Commission's Directorate General for Economic and Financial Affairs.

[7]   Defined as the difference between output and input growth.

[8]   EUKLEMS is a database containing measures of economic growth, productivity, employment creation, capital formation and technological change at the industry level for all European Union member states from 1970 onwards. It is the responsibility of the Groningen Growth and Development Centre.

[9]   ORBIS is a database from Bureau Van Dijk and contains accounting information from private companies worldwide. iBACH, from the Bank for the Accounts of Companies Harmonized (BACH) database, is a European Commission initiative. It includes detailed balance sheet information and revenues for non-financial European enterprises.

empirical analysis. A comprehensive overview of such literature is out of the scope of this section. Its aim is, rather, to mention key studies in order to provide a conceptual framework and narrative for the report.

1.2.1 Macroeconomic drivers of productivity growth

Neoclassical growth models based on Solow (1957) assumed that productivity growth, measured as the Solow Residual or TFP growth, is exogenously determined. Later growth models (Romer, 1990; and Jones and Williams, 1998) endogenised TFP growth and assumed it depends on firms' decisions on investment in knowledge, human capital and spillovers[10] (Cohen and Levinthal, 1989; and Griffith et al., 2004).

A later vintage of macro empirical work drawing on growth theory and economic history expanded this framework to seek additional possible drivers of TFP growth (see for example Barro, 1991; Sala-i-Martin, 1997; and Acemoglu and Dell, 2010). A recent example of this work is Dieppe (2020), which explores partial correlations between productivity growth and some of its possible drivers in a large set of developing and developed countries using a Bayesian framework. The exercise shows that key initial conditions for subsequent productivity growth include higher investment, a better educated workforce, stronger institutions, more innovation, higher urbanisation and greater macroeconomic stability. Interestingly, the relative importance of these conditions changes over time, with openness (broadly defined and including participation in global value chains and foreign direct investment) and innovation gaining importance in the most recent period.[11]

The work stream has carried out a similar correlation analysis between various structural drivers and TFP growth, focusing on the EU. The exercise first accounts for the high cross-sectional dependence of EU countries as a result of financial and institutional links, and then correlates country-specific TFP growth with a large range of structural factors.[12] The results show that while labour market regulations hamper productivity growth, ICT patenting and financial openness have a positive and statistically significant correlation with cross-country differences in TFP growth. The tax structure is also found to be important: a tax mix that puts more weight on real estate and rent-seeking activities as opposed to production factors such as labour is found to favour TFP growth. More details can be found in Annex 1.

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[10] Spillovers refer to the inter-firm transfer of knowledge, be it voluntary or involuntary. Involuntary knowledge transfer occurs because knowledge is often regarded as a public good, i.e. non-rival and non-excludable. Spillovers can be relatively large. Jaffe (1986), for example, estimates that if all firms increased R&D spending by 10%, total patents would increase by 20%, with more than half the increase coming from a pure spillover effect.

[11] See also Masuch et al. (2018) for a thorough account of structural reforms with an impact on productivity growth.

[12] For this analysis we use a large set of structural (macro) indicators covering EU27 countries and the United States. The methodology is based on a panel factor model of TFP growth that disentangles the common productivity component across economies from purely idiosyncratic TFP dynamics. The latter element measures how a country performs compared to the regional average. For more details on methodology, data and results, please refer to Annex 1.

1.2.2 From macro to micro drivers of productivity growth

A distinctive characteristic of mainstream neoclassical growth models is that they are based on the notion of a representative firm and perfect competition in factor markets. Based on these assumptions, the workhorse growth model concludes that aggregate productivity growth can only be fostered in the medium to long term by policies designed to change representative firms' incentives to innovate.

A different strand of literature inspired by the Schumpeterian idea of creative destruction focuses on market selection mechanisms as drivers of growth; these models assume that firms with different technology and productivity levels coexist in the same market. Early theoretical models provide a formal explanation to Schumpeter's creative destruction process related to the process of learning by firms. Jovanovic (1982) describes a process of passive learning whereby new firms learn about their profitability over time. If profitability is below a certain threshold, firms contract or exit the market. By contrast, Ericson and Pakes (1995) assert that firms are active in the process of learning about their environment and invest to increase their productivity. Returns from investment determine the expansion, contraction or exit of the firm. Aghion and Howitt (1992) propose an endogenous growth model with creative destruction, where the creator of a new innovation obtains monopoly rents until others imitate or until the next innovation comes along, at which point the knowledge underlying the rents becomes increasingly or fully obsolete. According to the model developed by Caballero and Hammour (1994) to explain the importance of the entry and exit of firms, new technology can be adopted only by new establishments; therefore growth occurs only via entry and exit, which requires output and input reallocation. The common thread running through these models is the assumption that firms with different technology and productivity coexist in the same market.[13]

Increasing availability of firm-level data during the 1990s confirmed the existence of large firm heterogeneity within narrowly defined sectors, and of large flows of labour and capital across firms. The main stylised facts unveiled by firm-level data are summarised in Caves (1998), Bartelsman and Doms (2000), Foster et al. (2002) and Syverson (2011). Two of the most striking, pervasive and important of those facts refer to: i) the large-scale reallocation of outputs and inputs across firms, and ii) the large dispersion in firm size, productivity and growth rates within sectors. Regarding resource reallocation, early work by Davis and Haltiwanger (1999) showed that in the United States more than one in ten jobs are created and destroyed every year. Labour (and capital) reallocation occurs as a result of the expansion and contraction of incumbent firms, and firms' entry and exit. Although the pace and relative importance of reallocation might depend on the sector and moment of the cycle, it has been shown to occur mainly within, rather than across, sectors. And regarding the second point, firms' performance is highly dispersed within narrowly defined sectors, across all countries, sectors and years. Chart 2 (left panel) shows that in the EU the productivity level of the top 10% most productive firms in any given sector is from three to five times higher than the productivity of the bottom

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[13] A substantial strand of literature has explored the reasons for the coexistence of firms with different productivity levels in a market economy. For a review see Foster et al. (2002) and Syverson (2011).

10% of firms. Chart 2 (right panel) shows that the productivity distribution within any given sector is not only highly dispersed but also extremely skewed, having a very long right-tail and being most density concentrated around low levels of productivity. The consequence is that aggregate productivity growth is mainly driven by firms at the right-tail, i.e. at the productivity frontier, which is consistent with the view of endogenous macro-based growth models.

Firm heterogeneity, together with the existence of massive flows of resources across firms, implies that resource reallocation can enhance productivity. If production resources are reallocated from low to high-productivity firms, aggregate productivity growth could increase even when average firm productivity does not change. The important policy implication is that policy has a role to play in improving and facilitating resource reallocation, thus enabling the expansion and entry of high-productivity firms and the contraction and exit of their low-productivity counterparts.[14]

Chart 2

Within-sector dispersion in firms' labour productivity level in selected EU countries (left panel) and labour productivity density function in manufacturing (right panel), average 2001-13

Within-sector dispersion in firms' labour productivity level in selected EU countries, average 2001-13	Labour productivity density function in manufacturing, average 2001-13
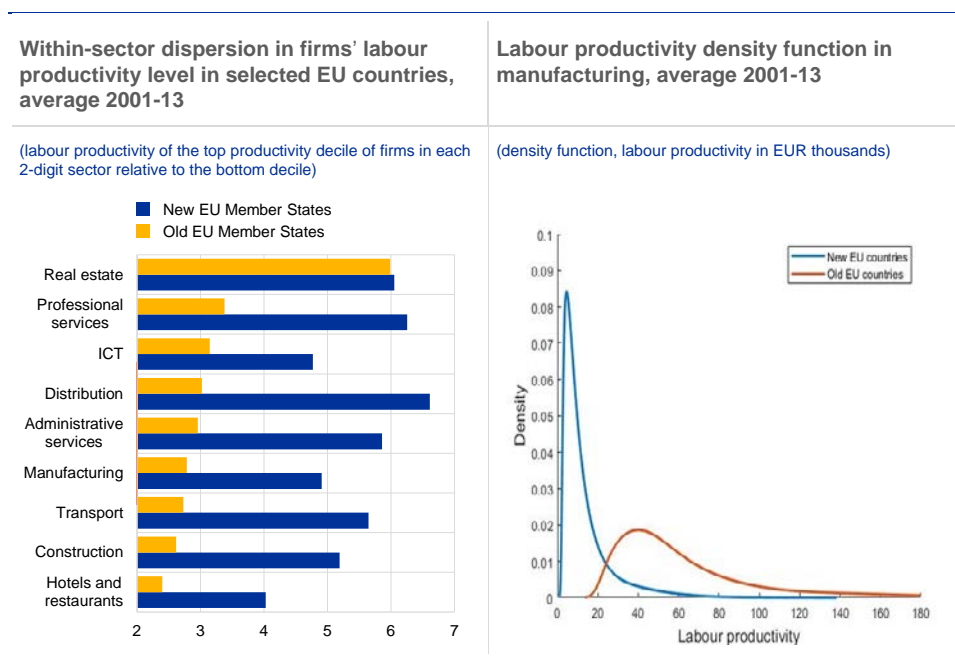
Sources: Giordano and Lopez-Garcia (2021) based on CompNet data.
Notes: Left panel: The old EU Member States are: Belgium, Denmark, Spain, France, Italy and Finland. The new EU Member States are: Croatia, Estonia, Lithuania, Hungary, Poland, Romania, Slovenia and Slovakia. The ratios in each 2-digit sector are aggregated to the macro-sector level using value-added shares; unweighted averages are taken across countries and years. 2013 data are not available for Lithuania, Hungary, Romania and Slovenia. Right panel: Unweighted averages are taken across countries and years. Labour productivity is measured as real value added per employee and expressed in EUR thousands. The chart refers to firms with at least 20 employees in manufacturing.

To connect micro-based findings with macro-based growth models, it is useful to express aggregate productivity as the sum of two components: the

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[14] Note that if the only factor at play is low-productivity firms shrinking or exiting the market, with no expansion or entry of other more productive firms, aggregate productivity growth might increase but welfare and aggregate output will decrease. Hence for resource reallocation to be productivity-enhancing and to increase output and welfare, both the destruction/downsizing of low-productivity units and the creation/expansion of high-productivity units are required.

unweighted average of firm productivity and the allocation of economic weight across firms with differing productivity levels. Aggregate (or sector) productivity A_t is the weighted average productivity of all firms operating in the market concerned (aggregate economy or sector) and can therefore be rewritten as the sum of the unweighted average of firm productivity and the covariance between a firm's weight and productivity.[15]

$$A_t = \sum \omega_{it} A_{it} = \sum A_{it} + \sum (\omega_{it} - \bar{\omega}_t)(A_i - \bar{A}_t) \tag{1}$$

where ω_{it} refers to the weight (market share) of firm i, A_{it} to its productivity and $\bar{\omega}_t$ and $\bar{A}_t$ to the average firm weight and productivity in the market of reference at time t. Aggregate productivity will he higher if firms become more productive (within-firm productivity growth) or if the weight of relatively more productive firms increases (between-firm reallocation).

Figure 1

Drivers of aggregate productivity growth
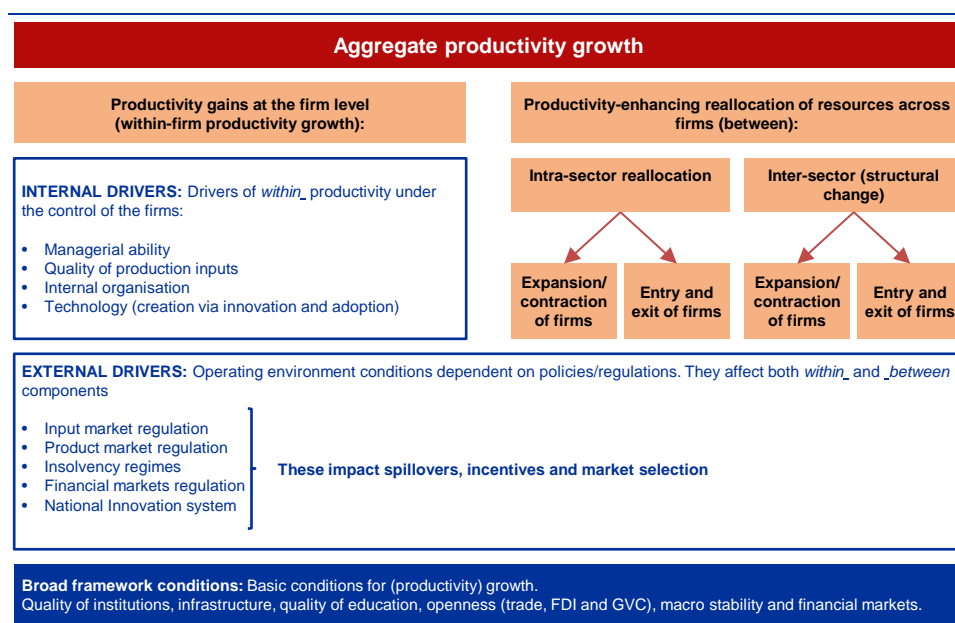
Sources: ECB based on Syverson (2011)

In this framework, aggregate productivity growth drivers and framing policies can be classified depending on whether they enhance firm-level productivity growth and/or facilitate resource reallocation. Figure 1 shows a schematic representation of the drivers of aggregate productivity growth based on Syverson (2011). According to equation (1), aggregate productivity growth depends on productivity growth within firms and on reallocation of resources between firms, which results from the expansion/contraction of incumbents and entry to and exit from the market. Within-firm productivity growth hinges on internal drivers that are

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[15]   See Baily et al. (1992), Olley and Pakes (1996), Foster et al. (2002) and Bartelsman et al. (2013) for similar decompositions of aggregate productivity level and growth.

dependent on firms' decisions related to the quality of production inputs. Broadly speaking, they also include managerial ability, internal organisational decisions and technology creation and adoption arising from investment in knowledge. Those decisions are also affected by external drivers, including for example market regulation, and framework conditions that set incentives for innovative investment, shape spillovers and affect the market selection process, so that only productive firms thrive. The bottom of the chart captures the fact that productivity growth requires certain basic conditions related to factors such as institutional quality, educational systems and country openness.

1.3   Report road map

Besides the introduction and conclusions, the report is organised in four sections, as described below.

Section 2 shows relevant productivity-related trends in EU countries and includes comparisons with the United States. Section 2.1 provides the macroeconomic picture and context for the report by presenting the main stylised facts related to aggregate productivity growth in the EU and the euro area, including in comparison with the United States. Section 2.2 uses sector-level data to explore the role, in explaining aggregate productivity growth trends, of changes in the relative importance of economic sectors resulting from structural changes triggered by economic development or sector-specific shocks. The section includes an in-depth analysis of productivity trends across different countries and economic sectors. Section 2.3 uses firm-level data to assess the relative importance, for sector productivity growth, of the reallocation of resources across firms and within-firm productivity growth. The decomposition of sector productivity growth follows the methodology proposed by Melitz and Polanec (2015) and uses a micro-distributed approach.

Section 3 examines the factors and drivers underlying within-firm productivity growth, with the focus on the role of technology. The main reasons for the emphasis on technology are twofold. First, technology creation and its use in production processes in the United States have been flagged as one of the key factors behind the US-EU productivity gap (van Ark et al., 2008). Second, technology has been at the centre of the productivity debate because of the "productivity paradox": despite recent technological advances, productivity growth continues to be very subdued.[16] Section 3.1 provides a review of the extensive literature on the impact of technology on productivity growth and then describes productivity developments in sectors of differing technology intensity. Section 3.2 explores technology creation and diffusion in the EU from a macro and a micro perspective.

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[16]   Note that this report does not explore the differential impact of the latest vintage of technology improvements, including artificial intelligence, machine learning, robotics etc. The reason is that the impact of digitalisation on the economy, including on productivity, has already been the subject of ECB analysis, including in the context of the strategy review. See Anderton et al. (2020a) and Anderton et al. (2020b).

Section 4 explores the literature and key facts related to the reallocation of resources across firms. The large dispersion in firm size and productivity even within narrowly defined sectors implies that resource reallocation across firms can be productivity-enhancing. However, the contribution of such reallocation to aggregate productivity growth has been declining in the EU since before the global financial crisis. There is an extensive body of literature exploring the role of the "increasing misallocation of resources" in the productivity growth slowdown. Section 4.1 provides an overview of the literature and carries out a meta-analysis of the broad strand of empirical papers seeking to quantify the TFP cost of resource misallocation.[17] Section 4.2 explores the contribution of resource reallocation as a result of the entry and exit of firms to aggregate productivity growth in the euro area. To this end, the section uses firm-level data and distinguishes between the short and medium-term impacts of net entry on productivity growth. Section 4.3 focuses on the "zombie" phenomenon: the delayed exit of weak firms, which prevents the reallocation of resources towards other, more productive, uses in the economy. Using a novel firm-level dataset, the section analyses the dynamics and characteristic of zombies in the European Union as well as the existence of possible contagion effects.

Section 5 explores other topics affecting productivity growth, including the impact of monetary policy, global trends and the possible impact of the COVID-19 shock. The analysis draws on studies carried out by the work stream and other ESCB colleagues as part of the monetary policy strategy review launched by the ECB in February 2020. Section 5.1 provides an overview of the literature on the impact of monetary policy on productivity growth, enriched with the work stream's analysis.[18] Section 5.2 reviews long-term economic trends that have a possible impact on productivity growth, including globalisation, the ageing of the population, digitalisation and climate change. The section summarises the main insights of different work streams of the ECB's strategy review. Section 5.3 reviews the small amount of evidence available so far, as well as the channels of impact, of the COVID-19 shock on aggregate productivity growth.

The concluding section discusses the implications of the findings for productivity growth and for monetary policy, also going forward. It also proposes a research agenda based on a monetary policy perspective.

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[17] A meta-analysis is a statistical analysis that combines the results of multiple scientific studies on one given topic. It is a very useful tool for gaining a deeper understanding of the state of research, the impact of publication bias, the different methods used and sample composition effects on the estimates.

[18] The section is based on a separate piece of work by the work stream focusing exclusively on this topic in the context of the strategy review.

2 Productivity trends in the EU

2.1 Setting the stage: the macro picture

This section establishes the context for the rest of the report by presenting the main stylised facts related to aggregate productivity growth in the EU and the euro area, including in comparison to the United States. The starting point is an analysis of the main factors that have a role in raising living standards, approximated by income per capita growth: the growth in labour productivity and in hours worked per capita. The analysis compares EU developments in income per capita and its main contributing factors with those in the United States (Section 2.1.1). Next, the relative contribution to labour productivity growth of capital deepening (i.e. change in capital intensity), capacity utilisation and TFP growth across countries and over time is shown using an enhanced growth accounting framework which takes time-varying capacity utilisation into account (Section 2.1.2).

The analysis uses AMECO data for EU27 countries and the United States. In charts showing long-term trends, the aggregate for the EA12[19] (or EA10: EA12 excluding Greece and Austria) as well as results for the four largest euro area countries are shown. All aggregates are weighted averages using the GDP share of each country as weight. Labour productivity is computed, unless otherwise stated, as PPP-adjusted GDP at 2010 constant prices per hour worked in order to capture the intensive labour adjustment margin. Aggregate TFP growth is measured as a Solow residual, that is, as the difference between the growth of GDP at constant prices and a weighted sum of the change in inputs used for production (labour and capital) and capacity utilisation. Most charts refer to the period from 1995 to 2019 although longer term series are used for a reduced number of countries to present trends over a longer time frame. For exposition purposes, results are averaged over 4 sub-periods: pre-euro, which runs from 1995 to 2001 given that we consider only the physical introduction of the euro; pre-crisis (2002-07); crisis (2008-13) and recovery period (2014-19).

The main findings of the section are that labour productivity growth is a key driver of a country's living standards, especially where hours worked per employee and demographics limit the growth of hours worked per capita. However, labour productivity growth has been declining since at least the 1970s. Up to the global financial crisis, the main factor behind the decline was the diminishing contribution of TFP growth. In the post-crisis period, however, capital intensity resulting from weak investment and the recovery of employment levels have also contributed to sluggish labour productivity growth.

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[19] EA12 includes Belgium, Germany, Ireland, Greece, Spain, France, Italy, Luxembourg, Netherlands, Austria, Portugal and Finland.

2.1.1 Labour productivity growth as a key driver of a country's living standards

In 2019 income per capita in the EA12 stood at 77% of that of the United States (Chart 3, left panel). There is, however, large country variation, with Germany at 86% and Spain at 66% of US income per capita in the most recent year for which figures are available. The euro area's convergence towards US levels stalled between 1995 and 2005, to pick up again thereafter. Taking the euro area "big four" (Germany, Spain, France, and Italy), the only exception was Italy, where income per capital diverged from that of the United States until the mid-2000s and then stalled between then and 2019.[20]

Chart 3

PPP-adjusted real GDP per capita in the EA12 relative to the United States over time (left panel) and PPP-adjusted real GDP per capita, labour productivity and hours intensity in the EA12 relative to the United States (right panel)

PPP-adjusted real GDP per capita in the EA12 relative to the United States over time	PPP-adjusted real GDP per capita, labour productivity and hours intensity in the EA12 relative to the United States

(index US =100%)

- EU27
- Germany
- Spain
- France
- Italy
- EA12

(index US =100%)

- Hour intensity
- GDP per hour
- GDP per capita
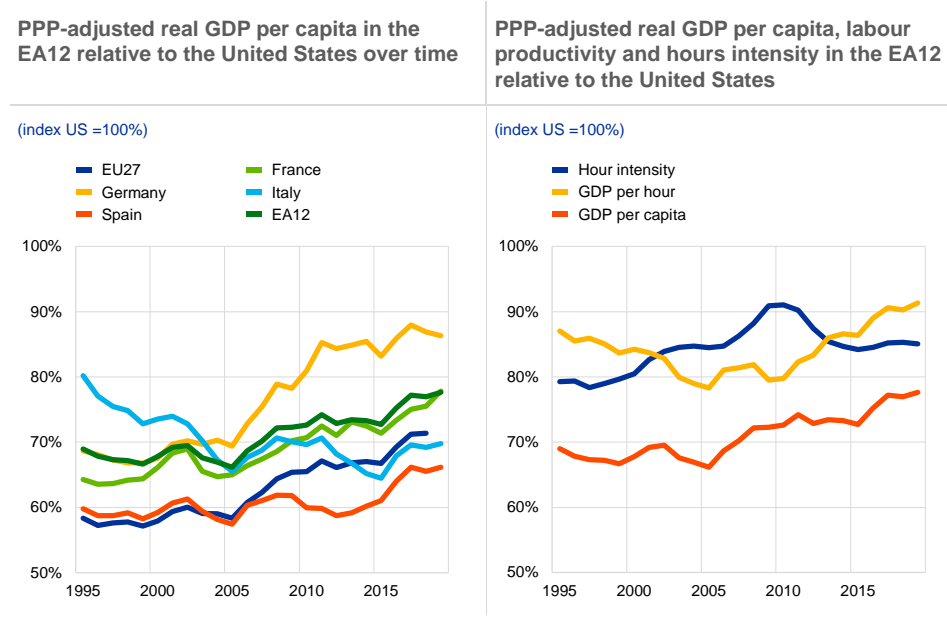
Source: Own calculations using AMECO data.
Notes: PPP stands for purchasing power parity. EA12 includes Belgium, Germany, Ireland, Greece, Spain, France, Italy, Luxembourg, Netherlands, Austria, Portugal and Finland.

One way to trace the sources of the EA12's gap with the United States is to rewrite income per capita as the product of labour productivity (GDP per hour worked) and hours worked per capita (also called "hours intensity").[21] Hours intensity depends on labour market developments – hours worked per employed person, the employment rate and the labour force participation rate – and on demographics captured by the share of population in working age (see Annex 2 for more details). Chart 3 (right panel) shows the dynamics of labour productivity and hours intensity in the EA12 relative to the United States over time. There are four

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[20] The series in Chart 3 are PPP-adjusted. Non-adjusted series are shown in Annex 2.

[21] $\frac{GDP}{Population} = \frac{GDP}{Hours\ worked} \times \frac{Hours\ worked}{Population}$. The growth rate of income per capita can thus be approximated as the sum of the growth rates of labour productivity and hours intensity.

distinct phases. Up to the mid-2000s, income per capita in the euro area did not converge towards that of the United States, as a result of two counterbalancing forces: higher growth in hours intensity on the one hand, and lower productivity growth rate on the other. From the mid-2000s until the global financial crisis the convergence process picked up as a result of the slowdown in US productivity growth, as shown in Chart 1 (right panel). The larger drop in employment rates during the global financial crisis in the euro area relative to the United States slowed the pace of income per capita convergence up to 2015 (see also Chart 4). The last phase starts in 2015 and shows a pick-up in convergence with the United States thanks to stronger productivity growth in the euro area.

Chart 4

Contributions to growth in hours per capita, different periods, EA12 and the United States

(in percentage points)
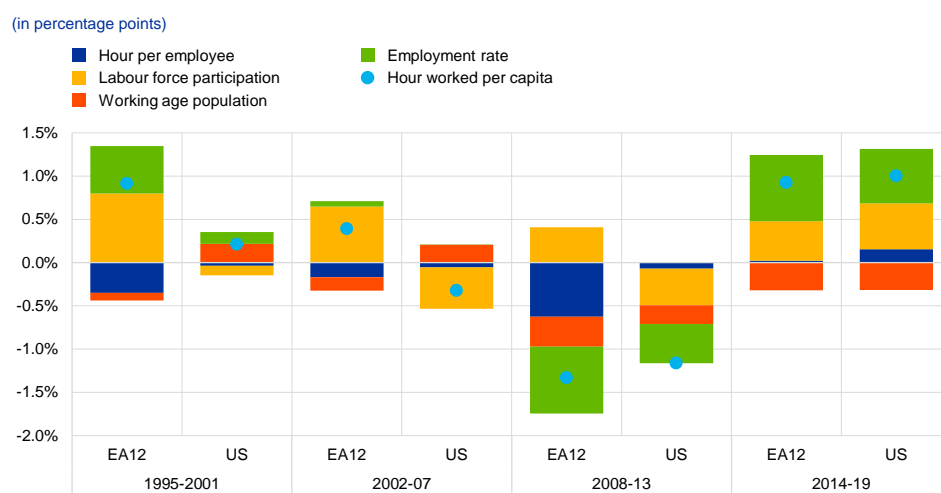
Source: Own calculations using AMECO data.
Note: EA12 includes Belgium, Germany, Ireland, Greece, Spain, France, Italy, Luxembourg, Netherlands, Austria, Portugal and Finland.

The convergence of hours intensity to US levels up to the global financial crisis was driven by higher labour force participation growth in the euro area relative to the United States, which offset less favourable demographic trends (Chart 4). Labour force participation has consistently been growing faster in the euro area than in the United States, thanks to the increasing participation of women and elderly workers. This facilitated convergence with the United States, in terms of hours intensity, until the global financial crisis. However, the working age population in the United States grew more strongly than in the euro area over the whole period thanks to very dynamic immigration flows. The larger (negative) impact of the global financial crisis on the euro area labour market, relative to the United States, halted the convergence process in hours intensity.

2.1.2 A growth accounting decomposition of productivity growth

A good starting point to capture the sources of labour productivity growth in each period is to apply a growth accounting framework. Growth accounting

exercises rest on the standard neoclassical framework and, under certain assumptions, decompose labour productivity growth into the contribution of capital deepening and that of TFP growth. We expand the specification to account for time-varying capacity utilisation, which would otherwise bias the TFP measure. For further details about the methodology and TFP measurement issues please refer to Box 1.

Box 1

Measuring TFP growth and its contribution to labour productivity growth: the importance of accounting for capacity utilisation

TFP measures the portion of output that cannot be explained by the amount of factor inputs used in the production process. It is thus a key indicator of economic efficiency. TFP is not directly observable and needs to be estimated. A common procedure, following the seminal work of Solow (1957), is to extract TFP by employing growth accounting techniques using data on prices and quantities from national income and product accounts.[22]

The starting point is a constant return-to-scale Cobb-Douglas production function, as shown in B1.1:

$$Y_t = A_t K_t^{\alpha_t} L_t^{1-\alpha_t} \tag{B1.1}$$

where Y_t is output in period t, K_t is capital stock, L_t is hours worked, A_t is TFP, and α_t is the capital income share. Logarithmic differentiation with respect to time means that TFP growth gA_t can be expressed as:

$$gA_t = gY_t - \alpha_t gK_t - (1-\alpha_t)gL_t \tag{B1.2}$$

where gY_t denotes output growth, gK_t the growth rate of capital input and gL_t the growth rate of labour input.

As outlined in Comin (2010), the Solow residual gA_t reflects TFP growth accurately if the production function is of the Cobb-Douglas-type, if there is perfect competition on product and factor markets, and if the underlying data adequately capture the required information on quantities and prices.

Regarding the latter, mismeasurement poses a significant challenge for determining TFP. Labour input, for example, often approximated by hours worked or persons employed, is typically not homogeneous and, critically, depends on the composition or quality of the workforce.[23] Measurement issues also play a prominent role for capital inputs. The stock of fixed capital goods is often unobservable and has to be estimated.[24] Limited information regarding depreciation, obsolescence and the decommissioning of capital can lead to substantial measurement errors.[25] Moreover, the inability to fully account for quality improvements can distort volume measures for the stock of capital. This might be particularly significant for information and communication equipment

[22] See Hulten (2010) for a detailed survey of the growth accounting literature.
[23] See, for example, OECD (2001) and Nilsen et al. (2011).
[24] See, for example, Diewert and Nakamura (2007).
[25] See, for example, Corrado et al. (2005, 2009), and Burda and Severgnini (2014).

and for intangible assets.[26] Despite continuously broadening the definition of fixed capital in the national accounts in recent decades, official estimates still account for only a limited range of intangible assets and probably fail to capture their growing economic importance.[27]

In addition to statistical challenges, time-varying capacity utilisation can substantially distort the measurement of inputs and therefore estimates of TFP and its contribution to labour productivity growth. Not-fully-utilised production factors, for example, can lead to an overestimation of factor inputs and an underestimation of TFP growth. Since production factors are typically utilised procyclically, this might bias TFP measurement more markedly in boom and bust phases. While statistical mismeasurements are hard to resolve, changes in utilisation rates can be accounted for when calculating TFP developments and the contribution of TFP growth to labour productivity growth.

Incorporating a proxy for the degree of capacity utilisation into the growth accounting framework is one way to adjust conventional TFP estimates for changes in utilisation rates (see Basu et al., 2006). The production function in B1.1 can thus be re-formulated as

$$Y_t = A_t (c_t K_t)^{\alpha_t} L_t^{1-\alpha_t} \tag{B1.3}$$

where c_t captures time-varying capacity utilisation of capital (assuming that the varying utilisation of employment is already accounted for by hours worked). Letting $y_t \equiv Y_t/L_t$ denote output per hour worked and $k_t \equiv K_t/L_t$ capital intensity, log-differentiating with respect to time yields the following expression for labour productivity growth:

$$\underbrace{gy_t}_{\substack{labour\ productivity \\ growth}} \approx \underbrace{gA_t}_{TFP\ contribution} + \underbrace{\alpha_t gc_t}_{\substack{capacity\ utilisation \\ contribution}} + \underbrace{\alpha_t gk_t}_{\substack{capital\ intensity \\ contribution}} \tag{B1.4}$$

Accordingly, TFP growth gA_t can be approximated as the difference between aggregate labour productivity growth gy_t and the weighted sum of the change in capital capacity utilisation gc_t and capital intensity growth gk_t or capital deepening. One way of capturing the development of time-varying capacity utilisation is to resort to survey-based capacity utilisation indicators, which provide information on the dynamics of capacity utilisation and are available for all EU countries and cover a prolonged period of time.[28]

For data availability reasons, the growth accounting results in the main text are generated using a hands-on approach which closely follows formula B1.4 outlined above. Basu et al. (2006) and Comin et al. (2020), in contrast, apply a more sophisticated method to adjust TFP growth estimates for changes in capacity utilisation. Their approach makes it possible to take sector-specific characteristics and a possible endogenous relationship between changes in TFP and capacity utilisation into account.[29] Using this alternative method, the contributions of TFP growth, capital

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[26]   See Byrne and Corrado (2017), Byrne et al. (2017), Ewens et al. (2019).

[27]   See Corrado et al. (2018).

[28]   For this particular exercise, data for GDP and hours worked were sourced from Eurostat and capital stock estimates from the AMECO database of the European Commission. The capacity utilisation indicator is based on the business survey data from the European Commission for the EU countries and, for the United States, from the Board of Governors of the Federal Reserve System: FRED, Federal Reserve Bank of St. Louis.

[29]   See also Deutsche Bundesbank (2021).

intensity growth and capacity utilisation to labour productivity growth were calculated for a subset of countries in the euro area (see Annex 2). While the aggregate contributions of capacity utilisation over the different periods are broadly in line with those shown in the main text, there are some differences in some countries. Nevertheless, both methods illustrate that, in view of the highly cyclical nature of capacity utilisation, changes in it generally have only a small effect on TFP growth rates in the long run.

In the euro area the main contributor to labour productivity growth, defined as growth in real GDP per hour worked, has been TFP growth (Chart 5, left panel). On average across countries and years, TFP growth has contributed about 60% to labour productivity growth. This contribution, however, has declined over time – a decline that, as will become clear throughout the report, is a reflection of manifold factors. Although the average contribution of capacity utilisation over the whole period is rather small, it played an important role during specific periods. During the global financial crisis, for example, the sharp drop in capacity utilisation dragged labour productivity growth down, while its recovery contributed to the growth seen in the post-crisis period. Capital deepening contributes on average about 40% to productivity growth. That average masks a very high contribution during the global financial crisis as a result of the large drop in total hours worked,[30] and a very small negative contribution during the post-crisis period as a result of weak investment and employment recovery. For more details on capital-intensity dynamics, see Box 2. Developments in the United States have been similar to those in the euro area, with TFP growth being the main factor behind labour productivity growth around the turn of the century and its contribution declining in more recent years (Chart 5, right panel). However, in the United States capacity utilisation did not contribute as much to labour productivity growth in the post-crisis period as it did in the euro area.

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[30] The post-crisis slowdown in capital intensity is more pronounced if computed in terms of employees instead of hours worked. The difference in the contribution of capital per employed worker relative to capital per hour can be explained by the fact that employment in the recovery period was driven to a large extent by part-time arrangements, with fewer hours worked.

Chart 5

Contributions to growth in GDP per hour worked in EA12 (left panel) and in the United States (right panel), different periods
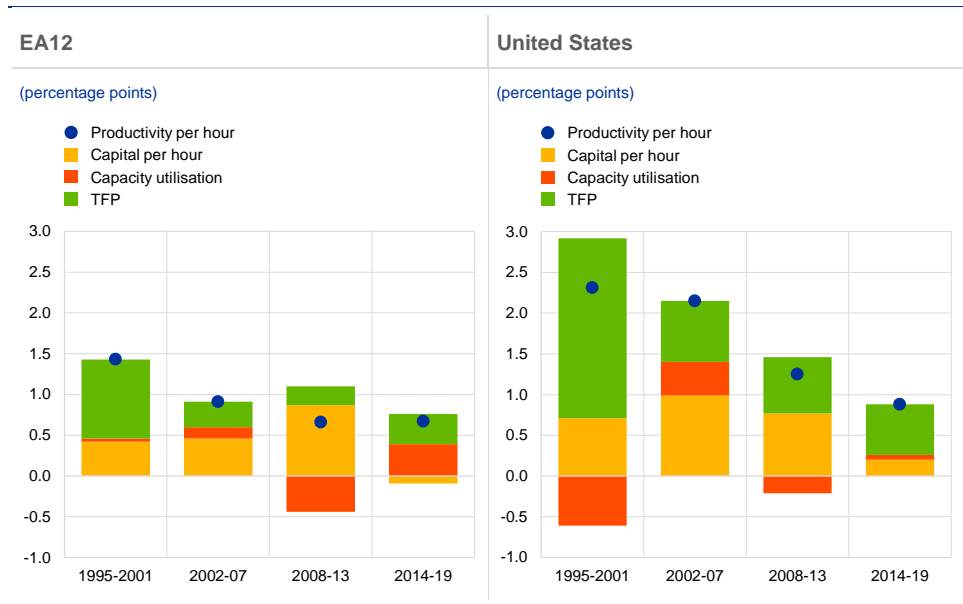
Sources: Own calculations using AMECO, Eurostat, European Commission and Board of Governors of the Federal Reserve System (US) data.
Note: EA12 includes Belgium, Germany, Ireland, Greece, Spain, France, Italy, Luxembourg, Netherlands, Austria, Portugal and Finland.

Box 2

Capital-intensity dynamics in the euro area

Capital deepening refers to the situation where capital per hour worked – or capital intensity – increases in the economy. As shown in the main text, capital deepening is a key driver of growth in labour productivity and, by extension, of output growth, contributing on average between one-third and 40% to labour productivity growth. Chart A (left panel) illustrates the strong relationship between capital intensity and labour productivity growth, while suggesting the pivotal role played by other factors (TFP growth but also changing labour share and capacity utilisation). Capital deepening can also affect TFP gains indirectly, for instance through the contribution of ICT. [31]

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[31] The issue has been extensively discussed in the literature. See, for example, Gordon (2003) and Anderton et al. (2020a).

Chart A

Labour productivity and capital intensity growth, 1947-2018 (left panel) and average annual growth in capital intensity per decade, different regions (right panel)

Labour productivity and capital intensity growth, 1947-2018	Average annual growth in capital intensity per decade, different regions

(y-axis: annual percentage changes in labour productivity growth; x-axis: annual percentage changes in capital intensity)

(annual percentage changes)
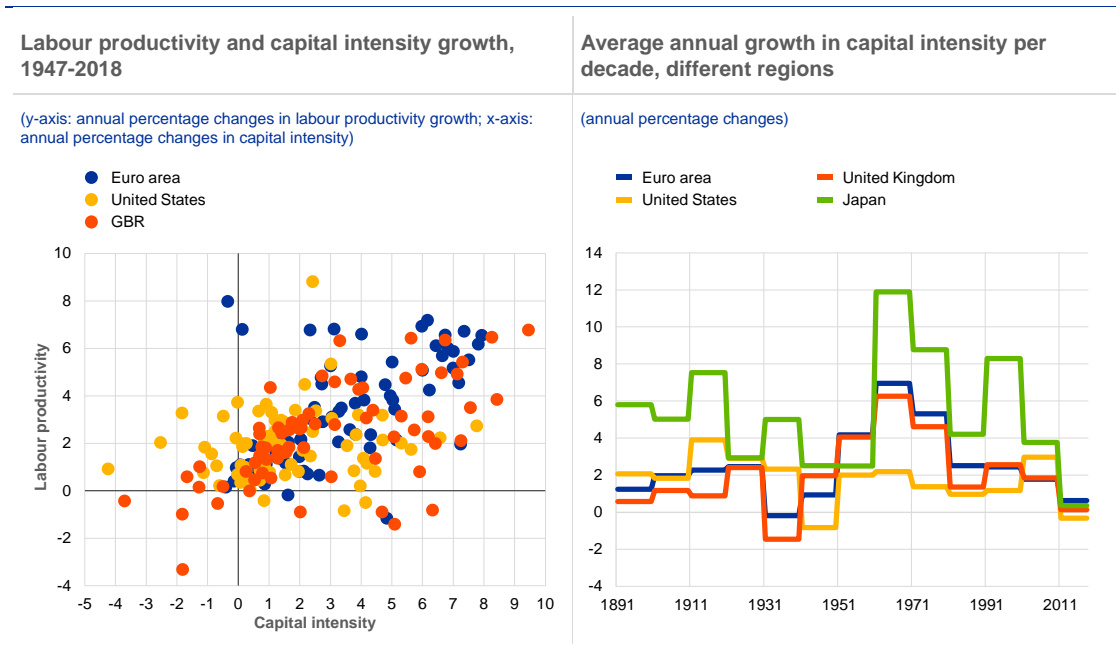
Sources: ECB staff calculations and Bergeaud (2016).
Notes: Left panel: The sample covers the years 1947 to 2018.

As shown in Chart A (right panel), since the end of the 19th century capital deepening has evolved very unevenly across countries. This disparity stems from the different impacts of external events such as wars across developed countries, and from the country-specific timing of successive industrial revolutions. In contrast, the recent slowdown following the global financial crisis, as described in the main text, is broad-based across all advanced economies. Throughout the period 2011-18 the growth in capital intensity ranged on an annual basis from -0.3% in the United States to 0.6% in the euro area.

The broad-based post-crisis slowdown in capital deepening mainly reflects a slower growth in capital stock and a recovery in employment growth. Capital stock growth has decelerated sharply in the euro area, to around 0.9% per year, over the 2013-19 period, less than half of the pre-crisis annual averages. However, the decline in capital deepening also reflects a marked offsetting effect arising from growth in employment, which has been relatively strong vis-à-vis the rebound in activity. Similar developments were at play in other advanced economies, albeit to different degrees, and notably in the United States.[32] These developments result from a combination of factors. Structural reforms introduced during and after the global financial crisis might have helped the strong rebound in employment. The recovery also hinged to a large extent on service activities that are often more labour-intensive and less prone to capital-labour substitution. At the same time, investment in construction (both dwellings and other buildings) has remained stubbornly low (Chart B, left panel). Finally, the gradual transition to an increasingly digital economy is leading to a

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[32]   See also ECB (2017).

shift from investment in machinery and equipment to ICT assets (chart B, right panel). However, the growth of the ICT capital stock has been slower, notably due to its higher degree of depreciation.[33]

Chart B

Capital deepening in construction assets (left panel) and other assets (right panel) in the four largest euro area countries
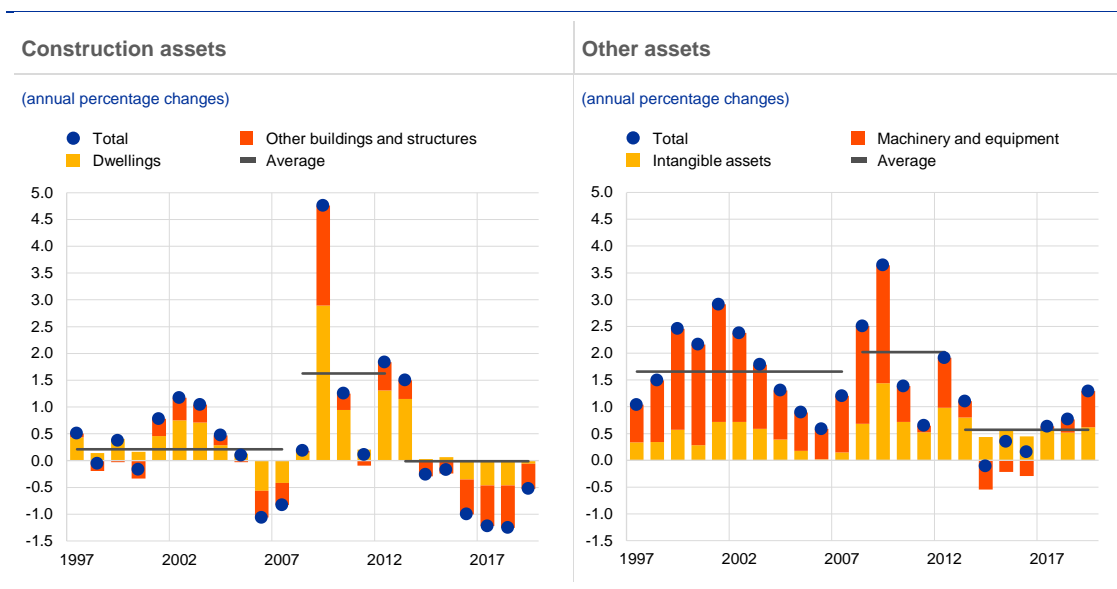
Sources: ECB staff calculations, Eurostat.

TFP growth has contributed less to labour productivity growth in the EU27 than in the EU12 (Chart 6). This can be attributed, at least in part, to the significant role of capacity utilisation in the new Member States of the EU and its effect on the residual measure of TFP growth, particularly during the first period of analysis and up to the global financial crisis. Indeed, capacity utilisation was low in these countries in the 1990s due to the collapse of the former Eastern bloc. This broke down the old economic relationships and left a large part of production capacity poorly utilised until it gained momentum in the following (transition) period. Even though the growth composition of the EU27 has been very similar to that of the EU12 in recent years, TFP growth seems to explain a smaller part of productivity growth in new Member States relative to the EU12. This reflects not just the larger role of capacity utilisation but also a more capital-dependant economic structure than in the old Member States. Indeed, in catch-up countries the industrial sector tends to account for a larger share of the economy than services (see also Section 2.2).

Trend TFP growth has been declining in the largest euro area countries and the United States since at least the 1960s (Chart 7).[34] Trend TFP growth declined in the four largest euro area countries and the United States from an annual average growth rate of about 4% in the 1960s to 1.5% in the late 1980s. It stagnated around that level until the early 2000s and then declined further to the current annual growth rate of just below 1%. While the slowdown in trend TFP growth is a common feature

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[33] However, there might also be a statistical issue involved, owing to the difficulty of valuing these assets. See, for example, Corrado et al. (2005, 2009), and Burda and Severgnini (2014).

[34] Note that TFP growth is not adjusted for capacity utilisation, given the lack of pre-1990s adjusted data.

across all EU27 Member States (Table A2.1 in Annex 2), in some countries the decline was non-monotonic.[35]

Contributions to growth in GDP per hour in EU27, average 1996-2019	Contributions to growth in GDP per hour in EU27, average across countries, different periods
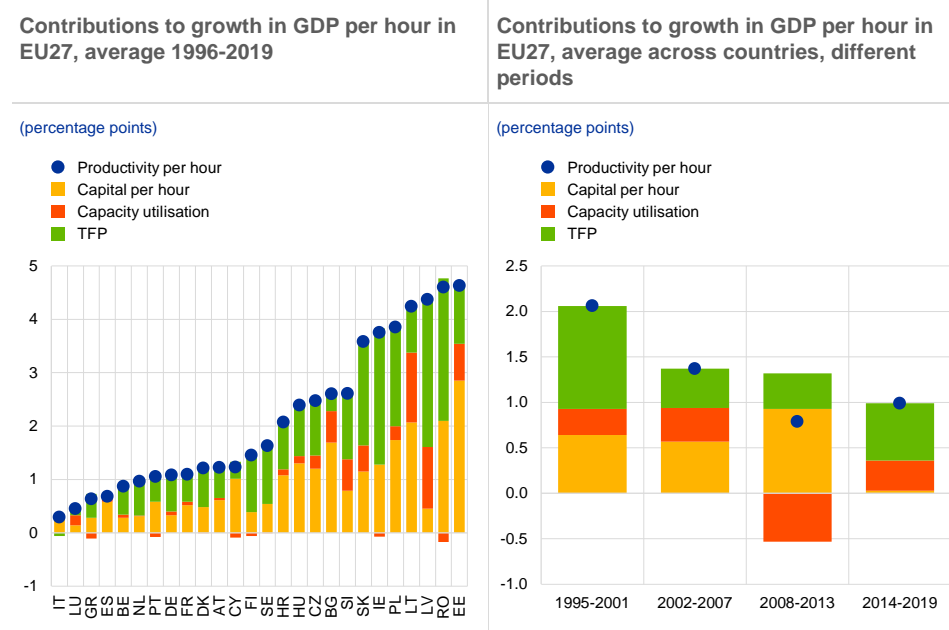
Sources: Own calculations using AMECO, Eurostat and European Commission data.
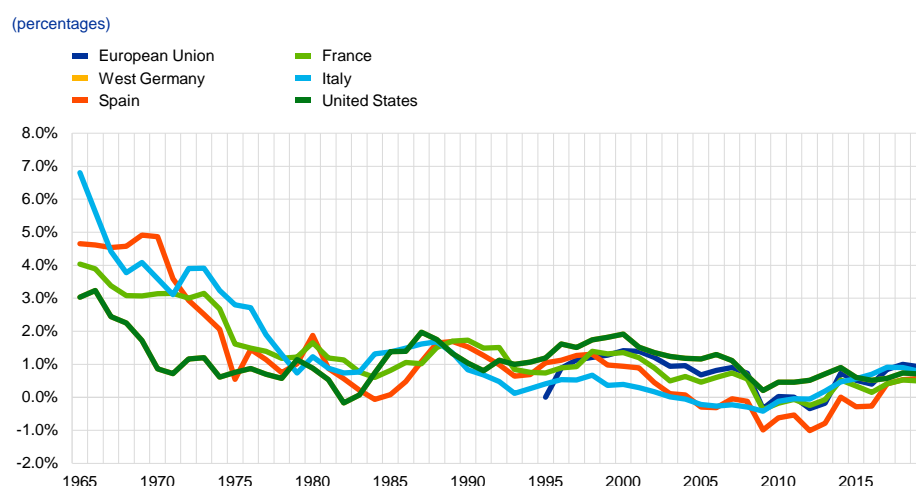
Sources: Own calculations using AMECO data.

To sum up, this section shows that labour productivity growth is a key driver of a country's living standards, particularly in an environment in which hours worked per

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[35] Particularly during the pre-crisis period (2002-07), average TFP growth rates in some countries was below those for the recovery period. In Ireland TFP growth was high in both the 1990s and in the recovery period, driven exclusively by multinationals (see OECD 2018b).

employee and demographics limit the growth of hours worked per capita. However, labour productivity growth has been declining in the EU since at least the 1970s. Up to the global financial crisis, the main factor behind the decline was the diminishing contribution of TFP growth. In the post-crisis period, weak capital deepening has also contributed to sluggish productivity growth.

2.2 The role of resource reallocation across sectors in explaining aggregate productivity trends

Aggregate productivity growth can be computed as the weighted average of sector-specific productivity growth, the weights being the economic share of each sector. Over time the relative importance of economic sectors changes as a result of structural change or shocks impacting different sectors asymmetrically. Given the large average productivity growth differences across sectors, these developments can affect aggregate productivity growth. **This section explores the relative role of the shift of resources across sectors over time in explaining the aggregate productivity growth trends described previously.**

To that end, Section 2.2.1 conducts a shift-share analysis to disentangle the role of changes in sectors' economic weight from the role of intra-sector productivity growth to explain aggregate productivity growth. Section 2.2.2, shows productivity differences in levels and growth rates, across countries and sectors.

The analysis is based on sector level data using the NACE Rev. 2 sector classification (2-digit industry) sourced from EUROSTAT and EU KLEMS. For reasons of data availability in terms of sector and time coverage, the EU covers only 20 countries (EU20[36]). Given the large impact of each country's stage of development on this analysis, the EU region is split into "EU-new" countries, which include all countries that joined the EU after 2004, and "EU-old" countries, which include all those that joined up to and including that year. Productivity is defined as sector's real value added per hour worked. For more details on the data, refer to Annex 3.

The main findings of the section are that productivity growth is driven by intra-sector developments, that is, by the productivity growth of each economic sector rather than by resource reallocation across sectors. Indeed, cross-sector reallocation has contributed very little – and negatively on average – to growth. This is a result of the loss of weight of manufacturing in favour of services sectors, whether less or more productive, such as administrative and support services or scientific and technical services, particularly in the older EU Member States. Despite its loss in employment weight, the manufacturing sector accounted for 20% of annual aggregate productivity growth from 1995 to 2017. In contrast, aggregate productivity growth in the United States is driven less by manufacturing and much more by developments in the ICT sector. Moreover, most sectors growing in productivity over time show an increase in the productivity gap between frontier and laggard countries.

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[36] Belgium, Czech Republic, Denmark, Germany, Greece, Spain, France, Croatia, Italy, Cyprus, Lithuania, Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, and Sweden.

Only in the newer EU Member States is there some productivity convergence across sectors.

2.2.1 How much of the trend slowdown in productivity growth is due to the shift of resources across sectors?

Change in sectors' relative economic weights caused by structural shifts in the economy or asymmetric shocks could have an impact on aggregate productivity growth. In this subsection we analyse the effects of structural change on the development of productivity using a shift-share analysis (see for instance European Commission, 2003; OECD, 2018c; or Dieppe, 2020).[37] This methodology helps trace productivity developments to three effects. First, the "intra-industry effect", which describes that part of productivity growth that results from sector productivity growth, assuming no change in sector weights. Second, the structural "shift effect", which describes the impact of changes in sector weights, measured by sectoral employment shares, on aggregate productivity growth, keeping the productivity of each sector constant. And third, the structural "interaction effect", which captures the interrelation between sectoral productivity growth and changes in sectoral employment shares. For more details about the shift-share methodology, see Box 3.

Box 3
Shift-share methodology[38]

Hourly productivity growth is defined as:

$$P_t = \frac{Y_t}{L_t} = \frac{\sum_i Y_{i,t}}{\sum_i L_{i,t}} \approx \frac{Y_{1,t}}{L_t} + \frac{Y_{2,t}}{L_t} + \cdots \tag{B3.1}$$

where P denotes hourly productivity, Y real value added, L hours worked and i industries.

After calculating differences, expanding some fractions, making some rearrangements and denoting shares and relative productivity using lower-case letters, hourly productivity growth can be expressed as follows:

$$\frac{P_t - P_{t-1}}{P_{t-1}} = \sum_i \frac{\Delta P_{i,t}}{P_{i,t-1}} y_{i,t-1} + \sum_i p_{i,t-1}\Delta(l_{i,t}) + \sum_i \frac{1}{P_{t-1}}\Delta P_{i,t}\Delta(l_{i,t}) \tag{B3.2}$$

The interpretation of the three components on the right-hand side of the equation is as follows. The first component is the intra-industry effect: the sum of individual sectors' productivity growth rates

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[37] A comparison of our results with results from other studies using the shift-share framework must be made with great care, as the country and industry selection, the definition of productivity (hours or heads) as well as the analysed time periods have a strong impact on the results. For a sensitivity analysis to these dimensions, see Annex 3.

[38] The shift-share analysis and the description of the methodology in this box is based on European Commission 2003, pp. 110 et seq. and p. 155. For details on the data and possible issues arising from using national accounts data (e.g. additivity) see Annex 3.

weighted by their respective output shares. It is equal to productivity growth in the absence of structural change if the employment shares of all individual sectors remained constant. The second component, the structural shift effect, is the sum of changes in input (employment) shares, weighted by their relative productivity levels (i.e. the ratio of sector productivity to average productivity). This effect is equal to the contribution to productivity growth of a shift of employment resources from low to high productivity sectors (or vice versa). The third component is the structural interaction effect. This captures the dynamic component of structural change and measures correlations between productivity and employment changes. Positive/negative efficiency gains could interact with the expansion/contraction of specific sectors. This term is positive when the intra-industry and shift effects are complementary (productivity growth is positive in expanding and negative in contracting industries). It is negative when the first two effects are substitutes (productivity growth is positive in contracting industries and negative in expanding sectors). We expect to find a negative sign of the interaction component, as the productivity change and labour input change very often have opposite signs.

The sum of the structural shift effect and the structural interaction effect define the overall structural effect. As the interaction effect is typically very small, indeed almost negligible, the terms "structural shift effect" and "structural effect" are often used synonymously.

In the EU and the United States, the reallocation of resources across sectors, or shift effect, has contributed negatively, albeit to only a small extent, to overall productivity growth.[39] Chart 8 (upper panel) presents the main results of the shift-share analysis for those EU-countries with sufficient data availability for NACE 2-digit industries, labelled EU20, and for the United States.[40] On average for the period 1995-2017, the contribution of structural change (shift effect)[41] to productivity growth amounted to -0.06 percentage points for the EU20 and to -0.11 percentage points for the United States over the period 2002-17.[42] In the years before and after the global financial crisis the negative impact of the shift effect was more pronounced in the EU20, but still small (-0.14 and -0.11 percentage points, respectively). During the global financial crisis the structural effect turned slightly positive because the crisis had a disproportionate effect on some low-productivity sectors, such as construction. Despite the differences in productivity growth between

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[39] Similarly to our results, in almost all studies that include developed countries the shift effect is much weaker than the intra-sector effect and its size decreases over time. In many cases the shift effect is negative or mixed (see, for example, European Commission 2003, which finds it negative for the United States and small but positive for the EU in the period 1996-2000), OECD 2018c (negative for Germany, France, the EU and the United States for the period 2000-10, but positive for Italy, the United Kingdom, and Japan). Dieppe (2020) finds that the shift effect makes a positive contribution to growth for the period 2003-08 and a positive, but very small, contribution for the period 2013-17.

[40] The EU20 includes Belgium, Czech Republic, Denmark, Germany, Greece, Spain, France, Croatia, Italy, Cyprus, Lithuania, Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, and Sweden. Due to data limitations, the analysis for the United States had to be conducted for restricted time periods.

[41] We discuss only the impact of the shift effect, as the interaction effect is mostly negligible.

[42] It is important to note that regional aggregates hide country-specific differences. In Germany, for example, structural change has contributed positively over the whole period, while in France the shift effect is negative in all sub-periods. In both countries, however, the contribution of structural change is almost negligible. In contrast, structural change contributed positively in the pre-crisis period in Italy and in Spain during the crisis, as a result of the declining weight of the construction sector.

the EU20 and the United States, the sign, the development and the relative size of the shift effects in both regions are similar.[43]

The negative contribution of structural change is more pronounced in the catch-up EU economies (Chart 8, bottom panel).[44] Given the heterogeneity of EU countries in terms of economic development, which could affect the results of the shift-share analysis, the exercise is repeated distinguishing between "new" EU Member States – countries that joined the EU in 2004 or later[45] – and "old" EU Members States. EU-new countries exhibit significantly higher productivity growth rates and a larger negative contribution of structural change, in line with standard economic theory on convergence (see also Section 2.2.2). The negative structural shift was most pronounced in the years before the global financial crisis but gradually weakened over time as EU-new economies converged towards EU-old economies. On average, the shift effect or structural change over the whole period contributed -0.30 percentage points to annual productivity growth in EU-new countries. The development of the "old" member countries is similar to that of the EU20 aggregate.

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[43] The results are similar for euro area countries only.

[44] Dieppe (2020) analysed the dynamics of the shift effect for developing countries (in some part "catching up" countries) and concluded that shift effects are more important for developing than for advanced countries, although their importance decreased over time (Dieppe 2020, page 364).

[45] "EU-old" includes Belgium, Denmark, Germany, Greece, Spain, France, Italy, Netherlands, Austria, Portugal, Finland, and Sweden. "EU-new" includes Czech Republic, Croatia, Cyprus, Lithuania, Poland, Romania, Slovenia and Slovakia (See Annex 3 for further data details).

Chart 8

Shift-share analysis for EU20 (top left panel), United States (top right panel), EU-old (bottom left panel) and EU-new (bottom right panel)
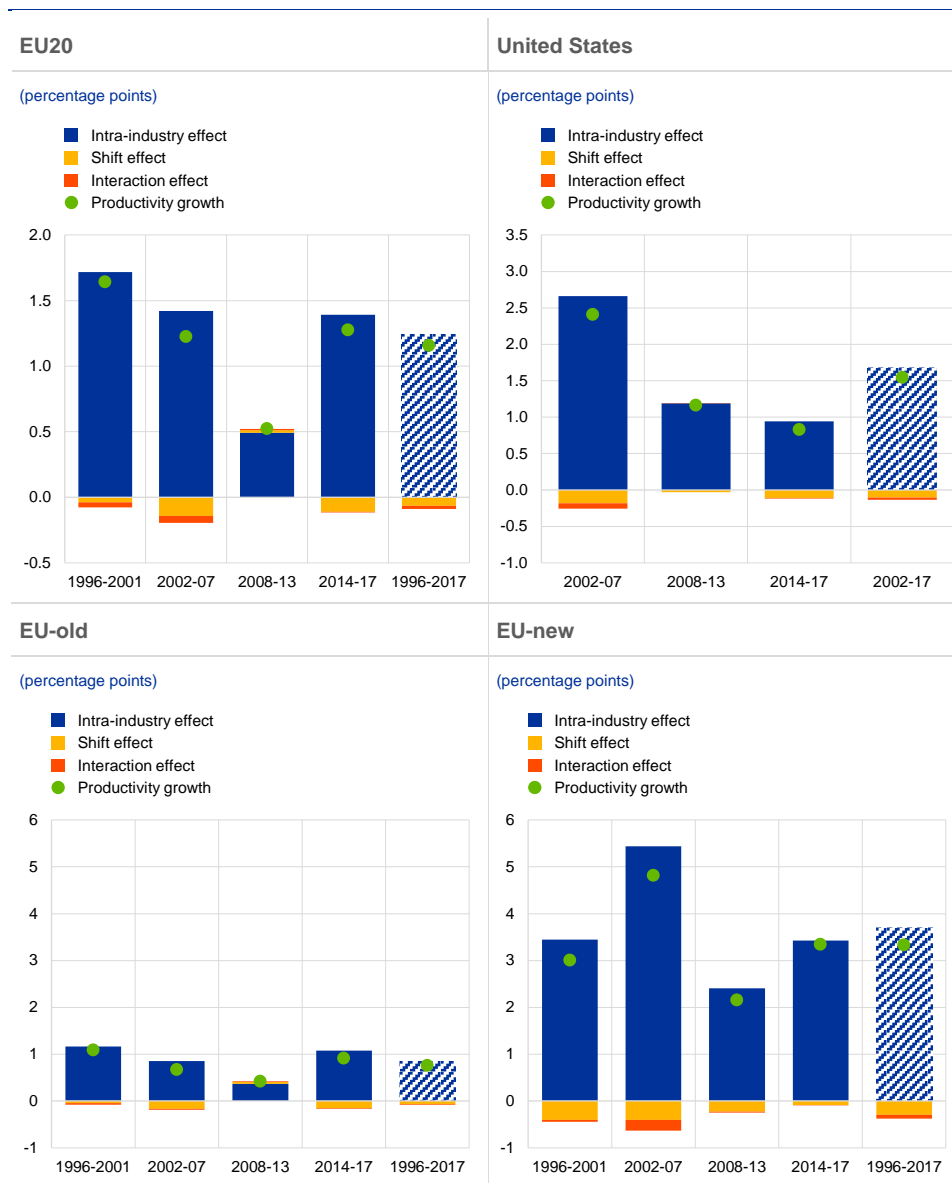
Sources: Own calculations using Eurostat, NACE 2-digit data.

The gradual loss of employment share of manufacturing in favour of both low and high productivity business services explains the small negative shift effect in the EU20 and the United States. Chart 9 shows the growth contributions of individual sectors to the shift effect for the EU20 and the United States. Administrative and support service activities with average low productivity, but also highly productive scientific and technical services, have been gaining employment shares over time (NACE M-N). Highly productive manufacturing (NACE C) and financial and insurance activities (NACE K), as well as low productivity construction (NACE F), have lost importance. The mixed bundle, in terms of productivity, of sectors gaining and losing economic share over time explains the relatively small contribution to aggregate productivity growth of resource reallocation across sectors

over time. Interestingly, the information and communication sector (NACE J and what is termed ICT throughout this study) played almost no role in the development of structural change in Europe. In the United States, manufacturing has contributed negatively, and to a similar extent as in Europe, to the shift effect in the last 20 years. However, the importance of the financial sector and scientific and technical services, as well as administrative and support service activities, has been much weaker. In contrast to the EU, the US technology sector ("information and communication", NACE J), contributed negatively to structural change.

The importance and contribution of individual sectors to the overall negative shift effect are very similar in new and old EU Member States (see Annex 3). The catching-up process has been accompanied by a stronger negative shift, driven in particular by manufacturing's loss of employment weight.

Chart 9

Growth contributions of sectors to shift effect: EU20 (left panel) and United States (right panel)
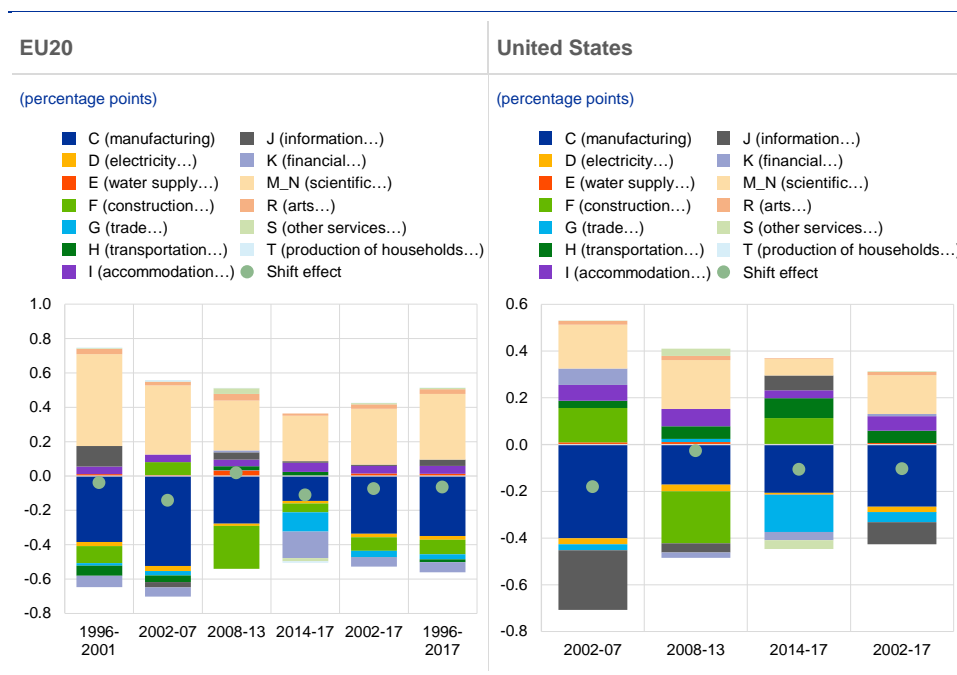
Sources: Own calculations using Eurostat, NACE 2-digit data.

Aggregate productivity developments are mainly driven by the intra-industry effect, i.e. by the productivity growth of each sector. On average over the period 2002-17, the intra-industry effect accounted for 1.07 percentage points of average annual productivity growth of 0.97% in the EU20, and for 1.68 percentage points of average annual productivity growth of 1.55% in the United States.

The main driver of the large intra-industry effect in Europe is manufacturing, unlike in the United States, where the ICT sector plays a major role. Chart 10 shows the contributions of the different sectors to, in turn, the intra-industry contribution to aggregate productivity growth for the EU20 and for the United States. On average over the period 1995-2017, manufacturing accounted for almost

0.5 percentage points of the aggregate intra-industry effect in the EU20, which represents about 20% of annual aggregate productivity growth. Following in importance is the trade sector (G), which contributed on average about 0.32 percentage points to the intra-industry effect. Among sectors with a high share of total value added, the construction sector (F) is the only one with a very weak contribution to productivity growth over the entire observation period 1995 to 2017.[46] US productivity growth, on the other hand, has been driven by the ICT sector, which is consistent with the much higher cumulative productivity growth of that sector, as will be shown below.[47] Manufacturing plays a secondary role, with a contribution smaller than that of the EU, and decreasing over time. The higher (lower) relative importance of manufacturing (ICT) for Europe's productivity growth compared with the United States is an important finding, particularly looking forward. It will be discussed again in Section 3, which examines the role of technology for productivity growth.

Chart 10

Growth contributions of industries to intra-industry effect: EA20 (left panel) and United States (right panel)
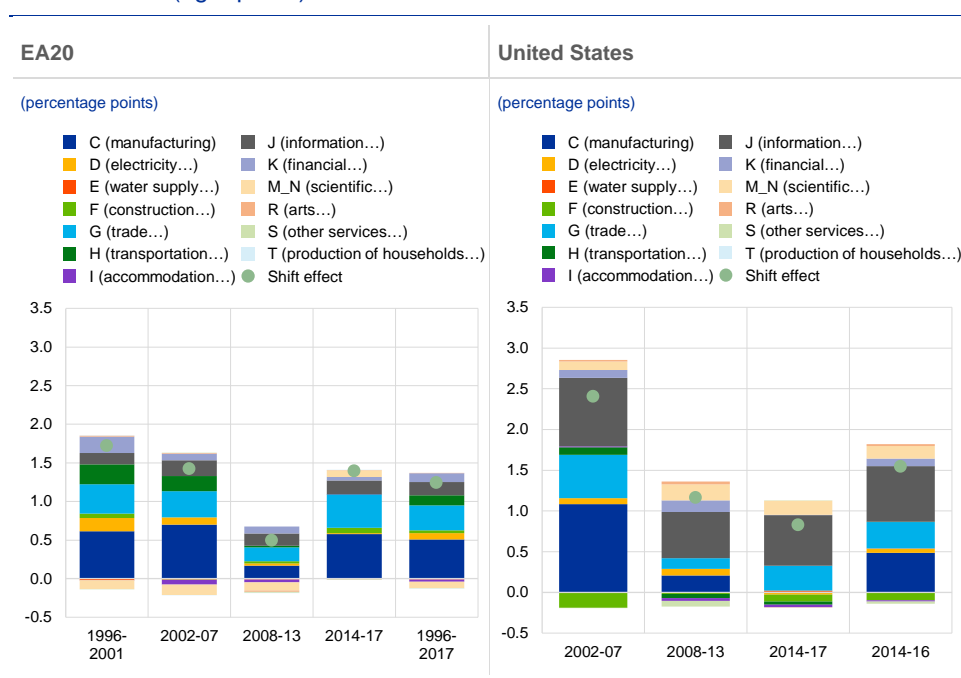
Sources: Own calculations using Eurostat, NACE 2-digit data.

In the last 20 years intra-industry productivity growth in the new EU countries has been more strongly driven by manufacturing than in the old ones. The sectors driving intra-industry productivity growth were similar to those of the old EU, although the importance of manufacturing was higher. This was especially pronounced between 2002 and 2007 (Annex 3).

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[46] The importance of the different sectors to the intra-sector effect was quite similar in those euro area countries with enough available data.

[47] We must point out that the size of this effect has been questioned in the literature, since the deflators used could lead to an overestimation of the importance of this sector.

2.2.2   Productivity level and growth differences across sectors and countries

There are important productivity level disparities across sectors in any given country, and across EU countries in any given sector. The utilities sector (electricity, gas and water supply), as well as financial and insurance activities, display the highest labour productivity levels – €77/hour and €71/hour[48] respectively on average across EU26[49] countries in 2017 (due to their high capital intensity). At the other end of the spectrum, construction and accommodation and food services show the lowest productivity level – €27/hour and €20/hour respectively. Business services activities are thus among the most and least productive sectors, which somewhat contradicts the notion of homogeneously low-productivity services.[50] Belgium, Denmark and Luxembourg are the countries that most frequently appear as the best performers in terms of productivity levels, with Bulgaria and Lithuania appearing most frequently among the poorest performers. If both European regions, old and new, were studied separately, the cross-country dispersion in productivity would diminish, although the sector ranking in terms of productivity would be similar in both regions (see Annex 3). Comparisons with the United States indicate that, in most sectors, US labour productivity levels are higher, especially in capital-intensive industries (Chart 11).

Chart 11
Labour productivity levels, 2017
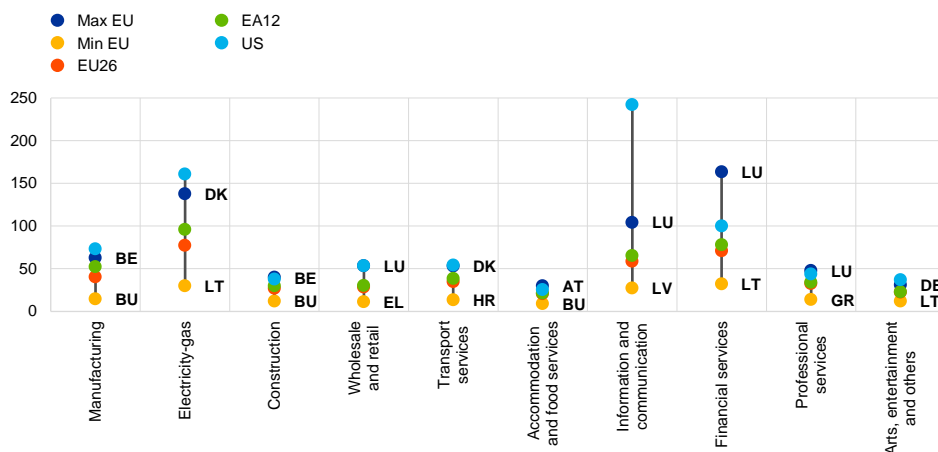
Sources: Own calculations using Eurostat and EU KLEMS.

There has been some convergence in sector productivity levels across countries since 1996, particularly in the newer EU Member States. In Annex 3 it

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[48]   Productivity levels are calculated using constant PPPs. See Annex 3 for more details on the calculation of productivity levels.

[49]   EU26 refers to EU27 excluding Ireland. The reasons Ireland is excluded are explained in Annex 3.

[50]   One of the most conventional statements in economics is that services feature a lower productivity level than other productive sectors. This statement is based on the personal nature of many services, which makes it difficult to substitute labour for the capital factor and the incorporation of technical progress. However, the statement is being redefined, given the importance of services and the role of innovation and knowledge on productivity growth within some services.

is shown the correlation between the level of productivity in 1996 and average annual productivity growth over the period 1996-2017 in each macro sector for EU-old and EU-new Member States. A negative correlation indicates (beta) convergence.[51] Convergence patterns have been strong across most sectors (some exceptions are transportation and storage, arts and entertainment). In EU-old Member States only a few sectors feature a regression line with negative slope and a reasonable goodness of fit – for example accommodation and food services, information and communication and utilities. In sectors such as manufacturing, wholesale and retail trade and professional services, there is no convergence at all.[52] In fact, many countries with relatively higher productivity levels in 1996 have experienced faster productivity growth in recent years.

Only a few sectors have experienced strong productivity growth since the 1990s (Chart 12). For the whole EU26, information and communication activities and manufacturing,[53] followed by wholesale and retail trade, transportation and storage and financial and insurance services, display the highest productivity growth rate. In all other sectors, labour productivity fell or was stagnant, even before the global financial crisis. In the United States sector productivity growth was larger than in the EU in all sectors but construction. This was particularly the case in the ICT sector, where cumulative productivity growth between 1996 and 2017 was more than 300%, compared with 82% in the EU26.

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[51] We show unconditional beta-convergence, which in this case captures the faster growth of initially low-productivity sectors, not conditional upon any other macroeconomic variable such as investment. In this case, given that convergence is analysed within groups of countries at a relatively similar stage of development, we could talk about "club convergence".

[52] The reasons behind the lack of convergence are beyond the scope of this section. However, several studies suggest that income, employment and other key economic indicators converged for some groups of member states before coming to a halt (or even diverging) at the onset of the global financial crisis.

[53] These two sectors are characterised by higher levels of ICT-capital accumulation and better technology diffusion, which means that a relatively better productivity performance can be expected.

[54] Note that frontier and laggard countries change over time and across sectors.

Chart 12

Labour productivity cumulative growth per sector, 1996-2017. EU26 and United States

(percentages)

- ■ EU-26
- ■ US
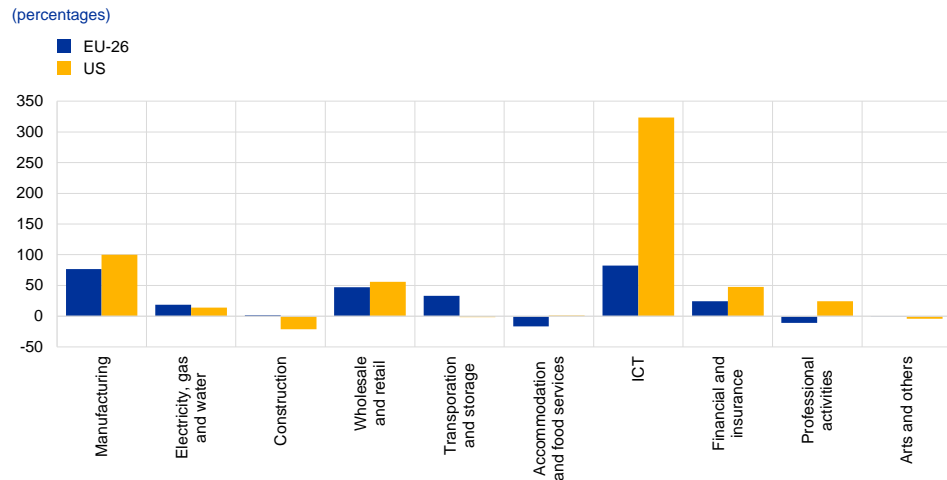
Sources: Own calculations using Eurostat and EU KLEMS.

In sectors where cumulative growth has been largest, the labour productivity gap between frontier and laggard countries has widened over time. The labour productivity gap is defined as the productivity difference between the three best performing countries (frontier countries) and the rest (laggards).[54] Chart 13 shows weighted average labour productivity levels (in euro per hour worked) in frontier and laggard countries during the pre-euro and post-global financial crisis periods. As expected, the productivity gap varies significantly across sectors. In sectors such as ICT, transportation and storage, financial services and manufacturing, where productivity growth has experienced large gains over time, the productivity gap has widened or has not diminished over time, which is consistent with the lack of convergence observed in Annex 3. Only few relatively low productivity sectors, like construction, accommodation and food services and professional services, show closing productivity gaps. In the utilities sector, even if the gap has narrowed, the difference in productivity levels between frontier and laggards continues to be large.

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54 Note that frontier and laggard countries change over time and across sectors.

55 Entry and exit are defined as appearance/disappearance in/from the sample.

Chart 13

Productivity gap between frontier and laggard countries by sector and periods, 1996-2017

(real euro per hour worked)

- Frontier
- Laggards
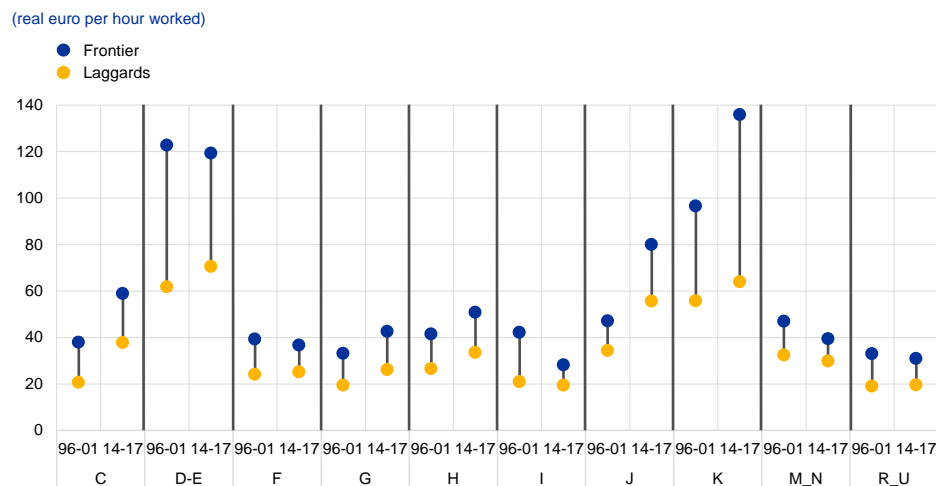
Sources: Own calculations using Eurostat and EU KLEMS.
Notes: C –Manufacturing; D-E- Electricity, gas and water supply; F- Construction; G –Trade; H –Transport; I –Accommodation and food services; J –ICT; K –Financial sector; M-N –professional services; R-U Arts. Sector productivity gap is calculated in EUR per hour worked.

To sum up, this section shows that aggregate productivity growth is driven by intra-industry developments, that is, by the productivity growth of each economic sector, rather than by the reallocation of resources across sectors. In fact, structural change has contributed very little – and negatively on average over countries and years – to growth, as a result of the declining share of manufacturing in favour of low and high-productivity services sectors, particularly in the EU-old Member States. Despite its loss in employment weight, the manufacturing sector accounts on average for 20% of annual aggregate productivity growth over the 1995-2017 period, as a result of the strong productivity growth of the sector. In contrast, manufacturing has played a secondary role in US productivity growth, which was driven to a much larger extent than in Europe by productivity growth in the ICT sector. We also find that in most sectors growing in productivity over time, the productivity gap between frontier and laggard countries has widened or has not been reduced. Sector productivity convergence across countries has occurred in EU-new Member States mainly in low-productivity sectors, and in the utilities sector. Conversely, sector productivity differences in EU-old countries have persisted over time.

2.3 A sector productivity decomposition with market entry and exit

The previous subsection showed that intra-industry productivity growth drives aggregate productivity growth. **This section introduces the main elements driving productivity growth in each of the economic sectors**; these elements will be further explored in the rest of the report. They include: i) the efficiency gains of incumbent firms; and ii) resource reallocation across firms in the sector concerned.

Resource reallocation results from the expansion and contraction of incumbents and from the entry and exit of firms.

The section applies a decomposition approach similar to the one applied in Section 2.2 to sector productivity growth, to quantify the relative contribution of each of these elements and show how they have changed over time and across countries and sectors. Section 2.3.1 presents details about the data and methodology used and Section 2.3.2 shows the results of the exercise.

The analysis uses firm-level data from the participating NCBs and results from a micro-distributed exercise whereby the same code is distributed to nine EU countries (Belgium, France, Croatia, Italy, Hungary, Netherlands, Portugal, Romania and Finland), with excellent coverage of micro firms and net entry. The period covered is 2007-16. The aggregated results are then compiled in such a way as to allow for cross-country comparisons of results while preserving firm-level confidentiality. Productivity is measured at firm level as the firm's real value added per employee. Nominal value added is deflated with 2-digit industry value added deflators sourced from EUROSTAT.

The main findings of the section are that within-firm productivity growth, if not adjusted for capacity-utilisation, is highly pro-cyclical and contributes most to the drop in labour productivity in busts and to its growth in booms. In contrast, resource reallocation across incumbents always contributes positively to sector productivity growth, although its contribution decreased between 2007 and 2016. As will be explored in Section 4 of the report, devoted to resource reallocation, this decline is both cyclical (churning peaks during recessions) and structural. The short-term contribution of net entry to sector productivity growth is positive but very small.

2.3.1 A decomposition of sector productivity growth

To understand the driving forces of intra-industry productivity growth, this section applies the decomposition proposed by Melitz and Polanec (2015). This methodology (see Box 4 below for details) decomposes sector labour productivity growth into three components. The first is the average productivity growth of incumbent firms, the within-firm component, which is related to the technological and managerial decisions made by entrepreneurs (Aghion and Howitt, 2009; Bloom and Van Reenen, 2010). The second component is resource reallocation or allocative efficiency, which is approximated by the covariance between size and productivity at the firm level and reflects the ability of an economy to allocate resources towards the most productive uses (Hsieh and Klenow, 2009; Olley and Pakes, 1996). The third component is linked to firm demography, that is, the selection process in and out of the market aimed at measuring how much the entry and exit of firms contribute to aggregate productivity growth (Aghion et al., 2004; Foster et al., 2016).

The data cover nine European countries (Belgium, France, Croatia, Italy, Hungary, Netherlands, Portugal, Romania and Finland) between 2007 and 2016. Because firm-level data are confidential and cannot be shared, the analysis was carried out following the micro-distributed approach. This entails the cooperation

of national experts in each country, who collect the data using a harmonised definition of key variables and use common codes on firm-level national databases. The resulting aggregate statistics are then compiled to build up the final database used for the analysis. Each dataset contains information on all active firms with at least one paid employee, including information on industry classification (NACE Rev.2), number of employees, value added as well as information on entry and exit (see Table A4.1 in Annex 4).[55] We focus our analysis on the manufacturing and private non-financial business sectors. At the aggregate level our micro-aggregated firm-level data closely mimic the national account statistics: the correlation coefficient between the two sources for labour productivity growth rates is 0.7 (Chart 14). More details on the data are provided in Annex 4.

Chart 14

Correlation between labour productivity growth in micro-aggregated dataset and national accounts data
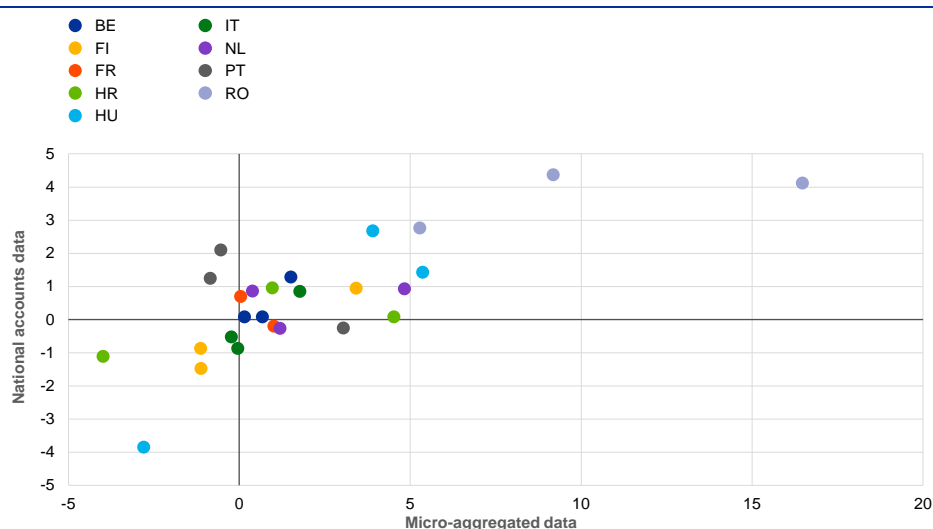
Sources: Micro-aggregated data and national accounts.
Note: Each dot represents a 3-year window productivity growth rate for the periods 2007-10; 2010-13 and 2013-16.

The aggregate dynamics of labour productivity show heterogeneous patterns across countries. Aggregate labour productivity – measured as real value added per employee – declined during the global financial crisis (2007-09), almost stagnated during the sovereign debt crisis (2012-13) and recovered subsequently (2013-16). According to our micro-aggregated firm-level data, in Italy, Portugal and Finland productivity growth was negative in the first two periods and recovered only afterwards. In Belgium, France and the Netherlands productivity increased in all three periods, although at a slow pace. Croatia, Hungary and Romania are characterised by large swings; overall, they recorded the largest growth rates.

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[55] Entry and exit are defined as appearance/disappearance in/from the sample.

Box 4
Productivity decomposition

As mentioned in the introduction, aggregate labour productivity equals the weighted average of individual firms' productivity, where weights are given by each firm's share with respect to total employees. Olley and Pakes (1996) proposed a simple static decomposition of two terms: the unweighted average firm productivity and the covariance between firm productivity and the share of employees (i.e. firm size). The covariance term is often referred to as static (Olley and Pakes (OP) covariance) and captures efficiency in the allocative mechanism. Melitz and Polanec (2015) recently proposed a dynamic version of this decomposition, which is useful in providing insights to different factors through which aggregate growth may change over time. In particular, it is possible to distinguish the relative contribution of three groups of firms: surviving firms (S) (also called incumbents), entrants (E) and exiting (X) firms.

Considering two periods, it is possible to express the change in aggregate or sector productivity as:

$$\Phi_2 - \Phi_1 = (\Phi_{S2} - \Phi_{S1}) + \omega_{E2}(\Phi_{E2} - \Phi_{S2}) + \omega_{X1}(\Phi_{S1} - \Phi_{X1}) \tag{B4.1}$$

The first term $(\Phi_{S2} - \Phi_{S1})$ represents the change in the productivity of incumbent firms, i.e. those active in both subsequent years. The second term $(\Phi_{E2} - \Phi_{S2})$ is the contribution of entrants, which is positive (negative) if their productivity is higher (lower) than that of the incumbents and larger, in absolute value, the higher their weight in terms of employment (ω_{E2}, a sort of entry rate). The third term $(\Phi_{S1} - \Phi_{X1})$ is the contribution of exiting firms, which is positive (negative) if their productivity is lower (higher) than that of the incumbents and larger in absolute value the higher their weight in terms of employment (ω_{X1}, a sort of exit rate). Finally, in the spirit of the static OP decomposition the productivity growth of incumbent firms can be further expressed as the change in the incumbents' simple (unweighted) average productivity and that in the covariance between incumbents' productivity and their share of employees, thus capturing the efficiency of the reallocation process among incumbents.

We apply the dynamic decomposition to labour productivity, measured as real value added per worker, in levels. Measuring productivity in levels rather than in logs, as it is often done in empirical works, is to be preferred when evaluating welfare implications (Petrin and Levinsohn, 2012). The covariance term, however, would not be invariant to changes in average productivity; in other words, a uniform increase in productivity for all firms would not only affect the within component as it should, but also the covariance term. Melitz and Polanec (2015, p. 374) explain how these issues can be addressed by showing the decomposition applied to data in levels and defining a scale-independent covariance term.

There are some drawbacks in the way we measure productivity and allocative efficiency. First, our measure of productivity (value added per employee) might not provide information about the underlying dynamics of technical efficiency since it could reflect changes in prices and markups. Second, despite the dynamic OP covariance having several attractive features, as discussed above, it can be negatively correlated with model-based measures, where the dynamics of aggregate productivity are typically captured by changes in output that are not explained by changes in inputs expenditure (in the spirit of Solow, 1957; see Petrin and Levinsohn, 2012 for a detailed discussion). Following the pioneering contribution of Hsieh and Klenow (2009), several studies have used the dispersion in revenue productivity as a proxy for misallocation (see also

Section 7.1). However, Bartelsman et al. (2013) argued, both theoretically and empirically, that the within-industry covariance between size and productivity (the OP covariance) is a robust measure to assess misallocation, as it does not suffer from specification problems and is fairly intuitive.

2.3.2 The relative contribution of within-firm productivity growth and resource reallocation to sector productivity growth

The contribution of the within-component was on average negative between 2007 and 2016, although it is highly cyclical: it is the main drag on sectoral productivity growth during periods of economic crisis and the main booster over economically stable periods. Chart 15 (left panel) shows, for each country, the period-average contribution to sector productivity growth of the productivity growth of incumbent firms (the within component); the contribution of reallocation among surviving firms (the between component); and the contribution of entry and exit (the net demography component). The first striking fact is that the average productivity growth of incumbent firms contributes negatively to sector productivity growth across most countries (the only exceptions are Romania and Finland). This negative contribution is driven by developments in 2007-13, i.e. periods of economic crisis (global financial crisis and sovereign debt crisis; see also Chart A4.1 in Annex 4). It must be acknowledged that this component reflects not only true changes in technical efficiency at firm level but also fluctuations in the demand faced by firms, which may influence capacity utilisation, especially in the short run (see Box 1), and firms' pricing strategies. This is inevitable when price variations cannot be perfectly controlled for and netted out at firm level; indeed, as in many other studies, the best we can do to move from a value-based measure of productivity to a quantity-based measure is to use (2-digit) sectoral price deflators.

The contribution of resource reallocation across firms is, in contrast, positive. The second finding concerns reallocation, which is the shift of employment across firms with different productivity levels within the same 2-digit sector. In all countries in our sample, its contribution has been positive, largely counterbalancing the decline in average firm productivity. This result may of course be the outcome of different adjustment mechanisms. It might reflect unemployed workers being absorbed into the labour market with labour demand steeply growing along with firm productivity. Alternatively, leaving the unemployment rate unchanged, another favourable scenario entails the hiring by the most productive firms of workers displaced by less efficient ones. Finally, a positive contribution from the reallocation effect could also come from a situation where unemployment grows due to firing but the relative size of the most productive firms increases. While some mechanisms are better than others from a social point of view, the data used in this analysis do not enable a deeper investigation of the exact mechanisms at play in the issues examined. In addition to contributing positively in all countries, the reallocation component also explains a large share of aggregate productivity dynamics, with the exception of Romania and Finland.

Though less important in absolute terms than the within and reallocation components, the contribution of net entry is always positive, except for Romania. Sector productivity growth is also influenced by firm demography: the entry and exit of firms. The positive contribution of firm demography mostly reflects the exit of low-productivity firms from the market. This more than offsets the negative contribution from the entry of small low-productivity firms. Although low-productivity at entry, new firms undergo a strong process of selection and learning thereafter. Start-ups that survive this process show high productivity growth rates and within a few years catch up with the average incumbent in the sector. New firms also compete with incumbents and thus incentivise incumbents to innovate, which might increase their productivity growth. Section 4.2 below explores all of these channels in more detail for a subsample of four euro area countries.

The contribution of each component has changed over time. Chart 15 (right panel) shows how the contribution of each component has changed over time, taking the average across all countries.[56] Three clear patterns emerge. First, the most important drag on productivity growth during the global financial crisis and sovereign debt crisis (2007/2013) was within-firm productivity growth in incumbent firms, which is consistent with labour-hoarding behaviour by firms and underutilised capital and labour capacity. This component, however, shows an overall improvement over time and across countries. This reflects both a generalised improvement in cyclical business conditions and the ability of firms to gain efficiency through labour input adjustment during crisis periods and a quick recovery of their export performance. Second, the positive contribution from allocative efficiency, although with different intensities across countries, is in overall terms declining over time. One possible reason is that crises are periods of high reallocation of inputs across firms. Finally, the support of net entry to aggregate productivity growth has more than doubled over time, which is consistent with the evidence of increased exits in the aftermath of recessions.

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[56] The patterns shown, with some caveats, are similar across countries. Differences, where present, are noted in the text.

Chart 15

Contribution of within, covariance and net entry to sector productivity growth, average over the period 2007-16 (left panel) and time dynamics of contribution of each factor, unweighted average across countries (right panel)

Contribution of within, covariance and net entry to sector productivity growth, average over the period 2007-16	Time dynamics of contribution of each factor, unweighted average across countries
(percentage points)	(percentage points)
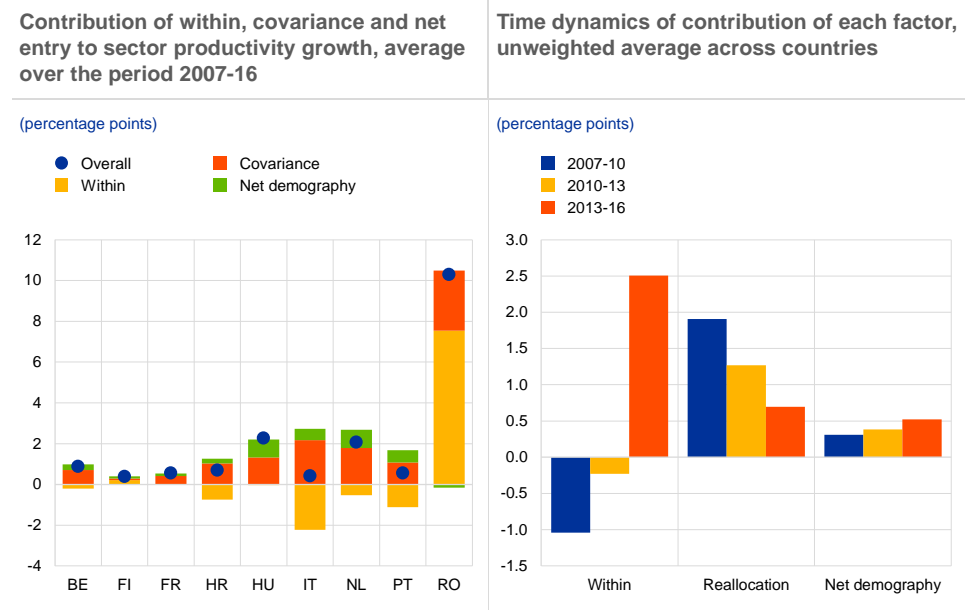
Source: Own calculations using micro-distributed data.
Notes: The analysis is conducted at the 2-digit industry level. Results are then aggregated using sector-country employment weights measured at the start of each period. Averages across countries are computed as simple averages so as not to reflect the dynamics of the largest countries (Italy and France), which account for two-thirds of employment in the sample.

Within-firm productivity growth has been negative in all sectors but accommodation. Chart 16 shows the decomposition of productivity growth by industry. With the exception of the accommodation sector, within-firm productivity growth has been negative and has acted as a drag on productivity growth in all sectors. The reallocation component has largely counterbalanced this negative contribution and boosted productivity growth, again in all sectors. It is interesting to note that the contribution of reallocation is largest in manufacturing. On the one hand, this might reflect the fact that the trade collapse and the global financial crisis spurred a profound reorganisation of this sector. And on the other, manufacturing is more exposed to international competition even in normal times, making firms more exposed to continuous positive and negative shocks. Finally, the contribution of net demography has been positive in all industries except accommodation.

Chart 16

Contribution of within, between and net entry to sector productivity growth, sector details. Average across countries 2007-16

(percentage points)

- ● Overall
- ■ Within
- ■ Between
- ■ Net demography
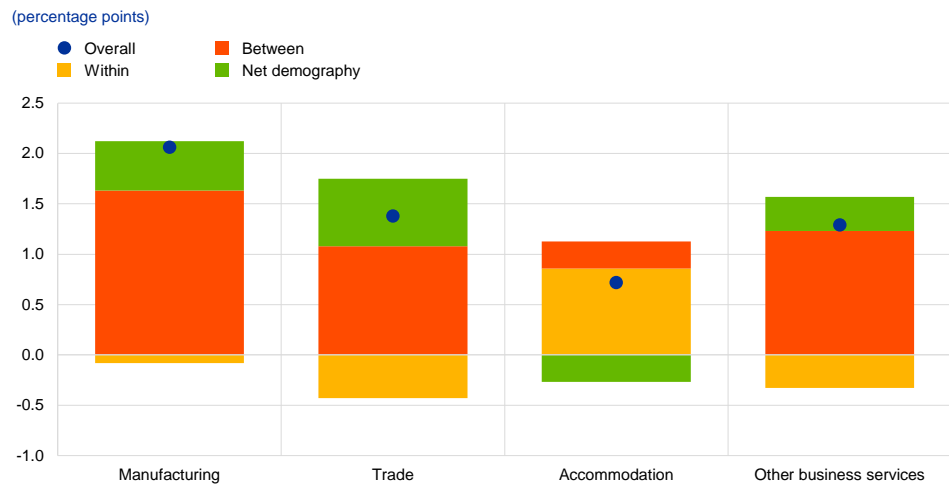
Source: Own calculations using micro-distributed data.

To sum up, this section finds that within-firm productivity growth is highly pro-cyclical and contributes most to the drop in labour productivity in busts and to its growth in booms. In contrast, the reallocation of resources across incumbents always contributes positively to sector productivity growth, although the contribution has been decreasing over time. As will be explored in Section 4 of the report devoted to resource reallocation, this decline is partly cyclical, given churning peaks during recessions, but also partly structural. The contribution of net entry to sector productivity growth is positive but very small.

3 Technology and productivity growth

3.1 Technology and productivity growth in EU countries

This section provides an overview of the extensive literature on the link between technology and productivity growth (Section 3.1.1), with a focus on the "productivity paradox" and its possible drivers. Section 3.1.2 explores the role of technology for productivity growth by showing productivity patterns in sectors of different technology intensity, also compared with the United States.

The analysis uses data from AMECO and EU KLEMS. Labour productivity is defined, as in Section 2.2, as real value added for the sector per hour worked.

The main findings of the section are that there are two schools of thoughts regarding the apparent lack of productivity impact of the increasing presence of new technologies. The techno-optimists think that new general-purpose technologies take time to induce efficiency gains, not least because of the need for complementary investments and skills. Techno-pessimists argue that current technological innovations are relatively small compared with previous ones. The section finds, however, that productivity growth in sectors with high technology intensity is significantly larger than in low technology sectors, particularly in the United States.

3.1.1 Literature overview: the productivity paradox

Investing in new technologies should bring large productivity gains through various channels. Yet despite the apparent rapid advance of new technologies, labour productivity growth in most developed economies has been slowing since before the global financial crisis, as shown in Section 2.1. This broad deceleration in productivity at a time of intense technological acceleration has been widely described as a puzzle (see for example Brynjolfsson et al., 2018 and Brynjolfsson et al., 2021), even as a paradox. The extensive research and ongoing debate on what lies behind this development is discussed below.

Techno-pessimists argue that the recent slowdown is a permanent phenomenon and that new technological innovations are simply less revolutionary than in the past. Ideas may be getting harder to find, meaning that research productivity itself, and therefore new path-breaking technology development, is declining (Bloom et al., 2020a). This, say the pessimists, is especially true when compared with the wave of productivity that was induced by the second industrial revolution. Under this long-standing stagnation hypothesis, new technologies and ICT are less pervasive than earlier inventions such as the railways, electricity, or the telephone (see, among others, Gordon, 2012 and 2015; Bergeaud et al., 2016). Moreover, according to this view the productivity-enhancing effect of future innovations is expected to be less significant.

Techno-optimists, in contrast, posit that ICT and other new technologies will have a profound impact on productivity growth in coming decades (Brynjolfsson and McAffee, 2014; Brynjolfsson et al., 2021). They argue that we might not have seen the full benefits of the new technologies yet, since they are still being developed. Furthermore, complementary investments are needed before the full productivity potential of the ICT revolution can be realised. An additional argument is that it takes time for new technologies to be diffused, for companies and workers to adapt, and for complementary investments to be made (David, 1990; Gordon, 2015). In a similar vein, van Ark (2016) supports the idea that new technologies are still in an installation phase, and productivity effects will occur once the technology enters the deployment phase.

Cross-country data on firm-level adoption of new technologies suggest that there is wide dispersion across firms, as well as significant differences across countries (see for example Hagsten and Kotnik, 2017). These differences among countries, industries, and firms determine how technology innovations affect productivity. Institutional and structural reforms that support innovation and the adoption of technologies as well as investment in human capital are necessary (Acemoglu et al., 2006). In fact, institutional and structural factors have been assessed as having a large impact on productivity developments between countries (Cette et al., 2017, and also the analysis in Section 1). Furthermore, in periods of fast technological change we should expect skills associated with new technologies to be in too-short supply and skill-biased technological change to lead to a differential impact on occupations and a growing skills mismatch (Acemoglu and Autor, 2011).

In addition, a recent strand of literature suggests that technology diffusion, not only technology creation, could have slowed over time. The knowledge diffusion channel accounts for most symptoms of declining business dynamism (see for example Akcigit and Ates, 2021)**.** In particular, Andrews et al. (2015, 2018), using a dataset covering firms in 24 Organisation for Economic Co-operation and Development (OECD) countries for the period 2001 to 2014, show that, especially in services sectors, firms at the global productivity frontier exhibit stronger productivity growth rates than other firms in the same sector. This results in increasing productivity divergence between frontier firms and the rest of the distribution.[57] The divergence in growth rates is taken as a proxy for the speed of technology diffusion across firms. Several country-specific studies reach similar conclusions (De Mulder and Godefroid, 2018; Lotti and Sette, 2019; Cette et al., 2018; Heuvelen et al., 2018; Le Mouel and Schiersch, 2020; Bersch et al., 2019; Decker et al., 2016). See Box 5 below for an analysis of the Belgian case.

Box 5
Case study: Technology diffusion in Belgium

For all EU countries included in the sample, productivity is not evenly distributed among firms. In fact, there is evidence that firms with performance close to the European technological frontier co-

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[57]   In a similar vein, Bahar (2018) documents a rising productivity dispersion within narrowly defined sectors.

exist with a large number of firms with much lower performance records (Chart A and also Section 1). In an optimally functioning economy, firms lagging behind the technological frontier could be expected to have strong incentives to innovate in order to catch up or even overtake the leaders in a given sector of the economy. If they fail to do so, the gap with frontier firms widens over time and laggard firms will end up shutting down, as their efficiency levels are too low to survive in the face of high competition from those at the frontier. Technological diffusion should, therefore, enable firms to accumulate more productivity gains.

Chart A

TFP level distribution in selected EU countries, 2010

(private sector, in EUR thousands)
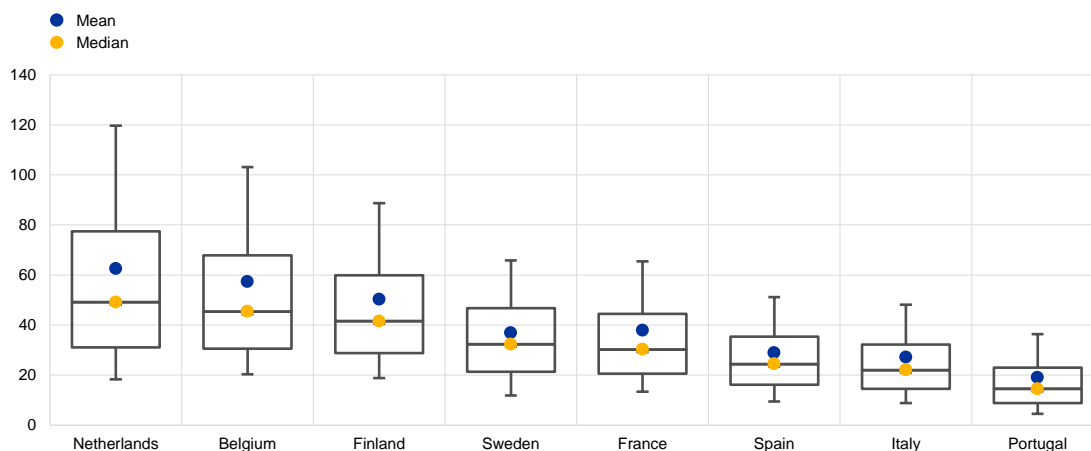
Source: CompNet.
Note: The chart covers firms from different branches of activity, among which there are large difference in TFP.

The above hypothesis was tested using Belgian firm-level data. From the full sample of firms that filed annual accounts between 1996 and 2016, two subsamples were formed. The first is a subgroup of "frontier firms" at year t, i.e. firms with productivity levels at year t and t-1 (or longer) above or equal to the 90th percentile of the TFP distribution for their sector of activity (defined at 2-digit level according to the NACE Rev. 2 classification). The second is a subgroup of "all other" firms, i.e. firms considered to be technologically lagging or "non-frontier" firms.

The analysis shows that the gap in the two subgroups' TFP growth has gradually widened. In particular, between 1996 and 2016 cumulative TFP growth was almost 29 percentage points higher in frontier firms than in non-frontier firms. This technological disconnect is particularly pronounced in manufacturing: the gap in TFP growth was about 36 percentage points in manufacturing, compared with 21 points in services. This could be partly linked to the fact that firms in manufacturing tend to be more efficient in improving their production processes than firms in services, where sources of within-firm productivity growth are traditionally more limited. As a result, frontier firms in manufacturing may capitalise on much higher productivity gains than frontier firms in services.

The contribution of frontier firms to aggregate TFP growth is very large, explaining almost all of aggregate performance. This large contribution stems not only from within-firms' productivity growth but also from the reallocation of resources from non-frontier (and low productivity) firms to frontier firms. This last component was indeed extremely important during the post-global financial crisis period (Charts B and C).

Chart B

Internal TFP growth (left panel) and contribution to aggregate TFP growth (right panel)

Internal TFP growth	Contribution to aggregate TFP growth

(cumulative growth over the period 1996-2016, percentages)

- ■ Frontier firms
- ■ Non-frontier firms

(percentage points)

- ■ External growth or reallocation – towards non-frontier firms
- ■ Internal growth – non-frontier firms
- ■ External growth or reallocation – towards frontier firms
- ■ Internal growth – frontier firms
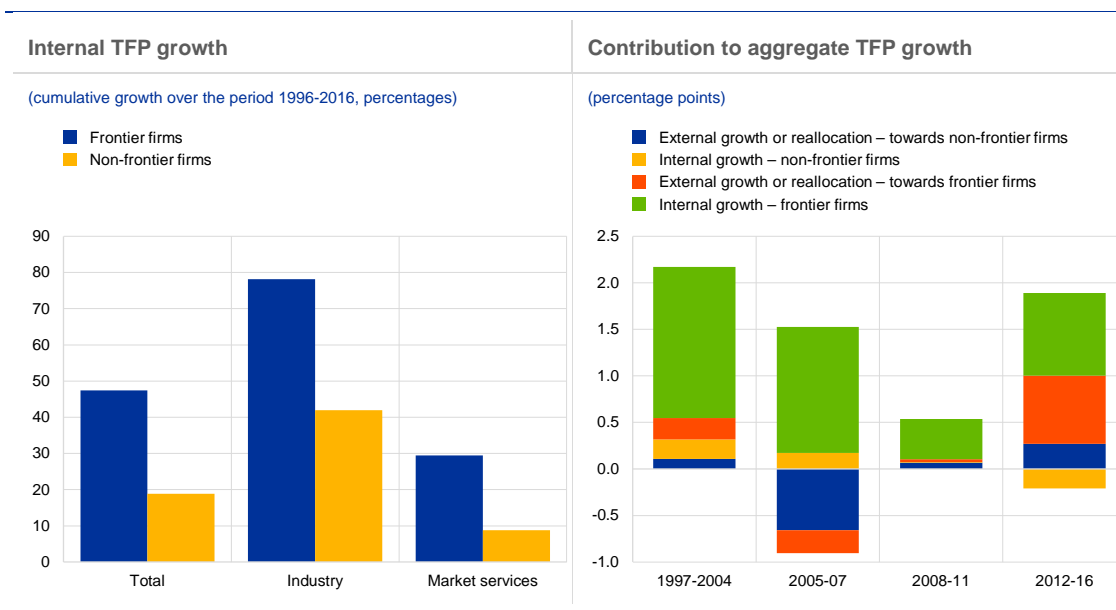
Source: Nationale Bank van België/Banque Nationale de Belgique.
Note: The frontier firm category covers all firms recording productivity levels above or equal to the 90th percentile of the TFP distribution for their sector for at least two consecutive years.

However, a particular feature of Belgian firm-level data is that a large share of frontier firms are subsidiaries of a foreign firm. Over the period 2010-15 11% of frontier firms, on average, were subsidiaries of foreign companies, as compared with only 0.6% of non-frontier firms. Moreover, foreign frontier firms play a major role in aggregate productivity growth: on average they contribute 80% to TFP growth (whether positive or negative). These specific characteristics of Belgian firms might explain the differences observed in their development relative to the ones shown in Section 3.2.2 below.

The literature has provided various potential reasons for such a slowdown in technology diffusion and its role in explaining declining business dynamism (see Akcigit and Ates, 2019 and 2021; Bergeaud, 2019; Berlingieri et al., 2020 for a review). A plausible explanation is that the growing importance of tacit knowledge and the complexity of technologies has increased, thereby creating barriers to the catch-up of laggard firms. Also, the use of both new technologies and intangible capital is often characterised by a high ratio of fixed to variable costs and by network effects, possibly implying non-replicable increasing returns to scale (e.g. Gao and Kehrig, 2017; Haskel and Westlake, 2018; Aghion et al., 2019; de Ridder, 2019). This can also lead to "superstar" and "winner-takes-all" effects which might discourage firms behind the technology frontier from investing in technology creation and adoption and thereby increase market power and concentration.

Although a number of studies have found that market concentration in the United States has increased over time, the European evidence is more mixed (Autor et al., 2020; De Loecker et al., 2020; Deutsche Bundesbank, 2017; OECD, 2018a; Cavalleri et al., 2019; and Gutierrez and Philippon, 2020). Thus, it

is unlikely that this channel plays a very large role in explaining the slow technology diffusion rate, at least in Europe. Finally, even if incentives to innovate and adopt technologies exist, the necessary complementary inputs might be missing. One of the most important complementary investments is human capital, both workers and managers. It has been shown that employees need complementary information technology skills to exploit the full potential of these technologies (e.g. Autor et al., 2003; Bartel et al., 2007; Spiezia et al., 2016; Falk and Biagi, 2016). Bloom et al. (2012) show the importance of managerial skills to reap the full benefits of investment in technology. Investment in high-quality infrastructure is another foundational element. While broadband access and basic applications such as websites are common among most firms, more advanced applications such as enterprise resource planning are used by a much smaller share of firms (OECD, 2017).

Other studies have examined the role of firms' capital structure in technology creation and diffusion. Small, medium, and young companies in high-tech sectors are deemed to be a major source of innovation and development for the economy. These firms, however, suffer from insufficient access to capital, most notably in the case of young firms which lack track record, stable cash flows, and collateral. Giraudo et al. (2019) indicate that financial constraints can be especially severe for bank-based economies like Europe. In standard neoclassical models, financial development fosters growth mainly by supporting a higher level of investment activity (for a review see Levine 2005). However, recent studies have found evidence that in developed economies TFP is a more significant channel through which financial intermediation affects economic growth (Papaioannou, 2007). Countries with more developed financial systems are in a better position to finance technology-related investments or to help firms adopt new technologies more quickly. According to this argument, developed financial markets help channel scarce capital from declining sectors to firms that are expected to grow faster, and make it easier for firms to enter industries with positive growth prospects.

More innovative firms make different financing choices from less innovative ones. Hall (2010) addresses the extent to which innovative firms differ from established companies in terms of financing. An important strand of the literature concerning the financing of innovative firms focuses on venture capital (VC) and other forms of equity financing tailored to risky, innovative projects. Previous literature shows that innovative firms are more dependent on equity than debt financing (Brown et al. 2009 and 2013). In this respect, several papers have attempted to identify the relationship between VC and innovation. Kortum and Lerner (2000) find that a rise in VC causes higher rates of patenting. Akcigit et al. (2019) find empirically that VC-backed start-ups have higher growth rates at earlier stages and patenting levels than non-VC-backed ones. Consistently with this, Howell et al. (2020) use US patent data over the 1976-2017 period as evidence that VC–backed firms were between two and four times more likely than non-VC-backed firms to have filed patents that were in the top percentiles of influence (as measured by citations, originality, generality, and closeness to science). However, as Lerner and Nanda (2020) assert, VC financing also has real limitations in terms of its ability to advance substantial technological change, given the very narrow band of

technological innovations that fit the requirements of institutional VC investors. Overall, VC investments could constitute an important alternative instrument of funding for young and innovative firms that encounter barriers to access more traditional financing (e.g. bank loans). Despite rapid growth in recent years, the European VC industry is still small and in 2013-18 the United States remained the main investor worldwide, whereas China replaced the EU as the second global player (Bellucci et al., 2021). VC funds have increasingly focused on mature companies, while a large share of European companies (especially SMEs) needs to resort to non-VC funding sources to finance their innovative activity (Nepelski et al., 2016). As documented in a recent communication from the European Commission for advancing the capital markets union action plan, smaller companies need to have unimpeded access to equity funding. The lack of equity in the funding structure of firms may put Europe at a disadvantage with respect to economies with more diversified funding portfolios (European Commission, 2020b).

The literature has stressed that the informational opacity of new technology firms makes it difficult for them to raise either external debt or external equity (Moore, 1994; Westhead and Storey, 1997; Guidici and Paleari, 2000). This observation is consistent with the pecking order and life cycle theories, both of which contend that firms will start out by relying on internally-generated funds before gaining access to external sources. In the case of technology-based firms, reliance on internal sources may be intensified by higher levels of asymmetric information. It is difficult for external investors to evaluate the potential of new technologies and the firms that develop them. Audretsch and Lehman (2004) found that small and innovative firms are more likely to be financed by venture capitalists, rather than banks, the former acting positively to the potential enhancement of their growth rates. This finding concurs with that of Colombo and Grilli (2007): new technology-based firms resort to external financing only when personal financial resources are exhausted (financial hierarchy). While some technology-based firms may be able to attract external equity in the form of angel investors and VC (Audretsch and Lehmann, 2004; Hogan and Huston, 2005) since these investors are attracted by their growth potential, this can also be challenging, as it is difficult for investors to evaluate the demand for new technologies and products.

Investigating the influence of intangibles on the corporate capital structure is of vital importance, as intangibles make up a large part of technology-based companies' assets. It has been argued in the literature that collateral may be used by banks both as a signalling device to separate high-quality from low-quality borrowers and as an incentive device to deter entrepreneurs' opportunism. However, most high-tech investments are in intangible and/or firm-specific assets that provide little collateral value. As Hall (2010) stresses, with the exception of certain types of patents there is only a small market for distressed intangible assets. This is one more reason why debt financing is poorly suited to the financing of research and development (R&D)-intensive sectors. Unless outside collateral is available, high-tech start-ups will find it difficult to resort to debt financing.

Finally, the increasing prevalence of new technologies may have aggravated the mismeasurement issues highlighted in Box 1 and could partially explain

the productivity paradox. New technologies require both new measures and the development of indicators which would complement traditional measurement frameworks, such as those used for GDP and trade. Most analyses seeking to correct for these biases conclude that this explanation alone is not enough to justify the productivity slowdown (see Syverson, 2017).[58]

3.1.2 Productivity trends in sectors of different technological intensity

To assess the role of technology in recent EU productivity growth, we depict labour productivity developments in sectors of different technological intensity. The split of sectors into high and low technology intensity follows the recent analysis by Calvino et al. (2018) and is detailed in Table A5.1 in Annex 5.[59] It should be noted that the lack of data means that the split does not take into account the development and adoption of certain digital technologies (for example machine learning and artificial intelligence). It also excludes sectors which are classified as medium-high or medium-low technology intensive and focuses on the extremes: low and high-technology sectors.

High technology-intensity sectors exhibit higher labour productivity growth than low technology-intensity sectors (Chart 17, left panel). This holds for both old and new EU Member States, defined as in Section 2.2, and, notably, for the United States, thus confirming the important link between technology and productivity growth. The striking difference between the United States and the EU confirms the sector productivity growth differences between the two regions shown in Section 2.2.2 (see also Cette et al., 2020).

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[58]   One recent example is Brynjolfsson (2021), who argues that intangible assets are both inputs and outputs of production, while they are hard to measure precisely. These two factors lead to under-measurement of productivity gains initially, but to an over-measurement later on.

[59]   Specifically, the high technology-intensity sector comprises industries with a high proportion of ICT tangible and intangible investment, intermediate purchases of ICT goods and services, ICT specialists, turnover from online sales, and stock of robots per hundreds of employees. These industries are far from uniform and vary widely in their characteristics and performance. In fact, the performance of some of the high technology-intensity industries appears to be closer to that of the low technology-intensity industries. According to Calvino et al. (2018), ICT-intensive sectors such as telecommunications and information technologies appear to be the most digitally intensive, whereas sectors emerging as the least digitally intensive, such as mining, also align with expectations. We focus our analysis on high and low technology-intensity sectors with the aim of examining whether differences exist in productivity developments from one end of the distribution to the other. See also Gal et al. (2019) and Sorbe et al. (2019).

Chart 17

Labour productivity dynamics in the EU27 and the United States (left panel), in EU-new and EU-old (right panel) by technology intensity

EU27 and the United States	EU-new and EU-old
(2000=100)	(2000=100)

Left panel legend:
- High intensity sectors – EU27
- High intensity sectors – US
- Low intensity sectors – EU27
- Low intensity sectors – US

Right panel legend:
- High EU – new
- High EU – old
- Low EU – new
- Low EU – old
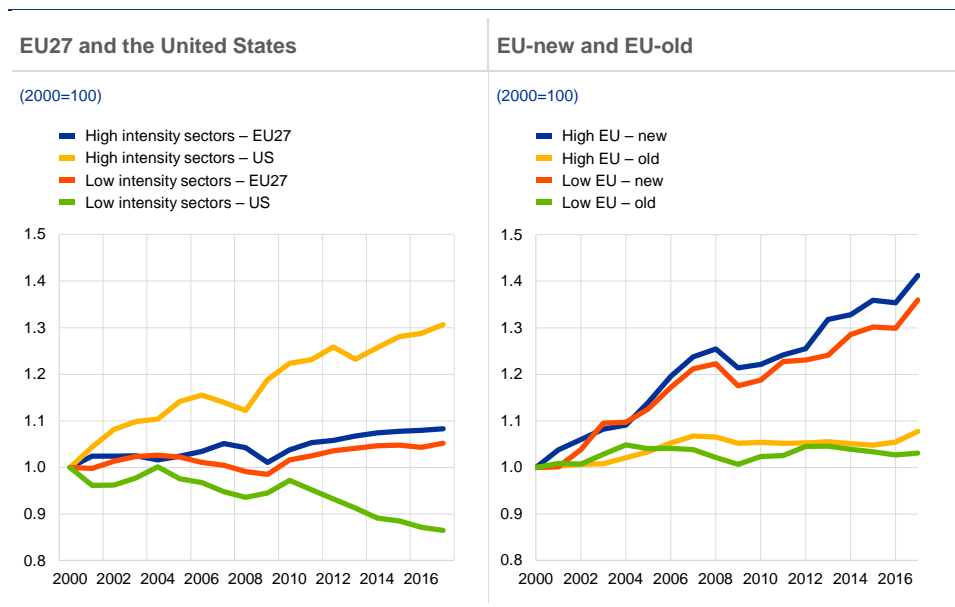
Sources Own calculations using Eurostat.
Notes: High technology sectors include manufactures of motor vehicles, telecommunications, computer, programming and consultancy services, financial services, legal activities and other professional services and administrative services. See Annex 5 for a complete list of high and low technology sectors. Low technology sectors include manufactures of food, utilities, transport and storage, construction and hotels and restaurants.

Productivity growth in high-technology sectors in the EU27 is entirely driven by developments in the EU catch-up economies (Chart 17, right panel). Note that this statement refers only to high technology sectors, not to medium-high or medium-low technology sectors.[60]

Productivity dispersion between frontier and laggard countries, computed as the difference between the best and worst-performing countries, has been increasing on average in high technology sectors (Chart 18, left panel). Even though the inter-quartile range of productivity levels has decreased over time, high technology sectors are characterised by an increasing distance between frontier and laggard countries. This is in line with the findings in Section 2.2.2. Within the low intensity split, country dispersion has remained stable or decreased (Chart 18, right panel). As shown in Annex 5, the electricity and gas sector had the largest divergence; in the case of gas this could reflect the regulated nature of the sector. For more country and industry-specific results, refer to Annex 5.

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[60] Over this period several of the underlying high-tech subsectors such as manufacture of motor vehicles (C29-C30), telecommunications (J61) or computer programming activities (J62-J63) exhibit clearly positive productivity growth rates in the EU-old countries. However, within this specific high-tech aggregate their positive growth rates are dominated by much lower or even negative growth rates from sectors such as legal activities (M69-M70), other professional services (M73-M75), administrative services (N) or other services (e.g. religious organisations or hairdressing activities) (S) which, particularly in Europe, jointly have a considerably higher economic weight (in terms of value added) than those high-growth high-tech sectors.

Chart 18

Labour productivity dispersion in the high technology (left panel) and low technology (right panel) intensity sector in the EU27

| High technology | Low technology |
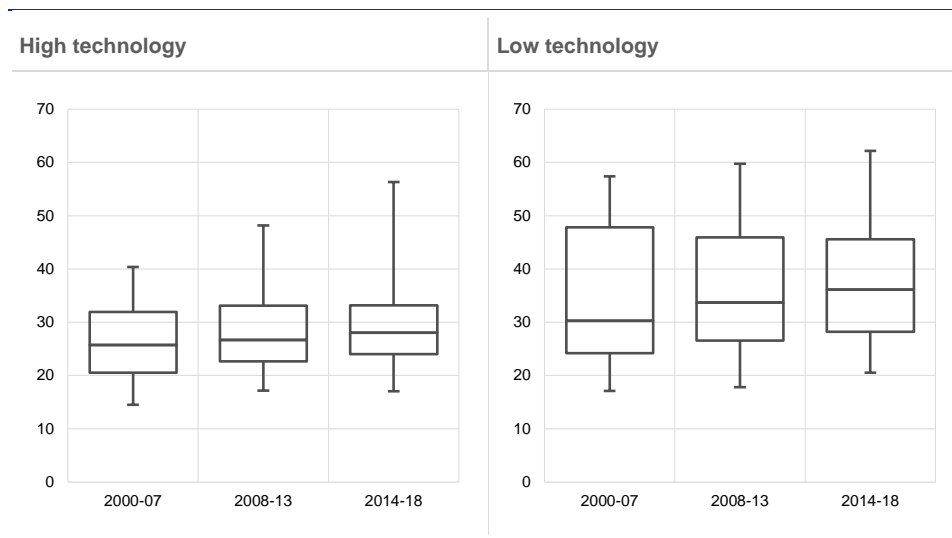
Sources: Own calculations using Eurostat.
Notes: Dispersion is calculated as the labour productivity difference between the best and worst country each year. Labour productivity is in euro per hour worked.

To sum up, there are two schools of thought regarding the apparent lack of productivity impact resulting from the increasing presence of new technologies. The techno-optimists think that new general-purpose technologies take time to induce efficiency gains, not least because of the need for complementary investments and skills. Techno-pessimists argue that current technological innovations are relatively small compared with previous ones. Finally, most high-tech investments are in intangible and/or firm-specific assets that provide little collateral value. Hence, collateral-based debt financing is ill-suited to finance R&D-intensive sectors. The section finds that productivity growth in sectors with high technology intensity is significantly larger than in low technology sectors, particularly in the United States.

3.2   Technology creation and diffusion in the EU

Innovation can advance either because there is investment in knowledge resulting in technology creation, or because there is investment in the adoption of already existing technologies (technology diffusion). **This section explores technology creation by frontier firms and diffusion to the rest of firms in the country or sector in the EU, including in comparison with the United States**, from a macro (Section 3.2.1) and a micro perspective (Section 3.2.2).

The macro analysis uses aggregate data on patents, R&D investment and technology exports and imports from the European Patent Office (EPO), EUROSTAT and the OECD. **The firm-level analysis uses firm-level data** from ORBIS and iBACH for six euro area countries (Belgium, Germany, Spain, France, Italy and Portugal) over the period 2006-18. Productivity is measured by the efficiency with which both inputs, labour and capital are used in production, or TFP, at the firm level.

TFP is estimated using the Levinson-Petrin approach (for more details about the dataset and estimation procedure see Annex 6). The choice of focusing on TFP in this section follows on from the need to explore efficiency gains stemming from technological progress rather than from capital intensity.

The main findings of the section are that according to macroeconomic indicators of innovation outcomes such as triadic patent applications or the market share in high-technology manufactures, technology creation in the EU is lower than in the United States and might have slowed over the recent period. These findings are supported by the micro-based analysis showing decreasing TFP growth in manufacturing frontier firms, particularly in high-tech sectors. Technology creation in services, in contrast, has accelerated but seems to benefit only frontier firms. The recent slowdown in productivity growth in the EU seems, therefore, to be related to a twofold phenomenon: reduced innovativeness of high-tech manufacturing firms, which are the traditional sources of vibrant technical progress and productivity growth, and a growing gap between frontier and laggard firms in the services sector.

3.2.1 Technology creation and diffusion developments from a macro perspective

It is difficult to find "good" direct macroeconomic indicators of technology creation and diffusion. In this section a variety of indirect indicators will therefore be used to shed light on various aspects related to technological developments: (i) R&D expenditure, capturing the efforts made (i.e. the inputs) to create technology; (ii) the number of patent applications and the percentage of innovative firms, which can be viewed as indicators of, respectively, the output of the innovation process and the effective use of innovation in firms; (iii) the percentage of high-tech trade, capturing international technology diffusion; and iv) the share of global high-tech manufactures exported by Europe.

R&D intensity[61] **in Europe has gradually risen in recent decades, although it still lags behind that of the United States (Chart 19).** The increase has been somewhat stronger in the EU-new Member States than in the EU-old countries, although the most recent data still show a considerable level gap between both groups of countries. The stronger growth of total R&D expenditure in the EU-new countries, given their much lower initial levels, is in line with the idea of a catching-up process. The United States, starting from a relatively high total R&D expenditure level in the 1980s, has registered no further increase since the global financial crisis in 2008. Nonetheless, the United States outperforms the EU27 in terms of both business and government sector R&D expenditure (see Annex 6).

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[61] Measured as R&D expenditure as a percentage of GDP. The information on R&D spending, however, does not provide information about technology creation as such, because it refers to the inputs of the innovation process. The output of that process also hinges on the efficiency of the technology creation process.

Chart 19

Total (public and private) R&D expenditure

(percentage of GDP)

- ■ EU27
- ■ EU – new
- ■ EU – old
- ■ United States
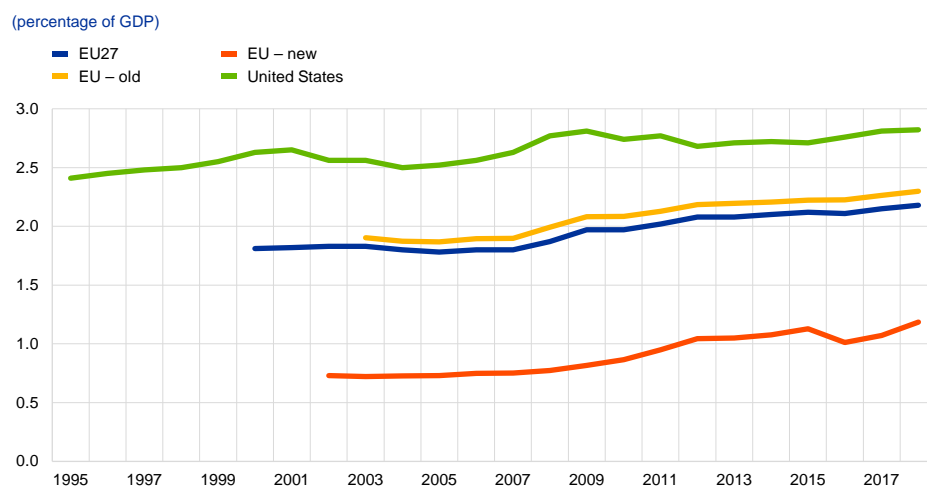
Sources: Own calculations using European Commission data.

An indicator of the output of the innovation process is the number of patent applications submitted.[62] Patents give an inventor the exclusive right to use a newly developed product or process. Others can use it only if the patent holder is compensated. Patents are, therefore, an important measure of innovation output, reflecting the inventive performance of countries and firms.[63] This holds particularly for the manufacturing sector, where a much higher share of innovations are protected by patents, compared with innovations in the services sector.[64]

The number of patent applications of EU27 countries per million inhabitants rose gradually until the mid-2000s, stalling thereafter (Chart 20).[65] This evolution reflects developments in the older EU Member States. In the newer EU countries, patent activity has gradually risen, but starting from a very low level. Triadic patent applications to the European, US and Japanese patent offices are of higher value and higher innovation content, given their higher costs and the significant delays involved in the patent-granting procedure. They increased until the end of the 1990s, to decrease markedly at the end of the period. This development was mainly driven by patent activity in the EU-old countries (Chart 20, left panel). US patent activity had a comparable evolution but at a structurally higher level (Chart 20, right panel). The somewhat flat profile of patent applications, particularly in more

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[62] In general, a couple of years are needed to complete a given patent-granting procedure; this leads to considerable time delays before the impact of a patent on the real output of the innovation process is seen. Therefore, we prefer to use patent applications instead, since these tend to show a stronger and more immediate link with innovation output and are available for more recent periods.

[63] Note, however, that patent rights can also lead to slower technology diffusion.

[64] For evidence on this, see for example the EU CIS (2016), which suggests that in all countries the share of innovative firms which apply for patents is higher in manufacturing than in the services sector. In Germany, for example, around 30% of innovative manufacturing firms apply for a patent, whereas only around 10% of innovative service firms do so.

[65] The analysis uses the number of patent applications to the EPO and the number of "triadic patent family" applications. The latter includes patents filed at the European (EPO), Japanese (JPO) and US (USPTO) patent offices.

recent years, is consistent with the dynamics of the share of innovative firms, sourced from the Community Innovation Survey (CIS) and shown in Annex 6.

Chart 20

Patent applications, EPO (left panel) and triadic (right panel)
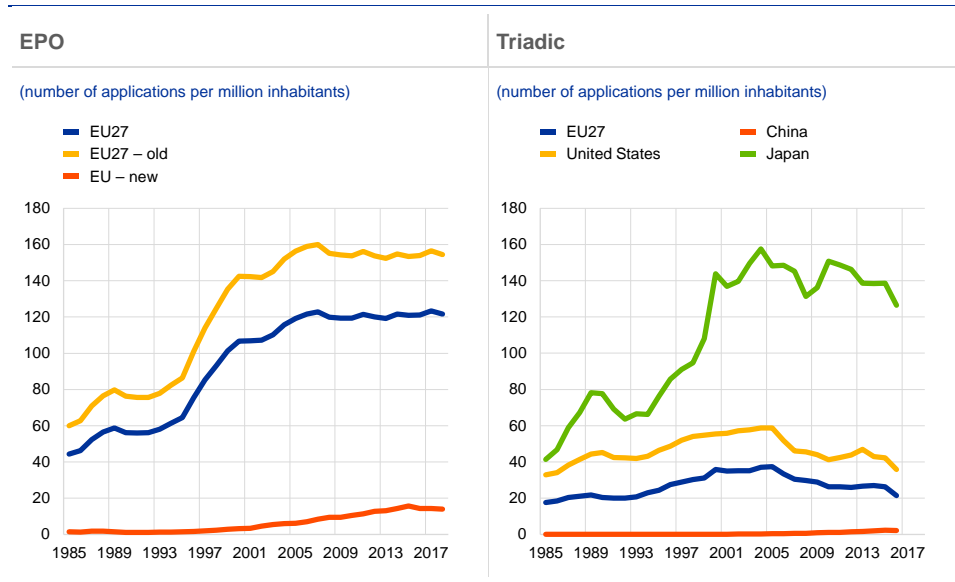
Sources: Own calculations using OECD.

The stagnation in innovation, measured by patents, in the EU and the United States might be related to increasing competition from China. Although the export market share of the EU (and the United States) in manufactures did not decline significantly between 2012 and 2018, there was a steep drop in the market share of high-technology manufactures, particularly in the EU (Chart 21).[66] In the same period, China increased its market share in the high-technology export segment by ten percentage points (from 26% of the market to 36%).

Conversely, technology diffusion across countries, measured by the technology content of European exports and imports, shows a gradual rise since 2007.[67] The increase has, however, been rather limited and in 2017 and 2018 a slight decrease is observed. The difference between EU-old and EU-new economies has narrowed over this period but for high-tech exports is still considerable. Consistently with the view that EU-new economies are catching up as a result of the fast technology adoption facilitated by their participation in international trade, the share of high-tech imports to the region is significantly higher than that of high-tech exports from it.[68] At the same time, the share of high-tech imports and exports in EU-old countries is similar, standing at around 14% of total trade (see Annex 6).

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[66] Over the 2012-18 period, EU high-tech exports increased by 7.6% but world high-tech exports increased by 31%, hence the loss in market share.

[67] High-tech export and import data from Eurostat are expressed as a percentage of total trade.

[68] By definition only international diffusion is captured, as domestic sales of high-tech products do not show up in these figures.

Chart 21

Export market share in manufactures (left panel) and high-technology manufactures (right panel), 2012 and 2018

Manufactures	High-technology manufactures
(percentage of world manufactures exports)	(percentage of world high-technology manufactures exports)
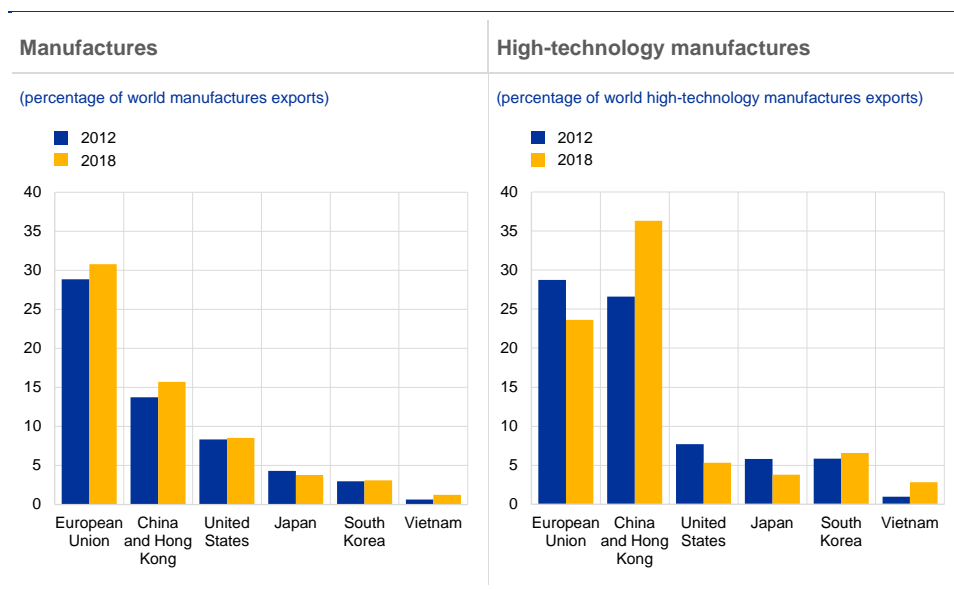
Sources: Own calculations using World Trade Organization (left panel) and World Bank (right panel).

3.2.2 Developments in technology creation and diffusion from a micro perspective

As an alternative to macroeconomic indicators of technology creation and diffusion, micro-based indicators are used in this section. Aggregate figures often mask notable heterogeneity across firms, even those operating within narrowly defined sectors of activity. For that reason, as mentioned in Section 3.1.1, a recent and very prolific strand of the literature uses firm-level data to highlight the large differences between frontier firms in any sector, i.e. those at the top of the productivity distribution and the rest, also known as "laggards" (see Andrews et al., 2015 and 2019). This strand of literature identifies technology creation using the TFP growth of frontier firms in a given sector, and technology diffusion using the TFP growth gap between frontier and laggard firms operating in the same sector.[69] It is assumed that if new technology spreads quickly from frontier firms to the rest their TFP growth developments should be similar, although starting at very different levels.

To explore this, we use the ECB's iBACH-ORBIS firm-level database. The dataset covers firms from six euro area countries (Belgium, Germany, Spain, France, Italy and Portugal) over the period 2006-17. To overcome the known industry and size biases of these databases (and particularly of ORBIS), we apply resampling weights at the country-sector-size class-year level. As shown in Annex 6, the raw data for Germany and France suffer from severe under-representation of micro firms.

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[69] This way of measuring technology creation thus not only encompasses technical innovations but also covers managerial and other organisation-related innovations which improve firms' productivity.

However, after applying the resampling weights the size distribution of each of the country samples mimics reasonably well, albeit to a lesser extent for Germany, the size distribution of the population (see Annex 6 for more details on the dataset and on TFP estimation at the firm level). To flag frontier and laggard firms, we pool all firms in each sector across the six countries and rank them according to their TFP level. In the rest of this section, frontier firms will refer to the euro area top 5% of TFP firms in a given sector, defined narrowly at the 4-digit level. Laggard firms will be approximated by the median firm in the sector from the pooled sample.

European frontier firms differ from laggards operating in their same sector of activity (Table 1). They are more than twice as productive as non-frontier firms (in terms of TFP levels), larger, more capital intensive (in particular with respect to the use of intangible capital) and slightly older. As regards their financial structure, frontier firms exhibit both higher profits and higher debt to equity ratios. Comparing service frontier firms to manufacturing ones, the former group uses intangible capital more intensively (as measured by the ratio of intangible capital to total capital), which might imply a lower ability on the part of service firms to provide collateral for financing purposes (see Annex 6).

Table 1

Characteristics of euro area frontier firms and laggards

	Frontier firms		Non-frontier firms	
	Mean	Median	Mean	Median
TFP growth (%)	2.7	2.9	0.4	0.4
TFP level	2.2	1.8	1.0	1.0
Employment (L)	13.5	6.6	3.9	4.0
Tangible capital/L	367.1	31.6	32.9	9.2
Intangible capital/L	13.8	6.1	1.7	26
Tangible capital / total capital	0.80	0.85	0.97	1
Profits	518.2	140.0	12.5	11.0
Debt / equity	40.5	7.7	2	1.8
Age (years)	13.3	11.6	11.5	11.0

Sources: Own calculations using ECB iBACH-Orbis Database.

TFP growth at the frontier has accelerated relative to the pre-crisis period, but only in services (Chart 22). The micro data suggest a dual development: innovation at the technological frontier seems to have accelerated in services after the global financial crisis, while in manufacturing there is no such acceleration but rather a slowdown in TFP growth. The result is that the services sector seems to have surpassed manufacturing in terms of innovative activity over the most recent period. Since patents reflect innovative outcomes for manufacturing firms to a larger extent than for service firms, the observed slowdown in manufacturing technology creation is consistent with the slowdown in patenting activity in the EU27 shown by the macro data.

Chart 22

Average annual TFP growth of euro area frontier firms, different periods

(average annual TFP growth, in percentages)
- 2005-07
- 2008-12
- 2013-17
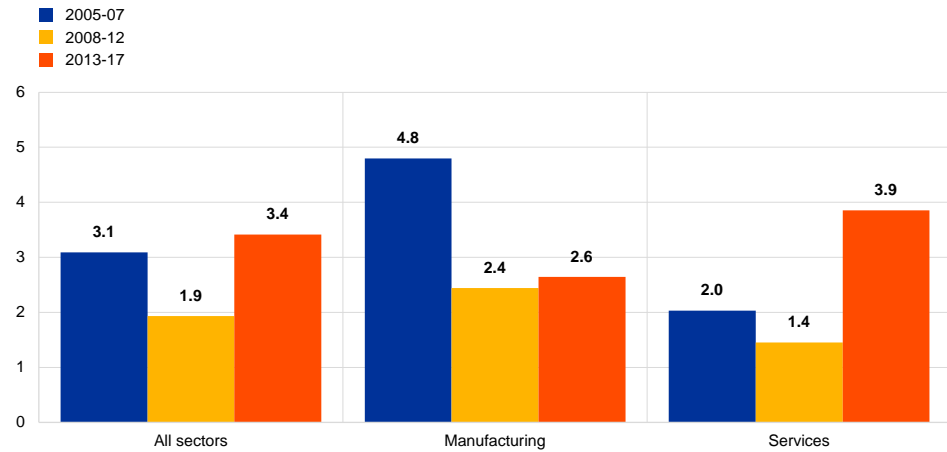
Sources: Own calculations using ECB iBACH-Orbis Database.
Note: The figure shows weighted average annual TFP growth rates of the top 5% most productive firms in a given year in a 4-digit industry.

The slowdown in the TFP growth of frontier firms in manufacturing is mostly driven by developments in high-tech industries (Chart 23, left panel). Before the global financial crisis, high-tech industries were characterised by rapid technology creation, as proxied by the TFP growth of euro area frontier firms in these sectors. Since the crisis, the pace of technology creation has slowed in high-tech industries and is now similar to that of low-tech industries. In contrast, in services technology creation in both knowledge intensive and less knowledge intensive industries has accelerated relative to the pre-crisis period (Chart 23, right panel).[70]

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[70] Manufacturing industries are classified according to their R&D intensity (R&D by value added of the industry) into high-technology and medium high-technology on the one hand, and medium low-technology and low-technology on the other hand following the Eurostat classification. Service industries are classified into knowledge-intensive services and less knowledge-intensive services based on the share of tertiary educated persons at NACE 2-digit level, also following Eurostat standards..

Chart 23

Average annual TFP growth of frontier firms by sectoral technology intensity in manufacturing (left panel) and services (right panel), pre and post-global financial crisis

Sources: Own calculations using ECB iBACH-Orbis Database.
Notes: Weighted average annual TFP growth rates of the top 5% most productive firms in a given year in a 4-digit industry. Manufacturing industries are classified according to their R&D intensity (R&D by value added of the industry) into high-technology and medium high-technology on the one hand, and medium low-technology and low-technology on the other hand following the Eurostat classification. Service industries are classified into knowledge-intensive services and less knowledge-intensive services based on the share of tertiary educated persons at NACE 2-digit level, also following Eurostat standards.

The reasons behind the slowdown in manufacturing technology creation are not clear-cut. One possible explanation could be the high (and increasing over time) average age of frontier firms (Chart 24, left panel). A higher average age of firms within an industry can be a sign of an advanced technology life cycle and of reduced firm dynamics (i.e. reduced entry and exit rates), which are often associated with lower innovation activity (see Klepper 1996, 1997 or Huergo and Jaumandreu, 2004 and Annex 6). Another possible reason, as explained in Section 5.2.1 on globalisation and productivity growth, could be related to the slowdown in trade integration. This may have contributed to the slowdown in technology creation by European manufacturing firms as a result of decreased incentives to engage in technology upgrading and innovation (Bustos, 2011) and muted learning-by-exporting (De Loecker, 2013).

TFP growth of laggards has decreased since the pre-crisis period as a result of dynamics in manufacturing (Chart 24, right panel). TFP growth of manufacturing non-frontier firms, proxied by the median firm in the sector, has decreased over time.[71] TFP growth of laggards in services has, however, been stable over time. Given the above-mentioned strong acceleration of TFP growth in service frontier firms, the flat profile of laggards points to an increase in the frontier-laggard gap in services.

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[71] Results are similar if an alternative definition of laggard firms, such as the bottom 95% of the TFP distribution, is used instead.

Chart 24

Age of frontier firms by technology-intensity in manufacturing industries, 2006-17 (left panel) and average annual TFP growth of non-frontier firms, different periods (right panel)
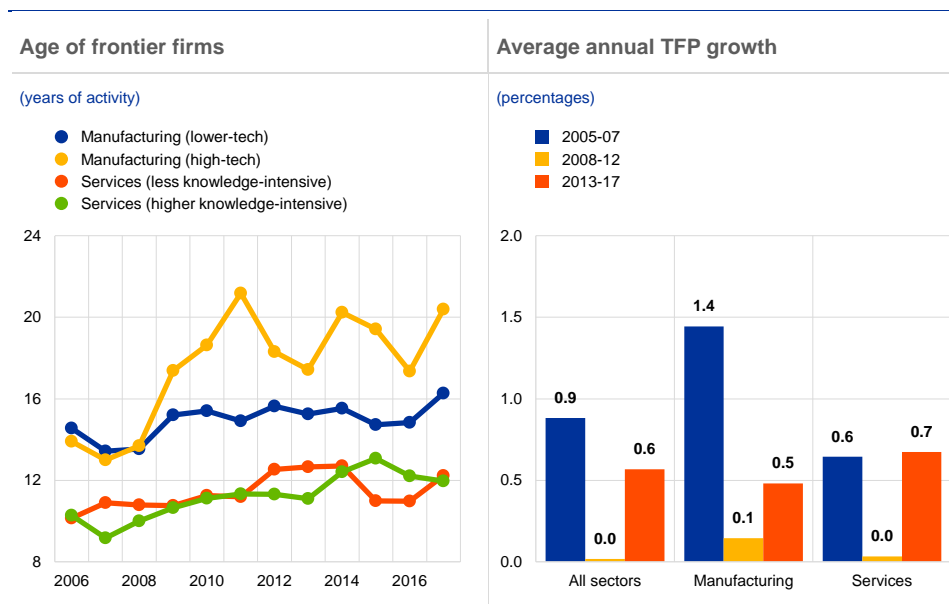
Sources: Own calculations using ECB iBACH-Orbis Database.
Notes: Left panel: Frontier firms defined as those at the top 5% of the TFP distribution in a given year in a 4-digit industry. Manufacturing industries are classified according to their R&D intensity (R&D by value added of the industry) into high-technology and medium high-technology on the one hand, and medium low-technology and low-technology on the other hand following the Eurostat classification. Service industries are classified into knowledge-intensive services and less knowledge-intensive services based on the share of tertia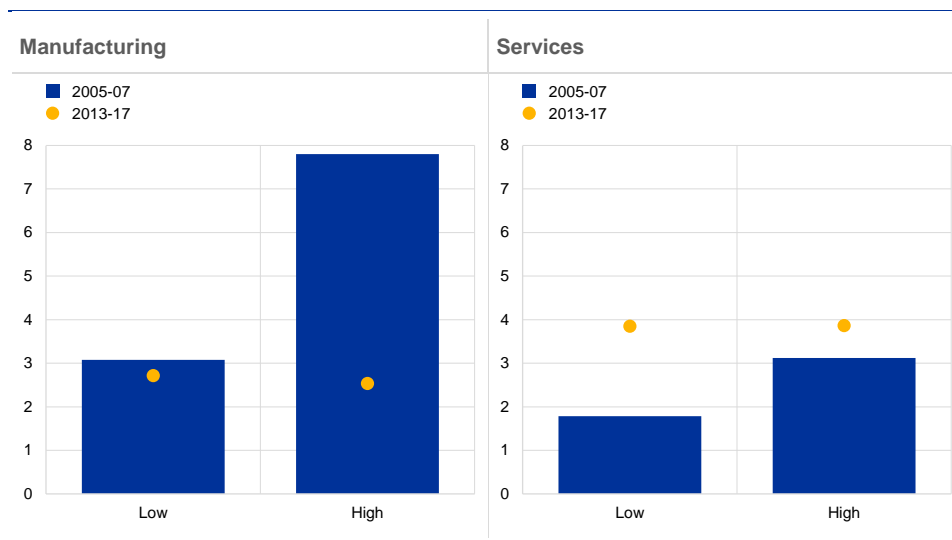ry educated persons at NACE 2-digit level, also following Eurostat standards Right panel: The figure shows weighted average annual TFP growth rates of the median firm in a given year in a 4-digit industry.

Taken together, the above findings suggest that the reasons behind the slowdown in productivity growth in the euro area, at least since the global financial crisis, differ in manufacturing and services. In manufacturing, and more specifically in high-tech manufacturing industries, frontier firms are becoming less innovative (or at least less capable of reaping the efficiency gains stemming from their innovation output). In services, although technology creation is accelerating, only frontier firms are enjoying the benefits. In fact, the widening TFP level gap between frontier and laggards in services, as shown in Chart 25 (right panel), suggests that technology diffusion is decreasing. These conclusions are broadly in line with findings from a range of other studies reviewed in Section 3.1.1.

To sum up, macroeconomic indicators of innovation efforts and outcomes, such as R&D expenditures or triadic patent applications, suggest that technology creation in Europe is lower than in the United States, and might even have decreased over the recent period. Firm-level evidence consistently shows decreasing TFP growth of manufacturing frontier firms, particularly in high-tech sectors. Technology creation in services, in contrast, has accelerated but seems to benefit only frontier firms. The recent productivity growth slowdown in Europe could thus be related to a twofold phenomenon: reduced innovativeness of European high-tech manufacturing firms, traditional sources of vibrant technical progress and productivity growth, and a growing gap between frontier and laggard services sector firms.

Chart 25

TFP levels gap between frontier and laggard firms over time – manufacturing (left panel) and services (right panel)

Manufacturing	Services

Sources: Own calculations using ECB iBACH-Orbis Database.
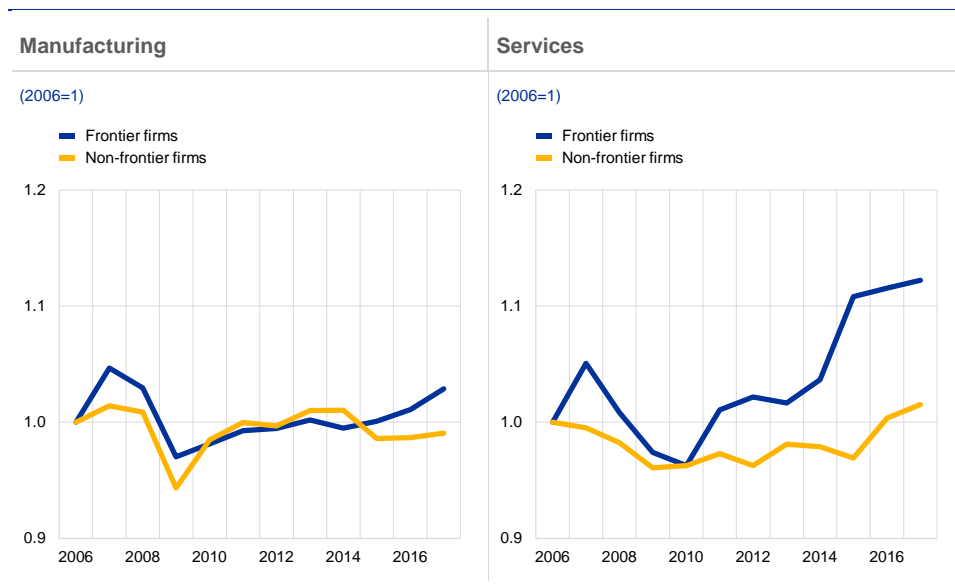Notes: Frontier firms are defined as those at the top 5% of the TFP distribution in a given year in a 4-digit industry. Laggards are defined as the median firm in a given year in a 4-digit industry.

4 Reallocation of resources

4.1 The productivity cost of resource misallocation

This section reviews the extensive literature on the drivers and consequences of resource misallocation. It starts with a discussion of the literature exploring the circumstances under which resource reallocation might be inefficient (Section 4.1.1). It then conducts a meta-analysis of the empirical papers aiming to quantify the cost, in terms of TFP level or growth losses, of misallocation (Section 4.1.2).

The meta-analysis shows that resource misallocation could cost up to 0.2 percentage points of annual TFP growth in the EU, or about 29% of the TFP level compared with a market without distortions.

4.1.1 Literature overview[72]

In well-functioning economies resource allocation is productivity-enhancing, but that is not always the case. Numerous recent contributions explore market distortions that can affect reallocation (Hsieh and Klenow, 2009; Restuccia and Rogerson, 2008; Bartelsman, Haltiwanger, and Scarpetta, 2013; and Gopinath et al., 2017).

The strength of productivity-enhancing reallocation will depend on the benefits of moving towards optimal size and the costs of achieving this. Larger shocks can increase potential benefits, as can a steeper relationship between profit and deviation from optimal size. Costs can depend on adjustment frictions and policy-induced distortions, but also on the available supply of productive inputs. A rich body of literature explores the effects of employment protection on reallocation (e.g. Bertola and Rogerson, 1997; Bassanini, Nunziata, and Venn, 2009; Hagedorn and Manovskii, 2008; Poschke 2009; and Bartelsman, Gautier, and de Wind, 2016). The costs of vacancy creation or of starting a new business can also change the reallocation calculus. A related body of literature exists on financing costs and capital reallocation. In heterogeneous firm models, frictions in capital arising from asymmetric information can result in allocations of capital that may not balance marginal costs and benefits (see, for example, Bernanke, Gertler, and Gilchrist, 1999; Cooley and Quadrini, 2001; Midrigan and Xu, 2014; Buera and Moll, 2015).

Each of these cost and benefit components can be subject to trends, for example owing to changes in technology, but can also differ across countries, for example through differences in policy stance. There is evidence that in the euro area (shown in Section 2.3 of this report), but also in the United States, the magnitude of job reallocation has been declining secularly (Hyatt and Spletzer, 2013; Decker et al., 2014), although no clear answer is available about the causes of the decline. Evidence in Bartelsman, Gautier, and de Wind (2016) shows that in the EU

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[72] This overview draws heavily on Bartelsman, Lopez-Garcia and Presidente (2019).

reallocation seems to be higher among innovative and ICT-intensive firms, probably because the magnitude of the shocks these firms are facing is larger.

Productivity-enhancing reallocation also may differ over the cycle, as the nature of the shocks changes and the relationship between benefits and costs is altered. Foster, Grim, and Haltiwanger (2016) review many of the discussions of reallocation cyclicality, with the general finding that it is less costly in downturns. However, this might not be the case in the presence of certain distortions. The exact nature of the cyclical changes depends on the factor concerned, labour or capital, but can also differ across recessions, owing to the underlying causes and magnitudes of the shocks. Another issue is whether the costs are associated with changes at continuing firms, or through entry and exit margins. "Scarring" through these margins can often lead to long-lasting effects of recessions.

For labour inputs, reduced tightness in the labour market during downturns should reduce search frictions. Krusell et al. (2017) present a model of the cyclical properties of gross worker flows within the search tradition. Policy may also change the incentives for firms to shed workers during downturns. Boeri and Bruecker (2011) study the effects of short-term work programmes and find that they reduce job losses at the onset of the crisis. They point out that effects may be asymmetric, causing more harm in upturns, and that the exact effects depend on interactions with other labour market institutions related to employment protection and wage bargaining regimes.

For capital inputs, the effect of the cycle on the costs and benefits of reallocation is less clear-cut. In empirical research using data on US firms from the Compustat database, Eisfeldt and Rampini (2006) find that the amount of capital reallocation between firms is procyclical. They find this surprising because, they argue, the benefits for reallocation are countercyclical, given that the dispersion of marginal capital productivity is higher in recessions. While the benefits of reallocation may be higher, so could the costs of attracting capital in a downturn. Consistently with this, Lee and Mukoyama (2015) find that firm entry is more procyclical than firm exits. The higher costs of capital reallocation may also lead to scarring, such that the negative productivity effects of a downturn can be felt long after the recession is over, as found by Buera and Moll (2015). The work of Gopinath et al. (2017) shows that financial market inefficiencies might explain capital misallocation in times of large capital flows, given that credit might be directed to high worth, but low-productivity, firms.

The broad-based increase in resource misallocation found in recent empirical papers suggests that some common factors are at play. They could be related to information asymmetries and collateral-based lending, labour market regulation, or increasing concentration as a result of winner-takes-all dynamics. Other policies might also reduce productivity-enhancing reallocation, for example tariffs and other forms of trade protection, which may distort the allocation of resources across firms. Corporate tax policy, an important determinant of firms' investment decisions, may also distort resource reallocation if it provides the wrong incentives for high and low productivity firms. Last, size-dependent policies intended to reduce the administrative burden borne by small firms could prevent the expansion of productive

firms and again distort resource reallocation (Guner et al. 2008; and Garicano et al. 2016).

4.1.2   A meta-analysis of empirical findings in the literature

The decline in productivity-enhancing reallocation documented in Section 2.3 could be partly cyclical, as crises are moments of maximum churning, but could also be structural. The reason is that the increase in the misallocation of resources in advanced economies pre-dates the global financial crisis, as shown in Chart 26 (see also Gamberoni et al. 2016, Gopinath et al., 2017; Calligaris et al., 2018; and Bun and de Winter, 2019). The observed increase in misallocation over time could be an important factor behind the declining productivity growth rates shown in Section 2.1.

This section provides a meta-analysis of the extensive empirical literature quantifying the TFP cost of misallocation. A meta-analysis is a statistical analysis that combines the results of multiple scientific studies on a given topic. As such, it is a very useful tool to gain a deeper understanding of the state of research and the impact of publication bias, the different methods used and sample composition effects on the estimates. For more details on the meta-analysis methodology, please refer to Annex 7.

Chart 26

Capital misallocation (left panel) and labour misallocation (right panel) over time, selected countries
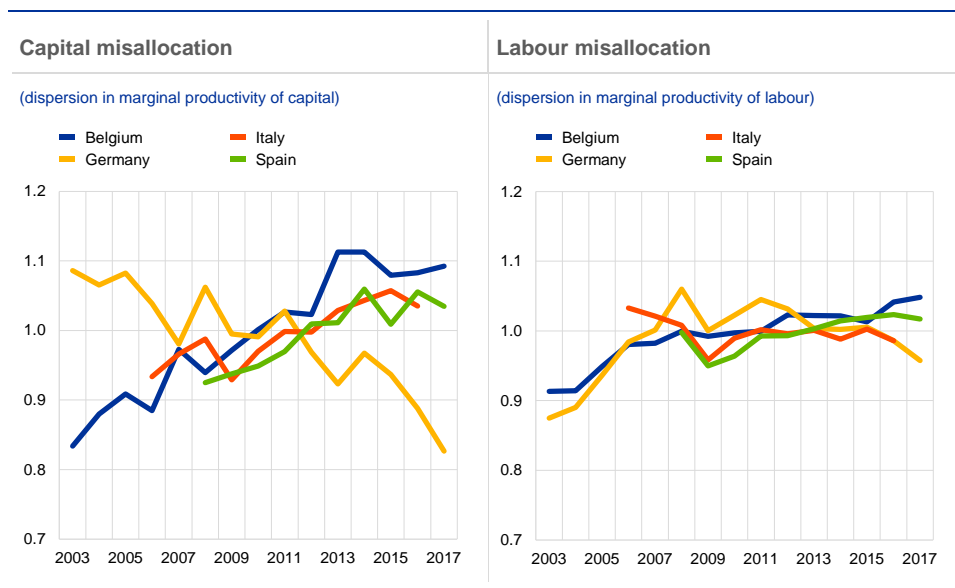
Sources: Own calculations using CompNet data.
Notes: Misallocation is measured by the within-sector dispersion in marginal revenue productivity of capital (left panel) and labour (right panel). Sector dispersion is then aggregated up using sector value added shares. Firm-level data are weighted to represent the distribution of firms in the population by sector and size class. For more information, refer to comp-net.org.

The impact of misallocation on the TFP level is found to be larger than the impact on TFP growth rates. To quantify the TFP loss due to misallocation, an estimate of the counterfactual TFP level, obtained from a hypothetical world without

distortions, is needed. Most studies follow Hsieh and Klenow (2009) and use their theoretical model to provide the benchmark. Some studies, however, consider the change in TFP loss over a number of years rather than the absolute level. This controls for sources of misallocation which stay constant over time, and intuitively leads to a smaller estimated effect size.[73] We therefore include in the meta-analysis a dummy variable indicating whether the TFP loss is measured against a benchmark TFP level or compared to the TFP loss observed in a base year. The estimated coefficient of the dummy indicates that the growth-effect size is on average 24.8% smaller than the level-effect size.[74]

The direct approach estimates a much smaller TFP loss than does the indirect approach. The direct approach (Restuccia and Rogerson, 2013) consists of identifying one or more explanatory factors of misallocation. This choice depends on a priori conjectures as to its empirical relevance and importance as a source of misallocation. To obtain a quantitative assessment of the extent to which these factors generate misallocation and affect aggregate TFP, a theoretical model and empirical measurement are required. Typically, the TFP loss due to a specific factor is not large. For example, Gilchrist et al. (2013) show that variations in effective borrowing rates lead to a TFP loss of only 2%. In contrast, the indirect approach does not distinguish across individual determinants but tries instead to quantify the overall effect of all possible factors on misallocation. The model produced by Hsieh and Klenow (2009) is a prime example of the indirect approach.[75] In their model any factor creating a wedge or distortion in the first order conditions of a firm's optimisation problem is attributed to misallocation. This cross-sectional dispersion in wedges has a direct impact on aggregate TFP. The estimated TFP loss using this approach is typically large (>10%).

The extent of misallocation and the corresponding inefficiency loss depends on the country of analysis. For example, Hsieh and Klenow (2009) find that TFP loss due to misallocation is larger in China and India (100%) than in the United States (35%).[76] Gamberoni et al. (2016) analyse five European countries (Belgium, Germany, Spain, France and Italy) and find the largest TFP loss in France (50%) and the smallest in Germany (<10%). In general, we expect low-income countries to

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[73] For example, in Gopinath et al. (2017) TFP level and growth effects are 28% and 10% respectively.

[74] Note that there is a decrease in the strength of observed effect size as the empirical evidence accumulates over time. In the misallocation literature there are multiple reasons for this. First, the recent literature emphasises the restrictive assumptions of earlier models. For example, Hsieh and Klenow (2009) assume that all firms apply the same markup and have constant returns to scale. Applying this model, Ho and Ruzic (2018) find an increase in misallocation over time in the United States. In a generalised set up, however, they find declining misallocation. Assumptions are therefore of high importance to quantitative results. Second, the variation in distortions in the indirect approach provides an upper bound for misallocation. In other words, all variation in distortions is attributed to misallocation. Allocative distortions originate from many sources, however. Some of these factors, such as heterogeneity in mark ups and production technologies, do not strictly cause misallocation. Recent studies (Ho and Ruzic, 2018; David and Venkateswaran, 2019; Bun and de Winter, 2019) disentangle the various sources of dispersion in wedges. Controlling for the various other sources, the contribution of pure misallocation becomes smaller.

[75] An alternative indirect approach is the within-industry sample covariance between firm size and productivity, for which see Bartelsman et al. (2013). This is the allocative efficiency term in the productivity composition referred to in Section 2.3. Given the lack of empirical estimates of TFP losses using this approach, we do not include this direct approach in the meta-analysis.

[76] Hsieh and Klenow (2009) also calculate the TFP gains of China and India relative to those of the United States. We however consider absolute TFP gains, which are typically reported.

show the largest TFP losses from misallocation because, first, the literature has shown that TFP differences across countries are a large contributor to income differences, and second, low income countries generally have weaker institutions that prevent the efficient allocation of resources. We therefore include in the analysis two dummy variables, for the United States and euro area countries respectively.[77] The TFP loss for the United States is found to be 28.8% smaller than for other countries. This is in line with the often adopted view that the United States is at the efficiency frontier. It also indicates, however, that even in frontier countries reductions in misallocation can contribute to growth.

Table 2

Results of the meta-analysis

(percentages)

	All studies	Euro area studies
Growth effect size	-24.77** (3.97)	-29.64** (5.97)
Direct approach	-23.55** (7.42)	-11.22** (3.64)
United States	-28.82** (9.64)	
Euro area	-24.23** (6.09)	
Publication year	-1.02 (0.89)	-1.47 (1.74)
Intercept	60.95** (5.65)	42.65** (5.70)
Observations	854	210

Notes: Standard errors in parentheses * p<0.10, ** p<0.05.

The results of the regression analysis[78] **show that the impact of increased misallocation on TFP growth in the euro area can be substantial, amounting to an annual productivity loss of 0.2%.** In the second column of Table 2 we provide estimates based on the 21 primary studies for euro area countries, which result in a subsample of 210 estimates of the effect size. The pattern of the estimates is qualitatively the same as when all studies are included. The growth effect size (measured as 42.6-29.6=13.0%) can be used as an estimate of the impact of misallocation over time on productivity in the euro area. Combining this with the average time span of the primary studies for the euro area, which is around 8.5 years, we find an annual productivity loss of 1.5%. This is a substantial effect, given the low productivity growth of various European countries, as reported in Section 2. Note that it provides an upper bound because the estimate is based on the indirect approach. In primary studies for the euro area using the direct approach the growth effect size is only 1.8%, resulting in a 0.2% annual productivity loss.[79]

Regarding the impact of misallocation on the TFP level, the meta-analysis shows that the average TFP loss for the euro area and US subsamples is

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[77] As an alternative we could consider the relevant country characteristics, for example GDP per capita.

[78] See Annex 7 for details on the regression model.

[79] There are not enough observations to provide an accurate average growth impact for the United States.

28.5% and 27.0% respectively. Note that these are percentage losses in TFP compared with those of a counterfactual world without distortions. Hence the implied TFP loss is similar in the euro area and United States but different from that in other countries with an average level impact close to 53%.

To sum up, the section discusses the recent literature exploring market distortions that can affect reallocation and could therefore explain the declining contribution of resource reallocation to aggregate productivity growth documented in Section 2.3. To quantify the productivity cost of this increase in misallocation, the section presents a meta-analysis that, after controlling for study-related factors that might bias the result, estimates the average impact of resource misallocation on TFP growth and levels. The meta-analysis shows that in the euro area resource misallocation, as compared with an efficient allocation of resources, could cost up to 0.2 percentage points of annual TFP growth, or about 29% of the TFP level.

4.2   Entry and exit of firms and productivity growth

Resource reallocation across firms can be the result of a process of creative destruction whereby new and more productive firms displace obsolete ones. **This section explores the channels of impact of the entry and exit of firms on sector productivity growth in the euro area.** In the short term, the productivity impact of firm demography depends on the relative productivity of new and exiting firms and entry and exit rates (Section 4.2.1). Over the medium and long term the productivity contribution of new firms increases as a result of a selection and learning processes. It also increases indirectly, through increased market competition (Section 4.2.2).

The analysis of this section uses firm-level data for four euro area countries (Belgium, Spain, France and Italy) over the period 2006-18, sourced from ORBIS and iBACH. The data are treated so that entry and exit rates resemble those in the population of non-financial corporations and average sector productivity levels match aggregate numbers from the national accounts. Labour productivity is defined at the firm level as real value added per employee.

The main findings of the section are that the relatively small short term contribution of net entry to productivity growth is the result of the low productivity of new firms, in some countries more than others. However, there is a strong selection process post-entry for the most productive entrants, as well as a catch-up process to the average sector productivity level. The section finds that this fast catch-up or learning process is driven by a few surviving young firms that grow much faster than incumbents. They thus increase substantially the contribution of entry to aggregate productivity growth over the medium term. Most young surviving firms, however, show low productivity growth rates.

4.2.1 The short-term impact of firm demography on productivity growth

This section explores the contribution of net entry to aggregate productivity growth, with a focus on the post-entry dynamics of new firms in the euro area. The data for the analysis are the same as those used in Section 3.2.2 on technology creation and diffusion from a micro perspective (see Annex 6 for details on the data). The data refer to four euro area countries – Belgium, Spain, France and Italy[80]- over the period 2006-18 and are sourced from ORBIS and iBACH. To mitigate possible sampling issues regarding entries and exits, we treat the data as follows. First, resampling weights for cells defined at the country/year and 2-digit sector of activity for entries, exits and incumbents are applied separately, using information on number of entries and exits of corporations by industry from Eurostat's firm demography statistics. The result is that the number of entries and exits closely follows that found in the overall population of firms in any given country, industry and year (Chart 27). And second, the productivity level of firms is re-scaled so that the sample sector mean is the same as the average industry productivity level provided by Eurostat's sectoral national accounts. Annex 8 provides further details on the definition of entries and exits in the sample and on the impact of weighting and re-scaling the data.

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[80] Data for Germany and Portugal could not be used given their very low numbers of entries and exits.

Chart 27

Entry and exit rates over time: sample vs. Eurostat

(percentage of all active corporations)

- Exit rate – sample
- Exit rate – Eurostat
- Birth rate – sample
- Birth rate – Eurostat
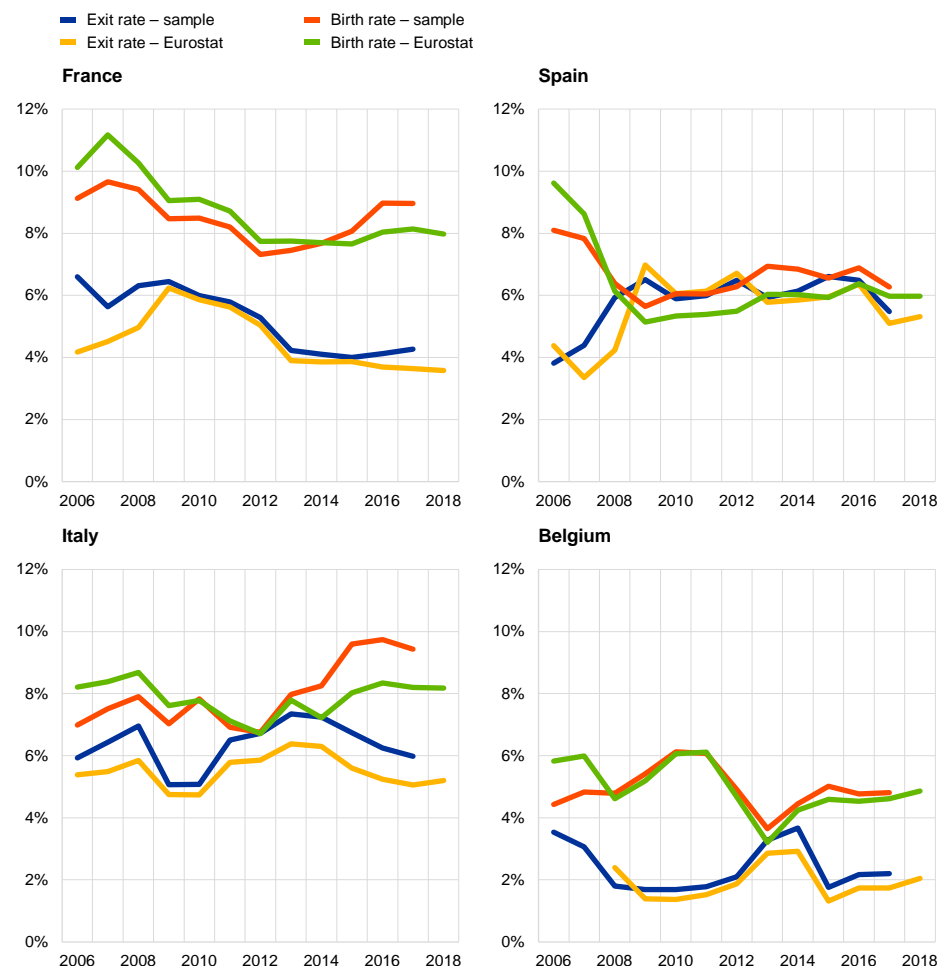
Sources: Own calculations using EUROSTAT and iBACH-ORBIS data.
Notes: Entries in the sample are defined as firms that appear for the first time in the sample and have zero or one years of activity, according to their incorporation date, and do not appear as inactive in ORBIS. Exits are defined as firms that disappear from the sample, are not reactivated within the next two years and have an ORBIS status consistent with "non active".

The productivity contribution of net entry is low across all countries as a result of the low productivity of new firms in their early years. Section 2.3 of the report shows that the contribution to aggregate productivity growth of resource reallocation across incumbents is larger than that of net entry. The reason is that, at entry, new firms are characterised by low productivity (Chart 28). This is particularly the case in Italy, where new firms are about half as productive as incumbents in their same sector, and to a lower extent in Spain. In contrast, new firms in France and Belgium are about 90% as productive as incumbents. It is not clear what is driving these country differences. The reasons could be firm-related characteristics such as being family-owned, or entry and exit costs whereby firms decide to enter very small to minimise costs in case of early failure.[81] The result is that in the short term firm entry acts as a drag on aggregate productivity growth across all countries, but particularly

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[81] According to the World Bank's "Doing business 2020", young Italian firms suffer higher initial costs than their counterparts in other countries, one reason being the difficulty of actually starting a business.

in the two southern European economies of the sample. This negative impact is, however, offset in all countries by the exit of even lower-productivity firms. The net contribution of entry and exit is thus positive overall, but relatively small.

Chart 28
Productivity of entrants and exitors relative to incumbents, different periods
(ratio of the productivity level of entrants or exitors to incumbents in their same sector)
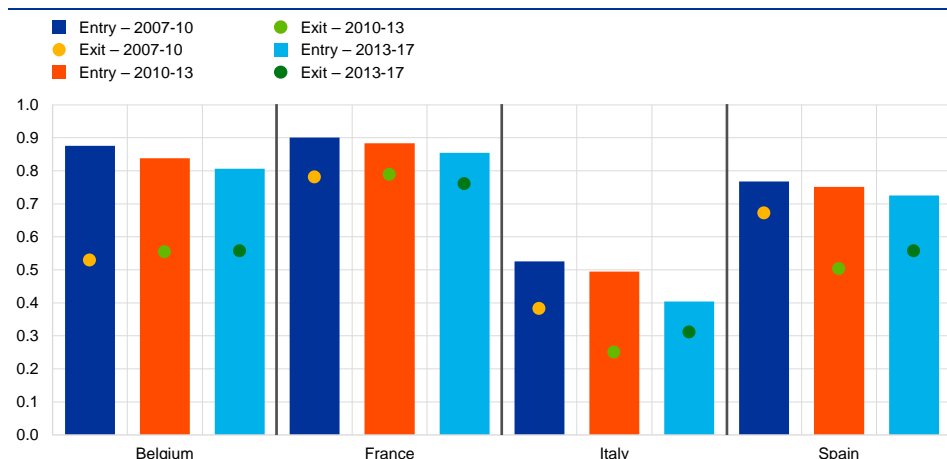
Sources: Own calculations using ORBIS-IBACH data.
Note: productivity defined as firm's real value added by employee.

The short-term contribution of net entry to aggregate productivity growth also depends on the rate of entry and exit of firms. Entry rates of corporations have declined over time in Europe, in particular after their cyclicality is accounted for (Chart 29, left panel).[82] The time period covered by entry data in Europe is too short to conclude that there is a long-standing decline in entry rates, as has been shown in other advanced countries like the United States (see Decker et al. (2016).[83] The observed decline in euro area entry rates has occurred across the industry, construction and business services sectors, although it is more pronounced in services (see Annex 8). The reasons provided in the literature to explain a potentially long-lasting decline are manifold and include waning population growth, population ageing and increasing market concentration resulting in higher entry barriers (see Calvino et al., 2015). Policy measures designed to support market incumbents could also have contributed to the decline. Exit rates have also decreased, albeit possibly to a smaller degree than entry rates (Chart 29, right panel).

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[82] Firm entry rates are usually found to be procyclical (see, for example, Lee and Mukoyama, 2015; and Tian, 2018).

[83] Other studies also show a decline in entry rates in Europe: see Bijnens and Konings (2020), Calvino et al. (2015), and Deutsche Bundesbank (2021).

Chart 29

Entry rate of corporations, business economy (left panel) and exit rate of corporations, business economy (right panel)

Entry rate of corporations, business economy	Exit rate of corporations, business economy
(percentage of active firms)	(percentage of active firms)
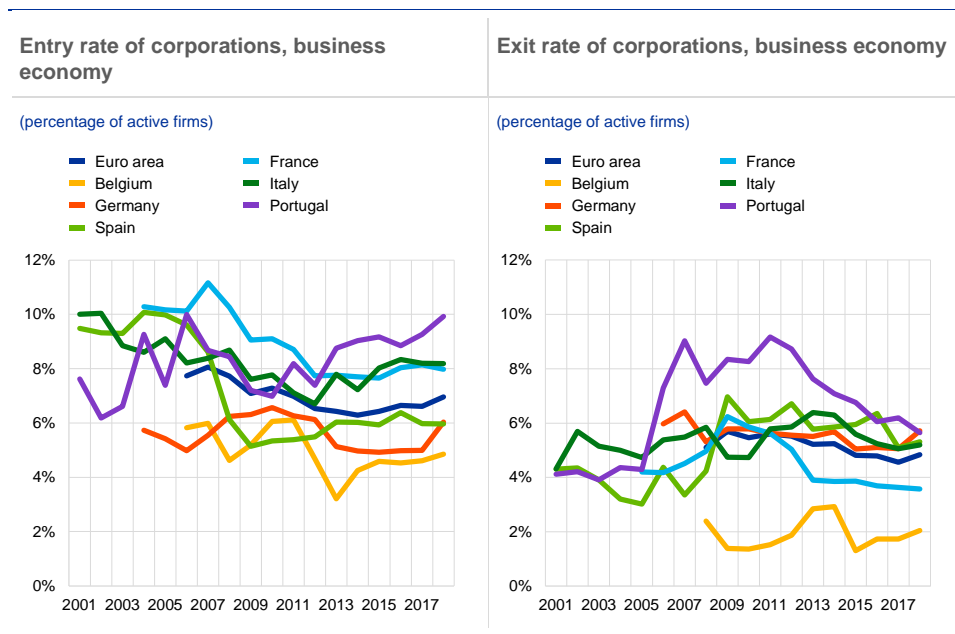
Sources: Own calculations using Eurostat business demography indicators.

4.2.2 The medium and long-term impact of firm demography on productivity growth

Post-entry selection of new firms increases the productivity contribution of young firms over the medium term. After entry, firms learn about their relative productivity and, if it is well below the average for the sector, exit after a few years of operation. This is called the "selection effect" (Jovanovic, 1982). In our sample, about one-third of firms exit before completing three years of activity (Chart 30, left panel).[84] Which firms survive the first years of operations depends on their productivity. We find that young surviving firms, defined as those surviving the three first years of operations, are up to 2.5 times as productive as young exitors in the same age bracket (Chart 30, right panel).

If they survive, firms converge to the average scale of efficiency in their industry. This implies that they grow faster in terms of productivity, particularly over the first five years, than young exits and also than incumbents in the same sector. This is known as the "learning effect". After controlling for sector of activity, sector demand conditions and entry year, it is found that young survivor firms in Belgium and France converge in about ten years to the productivity level of mature incumbent firms with more than 20 years of activity in their same sector. In Italy and Spain,

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[84] The results show selection for up to three years of activity for two cohorts of firms: those entering in 2006-08 and those entering in 2013-14.

where new firms' productivity level is well below that of incumbents, the catch-up process takes longer (Chart 31, left panel).

Chart 30

Share of new firms exiting the market before completing three years of activity (left panel) and productivity of young survivor firms relative to young exitors, different periods (right panel)

Share of new firms exiting the market before completing three years of activity	Productivity of young survivor firms relative to young exitors, different periods
(percentage of new firms in each cohort)	(ratio of productivity of firms surviving up to three years relative to exitors at or before three years)

■ Share of new firms exiting before 3 years of activity (cohort 2006-08)
■ Share of new firms exiting before 3 years of activity (cohort 2013-14)

■ 2007-10
■ 2010-13
■ 2013-17
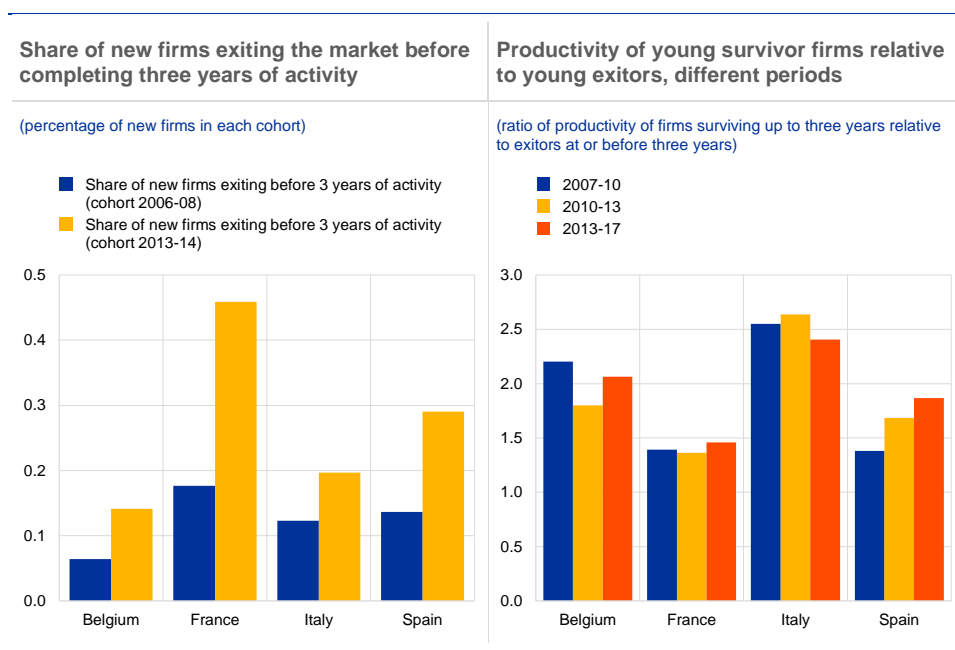
Sources: Own calculations using ORBIS-iBACH data.

The strong productivity performance of young survivor firms is driven by a few high-growth firms. Focusing on young firms entering after the global financial crisis in order to abstract from the possible negative impact of the crisis, we plot the distribution of average annual productivity growth during their first six years of activity and find it to be extremely skewed (Chart 31, right panel). Annual productivity growth of firms at the top 10% of the growth distribution is more than 100% on average, compared with up to 16% annual productivity growth of the median firm. Indeed, young firms have been shown to introduce radical innovations more frequently than mature firms (see Criscuolo, Nicolau and Salter, 2012 for UK evidence; and Acemoglu et al. 2018), although according to our findings only a few succeed. The higher innovation intensity of young firms could be related to the fact that they start operations with the latest vintages of capital in place and do not have to incur the reorganisation costs implied by the change to new technologies.[85] However, recent analysis for the United States has found that the prevalence of high-growth firms has declined over time. Our dataset does not cover a sufficiently long period to analyse this finding in the European context, but it merits future research when the data so allow.

New firms also contribute to aggregate productivity growth by increasing market competition. New innovative firms can stimulate the innovation efforts of

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[85] New firms could also be spin-offs of other technologically-intensive established firms.

incumbents through competition pressures, which can produce a positive impact on their within-firm productivity growth (Anderton et al. 2020).

Chart 31

Productivity convergence of new firms to incumbents in the same sector, conditional on survival (left panel) and productivity growth distribution of firms established in 2012-13, after 6 years of activity (right panel)

Productivity convergence of new firms to incumbents in the same sector, conditional on survival	Productivity growth distribution of firms established in 2012-13, after 6 years of activity
(deviation to productivity of reference category – firms with 20 or more years)	(average annual productivity growth)
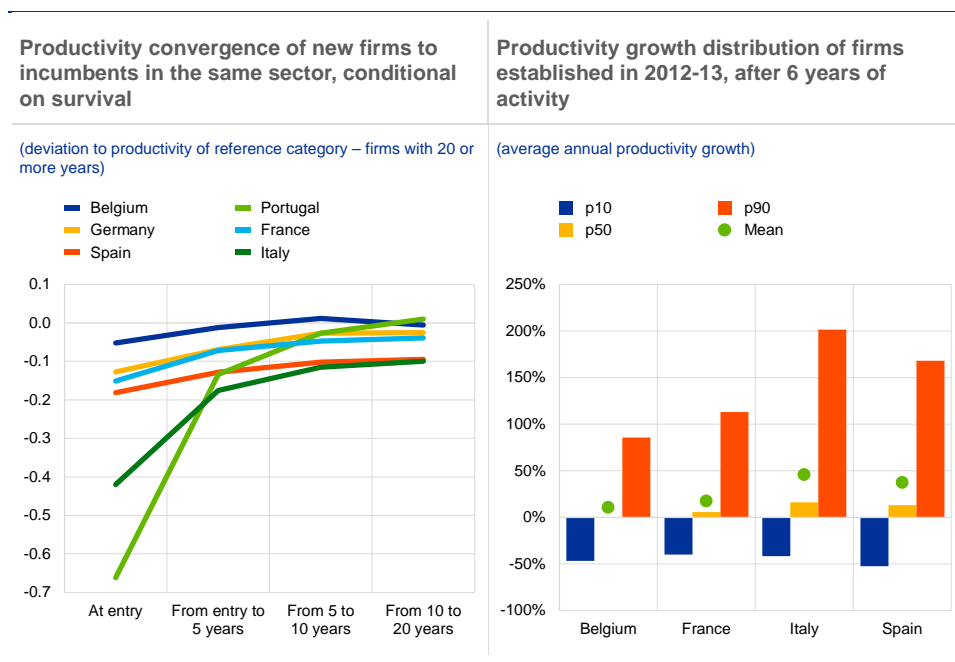
Sources: Own calculations using ORBIS-iBACH data.
Notes: The left panel shows the coefficient of each age bracket in a regression of labour productivity on age conditional on the survival of the firm and controlling for sector of activity, sector demand conditions and entry year of the firm.

To sum up, the relatively small contribution of net entry to productivity growth is the result of the low productivity of new firms, particularly, in terms of our sample, in Spain and Italy. However, strong selection upon entry and the fast post-entry growth of a few surviving young firms substantially increase the contribution of entry to aggregate productivity growth over the medium term. Most young firms, however, display low productivity growth rates.

4.3 Zombie firms: persistent resource misallocation or a necessary temporary evil?

The survival of poorly performing firms, referred to as "zombies" in the literature, is considered to result in resource misallocation and to be a drag on their sector and, in turn, aggregate productivity growth, as they are typically less productive than other firms and can congest the markets for healthy firms. **This section aims to gain a better understanding of the zombie phenomenon in Europe and to gauge its possible impact on sector and aggregate productivity growth.** Section 5 in turn will revisit the topic of zombies in connection to monetary policy.

This section first explores the incidence of zombie firms and their economic importance over time, as well as the rate of entry to and exit from distress: what we call "zombie demographics" (Section 4.3.1). Second, the section shows that not all firms flagged as zombies in this analysis are really in distress and that many of them are able to fully recover from a temporarily distressed state (Section 4.3.2). Next, the section analyses congestion effects, that is, the impact of zombies on healthy firms operating in their same sector (Section 4.3.3). The last part of the section discusses institutions and framework conditions that have a possible impact on the incidence of zombies (Section 4.3.4).

The analysis uses representative firm-level data for six EU countries (Belgium, Croatia, Italy, Netherlands, Portugal and Finland) covering the period 2000-18. Like the work described in Section 2.3, the analysis uses a micro-distributed approach where a common code is distributed to the country experts to ensure the comparability and confidentiality of results. Labour productivity is defined at the firm level as real value added per employee. The methodology follows the work on zombie demographics of Nurmi, Vanhala and Virén (2020), which originally focused on Finland.

The main findings of the section are that the crisis and post-crisis rise of zombies, defined by their interest coverage ratio (ICR), was cyclical and driven largely by the entry of firms into financial distress and not by more persistent zombie survival. Moreover, the data suggest that a large share of firms labelled as zombies should not be considered as weak performers: almost one-third of these allegedly distressed firms are in fact expanding their workforce and around half of them recover from zombie status to regain financial health. Finally, we show significant congestion effects of capital allocated to these weakly performing firms on healthy firms' investment, but not on their employment levels or productivity growth.

4.3.1 The rise and fall of zombies

Alternative definitions of zombie firms in the literature are generally based on some measure of a firm's weak performance. This section follows the approach taken in the recent literature by defining zombies as firms whose ICR, the ratio of operating income to interest expenses, is less than one (earnings before interest and taxes (EBIT)/(interest+financial charges)<1)) over three consecutive years. In practice, this means that a company must take on additional debt or receive other outside funding to cover its interest payments. A minimum age requirement is not imposed in the definition of zombies, as it is in, for example, Adalet McGowan et al. (2018), although the identification condition implicitly sets a three-year age threshold. Box 6 discusses in greater depth how best to identify zombies.

Box 6
Zombies – what are we talking about?

Several approaches are taken in defining zombie firms. In the seminal papers by Hoshi (2006) and Caballero et al. (2008) focusing on firm-bank relationships in Japan in the 1990s, the zombie

indicators attempt to identify firms with extremely low interest payments given their levels of debt and who are likely to receive financial aid from lenders. A number of recent papers have studied zombie firms in European countries along these same lines (e.g. Acharya et al., 2019 and Schivardi et al., 2017). In a second approach, recent studies have used various measures of firms' weak performance to identify zombies. These measures include firms with negative profits (Bank of England, 2013) or negative value added, or firms with a persistently low EBIT relative to interest paid and financial charges, as in, for example, Adalet McGowan et al. (2018) and Bank of Korea (2013), or low earnings before interest, taxes, depreciation and amortisation (EBITDA) relative to interest paid and financial charges. This chapter follows the recent literature (see, for example Adalet McGowan et al., 2018), by defining zombies as firms with an ICR that is less than one for three consecutive years (ICR(3)):

$$ICR(3) = EBIT/(interest + financial\ charges) < 1 \qquad\qquad (B6.1)$$

Although the current analysis, unlike that of Adalet McGowan et al. (2018), does not impose a minimum age requirement, by its construction the zombie indicator excludes the youngest firms from the data. This is important because according to this indicator the highest share of zombies is in firms of under five years of age, given their low profits and high leverage. Evidence from Italian and Finnish data suggests that within the sample of firms with more than three years of activity, the age threshold makes little difference to the results (see Annex 9 for a comparison for Italy and Finland).

The choice between EBIT and EBITDA in the ICR makes some difference in analysing distressed firms since EBIT is affected by depreciation and amortisation. EBIT may therefore be influenced by factors such as strategic accounting practices through investment and amortisation decisions. The analysis in this chapter was also conducted for Italy and Finland using EBITDA, with qualitatively similar results, although zombie shares are several percentage points lower when using this parameter (see Annex 9). Some of the results on zombie demographics differ somewhat in quantitative terms, but without changing the main conclusions of this section, namely that a large proportion of zombie-labelled firms are growing companies and even more recover from distress to become healthy firms.

We use the ICR as our starting point for a number of reasons. First, there are indications that subsidised loans are not a key issue, at least for some of the sample countries (see also Section 5). The implicit interest rate (gross interest expenses over total debt) in Finland and the Netherlands, for example, has been higher for firms flagged as zombies compared with other firms during the whole sample period. Therefore firm performance measures that rely on the ICR(3) condition seem more appropriate to capture distressed firms from our data than measures based on interest payments. Moreover, as Adalet McGowan et al. (2018) note, ICRs encompass channels other than subsidised credit through which zombie firms may be kept alive (e.g. government guarantees to firms). Second, the data in the six-country sample on interest payments by firms are not sufficiently detailed to construct relatively sophisticated measures similar to those used by Hoshi (2006), Caballero et al. (2008) or Schivardi et al. (2017). Furthermore, Schivardi et al. (2017) note that in their study the ICR-based definition is almost a strict subset of that based on the comparison between return on assets and their measure of the cost of capital for the safest borrowers in their sample.

Recent studies have documented a rise in the proportion of zombies in the firm population across OECD economies, particularly since the global financial crisis (e.g. Adalet McGowan et al., 2018 and Banerjee and Hofmann, 2018). One concern in the literature has been that the financial crisis and its aftermath have led to a long-lasting rise in and permanently higher proportion of zombie firms driven by weak banks' incentives to keep such lenders on their balance sheets. The firm-level data in this analysis, for six EU countries, also shows an increase in the proportion of zombie-labelled firms since the turn of the millennium. Unlike other studies, however, this one does not show a long-standing rise in zombie incidence, given the decline of zombie-share in all countries over the most recent period (Chart 32). These dynamics are also found in other work by the work stream, referring in this case to Germany and using a similar definition of zombie firm (see Annex 9). Possible explanations for the discrepancy with other studies are different definitions of zombie, samples of countries and, in particular, firm-coverage of the samples. As regards the latter, the work stream's analysis uses data covering micro-firms, while other studies cover only listed firms. Differences could also stem from the fact that the panel in this report covers more recent years, characterised by an economic expansion and decreasing market entry rates (see Section 4.2). We show that although the timing differs slightly across countries, zombie-incidence peaks at the height of the euro crisis and falls thereafter. The fall is particularly large in Italy and Portugal, to the extent that the incidence in Italy for the last available year's data is clearly below pre-crisis levels. This suggests that instead of a long-standing and steady increase, the rise in the zombie share has largely been driven by cyclical factors like the global financial crisis and its aftermath.[86]

The falling incidence of zombie firms occurred during a period of ultra-expansionary monetary policy. Interest rates were falling throughout this period, turning negative in June 2014. Correspondingly, the implicit interest rate (interest payments/debt) and the interest payments of zombie firms fell, with opposite impacts on the zombie incidence. On the one hand, very low interest rates reduced financing costs such that zombie firms which would have left the market in a more normal regime managed to remain, even with ICRs below 1. And on the other hand, the low interest rates helped other firms recover from zombie status to financial health (ICR>1). In addition, low interest rates have potentially prevented the ICR from falling below one in the first place, all else being equal. Moreover, the first two series of targeted longer-term refinancing operations (TLTROs) were announced in 2014 and 2015 and the asset purchase programme began in 2015. To the extent that expansionary monetary policy supported aggregate demand and therefore firms' profitability, it potentially contributed to their recovery from their distressed status. Section 5.1 below further explores the possible links between monetary policy, misallocation of resources and zombie firms.

The share of zombies, taken alone, may be a poor indicator of the macroeconomic implications of this phenomenon. The macroeconomic significance of zombies can be characterised more accurately by weighting the firms

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[86] If EBITDA was used to identify zombies, instead of EBIT, the average zombie share of firms would be about 2-3 percentage points lower in Italy and Finland, compared with the zombie shares measured using EBIT. The qualitative patterns remain similar for the headline figures.

by employment or capital (mis)allocated to them, or by the share of total value added they produced. In this respect the sample countries differ markedly (see also Chart 32). In Belgium and Finland, the employment and value-added shares exceed the share of zombie firms in the firm population, which reflects the fact that large firms are over-represented in zombies and also in the rise and fall of zombie incidence. This implies that in these countries the economic importance of zombies may be larger than the firm share alone indicates. The opposite is the case in the Netherlands and Portugal: the employment and value-added shares are lower than the share of zombie firms in the firm population. Hence small firms are over-represented in zombies. Croatia and Italy are intermediate cases. These differences may reflect sectoral differences in zombie incidence across countries.

Chart 32

Share of zombies over time

(percentage of all active firms)

- Firms
- Employment
- Value-added

Belgium
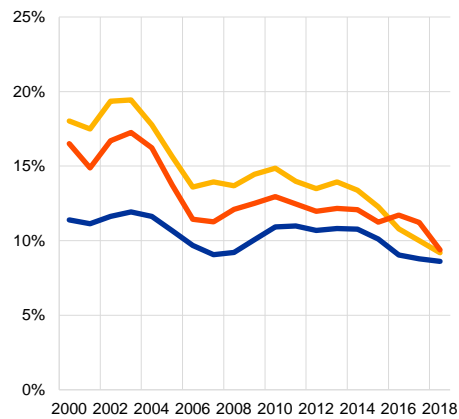
Croatia
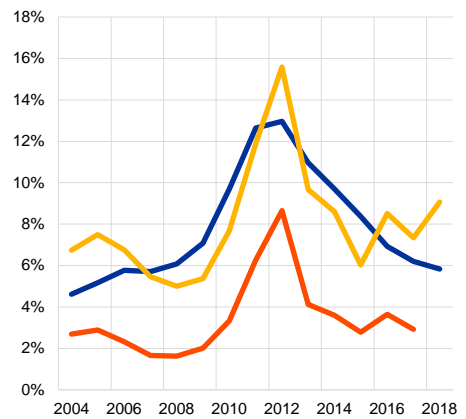
Finland
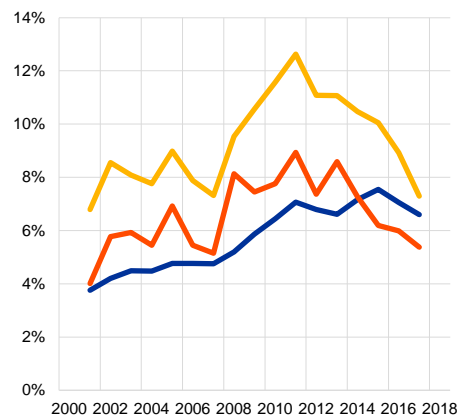
Italy
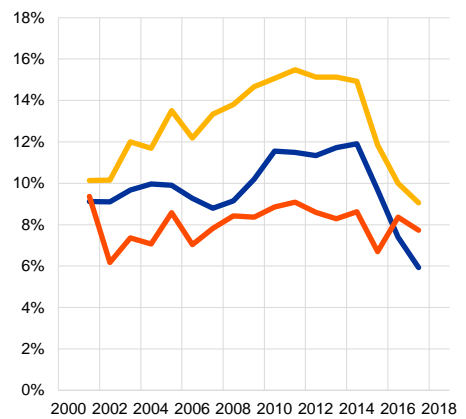
Netherlands
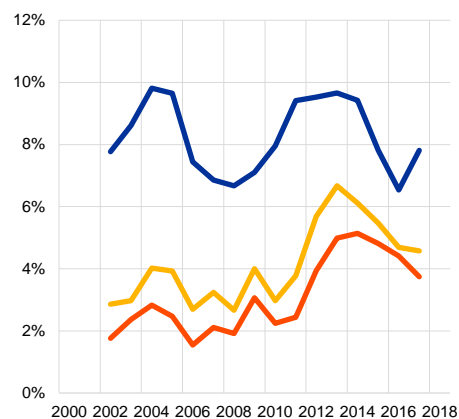
Portugal

Sources: Central Balance Sheet Database, Cerved Centrale dei Bilanci, Financial Agency (Fina), Istituto Nazionale della Previdenza Sociale, National Bank of Belgium Central Balance Sheet Office, Statistics Finland, Statistics Netherlands and authors' calculations. Notes: Zombies are defined as firms with a ratio of EBIT and interest paid+financial charges of less than one (EBIT/(interest+financial charges)<1) for three consecutive years. Manufacturing includes NACE Rev. 2 sectors 10-33 and private services includes sectors 45-63 and 69-82.

The change in the stock of zombies depends on firms' inflows (entry) to and outflows (exit) from distress. The flows are presented in Chart 33 as proportions of the starting group, that is, zombie entries are shown as a proportion of non-zombies and exits from "zombieness" as a proportion of the stock of zombies. As can be observed, the main driver of the change in zombie stock is zombie entries: these led to a rise in zombie incidence at the time of the financial crisis and remained at a high level for several years afterwards. In more recent years (2014-17) zombie entries have fallen, reflecting the improved cyclical conditions. Exits from distress, however, have remained relatively stable over the whole sample period. This implies that, on average, the durations of spells in zombieness have remained stable. In other words, the rise and fall of the incidence of zombie firms have been driven by firms' cyclical entry into distress and not by the more persistent survival of zombies, as popular narratives suggest.[87] It is worth noting, however, that a stable zombie exit rate is consistent with falling market exit rates for zombies occurring simultaneously with rising exits from zombie status back to financial health, especially in an environment of low and falling interest rates. This will be discussed below.

Chart 33

Zombie entries and exits, all six countries
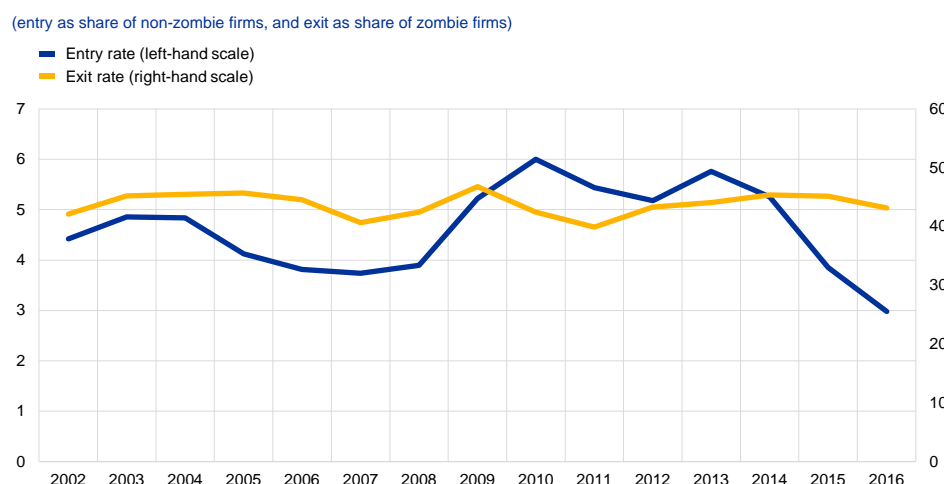
(entry as share of non-zombie firms, and exit as share of zombie firms)

Sources: Central Balance Sheet Database, Cerved Centrale dei Bilanci, Financial Agency (Fina), Istituto Nazionale della Previdenza Sociale, National Bank of Belgium Central Balance Sheet Office, Statistics Finland, Statistics Netherlands and authors' calculations.
Notes: entry flows into zombieness are computed from the pool of healthy firms. Exit flows from zombieness (into exit of market or recovery) are computed as share of the pool of zombie firms.

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[87] A possible reason for the discrepancy between this result and the common narratives may lie in the way zombie firms are sometimes characterised. To demonstrate this the flows are presented in Chart A9.3 in Annex 9 as proportions of all firms. If both flows are presented as proportions of all firms (instead of proportions from the group of departure), the entry rate behaves in a qualitatively similar way, rising after the financial crisis and then falling in the most recent years. However, the zombie exit rate seems to rise and fall with a time lag with respect to the entry rate. This rise and fall in the exit rate considered as a proportion of all firms reflects a "pool size" effect: when the pool of zombies becomes larger/smaller in a downturn/upswing, zombie exits relative to the firm population increase/decline even if the exit rate as a proportion of zombies remains constant.

4.3.2 True and false zombies: recoveries and growing firms

All zombies are not alike. The concern for zombies relies on the assumption that zombie-labelled firms are all weakly performing companies that manage to survive and remain in the market, even if they should, on economic grounds, exit. A deeper examination of zombie-labelled firms reveals striking differences within this group. The data suggest that a large share of firms labelled as zombies in this analysis are in fact not truly distressed, or at least only temporarily distressed, firms.[88]

One-third of zombie-labelled firms are expanding their employment size. A large share (up to 40% in some countries) of firms flagged as zombies is actually growing in terms of employment (Chart 34, left panel). Hence zombie status could be a temporal consequence of heavy investment in growth-enhancing activities. This might not be surprising for young start-ups, but the same pattern applies broadly across age groups and firm sizes. For example, in the Finnish data the share of growing zombie-labelled firms is on average 33% for all firms, and 32% for firms with over ten years of activity. In Italy the corresponding figures are 34% and 29%, respectively. In the light of these numbers, the rise of zombies seems to be less alarming than the aggregate figures suggest.[89]

Chart 34

Growing and declining zombies (left panel) and zombie exits to recovery and death (right panel)
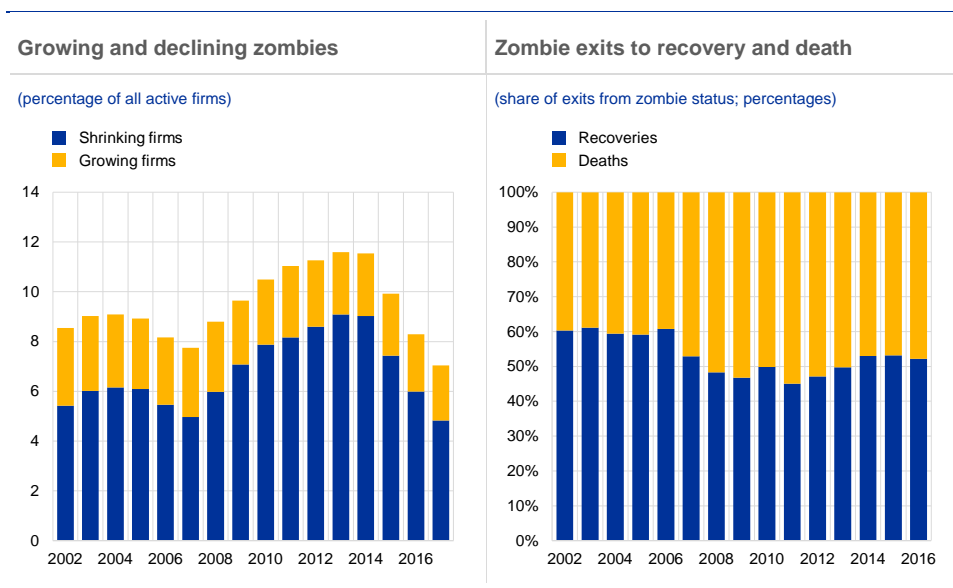
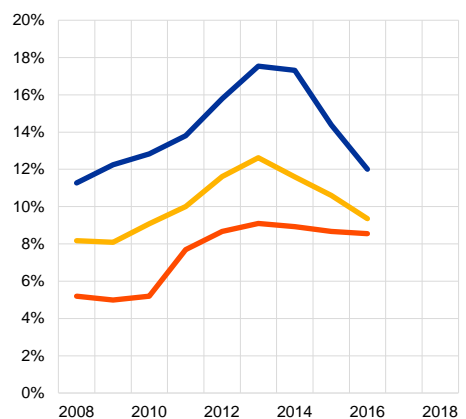| Growing and declining zombies	Zombie exits to recovery and death
(percentage of all active firms)	(share of exits from zombie status; percentages)

Sources: Central Balance Sheet Database, Cerved Centrale dei Bilanci, Financial Agency (Fina), Istituto Nazionale della Previdenza Sociale, National Bank of Belgium Central Balance Sheet Office, Statistics Finland, Statistics Netherlands and authors' calculations.
Notes: Zombies are defined as firms with a ratio of EBIT and interest paid+financial charges of less than one (EBIT/(interest+financial charges)<1) for three consecutive years. Manufacturing includes NACE Rev. 2 sectors 10-33 and private services includes sectors 45-63 and 69-82.

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[88] Evidence from the Finnish and Italian data shows that this is the case even when applying a ten-year age threshold to firms, thus weeding out young firms from the data. Ongoing analyses are studying this for other countries.

[89] The figures differ only a little, regardless of whether EBIT or EBITDA is used in the ICR. Belgian data show that the proportion of growing zombie-labelled firms is smaller (33% vs. 37%) when using EBITDA, whereas the difference is marginal in the case of Finland (36% vs. 37%) and Italy (32% vs. 33%).

Zombies often recover to become financially healthy firms. A firm may exit zombie status because it exits the market (firm death) or because it regains its financial health. The fate of the zombies is a key issue for policy recommendations, as providing life support (for example subsidies or low interest rates) to death-ripe firms is harder to justify than supporting temporarily unprofitable but recovering firms. Strikingly, in our data between 40% and 70% of zombie spells end in recovery (and, correspondingly, between 30% and 60% of spells spent in zombieness end in firm death) (Chart 34, right panel).[90] [91] The recovery share is also remarkably stable over time and across declining and growing zombies (Annex 9). The high recovery rate is consistent with the large share of firms classified as zombies being temporarily unprofitable as a result, for example, of restructuring or investments in future profitability.

Zombie productivity is generally lower than that of healthier firms (Chart 35). A number of studies find that the productivity of zombie firms is lower than that of other firms (Caballero et al. 2008; Adalet McGowan et al. 2018; Banerjee and Hoffman, 2018; and Nurmi et al. 2020). This implies that if resources were to be reallocated to healthy and more productive firms, aggregate productivity growth would increase. However, as has already been shown, firms flagged as zombies can be very different in nature, a factor which could deliver a more nuanced picture. Consistently with previous analyses we find that, on average, zombies' productivity is about 60% that of healthy firms operating in their same sector and country (yellow dot in Chart 35, left-hand axis). Within the group of firms exiting distress, the relative productivity of firms that recover to health is clearly higher than that of firms exiting the market. Hence the best performing firms among zombies recover and the worst performing zombies exit the market, which is positive from the resource allocation perspective. Note that zombies exiting the market account only for about 2% of all active firms (blue bar in Chart 35, right-hand axis). On average, about 6% of all active firms spend more than one spell (of three years) in zombie status.

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[90] These results hold independently n the firm age: in the Finnish data the share of all exits to recovery is 70% and that of exits to death 30%. For firms of at least ten years of age the recovery share is 74% and the death share 26%. In Italy the share of all exits to recovery is 49% and exits to death 51%. For firms of at least ten years of age the recovery share is 53% and the death share 47%.

[91] There is also a difference in the proportion of recovering zombie-labelled firms depending on whether EBIT or EBITDA is used in the ICR. The proportion of recovering zombie-labelled firms for Belgium is 70% using EBIT vs. 60% using EBITDA, and in Finland 63% using EBIT vs. 57% using EBITDA. In Italy the difference is larger and in the opposite direction, 49% using EBIT vs. 60% using EBITDA.

Chart 35
Productivity of different type of zombies relative to healthy firms in their same country-sector, and prevalence rate
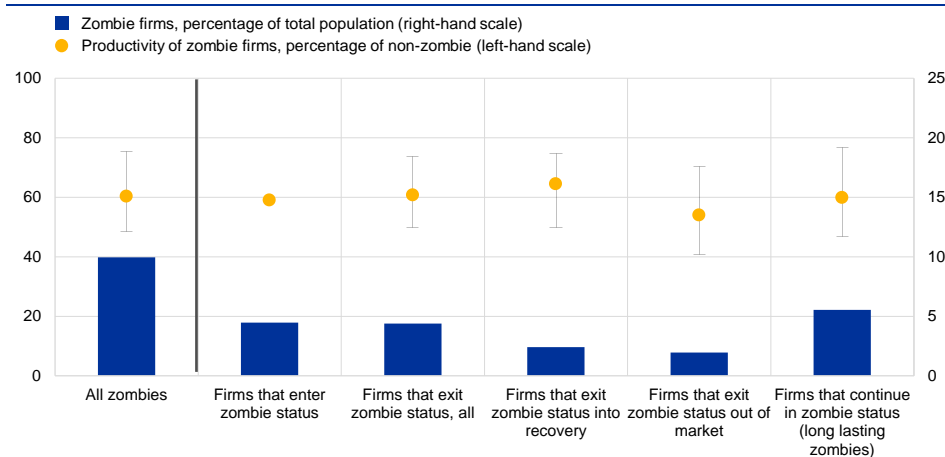
Sources: Central Balance Sheet Database, Cerved Centrale dei Bilanci, Financial Agency (Fina), Istituto Nazionale della Previdenza Sociale, National Bank of Belgium Central Balance Sheet Office, Statistics Finland, Statistics Netherlands and authors' calculations.
Notes: All zombie results derived from summing the share of firms entering distress in a given year and firms staying in distress. Firms exiting distress equals the sum of firms recovering financial health and firms exiting the market.

4.3.3 Zombie congestion

Zombie firms may drag on productivity growth not only because their productivity is lower but also because they could have a negative effect on the performance of other firms in their sector of operation. This congestion effect arises when zombies compete with healthy firms for the same resources (thus increasing input prices) and operate in the same market (thus increasing competition and reducing output prices) as healthy firms, thus squeezing the output, job creation and investment of the latter.[92]

To evaluate the effects of zombie firms on the performance of non-zombie firms, we follow a methodology similar to that in Caballero et al. (2008) and Adalet McGowan et al. (2018).[93] In those works, congestion is assessed by regressing various measures of firm performance against the share of resources (capital and labour) allocated to zombie firms according to expression (2) below:

$$\Delta \log(x_{it}) = a_0 + a_1(1 - zombie_{it}) + a_2 zombie_{share\,jt} + a_3(1 - zombie_{it}) \times zombie_{share\,jt} + a_4 age_{it} + a_5 szclass_{it} + u_{it} \quad (2)$$

where the dependent variable $\Delta \log(x_{it})$ is either growth in capital, employment, output (real value-added) or labour productivity in firm i in sector j in year t. zombie$_{it}$ is a

---

[92]   In addition, zombie firms may congest the market for obtaining finance if incumbent zombies obtain financing with small frictions or costs relative to, for example, start-ups.

[93]   Schivardi et al. (2017) suggest that the methodology used by these papers to identify the real effects of zombie firms might be mis-specified. In their paper they show that with an alternative specification the congestion effect of zombies is almost negligible.

dummy equal to one if the firm fills the ICR(3)<1 criterion and the zombie_share$_{jt}$ is either the employment or capital share of zombie firms in sector j. The regression controls for the age and size class of the firm. In addition to these general congestion effects, this subsection also evaluates the distinct impact of declining and growing zombies, as in Nurmi et al. (2020).

The variable of interest is the interaction term between the zombie share and non-zombies or healthy firms. Results, shown in Table 3, indicate that a large concentration of capital in zombie firms in an industry is associated with lower investment in healthy firms, pointing to a congestion effect arising from the zombies. A qualitatively similar congestion effect arises from labour allocated to zombie firms.[94]

When making a distinction between shrinking or stable and growing zombie-labelled firms, both types of zombies tend to have a negative congestion effect on healthy firms. In a number of countries, growing zombies have a stronger negative congestion effect on non-zombies. Taken at face value, this seems to imply that the congestion effect that weakens the performance of non-zombies in the market may not necessarily be a question of misallocation of resources to poorly performing firms. Instead it may simply be that higher numbers of firms in the market – more competition – constrain the investment and growth opportunities of all firms in that market.

At least in the short term, congestion effects on labour productivity growth in healthy firms are smaller than on investment. This applies to the effect of both capital and labour allocated to zombie firms (Table 4). However, as discussed below, the congestion impacts on productivity growth could emerge over the medium or long term.

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[94] The quantitative importance and statistical significance vary somewhat across countries.

Table 3

Zombie congestion effects on investment. Zombie industry share measured as share of industry capital in zombie firms

	Belgium	Croatia	Finland	Italy	Netherlands	Portugal
Zombie industry share measure:	**All zombies capital share**					
Non-zombie dummy	0.13*** (0.27)	0.25*** (0.26)	0.13*** (0.006)	0.1*** (0.001)	0.11*** (0.003)	0.22*** (0.01)
Zombie industry share	0.44*** (0.16)	0.03 (0.11)	0.02 (0.03)	-0.002 (0.01)	0.02 (0.04)	0.27*** (0.03)
Non-zombie dummy* zombie industry share	-0.04*** (0.16)	-0.30*** (0.11)	-0.12*** (0.04)	-0.03*** (0.01)	-0.06 (0.04)	-0.53*** (0.03)
Zombie industry share measure:	**Shrinking and equal zombies capital share**					
Non-zombie dummy	0.12*** (0.3)	0.24*** (0.26)	0.12*** (0.005)	0.1*** (0.001)	0.11*** (0.003)	0.20*** (0.01)
Zombie industry share	-0.01 (0.11)	0.04 (0.08)	-0.04 (0.04)	-0.01 (0.01)	0.01 (0.05)	0.18*** (0.04)
Non-zombie dummy* zombie industry share	-0.01 (0.11)	-0.37*** (0.08)	-0.11*** (0.05)	-0.02*** (0.01)	-0.07 (0.05)	-0.57*** (0.04)
Zombie industry share measure	**Growing zombies capital share**					
Non-zombie dummy	0.13*** (0.27)	0.23*** (0.26)	0.12*** (0.005)	0.1*** (0.001)	0.11*** (0.003)	0.18*** (0.004)
Zombie industry share	0.07*** (0.1)	0.03 (0.07)	0.12*** (0.06)	-0.01 (0.008)	0.14* (0.08)	0.80*** (0.06)
Non-zombie dummy* zombie industry share	-0.04** (0.1)	-0.22** (0.07)	-0.15*** (0.06)	-0.04*** (0.01)	-0.09 (0.09)	-0.77*** (0.07)
Observations	1,412,716	233,759	998,309	2,593,711	1,013,260	879,924

Sources: Central Balance Sheet Database, Cerved Centrale dei Bilanci, Financial Agency (Fina), Istituto Nazionale della Previdenza Sociale, National Bank of Belgium Central Balance Sheet Office, Statistics Finland, Statistics Netherlands and authors' calculations. Notes: Zombies are defined as firms with a ratio of EBIT and interest paid+financial charges of less than one (EBIT/(interest+financial charges)<1) for three consecutive years. Manufacturing includes NACE Rev. 2 sectors 10-33 and private services includes sectors 45-63 and 69-82. Standard errors in parentheses * p<0.10, ** p<0.05., ***p<0.01.

Table 4

Zombie congestion effects on labour productivity growth. Zombie industry share measured as share of industry capital or labour in zombie firms

	Belgium	Croatia	Finland	Italy	Netherlands	Portugal
Zombie industry share measure:	**All zombies capital share**					
Non-zombie dummy	0.01*** (0.27)	0.04** (0.21)	0.013*** (0.005)	0.06*** (0.003)	0.03*** (0.003)	0.06*** (0.01)
Zombie industry share	0.03*** (0.16)	-0.03* (0.11)	0.04** (0.03)	-0.07*** (0.01)	0.013 (0.05)	0.24*** (0.04)
Non-zombie dummy* zombie industry share	-0.03*** (0.16)	-0.10 (0.11)	-0.03 (0.03)	0.014 (0.01)	-0.04 (0.05)	-0.229*** (0.04)
Zombie industry share measure:	**All zombies labour share**					
Non-zombie dummy	0.01*** (0.27)	0.03** (0.21)	0.16*** (0.005)	0.06**** (0.002)	0.03*** (0.004)	0.06*** (0.01)
Zombie industry share	0.03 (0.08)	0.07 (0.06)	0.07* (0.04)	-0.07*** (0.014)	0.1 (0.08)	0.28*** (0.05)
Non-zombie dummy* zombie industry share	-0.04** (0.08)	-0.13 (0.05)	-0.07* (0.04)	0.01 (0.01)	0.03 (0.08)	-0.31*** (0.05)
Observations	1,403,710	207,746	1,078,879	2,421,177	1,024,943	835,508

Sources: Central Balance Sheet Database, Cerved Centrale dei Bilanci, Financial Agency (Fina), Istituto Nazionale della Previdenza Sociale, National Bank of Belgium Central Balance Sheet Office, Statistics Finland, Statistics Netherlands and authors' calculations. Note: Zombies are defined as firms with the ratio of EBIT and the interest paid+financial charges being less than one (EBITEBIT/(interest+financial charges)<1) for three consecutive years. Manufacturing includes NACE Rev. 2 sectors 10-33 and private services includes sectors 45-63 and 69-82. Standard errors in parentheses * p<0.10, ** p<0.05., ***p<0.01.

4.3.4 Institutional factors explaining the emergence of zombies in the EU

The emergence of zombies could also be closely associated with structural factors such as the efficiency of insolvency frameworks. Empirical evidence suggests that efficient insolvency regimes have been essential in helping prevent non-viable firms from exiting the market. In the case of an adverse aggregate shock, an efficient insolvency framework can enable fast restructuring or resolution of firms and thereby free up resources for other, more productive uses. Efficient insolvency frameworks therefore imply both a lower level of zombie firms and a lower intensity of zombie congestion (Andrews and Petroulakis, 2017).

A weak banking sector also seems to be associated with a large proportion of zombie firms. Schivardi et al. (2017) show that under-capitalised banks were more likely to continue lending to zombie firms during the global financial crisis than stronger banks. Andrews and Petroulakis (2017) provide evidence for several OECD countries showing that the reallocation process is slower in industries where firms obtain credit mainly from weak banks. Storz et al. (2017) show that weak banks appear to have impaired the deleveraging of weak firms in euro area periphery economies in the years following the global financial crisis. A typical mechanism is that weak banks seek to postpone the revealing of losses in their accounts in an attempt to avoid recapitalisation and gamble on resurrection. These findings suggest that by evergreening loans weak banks may try to avoid making losses on outstanding loans, which would further deteriorate their accounting capital in the event of under-provisioning.

Institutional factors can also help explain the existence of zombie firms. Weak institutional frameworks are associated with rent-seeking behaviour and the existence of "soft budget constraints" (Kornai et al., 2003). Soft budget constraints are characterised by distortions in private investment decisions (for example by overinvestment in certain projects) because firms can expect to extract a bigger subsidy ex-post than was socially efficient ex-ante. A soft public budget constraint may raise the expectations of both non-viable firms and banks that future (possibly hidden) public sector subsidies could help the firms to survive. Finally, there might be pressures from vested interests and politicians who want to protect employment or the wealth of firms' owners, but (temporarily) aim to hide the fact that this probably requires a redistribution from taxpayers towards the firms' owners, creditors or employees (García Santana et al., 2020).[95]

The macroeconomic consequences of zombie lending, that is, of rolling over bad loans, may become more significant in the economic recovery than during crises. The short-term effects on growth of capital misallocation are relatively small in a crisis period, when the entry of new firms is low and incumbent firms have fewer possibilities to expand. As low-productivity firms are kept alive, aggregate demand is temporarily strengthened, which partly offsets the negative demand effect stemming from the inefficient allocation of loans (Schivardi et al. 2017). However, over the

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[95] One example might be an important local employer whose failure could jeopardise the quality of mortgages in a region because unemployed people start struggling to repay their mortgage (with associated feedback loops on the real estate market).

medium and long term, interference with the creative destruction process is likely to create stronger consequences on employment, investment and growth as new sources of growth are stifled.

To sum up, our analysis suggests that the crisis and post-crisis rise of zombies was cyclical and driven largely by the entry of firms into financial distress, not by more persistent zombie survival. Moreover, the data suggest that a large share of zombie-labelled firms should not be considered unviable: one-third of these allegedly distressed firms are in fact growing companies and between 40% and 70% of spells spent in zombieness end in financial recovery. Finally, we show significant congestion effects on healthy firms' investment of capital allocated to weak performing firms, but not on their employment or productivity growth, at least in the short term. The incidence of zombies is also correlated with structural factors related to insolvency frameworks and the health of the banking system, which highlights the importance of policies that aim to facilitate the allocation of resources towards more innovative and productive firms. Most notably, this includes measures to address any remaining bank weaknesses and incentivise banks to move decisively when working out bad assets. It also points to the importance of improving legal frameworks, such as insolvency laws, and addressing capacity constraints in the courts.

5 The role of monetary policy, structural trends and COVID-19

5.1 The interplay between monetary policy and productivity growth

As outlined in the correlation analysis of Section 1 and shown by the literature on drivers of technology creation and diffusion and of resource reallocation surveyed in the report, national fiscal and structural policies can strengthen productivity growth by fostering greater efficiency in product, labour and financial markets and thereby providing the means and incentives for productive firms to thrive. National governments have therefore ample scope to set the right framework conditions and incentives for productive investment and innovation decisions that determine long-term productivity growth.

Having said that, cyclical polices, including monetary policy, may support productivity growth under certain circumstances, by increasing demand and stimulating investment. However, in recent years it has increasingly been argued that very low interest rates over a long period of time could have negative effects on resource allocation and productivity growth through their interaction with financial frictions, weak banks or weak banking supervision, among other things.

In this context, the work stream on productivity, innovation and technological progress was responsible for drafting a note devoted solely to the possible side effects of monetary policy on productivity growth in the context of the 2020-21 ECB monetary policy strategy review. The note included an overview of existing literature and the work stream's own new research. **This section summarises the main findings of that work.** The section is structured in three parts. Section 5.1.1 reviews the channels by which monetary policy can affect productivity growth. Section 5.1.2 concentrates on the impact of monetary policy on the productivity of incumbent firms, either by facilitating investment in productivity-enhancing activities (within-firm productivity growth) or by affecting resource reallocation across incumbent firms. Section 5.1.3 explores the role of monetary policy in driving the entry and exit of firms.

The main findings of the section are that according to the extensive literature on the topic, an accommodative monetary policy which eases financial conditions will support productivity growth through the positive effect it has on aggregate demand, which will also stimulate firm entry and productivity-enhancing investments. This procyclicality also helps explain the missing disinflation in the downturn and missing inflation in the upturn. However, in the presence of financial frictions a very accommodative monetary policy could defer necessary balance sheet repair by firms and banks, delay firms' exit and increase risk-taking by banks, which could encourage resource misallocation. Thus, the channels of impact of monetary policy on productivity growth are manifold and the net effect needs to be determined

empirically. This is complicated by the fact that the effects of monetary policy depend on institutional arrangements and market structure and on its interaction with financial frictions. Moreover, these interactions will have a time-varying effect on productivity, as was shown, for example, during and after the global financial crisis. The work stream's own (partial) empirical analyses do not confirm the negative impacts of monetary policy on productivity found elsewhere. A better understanding of the possible channels, extended to the interaction between monetary policy and market structure as well as institutions, should have a prominent role in future research and modelling efforts.

5.1.1 A literature overview: Possible channels of impact of monetary policy on productivity growth

In endogenous growth models an accommodative monetary policy supports productivity growth by stimulating aggregate demand. There is a growing body of endogenous growth models in which productivity or technological progress is driven by innovation, R&D or the rate of diffusion and adoption of new technologies.[96] By stimulating aggregate demand through favourable financing conditions, an accommodative monetary policy stance may play a part in changing firms' incentives to increase investment in productivity-improving technologies or to increase the pace of new technology adoption and diffusion, with a positive impact on productivity beyond the short-term cyclical effects (Garga and Singh, 2020; Ikeda and Kurozumi, 2019; Moran and Queralto, 2018; Anzoategui et al. 2019; Schmöller and Spitzer, 2020; and Jordà et al. 2020). In the same vein, favourable financing conditions may increase corporate profitability or decrease the profit threshold, which also stimulates firm entry and delays firm exit.

However, in the presence of financing frictions the effects of monetary policy on productivity become ambiguous. First, low interest rates stimulate risk-taking, which can worsen resource allocation. Second, while an accommodative monetary policy stance can facilitate the flow of resources from firms with low productivity to firms with high productivity, particularly if the latter had been financially constrained,[97] the opposite can also occur. For example, if low productivity firms are less financially constrained because of high collateral (as in, for example, the construction sector), resources could flow to this type of firm and away from high

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[96] This growing literature has broader implications than those analysed here. For example, endogenous growth models predict not only positive long-run effects of monetary policy on productivity, but also that hysteresis effects in productivity could arise if persistent shortfalls in demand weighed on productivity-improving investments (Jordà et al. 2020); if monetary policy is constrained by the zero lower bound (Moran and Queralto, 2017 and Garga and Singh, 2018); or if economies end up in stagnation traps (Benigno and Fornaro, 2018). This could have implications for the design of optimal monetary policy. However, as argued later, there are other channels which make the net effects ambiguous. Another prediction from this type of model, concerning the effects of weak aggregate demand on TFP growth, is not addressed in this section, since we are using firm-level data/partial analysis.

[97] See, for example, Aghion et al. (2012) and Aghion et al. (2019a), Levine and Warusawitharana (2021), and Manaresi and Pierri (2019).

productivity firms with more financial frictions (low net worth, information asymmetries due to age or intangible assets, etc.).[98]

Moreover, in the special case in which it is maintained for a long period, monetary policy accommodation may also have negative impacts on productivity growth by keeping non-viable firms in the market or allowing the entry of low productivity firms. This is because easier financing conditions may reduce the incentives for firms and banks to carry out necessary restructuring and balance sheet repair, with adverse effects on resource allocation (see Storz et al., 2017; and Gropp et al., 2017). Other factors at play are that regulatory factors could give banks an incentive to grant evergreen loans; low yields could lead to increased risk-taking; and lending standards could become lax or banks might tend to subsidise weak firms by offering them low interest rates. Thus, the impact of monetary policy on productivity and resource reallocation in the presence of financial frictions is theoretically ambiguous and must be determined empirically.

5.1.2 Monetary policy and the productivity of incumbent firms

New analysis by the work stream suggests that within-sector resource reallocation does not worsen, and in some cases might improve, following an unexpected accommodative monetary policy shock (Chart 36).[99] The work is based on Albrizio and González (2020) who, building on ongoing work on the United States (Albrizio et al. 2020), estimate the dynamic impact of an ECB monetary policy shock, borrowing from Jarocinski and Karadi (2020), on capital misallocation proxied by within-sector dispersion of the marginal revenue productivity of capital (MRPK) in Spain, Italy and Portugal.

The reason is that a decrease in the interest rate might increase investment relatively more in firms with a high MRPK, indicating a positive effect of monetary policy on capital reallocation. In a second stage, and using data only for Spain given its granularity, the exercise explores the impact of the monetary policy shock on investment by different types of firms. The results of this exercise (shown in Annex 10) imply that a firm with high marginal productivity of capital (firm in the 75th percentile of MRPK distribution) would increase its investment rate 22 percentage points more than a firm in the 25th percentile of MRPK at impact (year 0), 18 percentage points more in the first year, and 15 percentage points more in the second year.

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[98] Bianchi et al. (2019), Cloyne et al. (2018), Neuhann and Saidi (2018), Cette et al. (2017), Linarello et al. (2019), Ruiz-Garcia (2020) and Gopinath et al. (2017) among others.

[99] The dynamic effect of a monetary policy shock on the variance of MRPK, a proxy for capital misallocation, of each country is estimated using local projections (Jordà, 2005). For more details, see Annex 10.

Chart 36

Response of MRPK variance to a 100 basis points decrease in interest rates
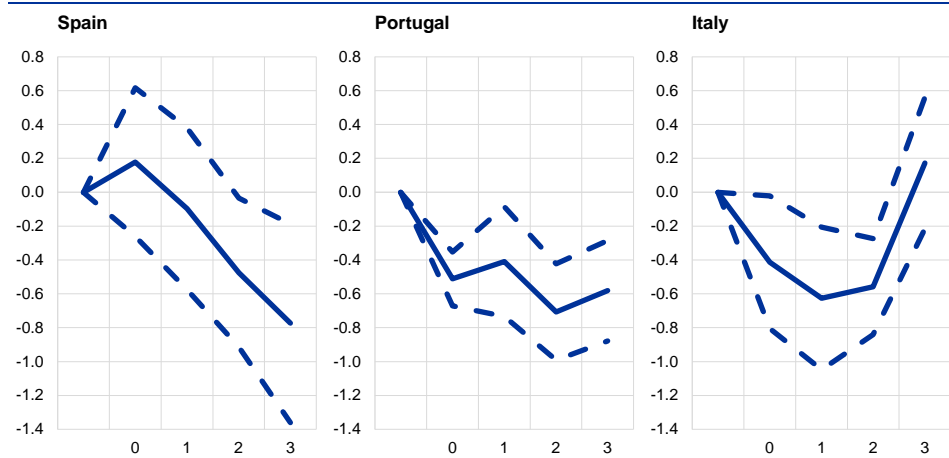
The main channel of impact is the easing of financial frictions. The analysis computes the differential effect of monetary policy on firms' investment, taking into account their characteristics such as age, financial position and markups. The exercise finds that investment increases relatively more in high MRPK firms with a higher probability of being financially constrained. These results therefore confirm the hypothesis that productivity increases when easier financial conditions facilitate capital reallocation from low to high productivity firms which were previously financially constrained.

The effect of monetary policy on resource reallocation can be also affected by the lending decisions of banks. Some authors have argued that in a low interest rate environment banks relax lending standards (lower interest rates, lower margins and less risk aversion). They tend to lend to riskier firms, which may put pressure on aggregate productivity growth. However, the effect on the aggregate is ambiguous since both low-productivity companies with low repayment capacity (also referred to as "zombies" in the literature and in this report) and high productivity firms with unproven operating history (gazelles) may benefit from easier lending standards and higher risk-taking by banks (Banerjee and Hofmann, 2018). Albrizio et al. (2019) find evidence in the United States for a risk-taking channel activated by monetary policy which disproportionally facilitated investment in the tangible assets of low-productivity firms.

Chart 37

Improvements in the availability of bank loans by firm type after selected monetary policy decisions

(net share of firms responding that access to finance had improved over the preceding six months; weighted percentages of respondents)
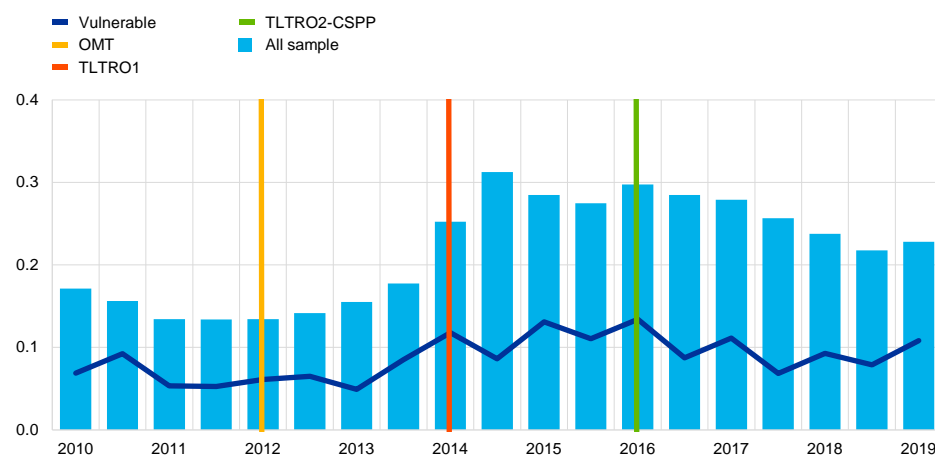
Source: ECB/EC SAFE.
Notes: Enterprises that had applied for bank loans. Vulnerable firms are firms that have reported simultaneously lower turnover, decreasing profits, higher interest expenses and higher or unchanged debt-to-total assets in the last 6 months (ECB, 2018). The first vertical line denotes the announcement of Outright Monetary Transactions; the second vertical line denotes the start of TLTRO I and the negative rate policy; and the third vertical line denotes the start of TLTRO II and the corporate sector purchase programme. The figure refers to rounds three (March-September 2010) to 22 (October 2019-March 2020) of the survey.

The work stream has analysed whether the accommodative monetary policy of recent years facilitated the access to finance, and therefore the survival, of weak firms in the euro area. Their analysis drew on the ECB survey on the access to finance of enterprises (SAFE).[100] Firm weakness/viability is defined as a function of: i) a measure of vulnerability derived directly from the survey replies (vulnerable firms); ii) a measure based on the ICR (zombie firms), consistent with that in Section 4.3; iii) the Altman Z-score; and iv) the labour productivity of the firm relative to peers in the sector. For more information, please refer to Annex 10.

The analysis shows that access to finance improved for euro area firms as lending terms and conditions eased, but to a significantly lesser degree for weak or zombie firms (see Annex 10 for the econometric results). This is shown by the negative and significant interaction term between the improvement in lending terms and conditions as a result of the accommodative monetary policy stance and an indicator taking a value of one for financially weak firms, defined according to a variety of indicators, as explained above. This result may however mask heterogeneity across different types of weak or non-viable firms. In particular, there is evidence that large firms with an ICR below one reported an increase in the availability or size of bank loans when interest rates declined.[101] This result contrasts

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[100] This is a biannual survey covering 11 euro area countries with information about access to credit at firm level as well as the terms and conditions of this finance. One advantage of using survey data is that they are particularly timely, in this case covering the period 2009-19. See Annex 10 for more details on the data.

[101] This result is in line with Liu et al. (2019), who show that low interest rates can have a negative impact on productivity growth if they give a comparative advantage to the market leader and therefore play a part in increasing market concentration. Other papers document that low real interest rates may have contributed to the competitive advantages of large firms (Chatterjee and Eyigungor, 2019; and Ruiz-Garcia, 2020).

with the fact that weak micro/small firms experienced significantly lower increases in access to finance than the rest of firms when lending conditions improved (Annex 10). The different results across firm size could be driven by the fact that bank balance sheets are more sensitive to large firms in distress (Acharya et al. 2019) and large firms have more bargaining power. Additionally, there is some evidence that the reduction in collateral requirements helped weak micro/small companies obtain additional bank loans even if they were close to bankruptcy.

Related analysis by the work stream using credit registry data from France supports these findings. Credit misallocation is identified as the incidence of low solvency firms receiving an interest rate on their new loans that is lower than a "prime" rate reserved only for the highest quality firms, following Caballero et al. (2008).

Chart 38
Share of low solvency firms with loan rate below the "prime" rate

(percentage of firms within each category)
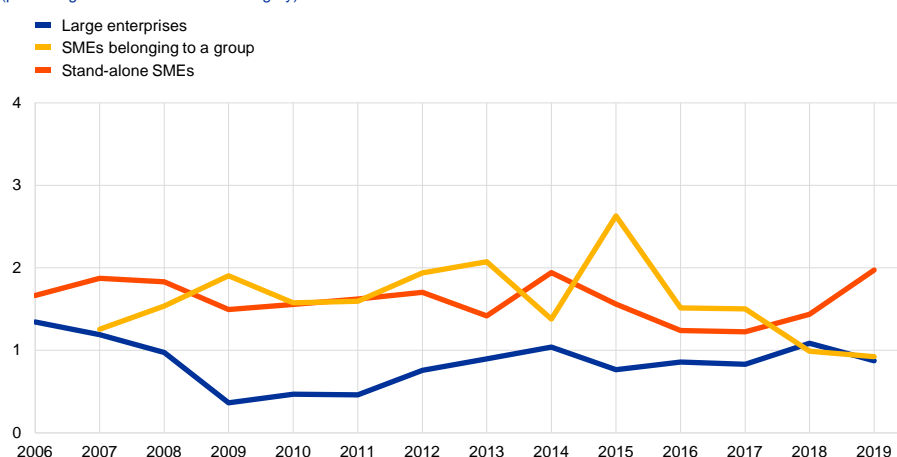
Sources: Banque de France and authors' calculations.
Notes: Share of less well-rated companies (Banque de France rating 5+ to 9 and P) receiving low interest rates, by business size (large enterprises, SMEs belonging to a group and stand-alone SMEs). Calculations based on new short-term and investment loans to NFCs. Latest observation: 2019.

In this exercise, it is found that the share of low solvency firms benefiting from exceptionally low interest rates has remained subdued and stable in France over the past decade (Chart 38). For each size category, the share has generally been below 2%. This suggests that in the case of France, accommodative monetary policy did not have a distortionary impact on the credit allocation process with respect to the rates banks charged weaker firms. One explanation is that since rates are already low, banks do not need to further subsidise weaker firms. Relative pricing across firms ought to be a key consideration in any evaluation of the degree to which the allocation of resources in the economy is efficient.

5.1.3   Monetary policy and firm demography

Monetary policy also affects firm demography, which, as shown in Section 4.2, can have an impact on aggregate productivity growth. Monetary policy can affect

the extensive margin through its effects on aggregate demand and thus on the incentives for entry and exit (Anzoategui et al., 2019; Syverson, 2011; Bergin and Corsetti, 2008; Hamano and Zanetti, 2020; Garga and Singh, 2020; and Hartwig and Lieberknecht, 2020). Higher aggregate demand increases corporate profitability and could also decrease the productivity threshold to stay in the market, thereby reducing firm exits and increasing incentives to entry. In the same vein, by loosening financial conditions an accommodative monetary policy facilitates the entry and survival of firms. The net effect on aggregate productivity depends on whether entrant (exitor) firms are more or less productive than incumbent (surviving) firms. While there are good reasons to assume that entrants (start-ups) are more innovative (Garga and Singh, 2020) and that low productivity firms are more likely to exit, looser financing conditions and an easing of financial constraints can make it easier for weak or unproductive firms to become profitable and enter the market or to regain their health, as has been shown in Section 4.3.

Low interest rates could have unintended effects on productivity growth if they reduce pressure on unproductive firms to exit. This is the zombie phenomenon, as analysed in Section 4.3, which stems from a reduction in the opportunity costs of cleaning up balance sheets and from incentives for banks to grant evergreen loans, given the lower funding costs of bad loans (Caballero et al., 2008; Banerjee and Hofmann, 2018). The impact of this phenomenon on productivity could be further amplified by congestion effects, whereby zombie firms crowd out investment and growth by more productive firms by locking resources and thus worsening resource allocation (Adalet McGowan et al., 2017 and Section 4.3.3). Moreover, zombie firms could also crowd out new firms' room to experiment with promising but uncertain technologies and business practices, which would further worsen their impact on aggregate productivity growth. While the direction of the effect on productivity is negative, its relative size, dynamics and impact on aggregate productivity need to be determined empirically.

Analysis of the impact of low interest rates on the entry and exit of firms into and from distress using the same micro-distributed data as in Section 4.3 helps shed some light on this channel of impact. The analysis confirms that the distinction between distressed firms that recover and distressed firms that finally exit the market is important. The results show that when interest rates fall, the exit of firms from distress into recovery increases, particularly in sectors more dependent on external finance (see Annex 10). At the same time, there is some evidence that low interest rates tend to slow the exit of distressed firms from the market. However, given that the share of firms that after a period in distress finally leave the market is below 2% of all firms (Chart 35 in Section 4.3), the aggregate impact of this channel is limited. The results also show that low interest rates slow the entry of firms into distress.

To sum up, endogenous growth models show that under certain circumstances monetary policy can support productivity growth by stimulating aggregate demand and easing financial conditions. This incentivises productivity-enhancing investments by supporting firm entry and delaying the exit of firms that may recover from distress. This procyclicality also helps explain the puzzle of missing disinflation in downturns

and missing inflation in upturns. In the presence of financial frictions, a very accommodative monetary policy for a prolonged time period could, however, defer necessary balance sheet repairs by firms and banks, delay firm exits and promote resource misallocation, as a result, inter alia, of higher risk-taking. The channels of impact of monetary policy on productivity growth are, therefore, manifold and net effects are difficult to estimate since they also depend on institutional arrangements and the interaction with financial frictions. They also vary over time, as was shown, for example, during and after the global financial crisis. The work stream's own (partial) empirical analysis does not support negative side effects of monetary policy on productivity growth. A better understanding of the possible channels should have a prominent role in future research and modelling efforts.

5.2 Long-term trends with an impact on productivity growth

As shown in Section 2.1, the productivity growth slowdown is a global phenomenon and might therefore respond to global factors such as globalisation, climate change, population ageing and digitalisation. Those global trends, not explicitly analysed in the report so far, alter the incentives of firms to invest in technology creation or adoption and the market selection mechanisms whereby productive firms thrive. **The objective of this section is to provide an overview of the channels of impact of each of these trends on productivity growth, as well as their expected impact on productivity in the medium and long term.**

The analysis was provided by ESCB researchers working on other work streams of the ECB's 2020-21 monetary policy strategy review. This section includes analyses of the impact on productivity growth of globalisation (Section 5.2.1), population ageing (Section 5.2.2), climate change and climate policies (Section 5.2.3), and digitalisation (Section 5.2.4).

The main findings of the section are that the impact of those global trends on future productivity is subject to uncertainty.

Globalisation has been a major channel for technology transfer and productivity-enhancing reallocation. However, after a period of expansive growth, trade and participation in global value chains slowed after the global financial crisis. Going forward, the current threats to the trade outlook, resulting, for instance, from the possible restructuring of global value chains after the pandemic and a further rise in trade barriers, may have adverse consequences for future productivity growth.

Population ageing might act as a drag on individual productivity as creativity and innovativeness declines. However, there are some counterbalancing factors such as growing experience and improved health and education in older cohorts, technology adoption, which might offset the loss of cognitive skills, and firms' strategies to mitigate the aggregate impacts of ageing. The future impact of an ageing workforce on aggregate productivity growth is uncertain and depends on the specific sector or task, and on the interplay with new technologies.

Climate change might directly affect labour productivity, as a result of uncomfortable temperatures and extreme weather events, but also indirectly, through climate policies. While the direct impact is expected to be negative, green policies could foster innovation in new green technologies and thereby increase productivity growth in the medium to long term. The overall impact of climate change and policies on productivity is, therefore, also uncertain.

Finally, **digital transformation**, which accelerated as a result of COVID-19, will increase productivity growth. However, its path and distributional impacts are still uncertain and depend on the development of institutions, infrastructure, skills, methods of production and management competencies.

5.2.1 Globalisation

This subsection presents the main insights on globalisation and productivity from the analysis for the strategy review work stream report on "The implications of globalisation for the ECB's monetary policy strategy" prepared for the Governing Council seminar on economic and monetary analysis.[102]

Productivity growth has been slowing across most advanced economies, which may point to a role played by global factors. This raises the question of whether the slowdown of globalisation since the global financial crisis (Chart 39, left panel) has been influencing the decline in productivity growth in advanced economies.

Globalisation can directly enhance productivity developments through trade integration by impacting within-firm productivity growth. First, enhanced export opportunities may lead to within-firm productivity gains via: (i) better access of domestic firms to foreign output markets, which increases incentives to engage in technology upgrading and innovation (see Bustos, 2011); and (ii) learning-by-exporting, which means that a firm's efficiency may benefit from knowledge gained through its presence in foreign markets (De Loecker, 2013). Second, foreign sourcing of intermediate goods may provide firms with cheaper inputs, inputs of higher quality, and/or inputs that have a better fit in the production function (Halpern et al., 2015), which can enhance production efficiency and output quality. And third, the impact of import competition on firm productivity is ambiguous a priori since, on the one hand, enhanced competition reduces rents from productivity-enhancing investment (such as R&D) and, on the other, lowers pre-innovation rents (i.e. the rents a firm can capture without innovation). Aghion et al. (2005) show that the former effect dominates in the case of a large technology gap between frontier and laggard firms, while the latter dominates in the case of closer competition. Moreover, pro-competitive effects from imports may enhance productivity by lowering other inefficiencies, for example by cutting managerial slack.

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[102] Work stream on globalisation (2021), "The implications of globalisation for the ECB monetary policy strategy", *Occasional Paper Series*, No 262, ECB, September.

These three channels may also increase aggregate productivity by affecting allocative efficiency. The reason is that trade integration tends to relocate market shares towards exporters and importers, typically the most productive firms (Melitz, 2003).

Globalisation may have affected productivity growth through other channels too, for example by exacerbating the difficulty of measuring firms' productivity as a result of global profit-shifting activities. Profit-shifting through transfer pricing and offshoring of intangible assets understates firms' measured output outside tax havens. Recent evidence shows that profit-shifting activities have increased over time and are sizeable, suggesting that in 2015 close to 40% of multinationals' profits were shifted to low-tax countries (Tørsløv et al., 2020). Bricongne et al. (2020) also provide evidence for French firms, measuring productivity declines after an establishment has been created in a tax-haven country.

Besides, financial globalisation played a role in the international propagation of the global financial crisis and in the excess credit growth that was at the centre of the initial phase of the crisis (Lane, 2013). The global financial crisis was marked by a large drop in demand, a tightening in financial conditions, and a spike in economic uncertainty. In such an environment, firms tend to hold back on investment. Recent studies investigating the productivity implications of the global financial crisis conclude that it indeed contributed significantly to the growth slowdown, mostly through reduced investment in intangibles and the sluggish adoption of new technologies (for example Ahn et al., 2020; Anzoategui et al., 2019; and Duval et al., 2020). Importantly, such cyclical factors can have quite persistent effects on productivity growth since it takes time for new technologies and innovations to be implemented in production.

Chart 39

Productivity and trade developments

Global trade openness	Skewness of intangible assets intensity and concentration of exports in French manufacturing
(global exports and imports of goods and services over global GDP)	(percentage, ratio)
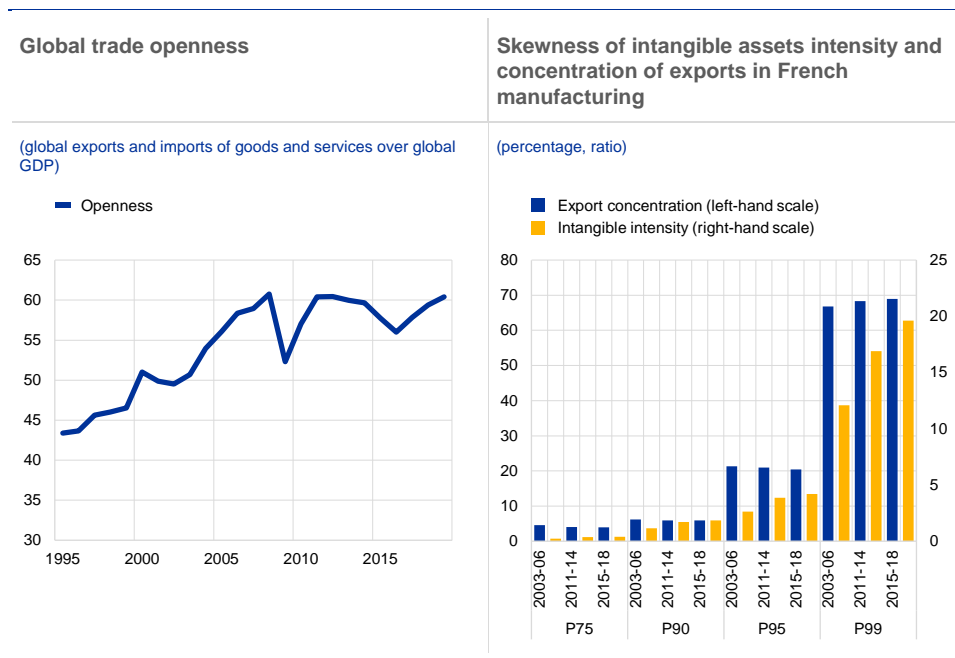
Notes: Left-hand side based on data from World Bank. Right-hand side based on iBACH, ECCBSO and ECB calculations. Chart is based on French manufacturing firms with annual turnover exceeding €750,000 and presents yearly averages for the indicated time periods. Export concentration refers to the share of total exports accounted for by any given percentile in the distribution of total manufacturing export sales. P99 refers to the top percentile, P95 to the next four percentiles, i.e. 95-99, etc. P99 of intangible assets intensity shows the ratio of intangible to tangible assets for firms at the 99th percentile of the variable's distribution.

Moreover, changes in market dynamics can be connected in part to globalisation. Recent evidence supports the view that the interplay between globalisation and the increased importance of intangible assets and digital technologies favours winner-takes-all dynamics. Such assets and technologies, which often require high upfront investments, allow firms to increase their scale at very low marginal cost, enabling a few high-quality producers or first movers to capture most of the market as discussed in Section 3.1.1. Globalisation tends to reinforce this mechanism by raising the returns of investment in these assets as a result of increased market size (Acemoglu and Linn, 2004), thereby fostering the emergence of "superstar" firms, which are usually considered to be large, globally active, intangible-assets intensive, and to have large sales per employee (see also Section 3.2.2). Indeed, this rationale seems consistent with the fact that only a relatively small set of firms tends to be highly intangible-asset intensive and heavily engaged in exports (Chart 39, right panel). It also fits with an increasing dispersion in productivity between a few highly productive global frontier firms and a much larger number of laggard firms (Section 3.2.2). An increasing dispersion in productivity driven by a fast-expanding global technological frontier is not necessarily an issue per se. However, a productivity slowdown in firms at the frontier and/or laggards could be responsible for an aggregate productivity growth slowdown, as shown in Section 3.

Existing threats to the trade outlook, for instance those resulting from the possible restructuring of global value chains after the pandemic and a further rise in trade barriers, may have adverse consequences for future productivity

growth. In this environment, the key challenge is to keep markets contestable globally, to foster the diffusion of technologies and, at the same time, to account for the inherently contested nature of intangible assets in order to provide incentives for both frontier and laggard firms to invest in new technologies and R&D.

5.2.2   Ageing

This subsection presents the main insights on ageing and productivity from the analysis presented in the 2020-21 strategy review background note on "The macroeconomic and fiscal impact of population ageing" prepared for the Governing Council seminar on economic and monetary analysis.[103]

The European labour force is ageing. As a result of the ageing of the baby boomer generation and rising pension ages in euro area countries, an increasing share of the working age population, labour force and employment is in the older age cohorts. This change in the composition of the labour force and related behavioural changes could affect aggregate productivity growth.

The relationship between age and productivity at the individual level is thought to have a reverse U-shape. This reflects the positive impact of the experience gained during an individual's career, which may be counterbalanced by the moderation of physical and cognitive abilities, less on-the-job training and lower incentives to keep up with the latest technologies. Empirical evidence in this respect is somewhat mixed: while there is empirical support for the declining physical abilities and innovativeness of older workers, there is no clear evidence of declining cognitive abilities (Aiyar et al., 2016). The relationship between age and productivity depends, among other things, on the sector in which individuals work, or the tasks they perform.

There are several counterbalancing factors to the decline in abilities. The educational level of the older population has risen considerably, while the age threshold beyond which abilities start deteriorating has risen due to longevity and longer healthy years of life (Burtless, 2013). At the same time, any potential decline in productivity at the individual level may not translate into lower productivity at the firm level. The reason is that firm-level policies may support productivity: at the individual level by providing age-specific equipment, or on a team level by setting up age-diverse teams. Macroeconomic policies may further support this by providing work incentives for older workers, incentivising the hiring and retaining of older employees, or through training and health-related policies.

Going forward, the impact of workforce ageing on aggregate productivity growth is uncertain and will depend, inter alia, on the interplay with new technologies and policies.[104] Further advances in health and longevity, as well as automation and the adoption of new technologies, could be expected to support the

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[103] For more information, please see Holm-Hadulla, F, Musso, A., Rodriguez Palenzuela, D. and Vlassopoulos, T. (eds) (2021), "Evolution of the ECB's analytical framework", *Occasional Paper Series*, No 276, ECB, September.

[104] See also Aksoy et al. (2019) or Deutsche Bundesbank (2021).

productivity of all workers, and specifically that of older workers. Additionally, as the baby boomer generation retires, the share of older workers in the labour force will again decrease, which will reverse the negative compositional effects. There may also be some headwinds to productivity growth: jobs which are more physically demanding and performed by low-skill workers might suffer, while labour shortages related to ageing may also keep productivity growth down. Demand for generally low-productivity service jobs in the economy (for example personal services supporting older people) might also increase on the back of an ageing population.

5.2.3 Climate change

This subsection presents the main insights on climate change and productivity from the work stream's work and the analysis presented in the 2020-21 strategy review report on "Climate change and monetary policy in the euro area" prepared for the Governing Council seminar on economic and monetary analysis.[105]

It has long been established that the comfort temperature of humans lies somewhere between 18 and 22 degrees Celsius. Very extreme temperatures either above or below that comfort zone can have important physiological effects that affect mortality, health and, in turn, labour supply and labour productivity (Seppanen et al. 2006). The physical stress induced by extreme temperatures is the "direct" impact of climate change on labour and might be of first-order importance and persistent over time. However, it is generally not included in the integrated assessment models designed to estimate the social costs of carbon. The implication is that these costs might be systematically understated in that they miss an important damage channel.

The existing estimations of the direct impact of climate change use historical relationships between temperature increases and labour productivity. There is remarkable consensus as to the magnitude of the causal impact of temperature shocks on labour productivity levels and related economic outcomes, with short-run damage estimates clustered around -2% per degree Celsius above comfort temperature (Heal and Park, 2016).

Given that temperatures increase only gradually, firms and workers might adapt with changes in timing, workplace location, level of effort, tasks or air conditioning acquisition. Adaptation might reduce the estimated impact of climate change on productivity. Barreca et al. (2016) and Park (2016) are among the few studies accounting for this possibility. Both studies analyse a rich country – that is, with no credit constraints in adapting to rising temperatures – and exploit the heterogeneity of the temperature-productivity link between regions with different initial characteristics. They report a lower impact of temperature fluctuations in regions with higher average temperatures relative to cooler-than-average regions, which suggests that hot regions have successfully adapted to extreme conditions.

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[105] Work stream on climate change (2021), "Climate change and monetary policy in the euro area", *Occasional Paper Series*, No 270, ECB, September.

However, they also report the limits to air conditioning and other adaptations in the face of extreme heat.

Although most studies find only a level effect of rising temperatures on labour productivity, the analysis of Dell et al. (2012) documents a persistent impact or growth effect. This increases the order of magnitude of the impact of climate change on real variables over longer time horizons. There could be different reasons supporting growth rather than level effects: the impact of rising temperatures on mortality and health, on human capital accumulation (Zivin and Shrader, 2016) and on political instability (Dell et al., 2012).

The physical risks of climate change also include extreme weather events such as storms, floods or droughts, which become more frequent as temperatures increase. These events tripled in frequency worldwide in the period 2000-18 relative to 1960-1979 (Dieppe 2020) and can affect productivity through several channels. First, these events impact morbidity and mortality rates, given that they can induce a temporal worsening of hygiene and health conditions, leading to large-scale infectious outbreaks. They might also interrupt schooling and commuting to working sites, at least for a certain period. Second, extreme weather events destroy installed physical capital, damage infrastructure, disrupt supply chains and could adversely affect investment as a result of increased uncertainty and reduced demand. Under certain conditions, if firms substitute their damaged machinery with the latest, more productive technology, these events could give a positive productivity boost to the affected region. But if the impairments of physical assets multiply, more capital will be deployed for replacement and repair investment, leaving firms with less funding for research and development and lowering their capacity to implement new technologies and invest in productivity-enhancing activities.

Most empirical studies find that natural disasters dampen productivity permanently by destroying productive capital, durable goods or causing a permanent loss of wealth. They could also increase uncertainty and insurance costs, again dampening investments. For example, Raddatz (2009) finds that GDP per capita is 0.6% lower in the long run as a result of a single climatic event caused by heatwaves, cold waves, droughts or forest fires. Dieppe (2020) estimates a cumulative impact on labour productivity of 7% three years on from the event. Moreover, extreme weather events might trigger other disasters like wars or financial crises, which would amplify their adverse effects. There are several mitigating factors, including the effectiveness of governance and access to finance, and insurance cover of households and corporates.

"Green" policies can also affect real variables, at least in the short term, such as capital accumulation or labour productivity growth. Green policies are defined as policies that mitigate the effects of climate change and/or foster adaptation. The impact of such policies on labour productivity are the "indirect

impact" of climate change on productivity.[106] In contrast to the direct impact, the indirect effect of climate change could already be substantial in the short term.

The channels of impact of green policies on productivity are manifold. Firms might need to invest to comply with regulation aiming to prevent and reduce pollution. This new investment might subtract resources from other productive investments and, moreover, does not generate any value added for the firm. The result is a decline in productivity growth in the short term. Additionally, some firms might not be able to make such investments and therefore be forced out of business. The impact on aggregate productivity growth will depend on the relative productivity of exiting firms. Similarly, green policies might increase entry barriers for new firms (see OECD 2006). Increasing the extra costs imposed on firms might also induce the reallocation of certain pollution-intensive tasks to other countries with laxer green regulation (this is known as the pollution-haven hypothesis), and therefore be detrimental to a country's competitiveness. Green policies could also reduce the choice of inputs and production processes available to firms, reducing possible within-firm complementarities and synergies. The result could be a sub-optimal choice of inputs and, therefore, reduced productivity growth.

The impact of green regulation can also be positive, above all in the long term. The Porter hypothesis (Porter and van der Linde, 1995) states that well-designed environmental policies can enhance innovation and productivity, resulting in long-term benefits which outweigh possible short-term costs. Green policies might also encourage the emergence of new sectors or activities with positive spillovers to the rest of the economy. Empirical analyses support a weak version of the Porter hypothesis whereby green policies foster innovation in green technologies (Lee et al., 2011; Calel and Dechezleprêtre, 2016; and Dechezleprêtre and Sato, 2017). Aggregate impacts might hide the heterogeneous impact of green regulation on different types of firms. Albrizio et al. (2014) examine this hypothesis using cross-country firm-level data from OECD countries over the period 2000-12 and a new OECD synthetic indicator of environmental policy stringency. They show that an increase in green policy stringency has a short-term positive impact on the productivity growth of one-third of firms in a given sector, and a negative impact on the rest. The firms benefitting from the policy are the technological leaders in the sector, and therefore the best suited to seize new opportunities and rapidly deploy new technologies. Less advanced firms may need more investments to comply with the new regulation and therefore exhibit a temporary fall in productivity growth. Additionally, frontier firms are usually large and have international production chains, as highlighted above, a factor that facilitates the outsourcing of the more polluting activities (Kozluk and Timioliotis, 2016), thus partly confirming the pollution-haven hypothesis.

Climate change is expected to have a relatively benign impact on EU countries, particularly Northern EU countries that have lower temperatures to

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[106] Green policies can have an impact on capital accumulation through the implied acceleration of the obsolescence of capital stock, which would decrease capital intensity and the productive capital available to firms (see Hamamoto, 2008). They can also result in stranded assets, i.e. assets acquired under a policy regime conducive to profitability, unlike the new and less profit-friendly green regulatory framework.

start with. It might, however, exacerbate regional disparities within the EU, with a clear north-south divide. Regardless of the initial point, all EU countries are wealthy and so can invest resources in adaptation and mitigation policies which will reduce both direct and indirect impacts. Identifying the losers and the winners will be essential to achieving a just transition to a low-carbon economy.

5.2.4   Digitalisation

This subsection presents the main insights on digitalisation and productivity from the analysis presented in the 2020-21 strategy review work stream report on "Digitalisation: channels, impacts and implications for monetary policy in the euro area", prepared for the Governing Council seminar on economic and monetary analysis.[107]

Digitalisation is one of the major structural changes transforming the functioning of the euro area and the global economy, interacting with globalisation, demographic trends and climate change. Digitalisation is a long-duration technology shock which has accelerated since the 2003 strategy review, latterly, and notably, in conjunction with the COVID-19 pandemic.[108] Its overall economic impacts require close monitoring, combined with further conceptual and empirical work regarding its mechanisms and impacts. The report prepared by the work stream on digitalisation for the strategy review assesses its implications for: a) price measurement, b) productivity, c) labour markets and d) inflation. What follows is a short summary of the insights related to productivity growth.

Digital adoption differs across EU countries, implying heterogeneous impacts, with most countries lagging behind the United States and Japan (Chart 40). Heterogeneity across the euro area countries may create diverging economic conditions, while there is again a general lag in digital adoption compared with the United States and Japan.

Measurement challenges related to digitalisation have implications for welfare as well as for nominal and real variables, including productivity.[109] First, digitalisation has exacerbated old/traditional/known price measurement issues. Frequent and disruptive innovations stemming from digitalisation have led to more frequent product replacements and greater difficulties in computing quality-adjusted price indices. In addition, the emergence of e-commerce amplifies measurement issues related to outlet substitutions. Second, digitalisation has brought new measurement issues such as complex pricing strategies (dynamic pricing,

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[107] Work stream on digitalisation (2021), "Digitalisation: channels, impacts and implications for monetary policy in the euro area, Occasional Paper Series, No 265, ECB, September.

[108] Digitalisation is here defined very broadly, to include inter alia: the application of the wide variety of ICTs; technologies enabling automation and robotisation; and technologies related to the processing and analysis of digital data, including big data, such as artificial intelligence/machine learning and quantum computing.

[109] The challenges were documented and the associated biases estimated by, for example, the Stigler Commission (Stigler, 1961) and the Boskin Commission (Boskin et al. 1997 and 1996). Later studies found the biases to be somewhat reduced, e.g. Gordon (2000) for the United States, Hoffman (1998) for Germany and Lequiller (1997) for France.

customised pricing, etc) and "free" services which previously required payment. Measurement challenges relating to digitalisation have implications for welfare as well as for nominal and real variables. These challenges apply unevenly across different price deflators, with estimates suggesting upward measurement biases. The implied underestimation of GDP growth may contribute to, but cannot explain, the observed productivity slowdown in recent decades, while welfare improvements arising from new product varieties and online services may be significant.

Digital technologies are pervasive across the economy, promising large productivity gains through improved production process efficiency and higher rates of automation and robotisation.[110] Despite the rapid growth in digital technologies, aggregate productivity growth has decreased in most advanced economies since the 1970s, with the notable exception of a productivity revival in the United States between 1995 and 2005, as shown in Section 2.1. At the global level, the productivity gains induced by digitalisation are still low, but it is likely that without the observed growth in digital innovation the productivity slowdown would have been even more pronounced. Expanded growth accounting decompositions suggest that it is the declining TFP contribution, rather than the ICT capital and robot contributions, that are the main factor explaining the productivity slowdown.

Chart 40

Degree of digitalisation in the euro area and selected countries

(digital economy value added as percentage of GDP, current prices)

■ Manufacture of computer, electronic and optical products
■ Manufacture of electrical equipment
■ Publishing activities
■ Audiovisiual and broadcasting activities
■ Telecommunications
■ IT and other information services
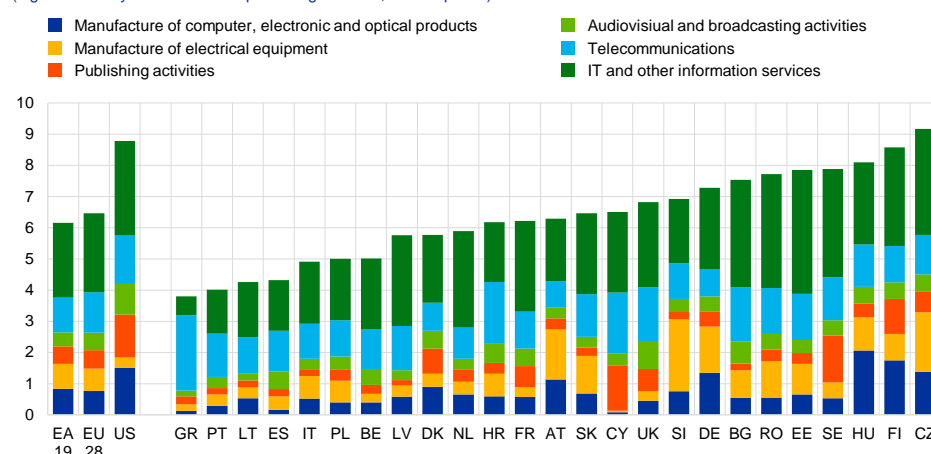
Source: OECD database, ECB staff calculations.
Notes: The data for BE, DE, EE, ES, IT, CY, LV, LT, HU, AT, PL, PT, RO, SI, SE, EU, EA and US refer to 2018, those for BG, GR, HR, NL and UK to 2017, those for EU and EA to 2016.

One explanation for the low productivity gains from digitalisation at the aggregate level is that the adoption, diffusion and full operationalisation of digital technologies is too slow, thus delaying a new wave of potential productivity growth. This slow diffusion results from factors such as resource misallocation, inadequate economic institutions, skill shortages and insufficient

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[110] Recent studies show that industrial robots are still used in a few industries, including automotive, rubber and plastic and metal industries (see Fernández--Macias et al. 2021).

infrastructure.[111] Also, firms' organisational capital and management practices are important factors in reorganising production and fully reaping the benefits of new digital technologies. This partly explains cross-country productivity divergences across the euro area.[112]

Following the onset of COVID-19, there has been an increase in the take-up and use of digital technologies. Early signs suggest that, other things equal, the more digitalised EU economies (and those with higher potential teleworking capabilities) weathered the COVID-19 shock better than the less digitalised economies.[113] The COVID-19 pandemic and the associated acceleration in digitalisation implies potentially far-reaching structural change which can boost the productivity gains from digitalisation. However, its path and distributional impacts are still uncertain and depend on the development of institutions, infrastructure, skills, methods of production and management competencies.

5.3   The impact of COVID-19 on productivity

Lockdown measures and supporting policies to contain the COVID-19 pandemic could have both intended and unintended effects on productivity growth. This section lays out, first, the possible channels of impact (Section 5.3.1). Section 5.3.2 shows the little available evidence at the time of closing this report on the impact of COVID-19 on within-firm productivity growth. Section 5.3.3 shows some preliminary results from the work of the work stream on the impact of the crisis on the entry and exit of firms as well as available evidence on the impact of COVID-19 on resource reallocation. Finally, Section 5.3.4 reflects on the long-term impacts of the unprecedented set of policies implemented by European governments, and indeed worldwide, in support of households and firms.

The main findings of the section are that the COVID-19 shock might impact within-firm productivity growth and resource reallocation. Within-firm productivity growth could be affected in the short term by labour hoarding, but also in the long term because of skill deterioration, a drop in investment in productivity-enhancing activities or supply chain disruptions. On the upside, the shock has accelerated digital uptake by firms across advanced economies, with medium to long-term positive impacts on productivity growth. Regarding resource reallocation as a result of entry and exit of firms, financial stress caused by the shock might deter firm entry. Firm exit is being delayed, thanks to the extensive policy support provided. We find that the firms most vulnerable to the COVID-19 shock are less productive than other firms in their sector so the crisis could have a cleansing effect. Unlike in normal times, a large part of resource reallocation is happening across rather than within sectors, given the asymmetric impact of the shock. However, if unproductive sectors

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[111] As aptly put by Bresnahan et al. (2002), "Firms do not simply plug in computers or telecommunications equipment and achieve service quality or efficiency gains".

[112] See, for example, the evidence on raw correlations of productivity growth and management scores in Schivardi and Schmit (2020) and Akcigit and Ates (2021).

[113] See Anderton et al. (2020a).

shrink but other, more productive, sectors do not expand, sector reallocation might be productivity-enhancing but could be negative for aggregate output and welfare.

5.3.1 Possible channels of impact of the COVID-19 pandemic on productivity growth

The COVID-19 shock might reduce within-firm productivity growth. Productivity growth might be affected adversely by possible mismatches arising in the aftermath of the pandemic and following its impact on the euro area labour market. Within-firm productivity growth might also be affected in the long term by a deterioration in the quality of labour. The destruction of jobs resulting from a surge in firm exits would potentially lead to productivity losses if reallocation of displaced workers to other firms is slow and leads in the long run to a deterioration in workers' skills. Human capital accumulation might also be affected by the lockdown-induced disruptions to schooling and training, which might hurt aggregate and firm-level productivity in the long run. Supply chain disruption might be persistent, and firms might need to find new suppliers, new transport routes or new locations of production. This might be exacerbated if the current pandemic increases protectionism and accelerates de-globalisation (see Section 5.2.1 above). If this was the case, sectors that have greatly benefited in terms of productivity growth from international exposure and globalisation might experience a decline in productivity.

Investment in productivity-enhancing activities might be affected, with longer term impacts on productivity growth. Financial distress, together with high uncertainty, might increase the financing cost and reduce the expected benefits of new productivity-enhancing projects and delay investment, with impacts on productivity growth. Further, the uptake of new debt by corporates to cover liquidity gaps[114] could result in debt overhang and further reduce investment. Additionally, some scholars argue that COVID-19 will have adverse long-term economic implications through "scarring of beliefs", i.e. a persistent change in the perceived probability of an extreme, negative shock in the future (Kozlowski et al., 2020). A greater tail risk lowers incentives to invest and thus has implications for the productive capital stock and, ultimately, for productivity.

The acceleration of digital uptake forced by the COVID-19 crisis might be positive for (within-firm) productivity growth going forward. Containment measures have accelerated the progress of digital uptake in firms across all sectors, thus affecting the organisation of work and ways of doing business (e.g. e-commerce, teleworking and videoconferencing). The productivity response to the acceleration in digitalisation may need time and depends heavily on the joint development and digital transformation of institutions, infrastructure, skills and methods of production and management (see OECD 2020). The shift to remote work is likely to persist and could potentially open the door to substantial gains in terms of

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[114] The euro area corporate debt-to-GDP ratio grew by 7.9% in the first three quarters of 2020, following a decrease of 0.3% in 2019.

productivity and worker well-being, but could also increase inequalities across workers.

The COVID-19 crisis might improve resource reallocation within and across sectors. The COVID-19 shock has asymmetrically impacted various sectors of activity and might, therefore, result in productivity-enhancing sector reallocation. This would be the case if some low-productivity sectors were more persistently affected and lost economic importance to the benefit of less affected, high productivity, sectors. For example, during the global financial crisis productivity growth started to improve in some countries, notably Spain, through the reallocation of resources from the less productive construction sector to the relatively more productive manufacturing sector. The outbreak of the coronavirus pandemic has triggered an unprecedented demand for digital health technology solutions and the health sector is thus expected to be a prime beneficiary of digital technologies (Bank of Greece, 2020). Moreover, if low-productivity firms within any sector were relatively more affected by the shock, the crisis could have a cleansing effect.

Given the high degree of uncertainty about the possible impacts, one way to gain further insights is to look at past pandemics. The economic history literature on the relationship between pandemics and economic outcomes is hardly new (see Anyfantaki et al., 2020 for a comprehensive overview), with work primarily relying on aggregated data at the regional or national level. By far the most severe pandemic in terms of fatality rates was the Black Death (Plague), which killed between 30% and 60% of Europe's population in the 14th century. Most work has shown that, by sharply reducing the size of the working population, the Plague led to a substantial increase in nominal wages for workers that persisted into the 15th century, while the impact on per capita income was less clear. Given the availability of data, the most widely analysed major pandemic is the 1918 influenza pandemic, or Spanish flu, although the results of the analyses are mixed. A notable difference between the Spanish flu and COVID-19 is that the former primarily affected prime-age workers, which suggests that its economic effects were more severe, particularly for potential output. An econometric analysis conducted by the work stream to gauge the short and long-term impact of recent pandemic episodes on TFP growth shows a short-lived negative impact. It must be noted, though, that the health events in the analysis were of a much smaller scale in terms of infections than COVID-19 and occurred on a local rather than global level, implying fewer cross-country spillovers (see Box 7).

Box 7
The impact of pandemics on TFP growth: a historical overview

The potential impact of COVID-19 on productivity is subject to high uncertainty. This box therefore provides a historical overview of the impact on TFP growth of epidemics (severe acute respiratory syndrome, known as SARS, Middle East respiratory syndrome, known as MERS, Ebola and Zika) and pandemics (H1N1 swine flu) (all labelled hereinafter as "health events") in order to obtain a benchmark estimate for COVID-19. The dynamic impact of past health events on TFP is estimated through a local projections approach following that of Jordà (2005):

$$IRF(t, s, d_i) = E[TFP_{t+s} \mid health\ event_{i,t} = d_i\ ; X_{i,t}] - E[TFP_{t+s} \mid health\ event_{i,t} = 0\ ; X_{i,t}] \qquad \text{(B7.1)}$$

For each forecast horizon $(t + s)$, we compute the response of cumulative TFP growth (dependent variable) to a health event (independent variable) taking place at time t. In our panel dataset, the health event is specified as a dummy variable (d_i) that switches to 1 for each country and year during which the health event occurred. To account for other events that could potentially have affected productivity (control events), we add control dummies (X_t) for financial crises (using the database by Laeven and Valencia, 2018) and exogenous shocks.[115]

The univariate regression:

$$
\begin{aligned}
TFP_{i,\,t+s} &- TFP_{i,t-1} \\
&= \alpha_i + \beta_0 * health\ event_{i,t} + \sum_{p=1}^{4} \beta_p * health\ event_{i,t-p_0} \\
&\quad + \sum_{p=0}^{4} \gamma_p * control\ event_{i,t-p_0} + \sum_{p=1}^{4} \beta_p * \Delta TFP_{i,t-p_0} + \alpha_i + \varepsilon_{i,t}
\end{aligned}
\qquad \text{(B7.2)}
$$

estimates for each forecast horizon $t + s$ the difference between the cumulative TFP growth rate subject to the shock in year t ($health\ event_{i,t}$ takes the value 1), and the cumulative TFP growth rate if the epidemiological shock had not occurred. The coefficient of interest is thus β_0. Other regressors include four lags of the main dummy variable to control for their potential persistence ($health\ event_{i,t-p}$), dummies for financial crises and exogenous shock variables[116] ($control\ event_{i,t-p}$) and autoregressive growth terms of the four lags[117] ($\Delta TFP_{i,t-p}$). We also include country-fixed effects (α_i).[118]

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[115] The exogenous shocks considered are major wars (in terms of fatalities) and the OPEC oil embargo of 1973-1974.

[116] The events variable enters the model both contemporaneously and with lagged values in order to control for the persistence of the shocks.

[117] These regressors help control for potential endogeneity issues.

[118] To control for country-specific time-invariant characteristics. We do not include time dummies as they would capture all global events and thus potentially eliminate some of the effects of past epidemics and pandemics.

Chart A

Impact of past epidemics and pandemics on TFP levels

(index)
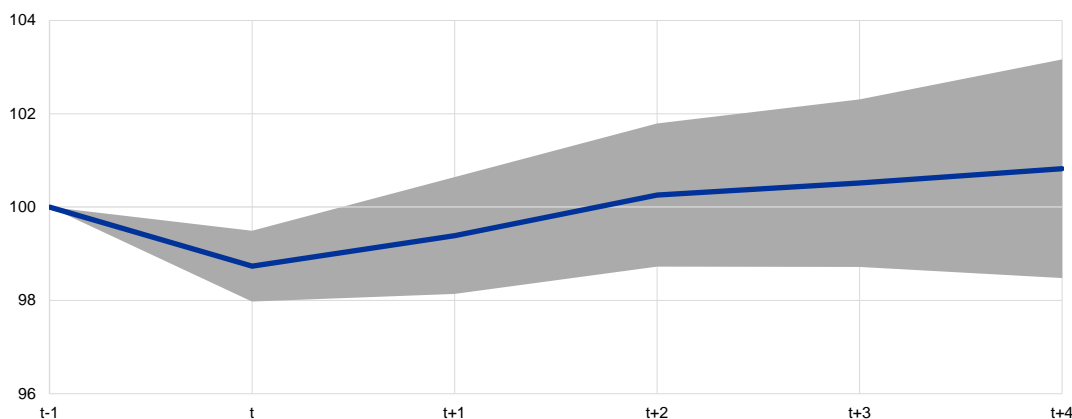
Sources: ECB calculations based on Penn World Tables (Feenstra et al., 2015).
Notes: The continuous line indicates the impact of the epidemic/pandemic in year t on the level of TFP up to the period t+4, i.e. four years after the end of the epidemic/pandemic, and the shaded area depicts the 95% confidence interval.

We use a dataset of 117 countries from 1970 to 2017, where countries are treated as affected ($health\ event_{i,t} = 1$) if they registered at least ten epidemiological cases during the year in question. TFP at constant national prices is obtained from the Penn World Tables (Feenstra et al., 2015). Country-specific data for health and control events are collected from a variety of sources, including the World Health Organisation and the European Centre for Disease Prevention and Control.

The results suggest an initial loss in the TFP level of around 1.3% in the year(s) of the health event (Chart A). However the impact is short-lived, as it is already insignificant in the first year after the end of event and turns positive (but insignificant) thereafter.[119] The negative impact on TFP could be driven by temporary shifts in the utilisation of certain factors (for example unutilised labour supply due to lockdowns of certain sectors of the economy), which would be consistent with the profile of a momentary slump followed by a fast rebound. The health event might also affect TFP in the medium to long term through a decline in innovation (on account of elevated uncertainty and cuts in R&D spending) and fewer knowledge spillovers as a result of the disruption of global value chains.

It should be noted that – with the exception of swine flu – compared with COVID-19 the health events in our sample were of a much smaller scale in terms of infections, and occurring on a local rather than global level, implying fewer cross-country spillovers. Therefore, our estimate of the impact of past health events on TFP could provide a lower bound estimate with respect to the contemporaneous impact of COVID-19 on TFP in the years 2020-21. Furthermore, in contrast to our findings, COVID-19 could also affect TFP in the medium to long term through several potential channels (see discussion in the main text).

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[119] Our results are similar to those of recent research by the World Bank, which also finds a negative and short-lived impact of epidemics on TFP growth, but a longer lasting and more pronounced negative impact on labour productivity. See Dieppe (2020), Box 3.1.

5.3.2 Available evidence on the impact of the COVID-19 crisis on within-firm productivity growth

Hard data show that within-firm productivity growth dropped substantially in the aftermath of the shock as a result of increasing intermediate costs produced by the COVID-19 crisis and the reallocation of management time to crisis-related issues. Bloom et al. (2020a) report results from UK data collected from a large and representative online panel of UK firms (the Decision Maker Panel). The information gathered includes values for sales, employment, capital and intermediate costs, including expected ones, and therefore permits the analysis of productivity in the short and medium term. Firms in the panel reported an increase in intermediate costs associated with containment measures (hand disinfection systems and supplies, masks etc.) which dragged down short-term productivity (-2% in labour productivity per hour up to mid-2021). Perhaps more worryingly, respondents reported a drop of 14% in R&D investment and a substantial reallocation of management time to deal with the crisis rather than increasing the firm's value in the medium term. As a result, firms expected a decrease in productivity over the medium term also.

Chart 41

Share of respondents agreeing/disagreeing with different narratives

(percentage of respondents)
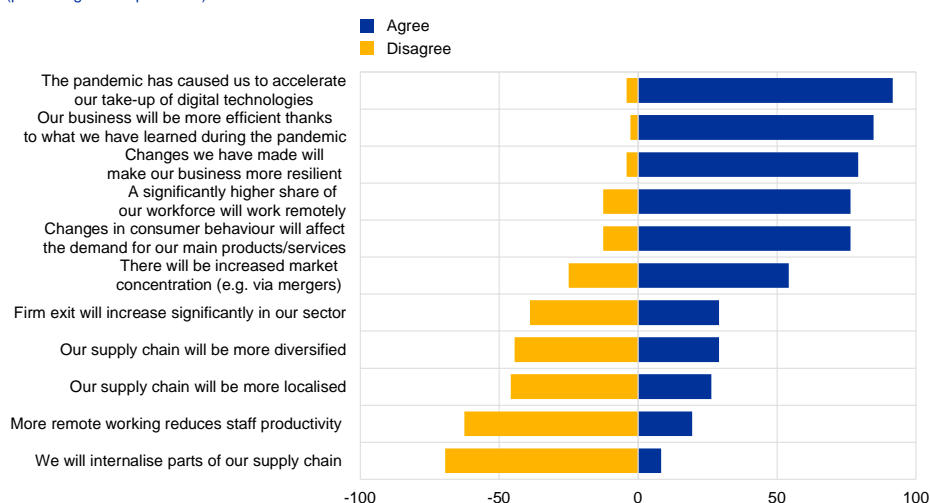
Source: ECB (2020c).

However, survey-based evidence shows a clear acceleration of digital uptake in firms and positive productivity impacts of increased teleworking. A recent ad hoc ECB survey of leading euro area companies looking at the long-term effects of COVID-19 asked respondents about the long-term impacts of the pandemic on their businesses (see ECB 2020c). Nine out of ten respondents confirmed that they had accelerated their take-up of digital technologies and/or automation, while more than three-quarters agreed that a significantly higher share of their workforce would continue to work remotely. Around 60% disagreed when asked if more remote working reduced productivity, compared with just 20% who agreed with the statement. In this regard, while reduced informal, personal interaction was seen as a

downside, many advantages were also perceived, including the reduction in lost time due to commuting, the possibility of better juggling home and work commitments, and increased connectivity (Chart 41). These results are supported by a US-based survey reporting that 40% of workers working from home stated that they were more efficient, compared with 15% who felt they were less efficient (Barrero et al. 2020). Bloom et al. (2020b) analyse the text content in US patent applications and show that COVID-19 has shifted the direction of innovation towards new technologies that support video conferencing, telecommuting, remote interactivity and working from home. Riom and Valero (2020) report results from a survey of 375 UK businesses conducted in partnership with the Confederation of British Industry. They find that over 60% of firms report that they have adopted new technologies or management practices since the onset of the pandemic, while a third have invested in new digital capabilities. [120] However, Bloom et al. (2015) show that the adoption of new management practices is important if the productivity gains produced by teleworking are to be reaped in full given that, even when teleworkers are found to be more productive, their promotion rate conditional on performance tends to fall.

5.3.3 Available evidence on the impact of the COVID-19 crisis on resource reallocation

The COVID-19 shock may affect resource allocation through the extensive margin, i.e. through the entry and exit of firms. As was shown in Section 4.2, resource reallocation through firm dynamics – the exit of unproductive businesses and the entry and growth of new ones – is a key factor for productivity growth in the medium-long run. Unfortunately, the current COVID-19-induced recession is likely to reduce new business formation, both because firm entry is procyclical and also because it is sensitive to the availability of external finance. In this respect, the most recent data show a substantial worsening of financing conditions for small businesses in Europe. In Spain, for instance, entry decreased by around 40% from March to July 2020, and the cumulative deficit in entry over these five months was comparable to the same deficit accumulated in the first 11 months of the global financial crisis.

Recent analysis by the work stream shows that the increase in financial frictions caused by the COVID-19 crisis could have large impacts on firm entry and post-entry growth. Using Global Entrepreneurship Monitor data, Albert, Caggese and González (2020) quantify, for the four main EU economies, the expected effect of GDP decline and the increase in financial frictions caused by the COVID-19 shock, both on overall firm entry and on the growth potential of new firms. If GDP decreases as a result of the COVID-19 pandemic, but spreads do not

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[120] These survey-based findings are supported by the latest available data at the point of going to press (September 2021). Data up to the first quarter of 2021 show a rise in average sector productivity per hour starting the second quarter of 2020 in the ICT sector, financial and real state and professional and business activities. These are sectors where workers can work remotely, and firms were able to take advantage of new digital solutions soon after the first wave of lockdowns. Those productivity gains persisted partially after the re-opening of the economies, suggesting that the acceleration of digital uptake can have a persistent positive impact on productivity. This is reinforced by the development in the wholesale and retail and accommodation sectors, where productivity gains started later but continue to be strong well into 2021.

increase, there is a reduction in firm entry but no effect on the post-entry growth of new entrants. In contrast, if the GDP contraction is accompanied by even a relatively small increase in financial frictions, it sharply reduces the entry of high-growth start-ups. This causes a further reduction in entry and fewer jobs created in the short run but, more importantly, also slower employment growth for this cohort of firms in the long run.

However, high-frequency US data on firm entry shows that business formation is increasing in the United States after an initial drop during the first lockdown. Syverson (2020) reports results for weekly new business applications in the United States and shows that, after an initial dip, business entry increased and is now above the average for 2015-19. There is not enough information yet as to whether this will be sustained and what type of businesses are being created. One possible explanation to this counter-intuitive development is that demand for new online and delivery services is exploding, which might create new opportunities for new firms. The impact on aggregate productivity growth will depend on the relative productivity and post-entry growth of these firms.

Regarding firm exit, simulations show that firms most vulnerable to the COVID-19 shock, given their fragile financial position, are on average less productive than healthier firms. Exit data is not as timely as entry data, so the work stream has performed a number of simulations based on financial accounts sourced from ORBIS-iBACH and assuming different sector-specific revenue and cost paths based on ECB projections and historical elasticities.[121] Identifying firms with negative working capital and high leverage as vulnerable, the analysis shows that the productivity of firms with higher exit risk as a result of the COVID-19 shock is below that of financially more robust firms in their same country and sector of activity (Chart 42, left panel). It was not clear a priori that the COVID-19 crisis would have a cleansing effect, given its exogenous origin, but preliminary findings seem to support the existence of a silver lining to this crisis too. These results are confirmed by Fernández-Cerezo et al. (2021) using survey data matched with administrative data for Spain. The study finds that small and less productive firms suffered a higher decrease in sales and employment as a result of the COVID-19 shock, pointing to the existence of cleansing effects.

Reallocation of resources across incumbent firms operating in the same sector has been found to be productivity-enhancing during the COVID-19 crisis. Recent work by Andrews et al. (2021) using Australian tax data matched with (lagged) firm financial accounts uses the methodology proposed by Foster et al. (2016) to estimate the strength of the link between a firm's productivity, relative to the average in the sector, and its employment growth. The authors find that employment flows initially rose but then declined as crisis policies prioritised preservation. Even then, relatively more productive firms were found to grow significantly more than their less productive counterparts.

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[121] Following the methodology proposed by Schivardi and Romano (2020).

Chart 42

Productivity of firms with an elevated risk of exit as a result of COVID-19 relative to other firms in the same sector (left panel) and sector productivity and sector-specific COVID-19 impact in the euro area (right panel)

Productivity of firms with an elevated risk of exit as a result of COVID-19 relative to other firms in the same sector	Sector productivity and sector-specific COVID-19 impact in the euro area
(EUR thousands)	(y-axis: sector deviation from country average productivity; EUR thousands; x-axis: sector turnover drop due to COVID-19 in 2020 relative to country average; percentage points)
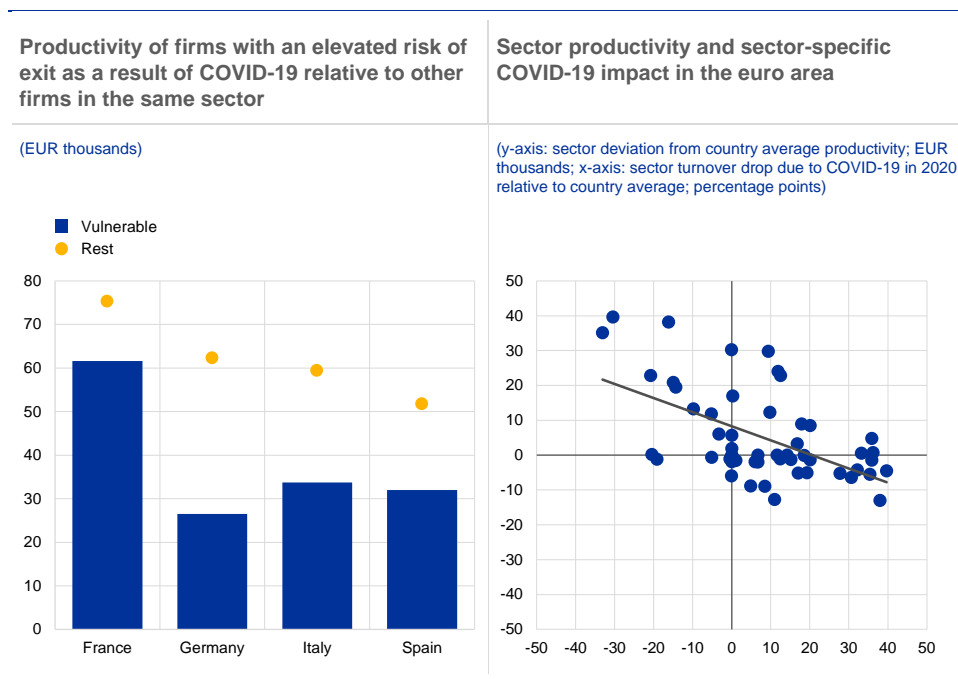
Sources: Left panel: Own calculations using ORBIS-iBACH data; right panel: Own calculation using ECB data, Eurostat's national accounts and structural business statistics.
Notes: Left panel: Productivity defined at firm level as real value added per employee. The figures reflect the ECB December projections and refer to the peak of the crisis, which is the fourth quarter of 2021 or the first quarter of 2022 depending on the country. Vulnerable firms are defined as those with negative working capital and at the top 25% of the leverage distribution within their country-sector. Right panel: Productivity is measured as the ratio between sector real value added and total hours worked. Shocks are defined as the loss in turnover value in April 2020 compared to the previous year. Deviations are calculated at the country-sector (NACE Rev. 2) level with respect to the country average. Sectors include manufacturing, construction, trade, transport, hospitality, ICT, professional and administrative services and other services.

The asymmetric sector incidence of the shock could also trigger across-sector reallocation of resources. Unlike in "normal" times, according to UK data about 75% of the productivity growth contribution of resource reallocation during the pandemic has been driven by resource reallocation across sectors, with only 25% within sectors (Bloom et al., 2020a). This is because the shock has affected different sectors of the economy asymmetrically, with a large impact on face-to-face, predominantly service, sectors that are relatively less productive than the average (Chart 42, right panel). However, even when across-sector reallocation could be productivity-enhancing as a result of the drop in weight of low productivity sectors, it will reduce output and welfare in the medium term unless other, high productivity sectors, do not expand over time. We have yet to see to what extent this change in the economic structure will be permanent or reversed over the medium to long term.

A shift-share analysis with quarterly euro area data shows that during the pandemic the reallocation of resources across sectors contributed one-third to aggregate productivity growth (Chart 43). This development is in sharp contrast to the pre-crisis period 2014-2019, when sector reallocation contributed on average little, and negatively, to annual productivity growth (see also the discussion in Section 2.2). Moreover, intra-sector productivity growth in the most exposed sectors acted as a drag on aggregate productivity growth between the first quarter of 2020

and the first quarter of 2021. In contrast, the least affected sectors contributed positively. These are the sectors where workers were able to work remotely, and firms could take advantage of new digital solutions soon after the first wave of lockdowns.

Chart 43

Contribution of sector-reallocation of resources to aggregate productivity growth, different periods

(in percentage points)
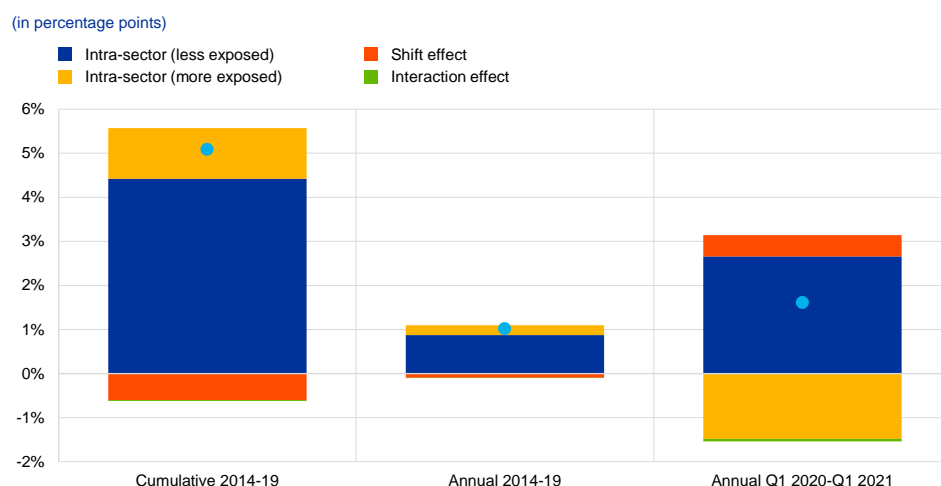
Source: Own calculations using Eurostat. Last data point is March 2021. Less exposed sectors are industry (except construction), manufacturing, ICT, financial and real estate services and professional and administrative activities. More exposed sectors are construction, retail and wholesale, transport, hotels and restaurants and arts, entertainment and recreation activities.

5.3.4 Unintended side effects of support policies on productivity growth

There is a concern that long-lasting support policies in the context of the COVID-19 pandemic could lead to a higher incidence of zombie firms. Accommodative monetary policy has enabled firms to take up funding at favourable conditions during the COVID pandemic. Fiscal policy support, especially through moratoria and state guarantees, incentivised banks to act as a backstop in the presence of dwindling corporate cash-flows. While this additional lending has helped cover corporates' increased liquidity needs, in the presence of financial frictions it could also provide sustenance to zombie firms. Indeed, non-financial corporations' debt increased substantially in the first half of 2020 (Chart 44, left panel). For the entire euro area, the corporate debt-to-GDP ratio grew by 7.9% in the first three quarters of 2020, following a decrease of 0.3% in 2019. Firms operating in sectors that are sensitive to lockdown measures had to resort to additional borrowing, fuelling concerns over lending to unprofitable and highly indebted firms.

However, the case against zombies seems second order in the crisis, at least in the short run. The COVID-19 shock has not discriminated between viable and non-viable firms, as it hit all firms affected by the lockdown and by containment measures. Only a very small share of firms under liquidity stress as a result of the COVID-19 shock could have been defined as zombies before the lockdowns

(Chart 44, right panel).[122] This suggests that the risk of viable businesses not receiving the necessary support was higher than the risk of policy support propping up zombie firms. Moreover, Schivardi et al. (2017) argue that there are good economic reasons to keep zombies alive in the acute phase of a crisis, as a result, for example, of local demand externalities or disruptions in supply chains (see also Barrot and Sauvagnat, 2016). This notwithstanding, it is important to ensure that the support measures, in particular from the fiscal side, are temporary and targeted to avoid the evergreening of loans to zombie firms with unviable business models in the medium-to-long run. Indeed, using firm-level, loan-level and supervisory data for euro area companies, the recent ECB Financial Stability Review (May 2021) finds that zombie firms may have temporarily benefited from loan schemes and accommodative credit conditions, but probably only to a modest degree. These firms, however, may face tighter eligibility criteria for support schemes and more recognition of credit risk in debt and loan pricing in the future.

Chart 44

Non-financial corporate debt (left panel) and share of illiquid firms at the peak of the crisis that were non-viable before the crisis (right panel)

Non-financial corporate debt	Share of illiquid firms at the peak of the crisis that were non-viable before the crisis
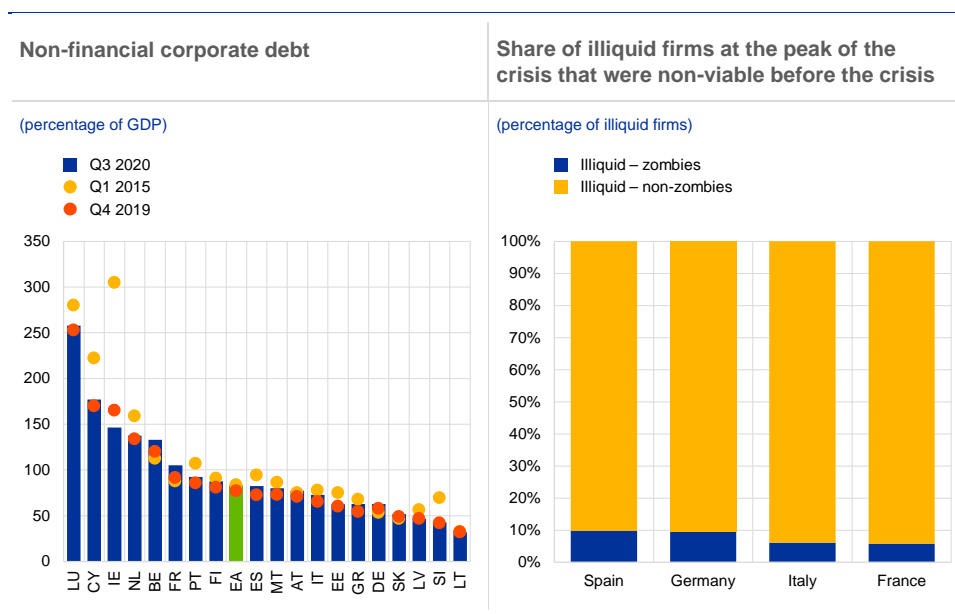
Sources: Left panel: Own calculations using Eurostat; right panel: Own calculations using ORBIS-iBACH.
Note: Left panel: Debt is loan plus debt securities (consolidated); right panel: Non-viable is defined as having a Z-score below 1.8 in 2017 (last year available with firm-level data). The figure reflects the ECB December projections and refer to the peak of the crisis, which is the fourth quarter of 2021 or the first quarter of 2022 depending on the country.

The macroeconomic consequences of zombie lending may become more significant in the economic recovery. The short-term effects of capital misallocation and an increased presence of zombie firms on growth are relatively small in a crisis period. As low-productivity firms are kept alive, aggregate demand is temporarily stabilised. This partly offsets the negative demand effect stemming from the inefficient allocation of loans (Schivardi et al. 2017). However, over the medium and long term, this interference with the process of creative destruction is likely to

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[122] Note that the share of firms with negative working capital as a result of the COVID-19 shock that could be flagged as "zombie" before the crisis is substantially higher (about half of all firms with negative working capital) than the share of illiquid firms following the shock.

have more severe consequences for employment, investment and growth as new sources of growth are stifled. Theoretical reasoning suggests that the negative effects of zombie lending are larger during an economic recovery or stable periods than during a crisis, when the entry of new firms is low and incumbent firms have fewer opportunities to expand. Moreover, as public support is gradually removed, higher insolvency rates than before the pandemic cannot be ruled out, especially in certain euro area countries. This in turn could weigh on sovereigns and banks which provided support to corporates during the pandemic (see also ECB, 2021).

These findings highlight the importance of reforms addressing the remaining weaknesses in banks and facilitating the allocation of resources towards more innovative and productive firms. The importance of structural factors for the existence of zombie firms was discussed in Section 4.3.4. In the current environment, failure to address high leverage in the corporate sector, in particular for many SMEs in sectors hit hard by the pandemic, could lead to a slower economic recovery and a rise in the numbers of non-viable firms. For the many viable, but over-indebted, firms, swift debt relief from their banks and other creditors or new equity financing could be preferable to further credit support, and could provide an important contribution to resilience and recovery. As the crisis will leave a legacy of higher debt, the economy will face more deleveraging needs and reduced policy space in the future. It is therefore important that the framework conditions of euro area economies are supportive to structural change so that capital and labour can move towards the most productive companies in the economy.

To sum up, the COVID-19 shock might affect within-firm productivity growth and resource reallocation. Within-firm productivity growth might be affected in the short term, by labour hoarding, but also in the long term as a result of a deterioration in skills, a drop in investment in productivity-enhancing activities, or supply chain disruption. On the upside, the shock has accelerated digital uptake by firms across the advanced economies, with a possible medium to long-term positive impact on productivity growth. As regards resource reallocation resulting from the entry and exit of firms, financial stress caused by the shock might deter firm entry, although recent data from the United States show an increase in business formation. Firm exit is being delayed, thanks to extensive policy support, which stabilises output in the short term but may harm long-term productivity growth by hindering the reallocation of resources. We find that the firms most vulnerable to the shock are less productive than other firms in their sector so the crisis may have a cleansing effect. Unlike in normal times, resource reallocation is to a large extent occurring across rather than within sectors, given the asymmetric impact of the shock. We find that across-sector resource reallocation contributed one-third to aggregate productivity growth between the first quarter of 2020 and the first quarter of 2021. However, if low productivity sectors shrink but other more productive sectors do not expand, sector reallocation might be productivity-enhancing but could be negative for aggregate output and welfare.

6 Conclusions and research gaps

6.1 Conclusions: putting everything together

There is no smoking gun. The long-term productivity growth slowdown in EU countries is driven by a variety of interacting factors. These include global, country and sector-specific, structural and temporary factors, as well as shocks with potential scarring effects on productivity and potential output growth, such as the global financial crisis or the COVID-19 pandemic. The purpose of this report has been to organise and complement the extensive literature on this issue and to reflect on future productivity growth and its interaction with monetary policy. The report first sets out the main productivity-related figures and describes trend developments in EU countries and in a broader international context, and from a multi-angle perspective. It then analyses possible drivers: those affecting within-firm productivity growth, with a focus on technology, and those with an effect on resource reallocation both across incumbent firms and as a result of entry and exit.

The report shows that technology, as the key driver of productivity dynamics, plays less of a role in EU countries than in the United States and may weaken even further over time. Three findings support this claim. First, productivity growth in ICT-intensive sectors (both ICT-producing and ICT-using) in EU countries is well below that of the United States. Second, there is some evidence, both macro-based and micro-based, that innovation in the manufacturing sector is slowing in the United States and in the EU. The macro evidence shows that patenting activity has been flat since the global financial crisis in both these advanced regions. In addition, their market share in high-technology manufacturing exports has declined sharply over time, to the benefit of China. This finding is supported by firm-level evidence showing a slowdown in TFP growth of EU manufacturing firms at the frontier. This slowdown is mostly concentrated in high-technology sectors. Third, technology creation in services has accelerated over time. However, the productivity gains from this development seem to be benefiting relatively few services firms at the frontier. In contrast, laggards in services continue to show low levels of productivity growth; this, means that technology diffusion in services is slowing. This phenomenon has been well documented elsewhere, including in the United States. It is related to the nature of the new technologies, which facilitates winner-takes-all dynamics, and also to low investment by laggard firms in the skills and intangibles needed to fully reap the benefits of technological innovations.

Resource reallocation across incumbent firms within the same sector is productivity-enhancing, but its contribution to aggregate productivity growth has been declining over time. Firms with different productivity levels carefully balance the benefits and costs of expanding or contracting in the face of shocks. These benefits and costs depend on expected revenues, but also on taxes, regulation, access to finance or hiring and firing costs. The set of sector-specific regulations and structural characteristics shaping this delicate balance between benefits and costs varies by country and over time. However, the broad-based

decline in the contribution of resource reallocation to productivity growth also suggests some common factors. These could be related to financial frictions (information asymmetries or collateral-based lending), labour market regulations, or increasing concentration as a result of winner-takes-all dynamics. The work stream has estimated that resource misallocation could cost up to 0.2 percentage points of annual TFP growth in the euro area.

The entry and exit of firms make a positive contribution to aggregate productivity growth, despite the low productivity of new firms. New entrants across the countries analysed by the work stream are less productive than incumbents in their same sector. However, there are stark country differences. Whereas new firms are between 80% and 90% as productive as incumbents in Belgium and France, they are about half as productive in Italy. It is not clear what is driving these country differences, which could be related to firm characteristics, such as family ownership, or entry and exit costs. After entry there is an intense selection process whereby about one-third of new firms exit the market before completing three years of activity. Surviving firms grow fast thereafter to catch up with average sector productivity levels. However, the report finds that the high productivity growth rates of young surviving firms are driven by very few firms. In contrast, most young surviving firms linger at relatively low productivity growth rates. Entry and exit rates of firms in Europe seem to have declined in recent years. Therefore, the positive impact of firm dynamics on productivity growth may weaken.

The share of zombie firms, defined by their interest coverage ratio, increased from 2007 to 2014 across the countries analysed, and declined thereafter. The report shows that zombie dynamics are driven by the rate of entry of firms into distress, which is very cyclical. By contrast, the speed at which weak firms exit financial distress, either to recovery or out of the market, has been relatively stable over time. Firms identified as zombies in this analysis are not necessarily non-viable, as about one-third of them are expanding their employment. Moreover, about half of firms exiting the zombie status achieve financial recovery; the other half, accounting for about 2% of all active firms, exit the market. Finally, zombies are found to crowd out resources that would otherwise be available to healthy firms (congestion effects) and thus could have an indirect negative impact on productivity growth.

Going forward, the COVID-19 shock will interact with the dynamics of innovation and productivity-enhancing reallocation discussed in the report, with uncertain impacts on aggregate productivity growth. First, despite recent encouraging signs some threats to the trade outlook remain, stemming, for instance, from the possible restructuring of global value chains after the pandemic and a further rise in trade barriers. These developments could weigh on productivity growth as a result of reduced technology transfer, input quality deterioration and reduced scope for productive firms to expand. Second, the massive policy support for the corporate sector in response to the pandemic crisis has been crucial to mitigate the initial impact of the shock. However, once the economic recovery takes hold on a sustainable basis, policy support needs to be lifted gradually to avoid impairing the efficient reallocation of resources by setting wrong incentives. Hence the design and timing of the exit strategy is expected to determine further (lagged) effects of the

pandemic crisis on aggregate productivity growth. And third, financial distress, together with high uncertainty, might increase the financing cost and reduce the expected benefits of new productivity-enhancing projects and delay investment, with impacts on productivity growth. Further, the uptake of new debt by corporates to cover liquidity gaps could result in debt overhang and further reduce investment.

The investment in green technologies and the acceleration of digital uptake could be a silver lining. Large investment in green technologies, as a result of both demand and supply factors, could push the technological frontier significantly outwards. This would also play an important role in offsetting the potential short-term negative productivity impacts of diverting resources from productivity-enhancing activities in order to comply with stringent environmental regulations. Last, and maybe most importantly, techno-optimists claim that the productivity gains of the new technological revolution will only be seen with a lag, given the time needed to adapt production processes and acquire the necessary skills, competencies and other intangibles. The acceleration of digital uptake as a result of COVID-19 could therefore provide a vital push to reap the benefits of new technologies and improve the technology adoption of laggards at an earlier stage, particularly among SMEs. However, its path and distributional impacts are still uncertain and depend on the development of institutions, infrastructure, skills, methods of production and management competencies.

In the current uncertain environment, tilting risks to the upside requires policies that foster an innovation-friendly environment, including easier re-scaling and entry and exit of firms, and incentivise and support investment in digital and green transformations. These policies hinge on fiscal and structural decisions that are in turn dependent on elected governments. In addition, monetary policy has the potential to support productivity growth in the recovery phase of the economy by monitoring and maintaining favourable financing conditions for as long as is needed to safeguard price stability in the euro area.

6.2   Possible implications for monetary policy

From a monetary policy perspective, low trend productivity growth has implications for potential economic growth and the natural rate of interest. In the long run, the potential growth of the economy is determined by population growth and TFP growth. Given the ageing of the euro area population, TFP growth, and productivity growth more generally, have a significant role to play in boosting the current low rates of potential economic growth. Available estimates suggest that the natural rate of interest has declined considerably in recent years, to close to or even below zero. If productivity growth, and implied potential growth, remain low, the natural rate of interest will remain subdued, with implications for the monetary policy space needed to deliver price stability over the medium term.

While national policies are responsible for setting the right framework conditions and incentives for productive investment and innovation, monetary policy may under certain circumstances also contribute to higher productivity

growth by increasing demand and easing financial conditions. However, in recent years it has increasingly been argued that very low interest rates over a long period of time could have negative effects on resource allocation and productivity through their interaction with financial frictions, weak banks or weak banking supervision, among other things. Overall, empirical analysis by the work stream does not find pervasive negative side effects of monetary policy on productivity.

6.3 Research gaps

Looking ahead, the work stream has identified several areas of interest for future research from a monetary policy perspective. The first group of topics relates to the long-term impacts of the COVID-19 pandemic on productivity. The link between reallocation and productivity and its interaction with institutions and regulations during the crisis deserves special attention in this respect. The same holds for the interaction between productivity-enhancing reallocation during the recovery phase of the COVID-19 crisis and support policies, and the consequences of the recent digitalisation push. The second group relates to the observed slowdown in technology diffusion and the role and lack of complementary investments and increasing concentration. Another strand of research should be devoted to analysing why technology creation seems to be decreasing in EU manufacturing firms, and its interlinkage with regulation, market concentration and the appearance and growing presence of new actors such as China in the market. The role of multinationals and foreign direct investment, and the implications of the relocation of production chains, might also be relevant in this respect. The third group of topics relates to the impact of climate policies on technology creation and competitiveness, and the required policies and investments to promote sector reallocation. The last group concerns the impact of unconventional monetary policy on credit allocation and productivity in the euro area. Gaining a better understanding of the interaction between monetary policy and market structures and institutions should also have a prominent role in future research and modelling efforts.

Bibliography

Acemoglu, D. and Linn, J. (2004), "Market Size in Innovation: Theory and Evidence from the Pharmaceutical Industry", *Quarterly Journal of Economics*, Vol. 119, Issue 3, pp. 1049-1090, August.

Acemoglu, D., Aghion, P. and Zilibotti, F. (2006), "Distance to Frontier, Selection, and Economic Growth", *Journal of the European Economic Association*, Vol. 4, Issue 1, pp. 37-74, December.

Acemoglu, D. and Dell, M. (2010), "Productivity Differences Between and Within Countries", *American Economic Journal: Macroeconomics*, Vol. 2, No 1, pp. 169-188.

Acemoglu, D. and Autor, D. (2011), "Skills, Tasks and Technologies: Implications for Employment and Earnings", *Handbook of Labor Economics*, Vol. 4, pp. 1043-1171, June.

Acemoglu, D., Akcigit, U., Alp, H., Bloom, N. and Kerr, W.R. (2018), "Innovation, Reallocation and Growth", *American Economic Review*, Vol. 108, No 11, pp. 3450-3491, November.

Acharya, V., Eisert, T., Eufinger, C. and Hirsch, C. (2019), "Whatever It Takes: The Real Effects of Unconventional Monetary Policy", *Review of Financial Studies*, Vol. 32, Issue 9, pp. 3366-3411, September.

Ackerberg, D., Caves, K. and Frazer, G. (2015), "Identification Properties of Recent Production Function Estimators", *Econometrica*, Vol. 83, Issue 6, pp. 2411-2451, November.

Adalet McGowan, M., Andrews, D. and Millot, V. (2017), "Insolvency regimes, zombie firms and capital reallocation", *OECD Economics Department Working Papers*, No 1399, June.

Adalet McGowan, M., Andrews, D. and Millot, V. (2018), "The Walking Dead?: Zombie Firms and Productivity Performance in OECD Countries", *Economic Policy*, Vol. 33, Issue 96, pp. 685-736, October.

Aghion, P. and Howitt, P. (1992), "A Model of Growth Through Creative Destruction", *Econometrica*, Vol. 60, No 2, pp. 323-351.

Aghion, P., Bond, S., Klemm, A. and Marinescu, I. (2004), "Technology and Financial Structure: Are Innovative Firms Different?", *Journal of the European Economic Association*, Vol. 2, Issue 2-3, pp. 277-288, May.

Aghion, P., Bloom, N., Blundell, R., Griffith, R. and Howitt, P. (2005), "Competition and Innovation: An Inverted-U Relationship", *Quarterly Journal of Economics*, Vol. 120, Issue 2, pp. 701-728, May.

Aghion, P. and Howitt, P. (2009), The Economics of Growth, MIT Press, Cambridge, Massachusetts.

Aghion, P., Askenazy, P., Berman, N., Cette, G. and Eymard, L. (2012), "Credit Constraints and the Cyclicality of R&D Investment: Evidence from France", *Journal of the European Economic Association*, Vol. 10, Issue 5, pp. 1001-1024, October.

Aghion, P., Bergeaud, A., Cette, G., Lecat, R. and Maghin, H. (2019a), "Coase Lecture –The Inverted-U Relationship Between Credit Access and Productivity Growth", *Economica*, Vol. 86, Issue 341, pp. 1-31, January.

Aghion, P., Bergeaud, A., Boppart, T., Klenow, P.J. and Li, H. (2019b), "A Theory of Falling Growth and Rising Rents", *Federal Reserve Bank of San Francisco Working Papers*, No 2019-11.

Ahn, J.B., Duval, R.A. and Sever, C. (2020), "Macroeconomic Policy, Product Market Competition, and Growth: The Intangible Investment Channel", *IMF Working Papers*, No 20/25.

Aiyar, S., Ebeke, C. and Shao, X. (2016), "The Impact of Workforce Aging on European Productivity", *IMF Working Papers*, No 16/238.

Akcigit, U. and Ates, S.T. (2019), "What Happened to U.S. Business Dynamism?", *NBER Working Papers*, No 25756.

Akcigit, U. and Ates, S.T. (2021), "Ten Facts on Declining Business Dynamism and Lessons from Endogenous Growth Theory", *American Economic Journal: Macroeconomics*, Vol. 13, No 1, pp. 257-298, January.

Akcigit, U., Dinlersoz, E., Greenwood, J. and Penciakova, V. (2019), "Synergizing Ventures", *Federal Reserve Bank of Atlanta Working Papers*, No 2019-17, September.

Aksoy, Y., Basso, H.S., Smith, R. and Grasl, T. (2019), "Demographic structure and macroeconomic trends", *American Economic Journal: Macroeconomics*, 11 (1): 193-222.

Albert, C., Caggese, A. and González, B. (2020), "The Short- and Long-Run Employment Impact of Covid-19 through the Effects of Real and Financial Shocks on New Firms", *Banco de España Working Papers*, No 2039, September.

Albrizio, S., Botta, E., Kozluk, T. and Zipperer, V. (2014), "Do Environmental Policies Matter for Productivity Growth? Insights from New Cross-Country Measures of Environmental Policies", *OECD Economics Department Working Papers*, No 1176, December.

Albrizio, S., Conesa, M., Dlugosch, D. and Timiliotis, C. (2019), "Unconventional monetary policy and productivity", *OECD Productivity Working Papers*, No 17, January.

Albrizio, S., David, J., Furceri, D. and Ruane, C. (2020), "US Monetary Policy and Misallocation", unpublished working paper, Banco de España.

Albrizio, S. and González, B. (2020), "Monetary Policy and Capital Misallocation in Europe", unpublished working paper, Banco de España.

Almunia, M., López-Rodríguez, D. and Moral-Benito, E. (2018), "Evaluating the macro-representativeness of a firm-level database: an application for the Spanish economy", *Banco de España Occasional Papers*, No 1802, March.

Altman, E.I. and Sabato, G. (2007), "Modelling Credit Risk for SMEs: Evidence from the U.S. Market", *Abacus*, Vol. 43, Issue 3, pp. 332-357, September.

Anderton, R., Di Lupidio, B. and Jarmulska, B. (2020), "The impact of product market regulation on productivity through firm churning: Evidence from European countries", *Economic Modelling*, Vol. 91, pp. 487-501, September.

Anderton, R., Jarvis, V., Labhard, V., Morgan, J., Petroulakis, F. and Vivian, L. (2020a), "Virtually everywhere? Digitalisation and the euro area and EU economies", *Occasional Paper Series*, No 244, ECB, December.

Anderton, R., Jarvis, V., Labhard, V., Rubene, I., Petroulakis, F. and Vivian, L. (2020b), "The digital economy and the euro area", *Economic Bulletin*, Issue 2, ECB.

Andrews, D., Bahar, E. and Hambur, J. (2021), ""The COVID-19 Shock and Productivity-Enhancing Reallocation in Australia: Real-time evidence from Single Touch Payroll", *OECD Economics Department Working Paper*, No 1677.

Andrews, D., Criscuolo, C. and Gal, P.N. (2015), "Frontier Firms, Technology Diffusion and Public Policy", *OECD Productivity Working Papers*, No 2, November.

Andrews, D., Criscuolo, C. and Gal, P.N. (2019), "The Best versus the Rest: Divergence Across Firms During the Global Productivity Slowdown", *CEP Discussion Papers*, No 1645, August.

Andrews, D., Nicoletti, G. and Timiliotis, C. (2018), "Digital technology diffusion: A matter of capabilities, incentives or both?", *OECD Economics Department Working Papers*, No 1476, July.

Andrews, D. and Petroulakis, F. (2019), "Breaking the shackles: Zombie firms, weak banks and depressed restructuring in Europe", *Working Paper Series*, No 2240, European Central Bank, February.

Anyfantaki, S., Balfoussia, H., Dimitropoulou, D., Gibson, H., Papageorgiou, D., Petroulakis, F., Theofilakou, A. and Vasardani, M. (2020), "COVID-19 and other pandemics: a literature review for economists", *Economic Bulletin*, Bank of Greece, Issue 51, pp. 1-36, July.

Anzoategui, D., Comin, D., Gertler, M. and Martinez, J. (2019), "Endogenous Technology Adoption and R&D as Sources of Business Cycle Persistence", *American Economic Journal: Macroeconomics*, Vol. 11, No 3, pp. 67-110, July.

Audretsch, D. and Lehmann, E. (2004), "Financing High-Tech Growth: The Role of Banks and Venture Capitalists", *Schmalenbach Business Review*, Vol. 56, Issue 4, pp. 340-357, October.

Autor, D., Dorn, D., Katz, L., Patterson, C. and Reenen, J.V. (2020), "The Fall of the Labor Share and the Rise of Superstar Firms", *Quarterly Journal of Economics*, Vol. 135, Issue 2, pp. 645- 709, May.

Autor, D., Levy, F. and Murnane, R.J. (2003), "The Skill Content of Recent Technological Change: An Empirical Exploration", *Quarterly Journal of Economics*, Vol. 118, Issue 4, pp. 1279-1333, November.

Bachmann, R. and Sims, E.R. (2012), "Confidence and the transmission of government spending shocks", *Journal of Monetary Economics*, Vol. 59, Issue 3, pp. 235-249, April.

Bahar, D. (2018), "The middle productivity trap: Dynamics of productivity dispersion", *Economic Letters*, Vol. 167, pp. 60-66, June.

Bai, J. (2009), "Panel Data Models With Interactive Fixed Effects", *Econometrica*, Vol. 77, Issue 4, pp. 1229-1279, July.

Baily, M.N., Hulten, C., Campbell, D., Bresnahan, T. and Caves, R. (1992), "Productivity Dynamics in Manufacturing Plants", *Brookings Papers on Economic Activity*, Microeconomics, Vol. 23, Issue 1992, pp. 187-267.

Banerjee, R. and Hofmann, B. (2018), "The rise of zombie firms: causes and consequences", *BIS Quarterly Review*, September.

Bank of England (2013), *Inflation Report, February 2013*.

Bank of Greece (2020), "Box IV.4: Digital technology for pandemic response", Monetary Policy Report 2020, June.

Bank of Korea (2013), Financial Stability Report, October.

Barreca, A., Clay, K., Deschenes, O., Greenstone, M. and Shapiro, J.S. (2016), "Adapting to Climate Change: The Remarkable Decline in the US Temperature-Mortality Relationship over the Twentieth Century", *Journal of Political Economy*, Vol. 124, No 1, pp. 105-159, February.

Barrero, J.M., Bloom, N. and Davis, S.J. (2020), "Why Working from Home Will Stick", *Becker Friedman Institute for Economics Working Papers*, No 2020-174, December.

Barro, R.J. (1991), "Economic Growth in a Cross Section of Countries", *Quarterly Journal of Economics*, Vol. 106, No 2, pp. 407-443, May.

Barrot, J.-N. and Sauvagnat, J. (2016), "Input Specificity and the Propagation of Idiosyncratic Shocks in Production Networks", *Quarterly Journal of Economics*, Vol. 131, Issue 3, pp. 1543-1592, August.

Bartel, A., Ichniowski, C. and Shaw, K. (2007), "How Does Information Technology Affect Productivity? Plant-Level Comparisons of Product Innovation, Process Improvement, and Worker Skills", *Quarterly Journal of Economics*, Vol. 122, No 4, pp. 1721-1758, November.

Bartelsman, E. and Doms, M. (2000), "Understanding Productivity: Lessons from Longitudinal Microdata", *Journal of Economic Literature*, Vol. 38, No 3, pp. 569-594, September.

Bartelsman, E., Haltiwanger, J. and Scarpetta, S. (2013), "Cross-Country Differences in Productivity: The Role of Allocation and Selection", *American Economic Review*, Vol. 103, No 1, pp. 305-34, February.

Bartelsman, E., Gautier, P. and De Wind, J. (2016), "Employment Protection, Technology Choice, and Worker Allocation", *International Economic Review*, Vol. 57, Issue 3, pp. 787-826, August.

Bartelsman, E., Lopez-Garcia, P. and Presidente, G. (2019), "Labour reallocation in recession and recovery: evidence for Europe", *National Institute Economic Review*, Vol. 247, Issue 1, pp. R32-R39, February.

Bassanini, A., Nunziata, L. and Venn, D. (2009), "Job Protection Legislation and Productivity Growth in OECD Countries", *Economic Policy*, Vol. 24, No 58, pp. 349-402.

Basu, S., Fernald, J.G. and Kimball, M.S. (2006), "Are Technology Improvements Contractionary?", *American Economic Review*, Vol. 96, No 5, pp. 1418-1448, December.

Bellucci, A., Gucciardi, G. and Nepelski, D. (2021), "Venture Capital in Europe. Evidence-based insights about Venture Capitalists and venture capital-backed firms", JRC technical report, Publications Office of the European Union, Luxembourg.

Benigno, G. and Fornaro, L. (2018), "Stagnation Traps", *Review of Economic Studies*, Vol. 85, Issue 3, pp. 1425-1470, July.

Bergeaud, A. (2019), "Market power and growth: new developments", Bulletin de la Banque de France, Issue 226, No 5.

Bergeaud, A., Cette, G. and Lecat, R. (2016), "Productivity trends in advanced countries between 1890 and 2012", *Review of Income and Wealth*, Vol. 62, Issue 3, pp. 420-444, September.

Bergin, P.R. and Corsetti, G. (2008), "The extensive margin and monetary policy", *Journal of Monetary Economics*, Vol. 55, Issue 7, pp. 1222-1237, October.

Berlingieri, G., Calligaris, S., Criscuolo, C. and Verlhac, R. (2020), "Laggard firms, technology diffusion and its structural and policy determinants", *OECD Science, Technology and Industry Policy Papers*, No 86, March.

Bernanke, B., Gertler, M. and Gilchrist, S. (1999), "The financial accelerator in a quantitative business cycle framework", *Handbook of Macroeconomics*, Vol. 1, Part C, pp. 1341-1393.

Bersch, J., Diekhof, J., Krieger, B., Licht, G. and Murmann, S. (2019), "Productivity Slowdown, Innovation and Industry Dynamics", in Lehmann, E.E. and Keilbach, M. (eds.), From Industrial Organization to Entrepreneurship, Springer Nature, Cham, Switzerland, pp. 229-242.

Bertola, G. and Rogerson, R. (1997), "Institutions and labor reallocation", *European Economic Review*, Vol. 41, Issue 6, pp. 1147-1171, June.

Bianchi, F., Kung, H. and Morales, G. (2019), "Growth, slowdowns and recoveries", *Journal of Monetary Economics*, Vol. 101, pp. 47-63, January.

Bijnens, G. and Konings, J. (2020), "Declining business dynamism in Belgium", *Small Business Economics*, Vol. 54, Issue 4, pp. 1201-1239, April.

Bils, M., Klenow, P.J. and Ruane, C. (2020), "Misallocation or mismeasurement?", *NBER Working Papers*, No 26711, January.

Blinder, A.S. (1997), "Distinguished Lecture on Economics in Government: What Central Bankers Could Learn from Academics–And Vice Versa", *Journal of Economic Perspectives*, Vol. 11, No 2, pp. 3-19, Spring.

Bloom, N. and Van Reenen, J. (2010), "Why Do Management Practices Differ Across Firms and Countries?", *Journal of Economic Perspectives*, Vol. 24, Issue 1, pp. 203-224, Winter.

Bloom, N., Sadun, R. and Van Reenen, J. (2012), "Americans Do IT Better: US Multinationals and the Productivity Miracle", *American Economic Review*, Vol. 102, No 1, pp. 167-201, February.

Bloom, N., Liang, J., Roberts, J. and Ying, Z.J. (2015), "Does Working from Home Work? Evidence from a Chinese Experiment", *Quarterly Journal of Economics*, Vol. 130, Issue 1, pp. 165-218, February.

Bloom, N., Bunn, P., Mizen, P., Smietanka, P., and Thwaites, G. (2020a), "The impact of COVID-19 on productivity", *NBER Working Paper Series*, No 28233, December.

Bloom, N., Davis, S. and Zhestkova, Y. (2020b), "COVID-19 Shifted Patent Applications toward Technologies that Support Working from Home", *Becker Friedman Institute for Research In Economics Working Paper Serie*s, No 2020-133, September.

Bloom, N., Jones, C.I., Van Reenen, J. and Webb, M. (2020c), "Are Ideas Getting Harder to Find?", *American Economic Review*, Vol. 110, No 4, pp. 1104-1144, April.

Boeri, T. and Bruecker, H. (2011), "Short-time work benefits revisited: some lessons from the Great Recession", *Economic Policy*, Vol. 26, No 68, pp. 697-765, October.

Boskin, M.J., Dulberger, E.R., Gordon, R.J., Griliches, Z. and Jorgensen, D.W. (1997), "The CPI Commission: Findings and Recommendations", *American Economic Review*, Vol. 87, No 2, pp. 78-83, May.

Boskin, M.J., Dulberger, E.R., Gordon, R.J., Griliches, Z. and Jorgensen, D.W. (1996), "Toward a More Accurate Measure of the Cost of Living – Final Report to the Senate Finance Committee from the Advisory Commission to Study the Consumer Price Index", December.

Bresnahan, T.F., Brynjolfsson, E. and Hitt, L.M. (2002), "Information Technology, Workplace Organization, and the Demand for Skilled Labor: Firm-Level Evidence", *Quarterly Journal of Economics*, Vol. 117, Issue 1, pp. 339-376, February.

Bricongne, J.C., Delpeuch, S. and Lopez Forero, M. (2020), "Productivity slowdown and MNEs' intangibles: where is productivity measured?", mimeo.

Brown, J.R., Fazzari, S. and Petersen, B. (2009), "Financing Innovation and Growth: Cash Flow, External Equity, and the 1990s R&D Boom", *Journal of Finance*, Vol. 64, No 1, pp. 151-185, February.

Brown, J.R., Martinsson, G. and Petersen, B. (2013), "Law, Stock Markets, and Innovation", *Journal of Finance*, Vol. 68, No 4, pp. 1517-1549, August.

Brynjolfsson, E. and McAfee, A. (2014), The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies, WW Norton & Company.

Brynjolfsson, E., Rock, D. and Syverson, C. (2018), "Artificial Intelligence and the Modern Productivity Paradox: A Clash of Expectations and Statistics", in Agrawal, A., Gans, J. and Goldfarb, A. (eds.), The Economics of Artificial Intelligence: An Agenda, University of Chicago Press, Chicago, pp. 23-57.

Brynjolfsson, E., Rock, D. and Syverson, C. (2021), "The Productivity J-Curve: How Intangibles Complement General Purpose Technologies", *American Economic Journal: Macroeconomics*, Vol. 13, No 1, January.

Buera, F.J. and Moll, B. (2015), "Aggregate Implications of a Credit Crunch: The Importance of Heterogeneity", *American Economic Journal: Macroeconomics*, Vol. 7, No 3, pp. 1-42, July.

Bun, M.J.G. and de Winter, J. (2019), "Measuring Trends and Persistence in Capital and Labor Misallocation", *De Nederlandsche Bank Working Paper*, No 639, June.

Burda, M.C. and Severgnini, B. (2014), "Solow Residuals Without Capital Stocks", *Journal of Development Economics*, Vol. 109, pp. 154-171, July.

Burtless, G. (2013), "The Impact of Population Aging and Delayed Retirement on Workforce Productivity", *Center for Retirement Research at Boston College Working Papers*, No 2013-11, May.

Bustos, P. (2011), "Trade Liberalization, Exports, and Technology Upgrading: Evidence on the Impact of MERCOSUR on Argentinian Firms", *American Economic Review*, Vol. 101, No 1, pp. 304-340, February.

Byrne, D.M. and Corrado, C. (2017), "ICT Services and Their Prices: What Do They Tell Us About Productivity and Technology?", International Productivity Monitor, Vol. 33, pp. 150-181, Fall.

Byrne, D.M., Fernald, J.G. and Reinsdorf, M.B. (2016), "Does the United States Have a Productivity Slowdown or a Measurement Problem?", *Brookings Papers on Economic Activity*, pp. 109-182, Spring.

Byrne, D.M., Oliner, S.D. and Sichel, D.E. (2017), "Prices of High-Tech Products, Mismeasurement, and the Pace of Innovation", *Business Economics*, Vol. 52, Issue 2, pp. 103-113, April.

Caballero, R.J. and Hammour, M.L. (1994), "The Cleansing Effect of Recessions", *American Economic Review*, Vol. 84, No 5, pp. 1350-1368, December.

Caballero, R.J., Hoshi, T. and Kashyap, A.K. (2008), "Zombie Lending and Depressed Restructuring in Japan", *American Economic Review*, Vol. 98, No 5, pp. 1943-1977, December.

Calel, R. and Dechezleprêtre, A. (2016), "Environmental Policy and Directed Technological Change: Evidence from the European Carbon Market", *Review of Economics and Statistics*, Vol. 98, Issue 1, pp. 173-191, March.

Calligaris, S., Del Gatto, M., Hassan, F., Ottaviano, G.I. and Schivardi, F. (2018), "The productivity puzzle and misallocation: an Italian perspective", *Economic Policy*, Vol. 33, Issue 96, pp. 635-684, October.

Calvino, F., Criscuolo, C. and Menon, C. (2015), "Cross-country evidence on start-up dynamics", *OECD Science, Technology and Industry Working Papers,* No 2015/06.

Calvino, F., Criscuolo, C., Marcolin, L. and Squicciarini, M. (2018), "A taxonomy of digital intensive sectors", *OECD Science, Technology and Industry Working Papers*, No 2018/14.

Cavalleri, M.C., Eliet, A., McAdam, P., Petroulakis, F., Soares, A.C. and Vansteenkiste, I. (2019), "Concentration, market power and dynamism in the euro area", *Working Paper Series*, No 2253, ECB, March.

Caves, R.E. (1998), "Industrial Organization and New Findings on the Turnover and Mobility of Firms", *Journal of Economic Literature*, Vol. 36, No 4, pp. 1947-1982.

Cette, G., Fernald, J. and Mojon, B. (2016), "The pre-Great Recession slowdown in productivity", *European Economic Review*, Vol. 88, pp. 3-20, September.

Cette, G., Lecat, R. and Ly-Marin, C. (2017), "Long-term growth and productivity projections in advanced countries", *OECD Journal: Economic Studies*, Vol. 2016, Issue 1, pp. 71-90, February.

Cette, G., Corde, S. and Lecat, R. (2018), "Firm-level productivity dispersion and convergence", *Economic Letters*, Vol. 166, pp. 76-78, May.

Cette, G., Devillard, A. and Spiezia, V. (2020), "Growth factors in developed countries: A 1960-2019 growth accounting decomposition", *Banque de France Working Paper Series*, No 783, July.

Chatterjee, S. and Eyigungor, B. (2019), "The Firm Size and Leverage Relationship and its Implications for Entry and Concentration in a Low Interest Rate World", *Society for Economic Dynamics Meeting Papers*, No 1041.

Cloyne, J., Ferreira, C., Froemel, M. and Surico, P. (2018), "Monetary Policy, Corporate Finance and Investment", NBER Working Papers, No 25366, December.

Cohen, W.M. and Levinthal, D.A. (1989), "Innovation and Learning: The Two Faces of R&D", Economic Journal, Vol. 99, No 397, pp. 569-596, September.

Colombo, M. and Grilli, L. (2007), "Funding Gaps? Access to Bank Loans by High-Tech Start-Ups", Small Business Economics, Vol. 29, Issue 1, pp. 25-46, June.

Comin, D.A., Quintana, J., Schmitz, T. and Trigari, A. (2020), "Measuring TFP: The Role of Profits, Adjustment Costs, and Capacity Utilization", *NBER Working Papers*, No 28008.

Comin, D.A., (2008), "Total Factor Productivity", in Durlauf, S.N. and Blume, L.E. (eds.), The New Palgrave Dictionary of Economics, pp. 260-263.

Cooley, T.F. and Quadrini, V. (2001), "Financial Markets and Firm Dynamics", *American Economic Review*, Vol. 91, No 5, pp. 1286-1310, December.

Corrado, C., Hulten, C.R. and Sichel, D. (2005), "Measuring Capital and Technology: An Expanded Framework", in Corrado, C., Haltiwanger, J. and Sichel, D. (eds.), Measuring Capital in the New Economy, University of Chicago Press, Chicago, pp. 11-46.

Corrado, C., Hulten, C.R. and Sichel, D. (2009), "Intangible Capital and U.S. Economic Growth", *Review of Income and Wealth*, Vol. 55, Issue 3, pp. 661-685, September.

Corrado, C., Haskel, J., Jona-Lasinio, C. and Iommi, M. (2018), "Intangible investment in the EU and US before and since the Great Recession and its contribution to productivity growth", *Journal of Infrastructure, Policy and Development*, Vol. 2, Issue 1, pp. 11-36.

Criscuolo, P., Nicolaou, N. and Salter, A. (2012), "The elixir (or burden) of youth? Exploring differences in innovation between start-ups and established firms", *Research Policy*, Vol. 41, Issue 2, pp. 319-333, March.

David, P.A. (1990), "The Dynamo and the Computer: An Historical Perspective on the Modern Productivity Paradox", *American Economic Review*, Vol. 80, No 2, pp. 355-361, May.

David, J.M. and Venkateswaran, V. (2019), "The Sources of Capital Misallocation", *American Economic Review*, Vol. 109, No 7, pp. 2531-2567, July.

Davis, S. and Haltiwanger, J. (1999), "On the Driving Forces behind Cyclical Movements in Employment and Job Reallocation", *American Economic Review*, Vol. 89, No 5, pp. 1234-1258, December.

De Loecker, J. (2013), "Detecting Learning by Exporting", *American Economic Journal: Microeconomics*, Vol. 5, No 3, pp. 1-21, August.

De Loecker, J., Eeckhout, J. and Unger, G. (2020), "The Rise of Market Power and the Macroeconomic Implications", *Quarterly Journal of Economics*, Vol. 135, Issue 2, pp. 561-644, May.

De Mulder, J. and Godefroid, H. (2018), "Productivity slowdown: findings and tentative explanations", *Economic Review*, Nationale Bank van België/Banque Nationale de Belgique, December.

De Ridder, M. (2019), "Market Power and Innovation in the Intangible Economy", *Cambridge Working Papers in Economics*, No 1931. Decker, R., Haltiwanger, J., Jarmin, R. and Miranda, J. (2014), "The Role of Entrepreneurship in US Job Creation and Economic Dynamism", *Journal of Economic Perspectives*, Vol. 28, No 3, pp. 3-24, Summer.

Decker, R., Haltiwanger, J., Jarmin, R. and Miranda, J. (2016), "Declining Business Dynamism: What We Know and the Way Forward", *American Economic Review*, Vol. 106, No 5, pp. 203-207, May.

Dell, M., Benjamin, F.J. and Olken, B.A. (2012), "Temperature Shocks and Economic Growth: Evidence from the Last Half Century", *American Economic Journal: Macroeconomics*, Vol. 4, No 3, pp. 66-95, July.

Dechezleprêtre, A. and Sato, M. (2017), "The Impacts of Environmental Regulations on Competitiveness", *Review of Environmental Economics and Policy*, Vol. 11, No 2, pp. 183-206, Summer.

Deutsche Bundesbank (2017), "Mark-ups of firms in selected European countries", *Monthly Report*, pp. 53-67, December.

Deutsche Bundesbank (2021), "The slowdown in euro area productivity growth", *Monthly Report*, pp. 15-46, January.

Dieppe, A. (ed.) (2020), Global Productivity: Trends, Drivers, and Policies, World Bank Group, Washington.

Diewert, W.E. and Nakamura, A.O. (2007), "The Measurement of Productivity for Nations", in Heckman, J. and Leamer, E. (eds.), *Handbook of Econometrics,* Vol. 6, Part A, pp. 4501-4586.

Duval, R., Hong, G.H. and Timmer, Y. (2020), "Financial Frictions and the Great Productivity Slowdown", *Review of Financial Studies*, Vol. 33, Issue 2, pp. 475-503, February.

Eisfeldt, A.L. and Rampini, A. (2006), "Capital reallocation and liquidity", *Journal of Monetary Economics*, Vol. 53, Issue 3, pp. 369-399, April.

Ericson, R. and Pakes, A. (1995), "Markov-Perfect Industry Dynamics: A Framework for Empirical Work", *Review of Economic Studies*, Vol. 62, Issue 1, pp. 53-82, January.

European Central Bank (2017), "The slowdown in euro area productivity in a global context", *Economic Bulletin*, Issue 3.

European Central Bank (2020a), "Access to finance for small and medium-sized enterprises after the financial crisis: evidence from survey data", *Economic Bulletin*, Issue 4.

European Central Bank (2020b), "Survey on the access to finance of enterprises: Methodological information on the survey and user guide for the anonymised micro dataset", June 2021.

European Central Bank (2020c), "The long-term effects of the pandemic: insights from a survey of leading companies", *Economic Bulletin*, Issue 8.

European Central Bank (2021), Financial Stability Review, May.

European Commission (2003), European Economy, No 6.

European Commission (2020a), The Joint Harmonised EU Programme of business and consumer surveys – User Guide.

European Commission (2020b), "Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – A Capital Markets Union for people and businesses – new action plan", COM(2020) 590 final.

Ewens, M., Peters, R.H. and Wang, S. (2019), "Measuring Intangible Capital With Market Prices", *NBER Working Papers*, No 25960, June.

Falk, M. and Biagi, F. (2016), "Relative demand for highly skilled workers and use of different ICT technologies", *Applied Economics*, Vol. 49, Issue 9, pp. 903-914, August.

Feenstra, R.C., Inklaar, R. and Timmer, M.P. (2015), "The Next Generation of the Penn World Table", *American Economic Review*, Vol. 105, No 10, pp. 3150-3182, October.

Fernandez-Macias, E., Klenert, D. and Anton, J.I. (2021), "Not so disruptive yet? Characteristics, distribution and determinants of robots in Europe", *Structural Change and Economic Dynamics*, Vol. 58, pp. 76-89, September.

Fernández-Cerezo, A., González, B., Izquierdo, M. and Moral-Benito, E. (2021), "Firm-level heterogeneity in the impact of COVID-19 pandemic", *Banco de España Working Papers*, No 2120, May.

Foster, L., Haltiwanger, J. and Krizan, C.J. (2002), "The Link between Aggregate and Micro Productivity Growth: Evidence from Retail Trade", *NBER Working Papers*, No 9120, August.

Foster, L., Grim, C. and Haltiwanger, J. (2016), "Reallocation in the Great Recession: Cleansing or Not?", *Journal of Labor Economics*, Vol. 34, No 51, pp. 293-331, January.

Gal, P., Nicoletti, G., Renault, T., Sorbe, S. and Timiliotis, C. (2019), "Digitalisation and productivity: In search of the holy grail – Firm-level empirical evidence from EU countries", *OECD Economics Department Working Papers*, No 1533, February.

Gamberoni, E., Giordano, C. and Lopez-Garcia, P. (2016), "Capital and labour (mis)allocation in the euro area: Some stylized facts and determinants", *Working Paper Series*, No 1981, ECB, November.

Gao, W. and Kehrig, M. (2017), "Returns to Scale, Productivity and Competition: Empirical Evidence from U.S. Manufacturing and Construction Establishments", mimeo.

García-Santana, M., Moral-Benito, E., Pijoan-Mas, J. and Ramos, R. (2016), "Growing like Spain: 1995-2007", *International Economic Review,* Vol. 61, Issue 1, pp. 383-416, February.

Garga, V. and Singh, S.R. (2020), "Output hysteresis and optimal monetary policy", *Working Papers*, No 331, University of California, Davis, Department of Economics.

Garicano, L., Lelarge, C. and Van Reenen, J. (2016), "Firm Size Distortions and the Productivity Distribution: Evidence from France", *American Economic Review*, Vol. 106, No 11, pp. 3439-3479, November.

Gilchrist, S., Sim, J. and Zakrajek, E. (2013), "Misallocation and financial market frictions: Some direct evidence from the dispersion in borrowing costs", *Review of Economic Dynamics*, Vol. 16, Issue 1, pp. 159-176, January.

Gilchrist, S. and Zakrajšek, E. (2012), "Credit Spreads and Business Cycle Fluctuations", *American Economic Review*, Vol. 102, No 4, pp. 1692-1720, June.

Giraudo, E., Giudici, G. and Grilli, L. (2019), "Entrepreneurship policy and the financing of young innovative companies: Evidence from the Italian Startup Act", *Research Policy*, Vol. 48, Issue 9, November.

Giordano, C. and Lopez-Garcia, P. (2021), "Firm heterogeneity and trade in EU countries: a cross-country analysis", *The Journal of International Trade and Economic Development, Taylor & Francis Journals*, Vol. 30(1), pp. 68-103, January.

González, B., Nuño, G. and Thaler, D. (forthcoming), "Optimal Monetary Policy with Heterogeneous Firms", work in progress, Banco de España.

Gopinath, G., Kalemli-Özcan, S., Karabarbounis, L. and Villegas-Sanchez, C. (2017), "Capital Allocation and Productivity in South Europe", *Quarterly Journal of Economics*, Vol. 132, Issue 4, pp. 1915-1967, November.

Gordon, R. (2000), "Does the 'New Economy' Measure Up to the Great Inventions of the Past?", *Journal of Economic Perspectives*, Vol. 14, No 4, pp. 49-74, Fall.

Gordon, R. (2003), "Five Puzzles in the Behavior of Productivity, Investment and Innovation", research memorandum, September.

Gordon, R. (2012), "Is U.S. Economic Growth Over? Faltering Innovation Confronts the Six Headwinds", *NBER Working Papers*, No 18315, August.

Gordon, R. (2015), "Secular Stagnation: A Supply-Side View", *American Economic Review*, Vol. 105, No 5, pp. 54-59, May.

Griffith, R., Redding, S. and Van Reenen, J. (2004), "Mapping the Two Faces of R&D: Productivity Growth in a Panel of OECD Industries", *Review of Economics and Statistics*, Vol. 86, Issue 4, pp. 883-895, November.

Gropp, R., Ongena, S., Rocholl, J. and Saadi, V. (2017), "The Cleansing Effect of Banking Crises", *CEPR Discussion Papers*, No 15025, July.

Guidici, G. and Paleari, P. (2000), "The Provision of Finance to Innovation: A Survey Conducted among Italian Technology-Based Small Firms", *Small Business Economics*, Vol. 14, No 1, pp. 37-53, February.

Guner, N., Ventura, G. and Xu, Y. (2008), "Macroeconomic implications of size-dependent policies", *Review of Economic Dynamics*, Vol. 11, Issue 4, pp. 721-744, October.

Gutierrez, G. and Philippon, T. (2020), "How EU Markets Became More Competitive Than US Markets: A Study of Institutional Drift", *NBER Working Papers*, No 24700, June.

Hagedorn, M. and Manovskii, I. (2008), "The Cyclical Behavior of Equilibrium Unemployment and Vacancies Revisited", *American Economic Review*, Vol. 98, No 4, pp. 1692-1706, September.

Hagsten, E. and Kotnik, P. (2017), "ICT as facilitator of internationalisation in small- and medium-sized firms", *Small Business Economics*, Vol. 48, No 2, pp. 431-446.

Hall, B. (2010), "The Financing of Innovative Firms", *Review of Economics and Institutions*, Vol. 1, No 1, pp. 1-30.

Halpern, L., Koren, M. and Szeidl, A. (2015), "Imported Inputs and Productivity", *American Economic Review*, Vol. 105, No 12, pp. 3660-3703, December.

Hamamoto, M. (2006), "Environmental regulation and the productivity of Japanese manufacturing industries", *Resource and Energy Economics*, Vol. 28, Issue 4, pp. 299-312, November.

Hamano, M. and Zanetti, F. (2020), "Monetary Policy, Firm Heterogeneity, and Product Variety", *WINPEC Working Paper Series*, No E2005, May.

Hartwig, B. and Lieberknecht, P. (2020), "Monetary policy, firm exit and productivity", Deutsche Bundesbank Discussion Papers, No 61/2020.

Haskel, J. and Westlake, S. (2018), Capitalism without Capital: The Rise of the Intangible Economy, Princeton University Press, Princeton.

Heal, G. and Park, J. (2016), "Temperature Stress and the Direct Impact of Climate Change: A Review of an Emerging Literature", *Review of Environmental Economics and Policy*, Vol. 10, No 2, pp. 1-17, August.

Heuvelen, H., Bettendorf, L. and Meijerink, G. (2018), "The contribution of small firms to the Dutch productivity frontier", mimeo.

Ho, S.J. and Ruzic, D. (2017), "Returns to Scale, Productivity Measurement, and Trends in U.S. Manufacturing Misallocation", *Society for Economic Dynamics 2018 Meeting Papers*, Vol. 119.

Hogan, T. and Hutson, E. (2005), "Capital structure in new technology-based firms: Evidence from the Irish software sector", *Global Finance Journal*, Vol. 15, Issue 3, pp. 369-387, February.

Hoshi, T. (2006), "Economics of the Living Dead", *Japanese Economic Review*, Vol. 57, Issue 1, pp. 30-49, March.

Howell, S.T. (2017), "Financing Innovation: Evidence from R&D Grants", *American Economic Review*, Vol. 107, No 4, pp. 1136-1164, April.

Howell, S.T., Lerner, J., Nanda, R. and Townsend, R.R. (2020), "How Resilient is Venture-Backed Innovation? Evidence from Four Decades of U.S. Patenting", *NBER Working Papers*, No 27150, May.

Hsieh, C.-T. and Klenow, P. (2009), "Misallocation and Manufacturing TFP in China and India", *Quarterly Journal of Economics*, Vol. 124, No 4, pp. 1403-1448, November.

Huergo, E. and Jaumandreu, J. (2004), "How Does Probability of Innovation Change with Firm Age?", *Small Business Economics*, Vol. 22, Issue 3-4, pp. 193-207.

Hulten, C.R. (2010), "Growth Accounting", in Hall, B.H. and Rosenberg, N. (eds.), *Handbook of the Economics of Innovation*, Vol. 2, 1st edition, Elsevier, Amsterdam, pp. 987-1031.

Hyatt, H.R. and Spletzer, J. (2013), "The Recent Decline in Employment Dynamics", *IZA Journal of Labor Economics*, Vol. 2, Issue 1, pp. 1-21.

Hume, D. (1752), Political Discourses, R. Fleming.

Ikeda, D. and Kurozumi, T. (2019), "Slow Post-financial Crisis Recovery and Monetary Policy", *American Economic Journal: Macroeconomics*, Vol. 11, No 4, pp. 82-112, October.

Jaffe, A. (1986), "Technological Opportunity and Spillovers of R&D: Evidence from Firms' Patents, Profits, and Market Value", *American Economic Review*, Vol. 76, No 5, pp. 984-1002, December.

Jarociński, M. and Karadi, P. (2020), "Deconstructing Monetary Policy Surprises – The Role of Information Shocks", *American Economic Journal: Macroeconomics*, Vol. 12, No 2, pp. 1-43, April.

Jones, C.I. and Williams, J.C. (1998), "Measuring the Social Return to R&D", *Quarterly Journal of Economics*, Vol. 113, No 4, pp. 1119-1135, November.

Jordà, O. (2005), "Estimation and Inference of Impulse Responses by Local Projections", *American Economic Review*, Vol. 95, No 1, pp. 161-182, March.

Jordà, Ò., Singh, S.R. and Taylor, A.M. (2020), "The Long-Run Effects of Monetary Policy", *Federal Reserve Bank of San Francisco Working Papers*, No 2020-01.

Jovanovic, B. (1982), "Selection and the Evolution of Industry", *Econometrica*, Vol. 50, No 3, pp. 649-670, May.

Jurado, K., Ludvigson, S.C. and Ng, S. (2015), "Measuring Uncertainty", *American Economic Review*, Vol. 105, No 3, pp. 1177-1216, March.

Kalemli-Özcan, S., Sorensen, B., Villegas-Sanchez, C., Volosovych, V. and Yesiltas, S. (2015), "How to Construct Nationally Representative Firm Level Data from the ORBIS Global Database", *NBER Working Papers*, No 21558, September.

Klepper, S. (1996), "Entry, Exit, Growth, and Innovation over the Product Life Cycle", *American Economic Review*, Vol. 86, No 3, pp. 562-583, June.

Klepper, S. (1997), "Industry Life Cycles", *Industrial and Corporate Change*, Vol. 6, Issue 1, pp. 145-182, January.

Kornai, J., Maskin, E. and Roland, G. (2003), "Understanding the Soft Budget Constraint", *Journal of Economic Literature*, Vol. 41, No 4, pp. 1095-1136, December.

Kozluk, T. and Timiliotis, C. (2016), "Do environmental policies affect global value chains?: A new perspective on the pollution haven hypothesis", *OECD Economic Department Working Papers*, No 1282.

Kortum, S. and Lerner, J. (2000), "Assessing the Contribution of Venture Capital to Innovation", *Rand Journal of Economics*, Vol. 31, No 4, pp. 674-692, Winter.

Kozlowski, J., Veldkamp, L. and Venkateswaran, V. (2020), "Scarring Body and Mind: The Long-Term Belief-Scarring Effects of COVID-19", *NBER Working Papers*, No 27439.

Krugman, P. (1997), The Age of Diminished Expectations: U.S. Economic Policy in the 1990s, 3rd edition, MIT Press, Cambridge, Massachusetts.

Krusell, P., Mukoyama, T., Rogerson, R. and Sahin, A. (2017), "Gross Worker Flows over the Business Cycle", *American Economic Review*, Vol. 107, No 11, pp. 3447-3476, November.

Laeven, M.L. and Valencia, M.F. (2018), "Systemic Banking Crises Revisited", *IMF Working Papers*, No 18/206.

Lane, P. (2013), "Financial Globalisation and the Crisis", *Open Economies Review*, Vol. 24, Issue 3, pp. 555-580.

Lee, J., Veloso, F.M. and Hounshell, D.A. (2011), "Linking induced technological change, and environmental regulation: Evidence from patenting in the U.S. auto industry", *Research Policy*, Vol. 40(2011), pp. 1240-1252, November.

Lee, Y. and Mukoyama, T. (2015), "Entry and exit of manufacturing plants over the business cycle", *European Economic Review*, Vol. 77, pp. 20-27, July.

Le Mouel, M. and Schiersch, A. (2020), "Knowledge-Based Capital and Productivity Divergence", *DIW Discussion Papers*, No 1868.

Lequiller, F. (1997), "Does the French Consumer Price Index Overstate Inflation?", *INSEE Documents de Travail*, No G9714.

Lerner, J. and Nanda, R. (2020), "Venture Capital's Role in Financing Innovation: What We Know and How Much We Still Need to Learn", *Journal of Economic Perspectives*, Vol. 34, No 3, pp. 237-261, Summer.

Levine, R. (2005), "Finance and Growth: Theory and Evidence", in Klenow, P.J. and Rodríguez-Clare, A., *Handbook of Economic Growth*, Vol. 1, Part A, Elsevier, Amsterdam, pp. 865-934.

Levine, O. and Warusawitharana, M. (2021), "Finance and productivity growth: Firm-level evidence", *Journal of Monetary Economics*, Vol. 117, pp. 91-107, January.

Levinsohn, J. and Petrin, A. (2003), "Estimating Production Functions Using Inputs to Control for Unobservables", *Review of Economic Studies,* Vol. 70, No 2, pp. 317-341, April.

Linarello, A., Petrella, A. and Sette, E. (2019), "Allocative Efficiency and Finance", *Banca d'Italia Occasional Papers,* No 487, August.

Liu, E., Mian, A. and Sufi, A. (2019), "Low Interest Rates, Market Power, and Productivity Growth", *NBER Working Papers*, No 25505, January.

De Loecker, J. and Warzynski, F. (2012), "Markups and Firm-Level Export Status", *American Economic Review*, Vol. 102, No 6, pp. 2437-2471, October.

Lotti, F. and Sette, E. (2019), "Frontier and superstar firms in Italy", *Banca d'Italia Occasional Papers*, No 537, December.

Manaresi, F. and Pierri, N. (2019), "Credit Supply and Productivity Growth", *IMF Working Papers*, No 19/107, May.

Masuch, K., Anderton, R., Setzer, R., Benalal, N. (editors), (2018), "Structural policies in the euro area", *ECB Occasional Paper Series*, No 210, June.

Meinen, P. and Röhe, O. (2017), "On measuring uncertainty and its impact on investment: Cross-country evidence from the euro area", *European Economic Review*, Vol. 92, pp. 161-179, February.

Melitz, M.J. (2003), "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity", *Econometrica*, Vol. 71, No 6, pp. 1695-1725.

Melitz, M.J. and Polanec, S. (2015), "Dynamic Olley-Pakes productivity decomposition with entry and exit", *RAND Journal of Economics*, Vol. 46, Issue 2, pp. 362-375, Summer.

Midrigan, V. and Yi Xu, D. (2014), "Finance and Misallocation: Evidence from Plant-Level Data", *American Economic Review*, Vol. 104, No 2, pp. 422-458, February.

Moore, B. (1994), "Financial Constraints to the Growth and Development of Small High-Technology Firms", in Storey, D.J. and Hughes, A. (eds.), *Finance and the Small Firm*, Routledge, New York, pp. 112-144.

Moran, P. and Queralto, A. (2018), "Innovation, productivity, and monetary policy", *Journal of Monetary Economics*, Vol. 93, pp. 24-41, January.

Nepelski, D., Piroli, G. and De Prato, G. (2016), "European Start-up Hotspots: An Analysis based on VC-backed Companies", *Joint Research Centre Scientific and Policy Reports*, No 28021.

Neuhann, D. and Saidi, F. (2018), "Do universal banks finance riskier but more productive firms?", *Journal of Financial Economics*, Vol. 128, Issue 1, pp. 66-85, April.

Nilsen, Ø.A., Raknerud, A., Rybalka, M. and Skjerpen, T. (2011), "The Importance of Skill Measurement for Growth Accounting", *Review of Income and Wealth*, Vol. 57, Issue 2, pp. 293-305, June.

Nurmi, S., Vanhala, J. and Virén, M. (2020), "The life and death of zombies – evidence from government subsidies to firms", *Bank of Finland Research Discussion Papers*, No 8, May.

OECD (2001), Measuring Productivity – OECD Manual: Measurement of Aggregate and Industry-level Productivity Growth, OECD Publishing, Paris.

OECD (2010), "Measuring Entrepreneurship: The OECD-Eurostat Entrepreneurship Indicators Programme", *Statistics Brief*, No 15, November.

OECD (2017), "Key Issues for Digital Transformation in the G20. Report prepared for a joint G20 German Presidency".

OECD (2018a), "Market Concentration", *OECD Issues Paper*, No 46.

OECD (2018b), "OECD Economic surveys: Ireland", March.

OECD (2018c), "OECD Compendium of Productivity Indicators 2018".

OECD (2019), "Roadmap: Digital intensity, a taxonomy of sectors", Measuring the Digital Transformation: A Roadmap for the Future, OECD Publishing, Paris.

OECD (2020), "Productivity gains from teleworking in the post COVID-19 era: how can public policies make it happen?", OECD Policy Responses to Coronavirus (COVID-19), September.

Olley, G. and Pakes, A. (1996), "The Dynamics of Productivity in the Telecommunications Equipment Industry", *Econometrica*, Vol. 64, Issue 6, pp. 1263-1297, November.

Oulton, N. (2016), "The Mystery of TFP", *International Productivity Monitor*, Vol. 31, pp. 68-87, Fall.

Papaioannou, E. (2007), "Finance and growth: A macroeconomic assessment of the evidence from a macroeconomic angle", *Working Paper Series*, No 787, ECB, July.

Park, J. (2016), "Will We Adapt? Temperature Shocks, Labor Productivity, and Adaptation to Climate Change in the United States (1986-2012)," Discussion Paper - Harvard Project on Climate Agreements, Belfer Center.

Pesaran, M.H. (2004), "General Diagnostic Tests for Cross Section Dependence in Panels", *Cambridge Working Papers in Economics*, No 0435.

Petrin, A. and Levinsohn, J. (2012), "Measuring aggregate productivity growth using plant-level data", *RAND Journal of Economics*, Vol. 43, Issue 4, pp. 705-725, Winter.

Porter, M. and van der Linde, C. (1995), "Toward a new conception of the environment-competitiveness relationship", *Journal of Economic Perspectives*, Vol. 9, No 4, pp. 97-118, Fall.

Poschke, M. (2009), "Employment protection, firm selection, and growth", *Journal of Monetary Economics*, Vol. 56, Issue 8, pp. 1074-1085, November.

Raddatz, C. (2009), "The Wrath Of God: Macroeconomic Costs Of Natural Disasters", *Policy Research Working Papers*, No 5039, September.

Restuccia, D. and Rogerson, R. (2008), "Policy distortions and aggregate productivity with heterogeneous establishments", *Review of Economic Dynamics*, Vol. 11, Issue 4, pp. 707-720, October.

Riom, C. and Valero, A. (2020), "The Business Response to Covid-19: the CEP-CBI survey on technology adoption", *Centre for Economic Performance Covid-19 Analysis Series*, No 009.

Romer, P.M. (1990), "Endogenous Technological Change", *Journal of Political Economy*, Vol. 98, No 5, Part 2, pp. S71-S102, October.

Ruiz-Garcia, J.C. (2020), "Financial Frictions, Firm Dynamics and the Aggregate Economy: Insights from Richer Productivity Processes", mimeo.

Sala-i-Martin, X. (1997), "I Just Ran Two Million Regressions", *American Economic Review*, Vol. 87, No 2, pp. 178-183, May.

Schivardi, F., Sette, E. and Tabellini, G. (2017), "Credit Misallocation During the European Financial Crisis", *BIS Working Papers*, No 669.

Schivardi, F. and Romano, G. (2020), "A simple method to estimate firms' liquidity needs during the COVID-19 crisis with an application to Italy", *CEPR Covid Economics, Vetted and Real-Time Papers*.

Schivardi, F. and Schmitz, T. (2020), "The IT Revolution and Southern Europe's Two Lost Decades", *Journal of the European Economic Association,* Vol. 18, Issue 5, pp. 2441-2486, September.

Schmöller, M. and Spitzer, M. (2020), "Endogenous TFP, business cycle persistence and the productivity slowdown in the euro area", *Working Paper Series*, No 2401, ECB.

Schreyer, P. and Koechlin, F. (2002), "Purchasing power parities – measurement and uses", *OECD Statistics Brief*, March.

Seppanen, O., Fisk, W. and Lei, H.Q. (2006), "Effect of temperature on task performance in office environment", Lawrence Berkeley National Laboratory, Berkeley, CA.

Solow, R. (1957), "Technical Change and the Aggregate Production Function", *Review of Economics and Statistics*, Vol. 39, No 3, pp. 312-320, August.

Sorbe, S., Gal, P., Nicoletti, G. and Timiliotis, C. (2019), "Digital Dividend: Policies to Harness the Productivity Potential of Digital Technologies", *OECD Economic Policy Papers*, No 26, February.

Spiezia, V., Koksal-Oudot, E. and Montaigner, P. (2016), "New Skills for the Digital Economy: Measuring the demand and supply of ICT skills at work", *OECD Digital Economy Papers*, No 258, June.

Stehrer, R., Bykova, A., Jäger, K., Reiter, O. and Schwarzhappel, M. (2019), "Industry Level Growth and Productivity Data with Special Focus on Intangible Assets", Report on methodologies and data construction for the EU KLEMS Release 2019.

Stigler, G. (ed.) (1961), The Price Statistics of the Federal Government. Report to the Office of Statistical Standards, NBER, New York.

Storz, M., Koetter, M., Setzer, R. and Westphal, A. (2017), "Do we want these two to tango? On zombie firms and stressed banks in Europe", *Working Paper Series*, No 2104, ECB, October.

Syverson, C. (2011), "What Determines Productivity?", *Journal of Economic Literature*, American Economic Association, Vol. 49, No 2, pp. 326-365, June.

Syverson, C. (2017), "Challenges to Mismeasurement Explanations for the US Productivity Slowdown", *Journal of Economic Perspectives*, Vol. 31, No 2, pp. 165-86, Spring.

Syverson, C. (forthcoming), "COVID-19, Resource Reallocation, and Productivity", OECD Workshop on COVID-19 and Resource Reallocation, December 2020.

Tian, C. (2018), "Firm-level entry and exit dynamics over the business cycles", *European Economic Review*, Vol. 102, pp. 298-326, February.

Tørsløv, T.R., Wier, L.S. and Zucman, G. (2020), "The Missing Profits of Nations", *NBER Working Papers*, No 24701, June.

Van Ark, B. (2016), "The Productivity Paradox of the New Digital Economy", *International Productivity Monitor*, No 31, pp. 3-18, Fall.

Van Ark, B., O'Mahoney, M. and Timmer, M. (2008), "The Productivity Gap between Europe and the United States: Trends and Causes", *Journal of Economic Perspectives*, Vol. 22, No 1, pp. 25-44, Winter.

Westhead, P. and Storey, D. (1997), "Financial constraints on the growth of high technology small firms in the United Kingdom", *Applied Financial Economics*, Vol. 7, Issue 2, pp. 197-201, October.

Zivin, J.G. and Shrader, J. (2016), "Temperature Extremes, Health, and Human Capital", *Future of Children*, Vol. 26, No 1, pp. 31-50, Spring.

Annex 1: Macro drivers of TFP

A.1.1 Estimation methodology

Investigating productivity determinants involves a two-step process. In the first step, a panel factor model is used to estimate a common factor in TFP growth rates using a sample made up of the EU economies. For each country, the panel factor model returns a series of idiosyncratic components of TFP growth. These series are then interpreted as a measure of production efficiency improvements originating on the domestic side, for example non-traded sectors. The second step involves an econometric analysis of the determinants of these components.

There are two reasons for which the common component should be filtered out from TFP growth. First, doing so eliminates the cross-sectional dependence (CD) detected in the data using the Pesaran (2004) CD test. The presence of CD can lead to biased statistical inference, thus jeopardising the reliability of the estimation. Second, the common component captures factors that cannot be explained by cross-country differences in structural economic characteristics and might be outside the control of national governments. Focusing on the idiosyncratic components of TFP growth helps identify the factors behind a country's over or under-performance.

A.1.2 Theoretical framework

This section presents a stylised model of aggregate productivity. Consider a set of N countries $i = \{1, \dots, N\}$. Aggregate output is produced with production technology $F(K_{it}, L_{it})$ using capital K_{it} and total hours worked H_{it} with efficiency TFP_{it}:

$$Y_{it} = TFP_{it} F(K_{it}, H_{it})$$

The production function $F(.)$ is assumed to satisfy the standard properties of degree-one homogeneity and decreasing marginal returns for each factor.

The N countries are linked through trade, labour and capital flows as well as through knowledge exchanges, as is the case in the European Single Market. International technological and economic factors therefore affect productivity developments in all countries through technology diffusion, production reallocation and various spillover effects. TFP of country i at time t can be decomposed into an idiosyncratic term A_{it} and a common factor Z_t that affects all countries simultaneously:

$$TFP_{it} = A_{it} Z_t^{\gamma_i}.$$

The variable A_{it} is the domestic component of TFP. It depends on a wide range of domestic structural characteristics affecting innovation and technology diffusion,

sector specialisation and intra-sector allocative efficiency. Examples of these structural characteristics include the educational level of the workforce, the quality of public institutions, the rule of law and labour market regulation.

The coefficient γ_i is a factor loading that establishes the sensitivity of aggregate productivity to international factors affecting the whole region. The common component Z_t captures a broad range of international productivity drivers that are not connected to technological progress, such as global recessions and financial crises. In an endogenous growth model, the term Z_t would be a function of the knowledge stock at the technological frontier or the total stock of R&D or patents in the region. However, when analysing productivity over a shorter time span, by influencing the rate of adoption of new technologies (i.e. trade and financial conditions), demand effects and changes in macroeconomic conditions in the country in question are assumed to be more important than innovation dynamics at the frontier. No structure is placed on the sources of cross-country spillovers and the component Z_t is assumed to be unobserved. This enables cross-sectional dependence between countries to be modelled efficiently and effectively.

Taking log-differences on both sides, we obtain a linear factor model of TFP:

$$g_{it} = \Delta a_{it} + \gamma_i \Delta z_t,$$

where $g_{it} = \Delta tfp_{it}$ is the growth rate of TFP. This equation provides a decomposition of productivity growth into two unobserved factors, which can be interpreted as TFP dynamics that are correlated with growth in other countries and a residual that measures the relative performance of the domestic growth engine compared with its peers.

The model can be estimated using least squares, as proposed in Bai (2009). It produces a series of N factor loadings γ_i, a series of T common factors f_t and a panel of NxT residuals ε_{it}. The residual captures the country-level productivity dynamics that are uncorrelated with regional and global trends.

In a second stage, the determinants of the idiosyncratic component of TFP growth, such as human capital and public sector efficiency, are analysed by means of a dynamic fixed effect model widely used in the literature of growth econometrics. We assume that national economic policy can have a direct effect on TFP growth via the idiosyncratic component and an indirect one via factor loadings, which are interpreted as the strength of adoption of global frontier technologies. This exercise focuses on the former, since the determinants of the factor loadings cannot be properly identified given the small sample size of γ_i. Intuitively, they may depend on the level of trade openness and economic development. If a process of cross-country productivity convergence exists, it is likely to be captured by these coefficients.

Table A.1.1

Estimation results – full sample

	(a)	(b)	(c)	(d)	(e)	(f)
Lag of dep. Variable	0.885*** (0.02)	0.889*** (0.03)	0.889*** (0.03)	0.917*** (0.03)	0.923*** (0.03)	0.918*** (0.03)
Labour market						
Labour market flexibility (t-1)	0.092* (0.04)					
Hiring and firing flexibility (t-1)		0.064* (0.03)	0.064* (0.03)	0.064* (0.03)	0.058* (0.03)	0.066* (0.02)
Decentralised collective bargaining (t-1)		0.017 (0.03)	0.017 (0.03)			
Human capital and innovation						
Human capital stock, y-o-y change (t-1)	-0.633 (2.35)	-1.399 (2.08)	-1.399 (2.08)	0.419 (2.66)	0.437 (2.54)	0.342 (2.58)
Log of ICT patents on GDP (t-2)	0.026 (0.03)	0.054* (0.02)	0.054* (0.02)			
Institutional framework						
Corruption (inverted scale)	0.083* (0.03)	0.070 (0.04)	0.070 (0.04)	0.054 (0.04)	0.051 (0.04)	0.049 (0.04)
Political rights	0.026 (0.06)	0.070 (0.07)	0.070 (0.07)	0.081 (0.06)	0.081 (0.06)	0.073 (0.06)
Financial openness	-0.511** (0.18)	-0.447* (0.20)	-0.447* (0.20)	-0.340 (0.21)	-0.301 (0.20)	-0.333 (0.20)
Fiscal policy						
Net lending excluding interest (t-1)	-0.007 (0.01)	-0.005 (0.01)	-0.005 (0.01)			
Total government expenditure, excluding interest (t-1)				0.008 (0.01)	0.004 (0.01)	0.007 (0.01)
Total tax revenues, percentage of GDP (t-1)	0.025 (0.01)	0.020 (0.02)				
Personal income taxes, share of total (t-1)				-1.631* (0.77)		-1.266 (0.69)
Consumption taxes, share of total (t-1)				0.173 (0.98)	1.696 (1.03)	
Property taxes, share of total (t-1)					3.354** (0.93)	2.045* (0.91)
Controls						
Gross fixed capital formation, construction, percent of GDP, y-o-y change (t-1)	-0.011 (0.02)	-0.007 (0.02)	-0.007 (0.02)	-0.019 (0.02)	-0.020 (0.02)	-0.019 (0.02)
Gross fixed capital formation, equipment, percent of GDP (t-1)	0.025 (0.02)	0.018 (0.02)	0.018 (0.02)	0.016 (0.03)	0.019 (0.02)	0.017 (0.02)
Share of employment in manufacturing, y-o-y change (t-1)	0.095* (0.03)	0.072* (0.03)	0.072* (0.03)	0.094* (0.03)	0.090* (0.04)	0.094* (0.03)
Inflation, consumer prices % change (t-1)	-0.033*** (0.01)	-0.030*** (0.01)	-0.030*** (0.01)	-0.025** (0.01)	-0.023* (0.01)	-0.025** (0.01)
Observations	448	448	448	456	456	456
Number of countries	22	22	22	22	22	22
Adj. R2	0.879	0.879	0.879	0.881	0.882	0.882

Note: Time trend included in all regressions. Standard errors in parentheses * p<0.10, ** p<0.05., ***p<0.01.

Annex 2: The macro picture

A.2.1 Dynamics of hours worked per capita in the EU12 and other advanced economies
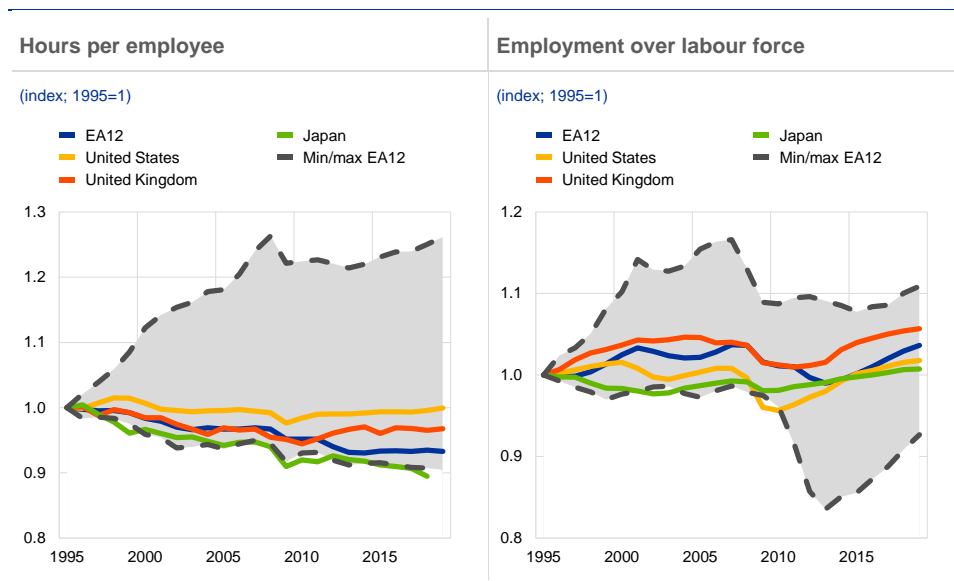
Hours worked per capita depend on labour market developments and can be further decomposed using variables such as hours worked per employee, (one minus) the unemployment rate and the labour force participation rate, and on demographics captured by the share of the working-age population:

$$\frac{Hours}{Population} = \frac{Hours}{Employment} \times \frac{Employment}{Labour\ force} \times \frac{Labour\ force}{Working\ Age\ Population}$$
$$\times \frac{WAP}{Population}$$

Hours intensity has been relatively stable over time in the EA12 and other advanced economies. This is the result of two opposite forces: i) declining hours per employee and an ageing population; and ii) greater labour force participation. Hours per employee have been declining for decades in advanced economies. Although in principle there could be a trade-off between the preference for leisure in those economies and the fact that work is the main source of income for consumption and saving, the fact is that hours per employee have steadily fallen over time in the euro area, as well as in other advanced economies (Chart A.2.1, left panel). The reasons behind this decline are numerous and change from country to country, ranging from institutional factors and labour market reforms to the impact of the crisis on the labour market in certain countries. The share of the working-age population has also been steadily falling over time in advanced economies, driven by ageing populations (Chart A.2.2, right panel). The increase in hours intensity is therefore fuelled solely by a higher labour force participation rate resulting from a massive influx of women into the labour market, the increasing presence of older workers and immigration, particularly into the EA12 (Chart A.2.2, left panel).
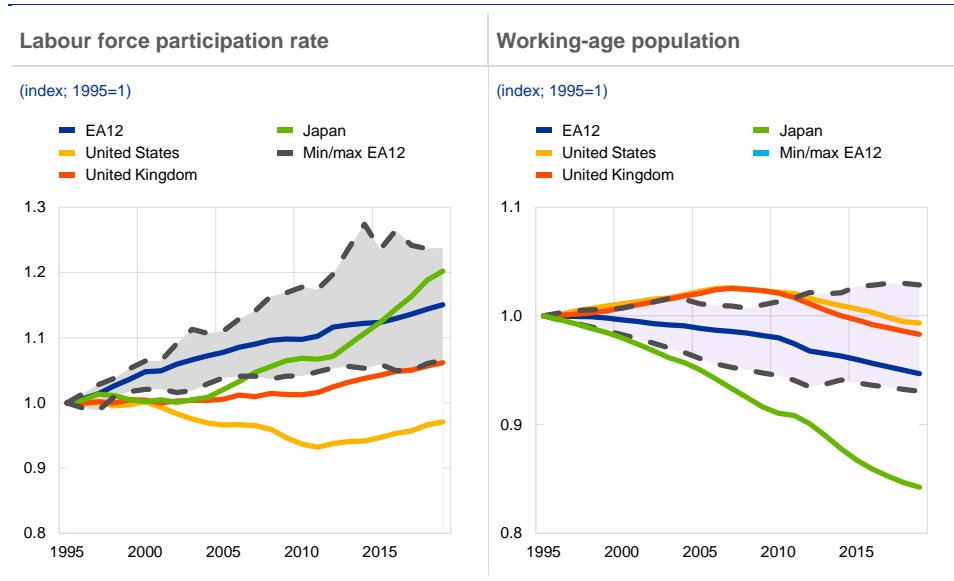
Chart A.2.1

Hours per employee (left panel) and employment over labour force (right panel)

Hours per employee	Employment over labour force
(index; 1995=1)	(index; 1995=1)

Legend:
- EA12
- United States
- United Kingdom
- Japan
- Min/max EA12

Sources: Own calculations using AMECO data.

Chart A.2.2

Labour force participation rate (left panel) and working-age population[123] (right panel)

Labour force participation rate	Working-age population
(index; 1995=1)	(index; 1995=1)

Legend:
- EA12
- United States
- United Kingdom
- Japan
- Min/max EA12

Sources: Own calculations using AMECO data.

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[123] Although some countries are raising the retirement age, to ensure cross-country comparability AMECO only provides data for the 15-64 age range. Therefore we have adopted this as the standard working age across all countries.

Chart A.2.3

GDP per capita relative to the United States over time, not adjusted for PPP (left panel) and GDP per capita, labour productivity and hours intensity in the EA12 relative to the United States over time, not adjusted for PPP (right panel)

GDP per capita relative to the United States over time, not adjusted for PPP	GDP per capita, labour productivity and hours intensity in the EA12 relative to the United States over time, not adjusted for PPP
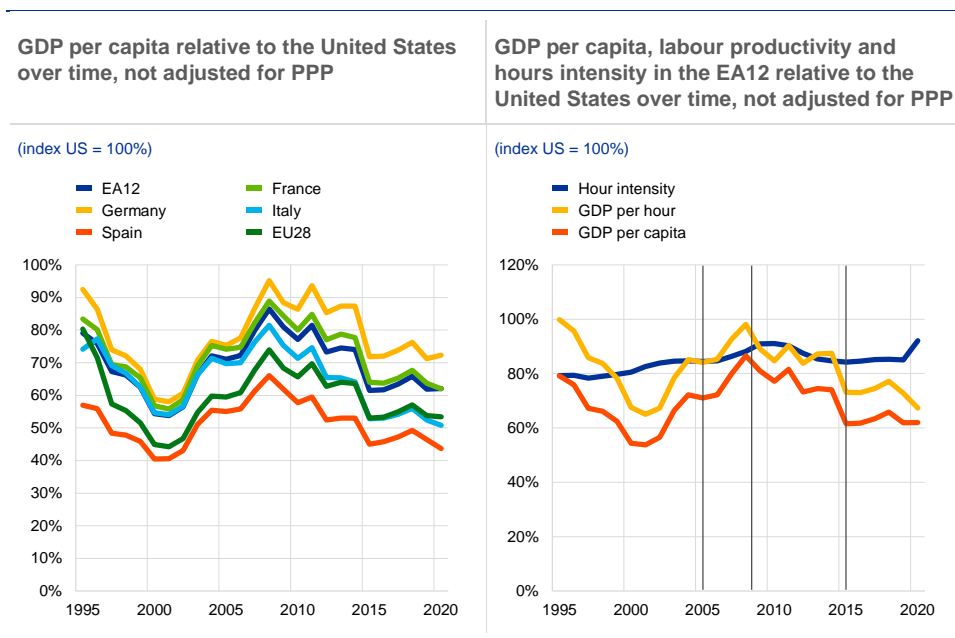
Sources: Own calculations using AMECO data

A.2.2 Measuring TFP growth and its contribution to labour productivity growth: the importance of accounting for capacity utilisation

The main text shows TFP growth measures that have been adjusted for changes in capacity utilisation by applying ad hoc calculations. The more refined correction method used by Basu et al. (2006) as well as Comin et al. (2020) accounts for possible endogeneity between changes in TFP growth and the rate of capacity utilisation as well as potential differences between different sectors of the economy.

At industry level, utilisation-adjusted TFP growth rates for sector i at time t can be expressed as:

$$g\tilde{A}_{it} = gY_{it} - \alpha(gK_{it} + gU_{it}^K) - (1-\alpha)(gL_{it} + gU_{it}^L) = gA_{it} + gU_{it},$$

where gA_{it} is the unadjusted, standard Solow residual and gU_{it} denotes the weighted sum of the growth rates of labour and capital utilisation.[124]

The adjusted growth rate $g\tilde{A}_{it}$ can be estimated using a two-step approach. First, the Solow residual, gA_{it}, is derived using data on gross value added, capital

---

[124] In contrast to the growth accounting exercises in the main text, this more general setup also allows for an adjustment of the utilisation rate of labour input.

services and (quality adjusted) labour. These computations only cover sectors of the market economy.[125] Next, to adequately capture the amount of inputs used in production, each Solow residual gA_{it} is regressed on changes in capacity utilisation gU_{it} and sector fixed effects (c_i):

$$gA_{it} = c_i + \beta gU_{it} + \varepsilon_{it}.$$

The utilisation-adjusted TFP growth of an industry is equal to the difference between the unadjusted Solow residual and the estimated impact of changes in capacity utilisation. Since exogenous changes in TFP can also cause changes in capacity utilisation, β is derived in an instrumental variable estimation (Basu et al., 2006; Comin et al. 2020). The following variables are used as instruments: an international oil shock, an international financial market shock and macroeconomic uncertainty shocks.[126] Aggregate TFP growth $g\tilde{A}_t$ is ultimately the sum of utilisation-adjusted industry TFP growth, weighted with gross value added shares.

Wherever data availability allowed, country-specific adjusted TFP rates were calculated using annual EU KLEMS data for 19 industries.[127] In line with Comin et al. (2020), information on the degree of capacity utilisation was sourced from European Commission business and consumer surveys.[128] To allow for some variation in β across segments, industries were grouped into three broad sectors (durable manufacturing, non-durable manufacturing, and non-manufacturing), each of which was estimated separately (see Basu et al., 2006; Comin et al., 2020).

Using this alternative method, aggregate contributions of capacity utilisation over the different periods, shown in Chart A.2.4, turn out to be broadly in line with those shown in the main text. It should be noted however, that – due to their strong cyclical nature – changes in capacity utilisation in particular affect TFP growth in the short run. Hence, we cannot rule out that the somewhat long-run perspective chosen in the main text masks heterogeneities in the measured contribution of capacity utilisation for specific sub-periods.

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[125] As outlined in Oulton (2016), this choice is motivated in part by the fact that measuring real output in non-market industry groups is problematic and likely to be inconsistent across countries. Moreover, since most of the non-market industries are publicly-owned, it appears questionable whether the underlying assumptions of the growth accounting methodology are appropriate in this case.

[126] Following the approach in Basu et al. (2006), the oil shock is calculated based on movements in the Brent oil price. The uncertainty shocks are derived from structural macroeconometric models (Jurado et al., 2015; Meinen and Röhe, 2017). Financial shocks are approximated by the excess bond premium indicator of Gilchrist and Zakrajšek (2012). Statistical tests confirm the relevance of the instruments. See Deutsche Bundesbank (2021) for details about the estimations.

[127] The sample comprises the following industries (and industry groups) according to the EU's NACE classification: C10-C12, C13-C15, C16-C18, C20-21, C22-23, C24-C25, C25-C26, C28, C29-C30, C31-C33 for the manufacturing sector, the sectors for electricity, gas, steam, air conditioning supply and water supply (NACE D-E), construction (NACE F), wholesale and retail trade (NACE G), transportation and storage (NACE H), accommodation and food services activities (NACE I), information and communication (NACE J), financial and insurance activities (NACE K), professional, scientific and technical activities, together with administrative and support services activities (NACE M-N), and arts, entertainment and recreation, and other service activities (NACE R-S).

[128] See European Commission (2020).

Chart A.2.4

Contributions to growth in GDP per hour in EA8, average 1999-2017 (left panel) and different time periods (right panel)

Contributions to growth in GDP per hour in EA8, average 1999-2017

(percentage points)

Contributions to growth in GDP per hour in EA8, in different time periods

(percentage points)
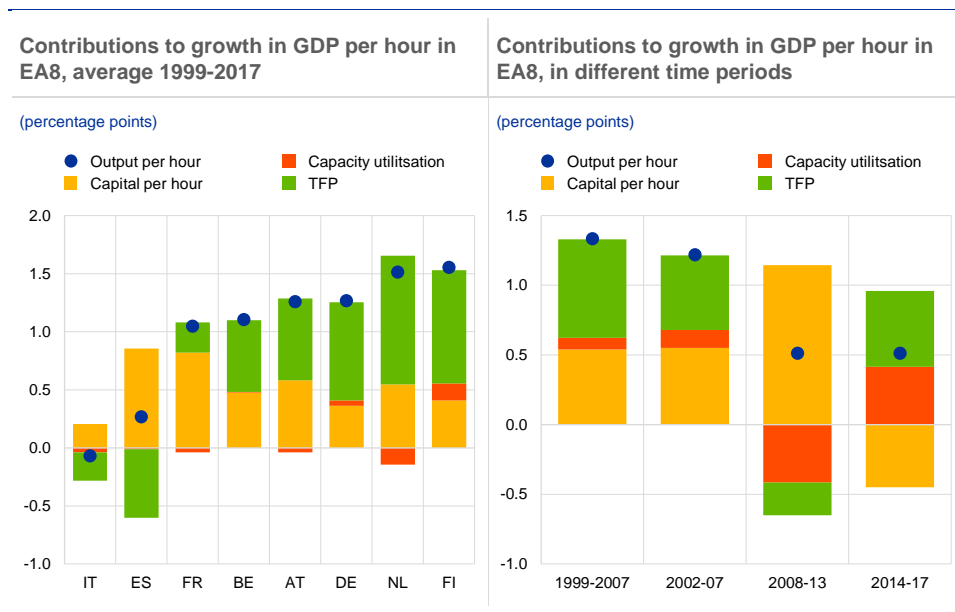
Source: Own calculations using data from EU KLEMS and the European Commission's business and consumer surveys.
Note: the EA8 countries are Belgium, Germany, Spain, France, Italy, Netherlands, Austria and Finland.

A.2.3   TFP growth in EU27 countries over time

Table A.2.1 shows average annual TFP growth rates in different time periods across EU27 countries.

Table A.2.1

TFP growth in EU countries, different periods

	1960-1970s	1970-1980s	1980-1994	1995-2001	2002-07	2008-13	2014-19
AT	3.3%	1.6%	0.8%	1.1%	1.0%	-0.6%	0.3%
BG	..	..	..	..	2.7%	-0.5%	1.9%
BE	3.2%	2.1%	1.1%	0.9%	1.3%	-0.2%	0.3%
CY	..	..	..	..	0.1%	-2.2%	0.9%
CZ	..	..	..	..	3.0%	-0.8%	1.9%
DE	..	..	..	0.5%	0.8%	-0.1%	0.8%
DK	2.8%	0.5%	1.2%	1.4%	0.5%	0.0%	0.8%
EA12	..	..	..	0.9%	0.5%	-0.4%	0.7%
ES	5.2%	2.0%	1.0%	0.4%	-0.3%	0.0%	0.7%
EST	..	..	..	..	2.8%	-2.2%	1.2%
FI	2.5%	2.2%	1.5%	2.7%	1.7%	-1.3%	0.5%
FR	3.6%	1.8%	1.0%	1.1%	0.6%	-0.2%	0.4%
GR	5.4%	1.8%	-0.8%	2.1%	1.8%	-3.5%	0.8%
HR	..	..	..	..	1.8%	-1.6%	0.6%
HU	..	..	..	..	1.6%	-1.1%	1.0%
IE	2.2%	1.7%	2.0%	4.2%	0.7%	-0.7%	6.3%
IT	4.8%	1.4%	0.8%	1.0%	-0.2%	-0.9%	0.4%
LT	..	..	..	..	4.3%	-0.3%	0.7%
LU	2.0%	0.7%	2.1%	0.9%	1.2%	-2.0%	0.3%
LV	..	..	..	..	4.6%	-0.2%	3.3%
MT	..	..	..	..	0.5%	-0.1%	2.1%
NL	2.6%	1.4%	0.9%	1.5%	0.8%	-0.3%	0.6%
PL	..	..	..	..	2.6%	0.5%	1.7%
PT	4.9%	3.3%	1.6%	0.9%	0.2%	-0.2%	1.1%
RO	..	..	..	..	5.8%	-0.4%	3.1%
SK	..	..	..	..	5.1%	0.5%	0.6%
SI	..	..	..	..	2.3%	-0.9%	2.2%
SE	1.9%	0.2%	0.4%	2.0%	2.1%	-0.3%	0.7%
EU28	..	..	..	..	0.9%	-0.2%	0.8%
US	1.9%	0.7%	1.0%	1.5%	1.1%	0.5%	0.7%

Sources: Own calculations using AMECO data.

Annex 3: Sector analysis

A.3.1   Description of the data

Computing productivity levels by sector is fraught with difficulties. In this sector analysis, labour productivity is computed as value added per hour worked in each sector using annual Eurostat national accounts data (September 2020) for all European countries, and EU KLEMS data for the United States (Stehrer et al., 2019). The time period is 1995-2017. Our analysis is based on chain-linked, value-added data. The non-additivity of chain-linked data can lead to incorrect or imprecise results. However, any possible error is likely to be small, as only year-on-year changes are used in the analysis. To make cross-country volume comparisons, value added is converted into a common unit that takes into account price differentials between countries, therefore current value added is converted into purchasing power parities (PPPs). Under these "current PPP" conversions, comparisons between countries within a specific year are straightforward, since volumes are measured with the same price structure. However, intertemporal comparisons require eliminating the effect of inflation over time. To combine spatial and temporal comparisons, the relative movements of value added growth in volumes in each country are replicated by fixing a "base" year – here 2015   – and extrapolating PPPs over time to obtain "constant PPPs" (Schreyer and Koechlin, 2002). Furthermore, given that data on PPPs are not available at sector level, economy-wide PPPs are used instead, with 2015 as the base year, assuming the global economy price structure in all industries of that year in each country.

The aggregate values for productivity are calculated from the bottom up, i.e. by first aggregating value added and hours worked across sectors and then calculating aggregated productivity. This analysis is carried out for all industries excluding agriculture, forestry and fishing (NACE A), mining and quarrying (NACE B), real estate (NACE L), public sector (NACE O-Q), and extraterritorial organisations and bodies (NACE U). Agriculture was excluded from the analysis, as the productivity measures are distorted by the declining numbers of part-time farmers. Mining and quarrying were excluded because their importance in terms of natural resources varied widely in the countries examined. Real estate is excluded because its value added per hour worked is distorted by the inclusion of imputed rents for owner-occupied dwellings. This is because owner-occupied dwellings are typically not regarded as productive capital and are produced without any additional measure of hours worked, thus artificially inflating the estimates of labour productivity in this sector. The shift-share analysis was carried out using data on the 2-digit NACE level. If 2-digit data were missing, data for the 1-digit level were used instead.

The sector analysis includes 26 EU countries, excluding Ireland, and comparisons are made with the United States. Ireland was excluded due to problems encountered with the calculation of Irish value added and to changes in the statistical calculation method of value added in the year 2015. However, when it came to the 2-digit NACE analysis, country coverage was restricted by missing data, as some of these data

are published with a delay of up to several years, and not published at all for some industries in certain countries. For this reason, two country aggregates with identical data coverage on the 2-digit NACE level were calculated: (i) EU20, including Belgium, Czech Republic, Denmark, Germany, Greece, Spain, France, Croatia, Italy, Cyprus, Lithuania, Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland and Sweden (Estonia, Ireland, Latvia, Luxembourg and Malta are excluded), and (ii) "EA14" including Belgium, Germany, Greece, Spain, France, Italy, Cyprus, Lithuania, Netherlands, Austria, Portugal, Slovenia, Slovakia and Finland (Estonia, Ireland, Luxembourg, Latvia and Malta are excluded due to data limitations). Even for these country samples we were obliged to exclude 2-digit NACE data for sectors G ("wholesale and retail trade") and H ("transportation and storage") and instead used 1-digit NACE data. Additionally, we used 1-digit data for all industries where no 2-digit data existed for sub-industries.
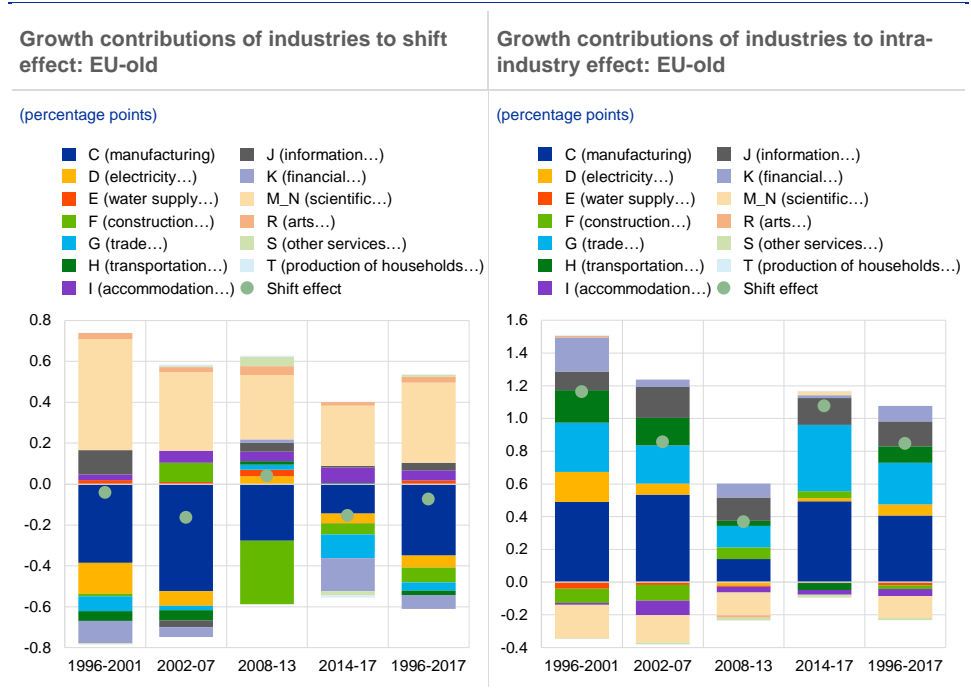
To analyse possible differences in developments between countries that joined the EU before and after 2004, the following aggregates were calculated: "EU-old" countries are those that joined the EU prior to 2004 (14 countries without the United Kingdom). We used a dataset for 12 of these countries (Belgium, Denmark, Germany, Greece, Spain, France, Italy, Netherlands, Austria, Portugal, Finland and Sweden, excluding Luxembourg and Ireland). "EU-new" countries are those that joined the EU in 2004 or later. In total there were 13 countries, of which 8 countries have complete data coverage (Czech Republic, Croatia, Cyprus, Lithuania, Poland, Romania, Slovenia and Slovakia). Bulgaria, Estonia, Hungary, Latvia and Malta had to be excluded due to the lack of data.

A.3.2   Shift-share analysis for EU-old and EU-new

The following charts show the shift-share analysis for EU-old (Belgium, Denmark, Germany, Greece, Spain, France, Italy, Netherlands, Austria, Portugal, Finland and Sweden) and EU-new countries (Czech Republic, Croatia, Cyprus, Lithuania, Poland, Romania, Slovenia and Slovakia), respectively.
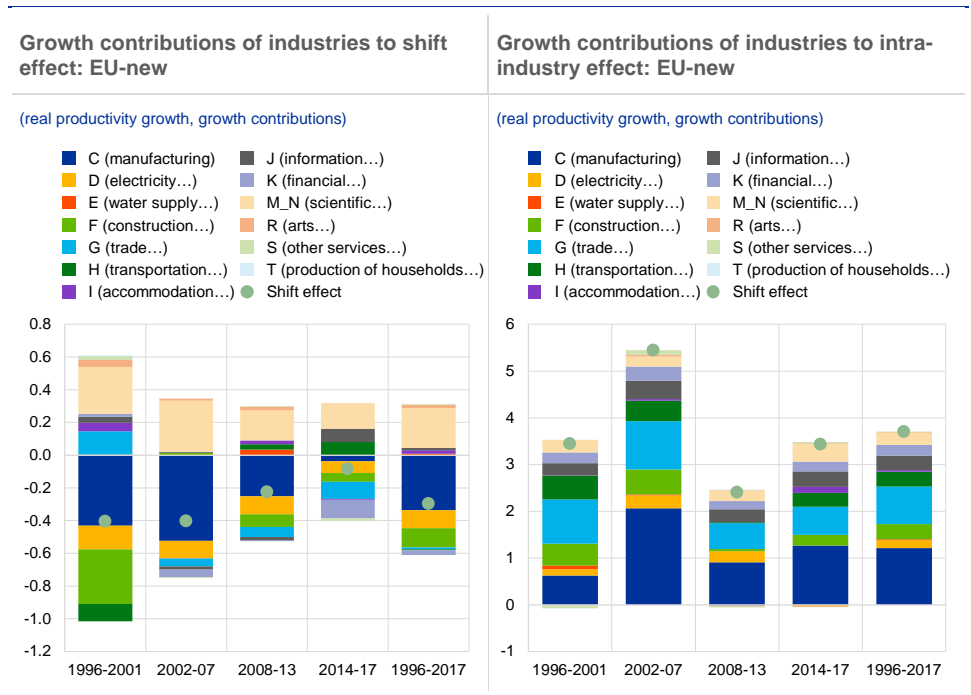
Chart A.3.1

Growth contributions of industries to shift effect: EU-old (left panel) and to intra-industry effect: EU-old (right panel)

Growth contributions of industries to shift effect: EU-old	Growth contributions of industries to intra-industry effect: EU-old

(percentage points) | (percentage points)

Legend:
- C (manufacturing)
- D (electricity…)
- E (water supply…)
- F (construction…)
- G (trade…)
- H (transportation…)
- I (accommodation…)
- J (information…)
- K (financial…)
- M_N (scientific…)
- R (arts…)
- S (other services…)
- T (production of households…)
- Shift effect

Sources: Eurostat NACE 2-Digit data, own calculations.

Chart A.3.2

Growth contributions of industries to shift effect: EU-new (left panel) and to intra-industry effect: EU-new (right panel)

Growth contributions of industries to shift effect: EU-new	Growth contributions of industries to intra-industry effect: EU-new

(real productivity growth, growth contributions) | (real productivity growth, growth contributions)

Legend:
- C (manufacturing)
- D (electricity…)
- E (water supply…)
- F (construction…)
- G (trade…)
- H (transportation…)
- I (accommodation…)
- J (information…)
- K (financial…)
- M_N (scientific…)
- R (arts…)
- S (other services…)
- T (production of households…)
- Shift effect

Sources: Eurostat NACE 2-Digit data, own calculations.

A.3.3   Sensitivity analysis

Table A.3.1

Shift-share analysis, sensitivity analysis

Differences between 1-digit and 2-digit analyses for EU20

	Reference analysis*): based on 2-digit NA data:				Reference analysis based on 1 -digit NA data:			
	Productivity growth	Intra-industry effect	Shift effect	Interaction effect	Productivity growth	Intra-industry effect	Shift effect	Interaction effect
1996-2001	1.6	1.7	0.0	0.0	1.9	1.9	0.0	0.0
2002-07	1.2	1.4	-0.1	-0.1	1.6	1.7	-0.1	0.0
2008-13	0.5	0.5	0.0	0.0	0.6	0.6	0.0	0.0
2014-17	1.3	1.4	-0.1	0.0	1.3	1.4	-0.1	0.0
1996-17	1.2	1.2	-0.1	0.0	2.8	1.4	1.4	0.0

Sensibility against different industry definitions (2-digit)

	Reference analysis adding real estate (NACE L):				Reference analysis adding agriculture (NACE A):			
	Productivity growth	Intra-industry effect	Shift effect	Interaction effect	Productivity growth	Intra-industry effect	Shift effect	Interaction effect
1996-2001	1.6	1.4	0.2	0.0	1.8	1.7	0.1	0.0
2002-07	1.3	1.3	0.0	0.0	1.6	1.5	0.1	-0.1
2008-13	0.7	0.7	0.0	0.0	0.6	0.6	0.1	0.0
2014-17	1.1	1.2	-0.1	0.0	1.4	1.4	0.0	0.0
1996-2017	1.2	1.1	0.0	0.0	1.4	1.3	0.1	0.0

	Reference analysis adding public sector (NACE O-Q):				Reference analysis using all sectors except NACE U:			
	Productivity growth	Intra-industry effect	Shift effect	Interaction effect	Productivity growth	Intra-industry effect	Shift effect	Interaction effect
1996-2001	1.5	1.5	0.0	0.0	1.6	1.4	0.2	0.0
2002-07	0.9	1.1	-0.1	0.0	1.3	1.1	0.2	0.0
2008-13	0.5	0.5	0.0	0.0	0.7	0.7	0.0	0.0
2014-17	1.0	1.1	-0.1	0.0	1.0	1.0	0.0	0.0
1996-2017	1.0	1.1	-0.1	0.0	2.4	1.2	1.1	0.1

Sensitivity against productivity measure ("heads") and against the selection of the countries for the EU20 aggregate (1-digit)

	References analysis based on "heads" (2-digit)**				Eurostat EU27 aggregate (1-digit) ***			
	Productivity growth	Intra-industry effect	Shift effect	Interaction effect	Productivity growth	Intra-industry effect	Shift effect	Interaction effect
1996-2001	1.4	1.5	0.0	-0.1	n.a	n.a	n.a	n.a
2002-07	1.2	1.4	-0.2	0.0	1.2	1.3	-0.1	0.0
2008-13	-0.1	0.0	0.0	0.0	0.8	0.7	0.1	0.0
2014-17	1.2	1.4	-0.1	0.0	1.2	1.3	-0.1	n.a
1996-2017	1.0	-0.1	0.0	0.0	n.a	n.a	n.a	n.a

* "Reference analysis": Based on the country sample and industries definition as used in the main text and described in this Annex.
** "Reference analysis" using heads instead of working hours.
*** Based on the industries definition of the reference analysis using the official Eurostat EU27 aggregate on the 1-digit NACE level.
Notes: A comparison with the results using the EU27 aggregate on the 2-digit level is not possible given the lack of data. Rounding errors may mean that the sum of components deviates from the totals.

A.3.4 Productivity level differences across sectors and countries

Chart A.3.3

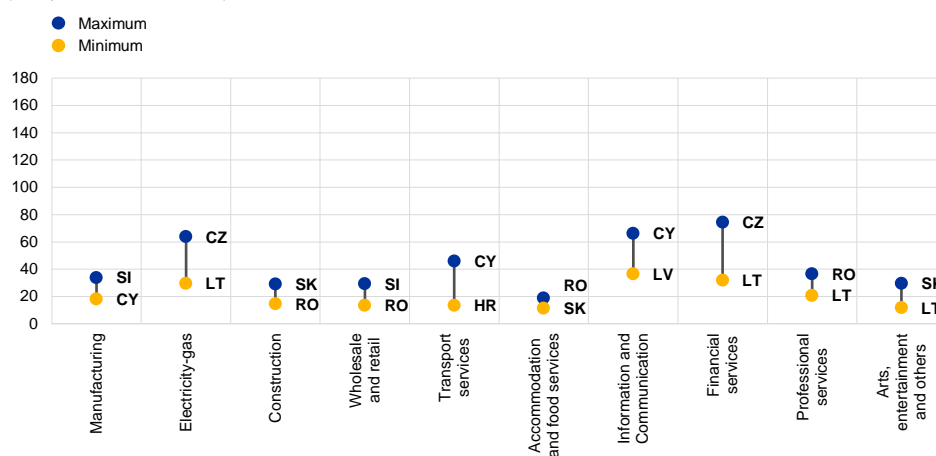EUR per hour worked, EU-old (2017)

(EUR per hour worked in 2017)

- Maximum
- Minimum
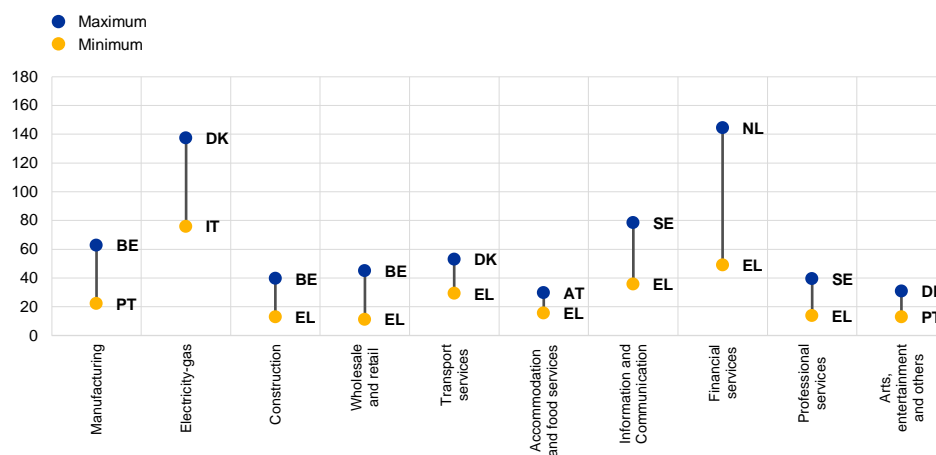
Sources: Eurostat, own calculations.

Chart A.3.4

EUR per hour worked, EU-new (2017)

(EUR per hour worked in 2017)

- Maximum
- Minimum

Sources: Eurostat, own calculations.

A.3.5 Productivity convergence across countries

Chart A.3.5

Productivity convergence in "Old-EU" and "New-EU" Member States

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Manufacturing

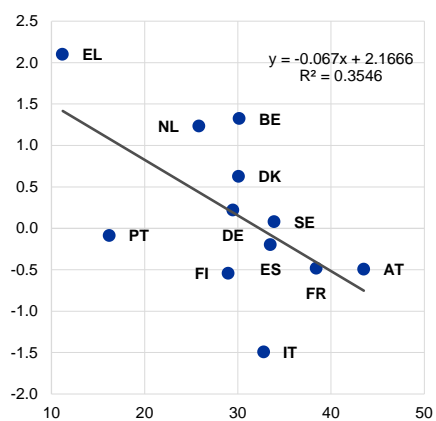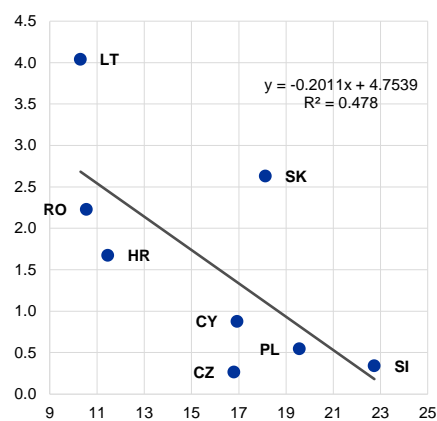| "OLD-EU" MEMBER STATES	"NEW-EU" MEMBER STATES
(y-axis: productivity growth 1996-2017 (percentages); x-axis: productivity level in 1996 (EUR per hours worked))	(y-axis: productivity growth 1996-2017 (percentages); x-axis: productivity level in 1996 (EUR per hours worked))

$y = 0.0084x + 2.5733$
$R^2 = 0.0041$

$y = -0.5118x + 10.24$
$R^2 = 0.7494$
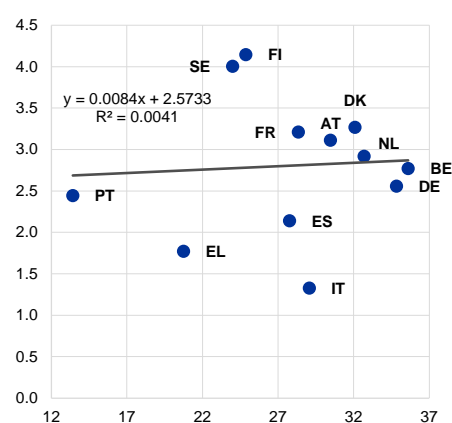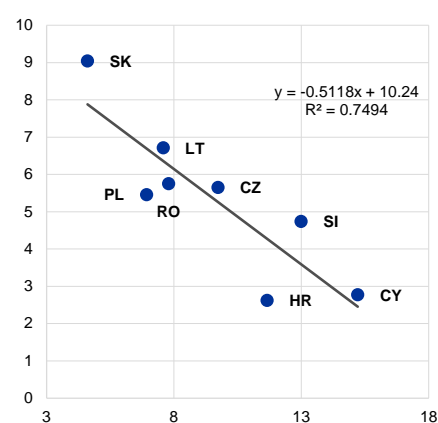
Electricity, gas and water supply

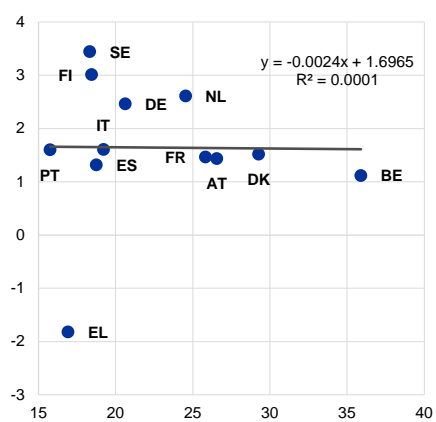| "OLD-EU" MEMBER STATES	"NEW-EU" MEMBER STATES
(y-axis: productivity growth 1996-2017 (percentages); x-axis: productivity level in 1996 (EUR per hours worked))	(y-axis: productivity growth 1996-2017 (percentages); x-axis: productivity level in 1996 (EUR per hours worked))

$y = -0.0406x + 4.3962$
$R^2 = 0.6273$
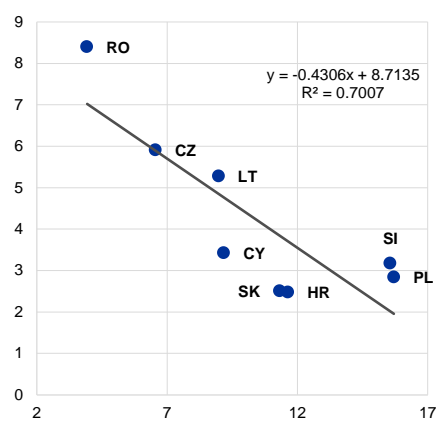
$y = -0.0651x + 4.4574$
$R^2 = 0.8019$
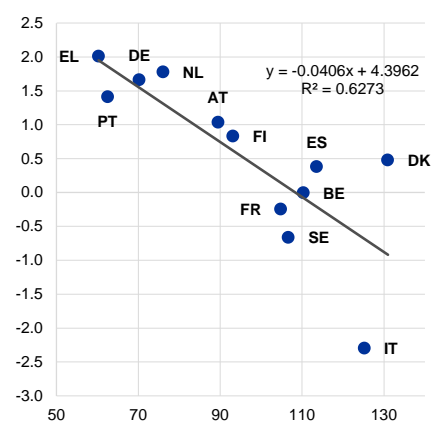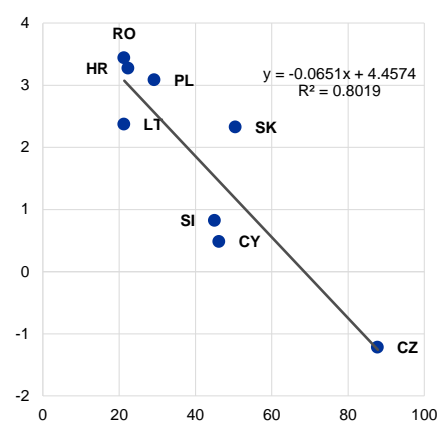
Construction

"OLD-EU" MEMBER STATES

(y-axis: productivity growth 1996-2017 (percentages); x-axis: productivity level in 1996 (EUR per hours worked))

y = -0.067x + 2.1666
R² = 0.3546

"NEW-EU" MEMBER STATES

(y-axis: productivity growth 1996-2017 (percentages); x-axis: productivity level in 1996 (EUR per hours worked))

y = -0.2011x + 4.7539
R² = 0.478

Wholesale and retail trade

"OLD-EU" MEMBER STATES

(y-axis: productivity growth 1996-2017 (percentages); x-axis: productivity level in 1996 (EUR per hours worked))
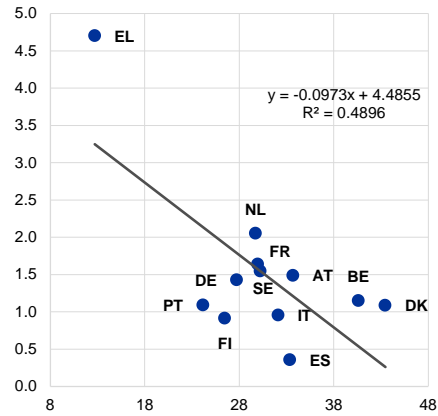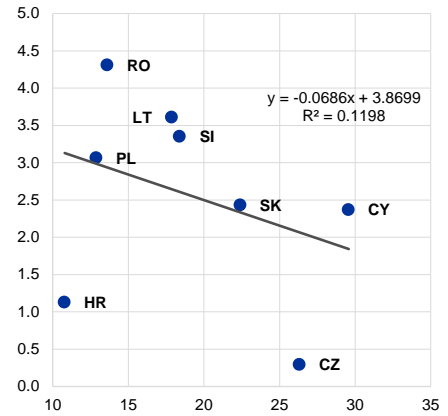

y = -0.0024x + 1.6965
R² = 0.0001

"NEW-EU" MEMBER STATES

(y-axis: productivity growth 1996-2017 (percentages); x-axis: productivity level in 1996 (EUR per hours worked))

y = -0.4306x + 8.7135
R² = 0.7007

Transportation and storage

"OLD-EU" MEMBER STATES	"NEW-EU" MEMBER STATES
(y-axis: productivity growth 1996-2017 (percentages); x-axis: productivity level in 1996 (EUR per hours worked))	(y-axis: productivity growth 1996-2017 (percentages); x-axis: productivity level in 1996 (EUR per hours worked))

y = -0.0973x + 4.4855
R² = 0.4896

y = -0.0686x + 3.8699
R² = 0.1198

Accommodation and food services

"OLD-EU" MEMBER STATES	"NEW-EU" MEMBER STATES
(y-axis: productivity growth 1996-2017 (percentages); x-axis: productivity level in 1996 (EUR per hours worked))	(y-axis: productivity growth 1996-2017 (percentages); x-axis: productivity level in 1996 (EUR per hours worked))

y = -0.0961x + 1.9256
R² = 0.6994

y = -0.3096x + 5.5159
R² = 0.7436

Information and communication services

"OLD-EU" MEMBER STATES

(y-axis: productivity growth 1996-2017 (percentages); x-axis: productivity level in 1996 (EUR per hours worked))
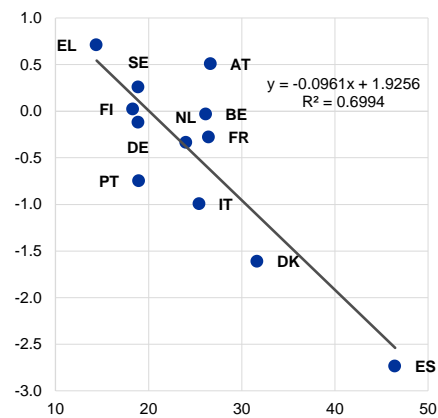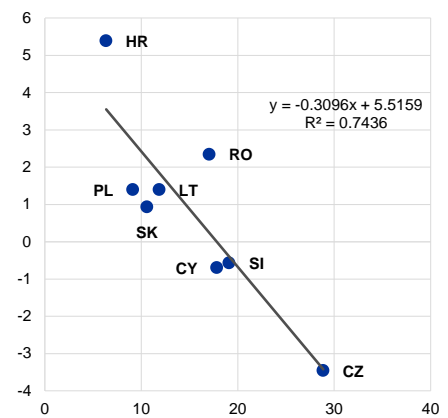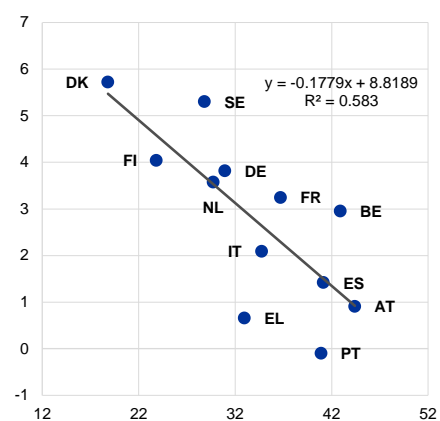
"NEW-EU" MEMBER STATES

(y-axis: productivity growth 1996-2017 (percentages); x-axis: productivity level in 1996 (EUR per hours worked))

y = -0.1779x + 8.8189
R² = 0.583

y = -0.2192x + 9.1389
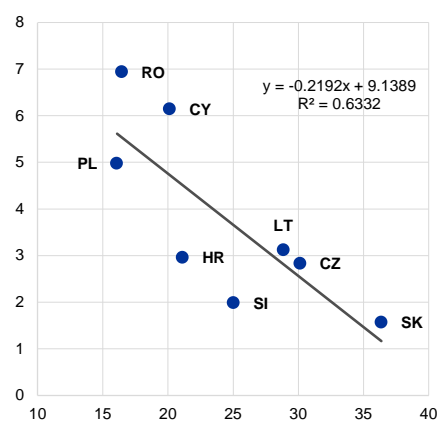R² = 0.6332

Financial and insurance activities

"OLD-EU" MEMBER STATES

(y-axis: productivity growth 1996-2017 (percentages); x-axis: productivity level in 1996 (EUR per hours worked))
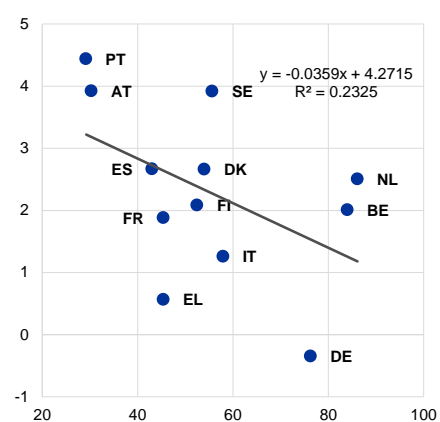
"NEW-EU" MEMBER STATES

(y-axis: productivity growth 1996-2017 (percentages); x-axis: productivity level in 1996 (EUR per hours worked))

y = -0.0359x + 4.2715
R² = 0.2325

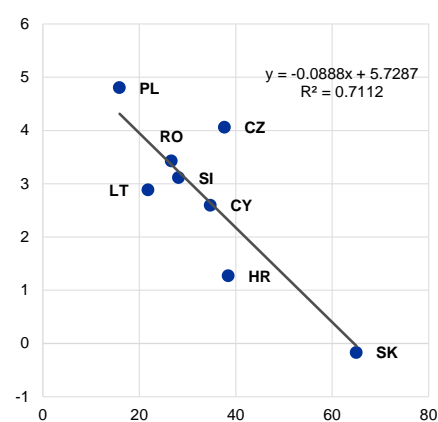y = -0.0888x + 5.7287
R² = 0.7112

Professional services

"OLD-EU" MEMBER STATES

(y-axis: productivity growth 1996-2017 (percentages); x-axis: productivity level in 1996 (EUR per hours worked))

"NEW-EU" MEMBER STATES

(y-axis: productivity growth 1996-2017 (percentages); x-axis: productivity level in 1996 (EUR per hours worked))

$y = -0.0189x + 0.0591$
$R^2 = 0.0226$

$y = -0.2894x + 7.7066$
$R^2 = 0.8477$

Art, entertainment and recreation; other service activities

"OLD-EU" MEMBER STATES

(y-axis: productivity growth 1996-2017 (percentages); x-axis: productivity level in 1996 (EUR per hours worked))
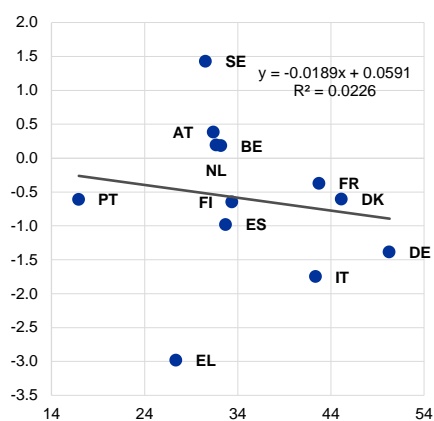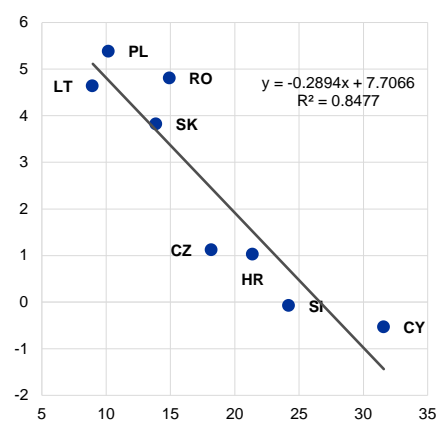
"NEW-EU" MEMBER STATES

(y-axis: productivity growth 1996-2017 (percentages); x-axis: productivity level in 1996 (EUR per hours worked))

$y = -0.0655x + 1.6261$
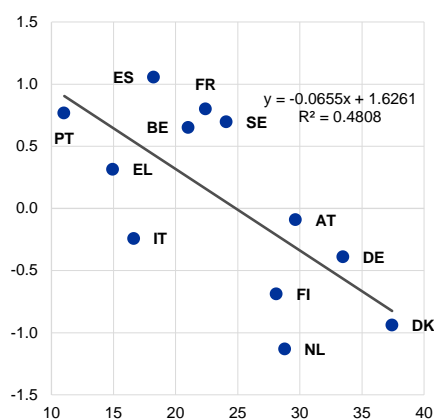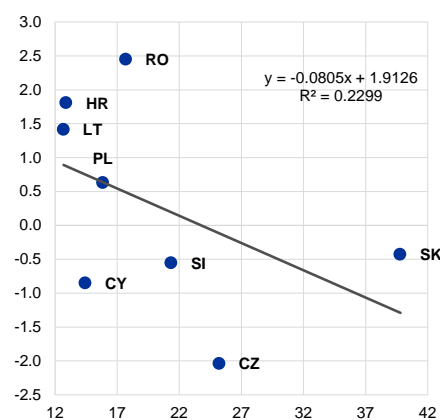$R^2 = 0.4808$

$y = -0.0805x + 1.9126$
$R^2 = 0.2299$

Sources: Eurostat, own calculations.
Notes: The black line is the regression line. The charts also include the regression equation and the R squared.

Annex 4: The role of within-firm productivity growth and resource reallocation

A.4.1 Data details

Table A.4.1 presents descriptive statistics on the number of firms and their total employment by country and year. Each dataset contains information on all active firms with at least one paid employee. Table A.4.2 shows the list of sectors used for the analysis.

Table A.4.1

Descriptive statistics

Country	Variable	Years			
		2007	2010	2013	2016
Belgium	Firms	83,117	83,229	8,4572	85,020
	Employment	1,402,425	1,406,721	1,435,932	1,477,980
Finland	Firms	85,301	84,714	86,376	75,117
	Employment	994,573	932,716	943,133	890,759
France	Firms	804,711	819,142	810,213	
	Employment	9,444,545	9,249,660	9,311,557	
Croatia	Firms	44,647	49,187	51,500	59,098
	Employment	631,429	610,389	595,740	644,322
Hungary	Firms	159,861	169,454	173,377	160,133
	Employment	1,554,445	1,507,434	1,526,108	1,621,699
Italy	Firms	1,045,456	1,065,882	1,097,238	1,095,488
	Employment	10,125,462	10,035,631	9,962,769	10,270,243
Netherlands	Firms	121,286	124,843	132,760	139,368
	Employment	2,574,207	2,645,168	2,784,850	2,964,890
Portugal	Firms	190,791	196,020	193,425	202,740
	Employment	1,941,453	1,925,261	1,793,409	1,970,875
Romania	Firms	302,945	273,545	256,703	270,935
	Employment	3,277,037	2,814,439	2,906,076	2,943,894

Table A.4.2

Sectors used in the analysis

	NACE Rev. 2, 2-digit sectors
Manufacturing	10 11 13 14 15 16 17 18 20 21 22 23 24 25 26 27 28 29 30 31 32 33
Trade	45 46 47
Accommodation	55 56
Other business activities	49 50 52 58 59 60 61 62 63 69 70 71 72 73 74 75 77 79 80 81 82

A.4.2 Contributions over time, by country

Chart A.4.1

Time dynamics of the contribution of each factor, by country
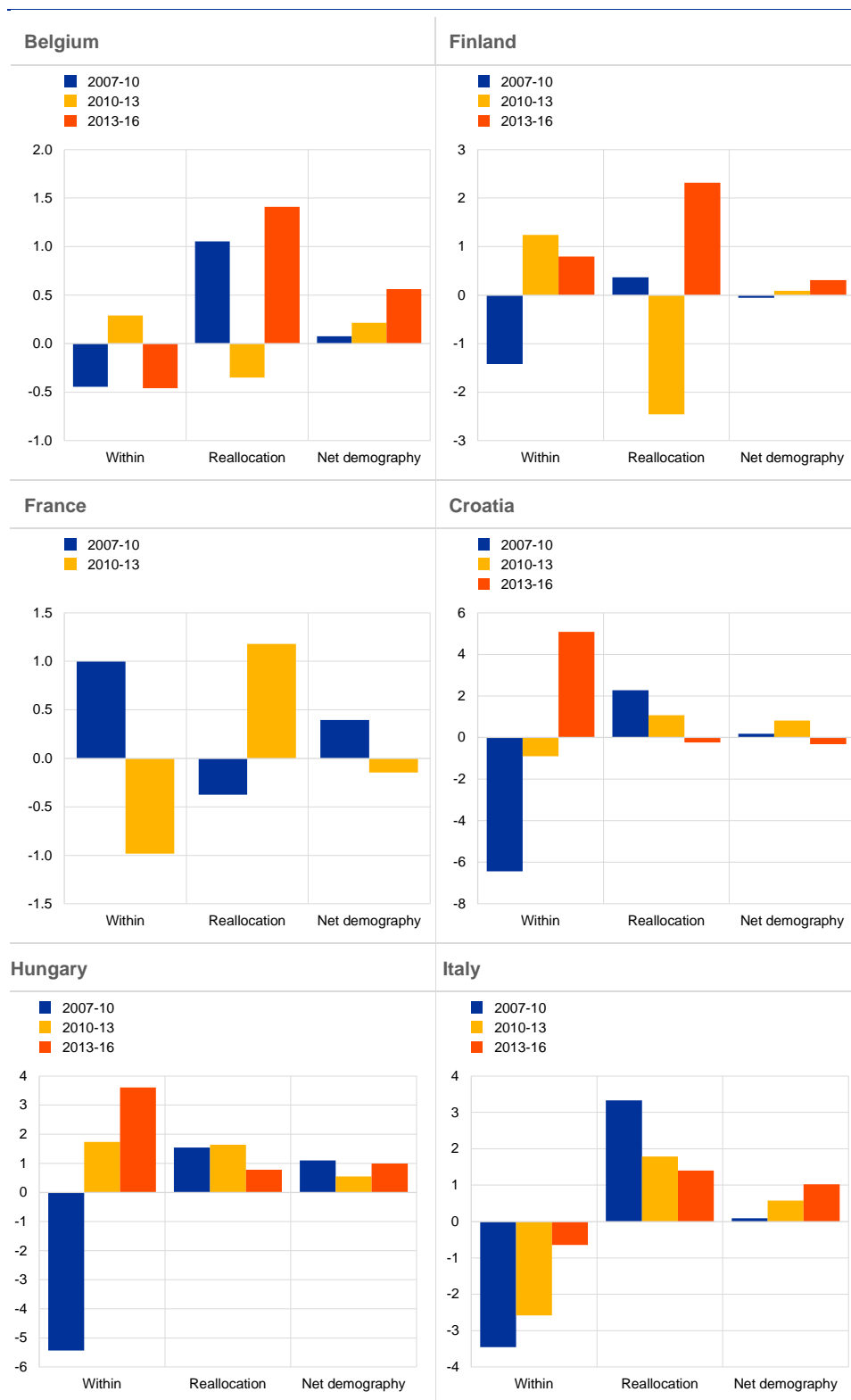
Netherlands

Portugal

Romania

Annex 5: Productivity growth in sectors with varying technology intensity
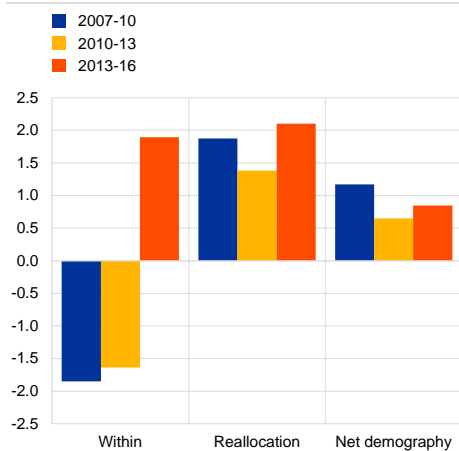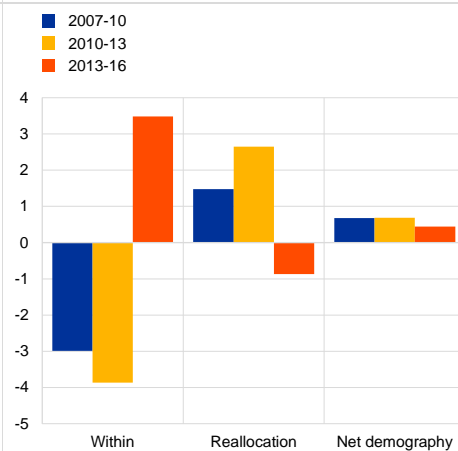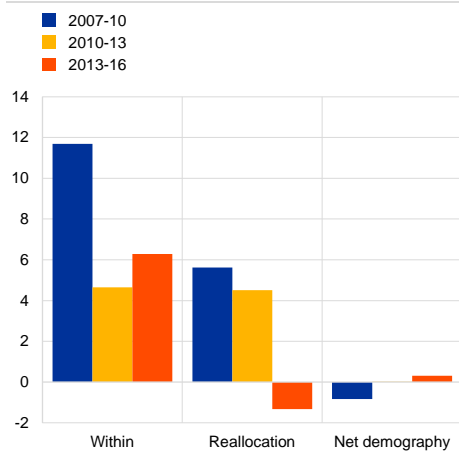
A.5.1 Sector division by technology intensity

To assess the role of technology in recent productivity growth in the EU, we depict labour productivity developments in sectors of varying technological intensity. We differentiate between sectors of high and low technology intensity, in line with recent analyses by Calvino et al. (2018) and the OECD (2019).

Table A.5.1

Breakdown of sectors by technology intensity

ISIC Rev.4 Industry denomination	Technology intensity
Manufacture of motor vehicles, trailers, semi-trailers and other transport equipment (C29-30)	High
Telecommunications (J61)	High
Computer, programming, consultancy and information service activities (J62-63)	High
Financial and insurance activities (K)	
Legal and accounting activities; activities of head offices; management consultancy activities (M69-70)	High
Advertising and market research; other professional, scientific, and technical activities; veterinary activities (M73-75)	High
Administrative and support service activities (N)	High
Other service activities (S)	High
Manufacture of food products; beverages and tobacco products (C10-12)	Low
Electricity, gas, steam and air conditioning supply (D)	Low
Water supply; sewerage, waste management and remediation activities (E)	Low
Construction (F)	Low
Transportation and storage (H)	Low
Accommodation and food service activities (I)	Low

Sources: Calvino et al. (2018) and OECD (2019).
Note: ISIC is the International Standard Industrial Classification of All Economic Activities (United Nations).

A.5.2 Labour productivity divergence across sectors of varying technology intensity

An analysis of the divergence of labour productivity levels reveals cross-sector disparities at EU27 level. Specifically, since divergence measures the distance in labour productivity between the frontier country and the weakest performer of the EU27, we see that: (i) for high technology-intensive sectors, telecommunications showed the largest divergence; and (ii) for low technology-intensive sectors, electricity and gas had the largest divergence (Charts A.5.1).

Chart A.5.1

Labour productivity divergence in high technology-intensive sectors (left panel) and low technology-intensive sectors (right panel), EU27 (2017)
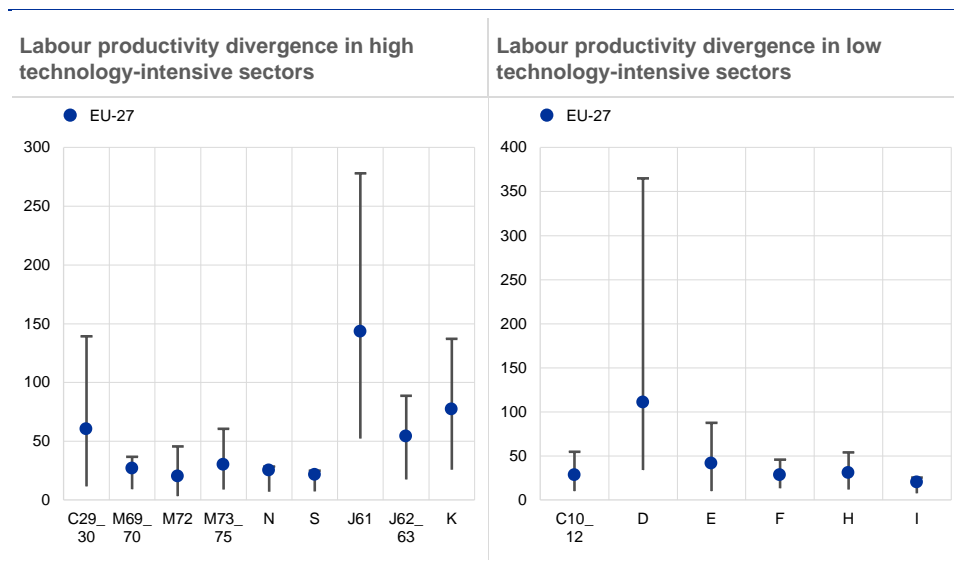
Sources: Eurostat, own calculations.

Given the large dispersion in productivity levels across countries, we also studied the dispersion patterns for the EU-old and EU-new countries separately and over time. The results indicate that there has been some convergence in the EU-new countries in terms of labour productivity since 2000. In fact, most sectors display convergence in the EU-new countries, with the exception of some non-high-intensity sectors (Chart A.5.2, left panel). As for the EU-old countries, there are fewer signs of productivity convergence in high technology-intensive sectors, corroborating previous evidence that only a few sectors show convergence, while others show no convergence at all (Chart A.5.2, left panel).

Chart A.5.2

Labour productivity divergence in high technology-intensive sectors in EU-new countries (left panel) and EU-Old countries (right panel)

Labour productivity divergence in high technology-intensive sectors in EU-new countries

Labour productivity divergence in high technology-intensive sectors in EU-Old countries
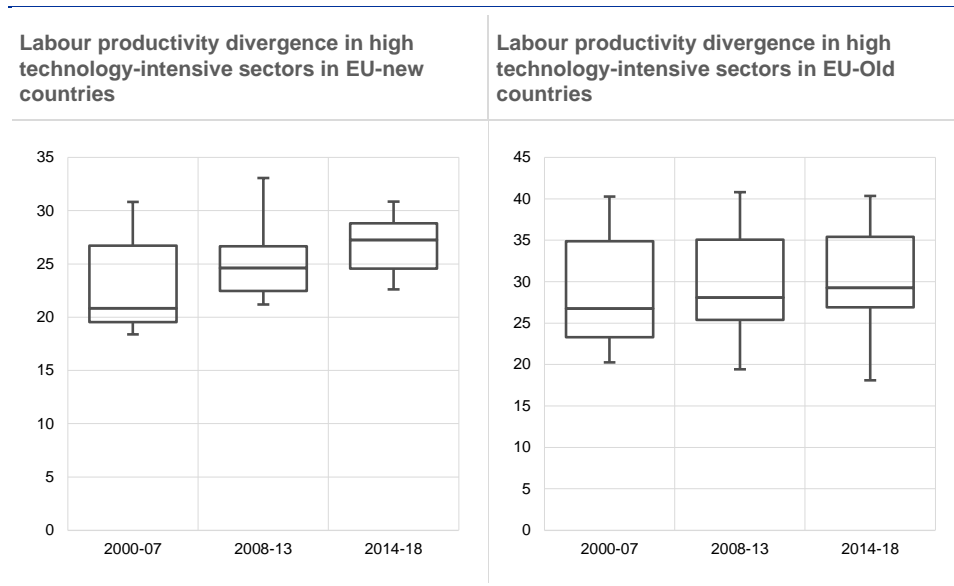
Sources: Eurostat, own calculations.

A.5.3   Labour productivity growth across sectors of varying technology intensity

Chart A.5.3 (left panel) shows that, also in the light of evidence from Section 2.2, most of the new-EU countries exhibited higher productivity growth rates in low technology-intensive sectors such as electricity and gas supply and manufactures of food products, beverages and tobacco than in high technology-intensive sectors. Chart A5.3 (right panel) shows that across the old-EU countries the picture is much more mixed.

Chart A.5.3

Labour productivity cumulative growth in new-EU countries (left panel) and old-EU countries (right panel) and in the United States (2017 relative to 2000)

Labour productivity cumulative growth in new-EU countries and in the United States (2017 relative to 2000)

Labour productivity cumulative growth in old-EU countries and in the United States (2017 relative to 2000)
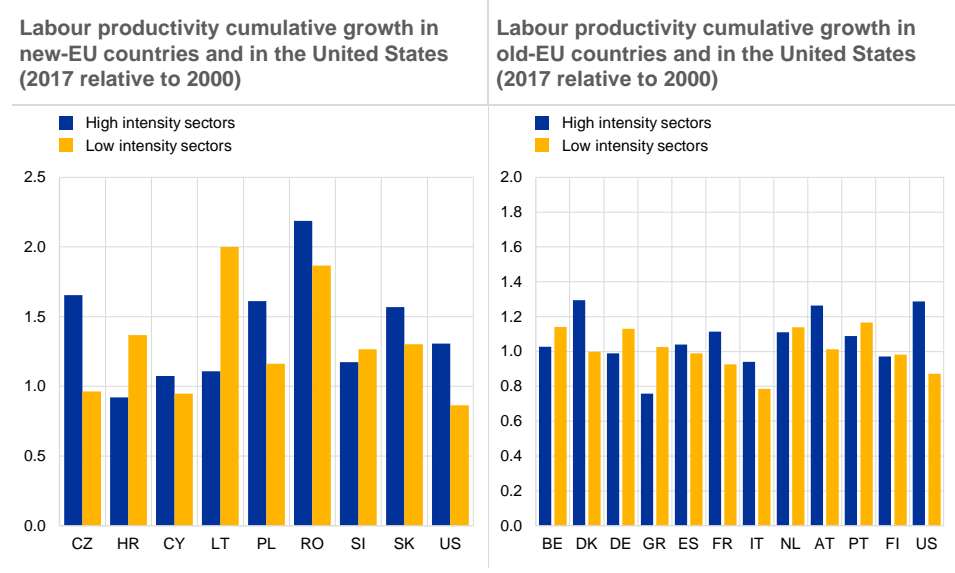
Source: Eurostat, own calculations.

Annex 6: Technology creation and diffusion

A.6.1 Macroeconomic indicators of technology creation and diffusion

A breakdown of total R&D expenditure based on the two sectors with the highest contributions, the business enterprise and government sectors, indicates that the United States clearly outperforms the EU27 in both sectors (Chart A.6.1).

Chart A.6.1

R&D expenditure in the business enterprise and government sectors (percentage of GDP)

(yearly averages 2003-2007 and 2014-2018, indicated by the filled and unfilled circles, respectively)
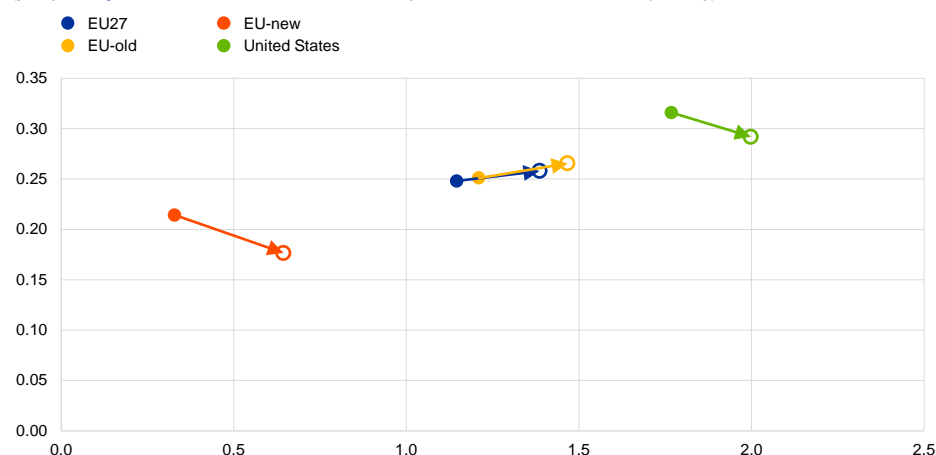


Sources: Eurostat, own calculations.

In addition to patent applications, firms' innovation activity can be measured using the share of firms with product and/or process innovations, expressed as a percentage of their turnover to total turnover (Charts A.6.2). The data are taken from Eurostat's Community Innovation Survey (CIS) and are therefore only available for EU countries.[129] According to this survey, the percentage of innovative firms in the EU slightly decreased between 2004 and 2016. This can be attributed to stabilisation

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[129] Caution is needed when studying these survey data, since the CIS has undergone various changes over time in terms of context and scope. Moreover, due to changes in the NACE classification, there is a break in the timeline between 2006 and 2008; it is impossible to estimate the impact of these changes. Caution should also be observed when looking at the results. First, the very high percentage of innovative firms (representing 60-80% of total turnover) observed in the EU28 likely shows that this indicator captures a rather wider concept of innovation than just newly-created technology. As it refers to all firms introducing a product and/or process innovation, it also includes a large number of firms adopting technological advances developed and previously used elsewhere. Therefore, this share also captures technology diffusion. Although technology creation and diffusion both have a positive impact on this indicator, it is impossible to parse these out from the CIS data. The observed decrease in the share of innovative firms might therefore be the result of a reduction in technology creation, weaker technology diffusion, or both. In addition, the data are derived from a survey where respondents are asked to evaluate the innovative capacity of their firm, and it is therefore possible that these figures overestimate the real proportion of innovative firms.

in the industrial sector, while innovation activity in the services sector decreased. The survey does not point towards a catching-up of the new EU Member States.

Chart A.6.2

Product and/or process-innovative firms in industry and services (left panel), in industry (middle panel), in services (right panel)
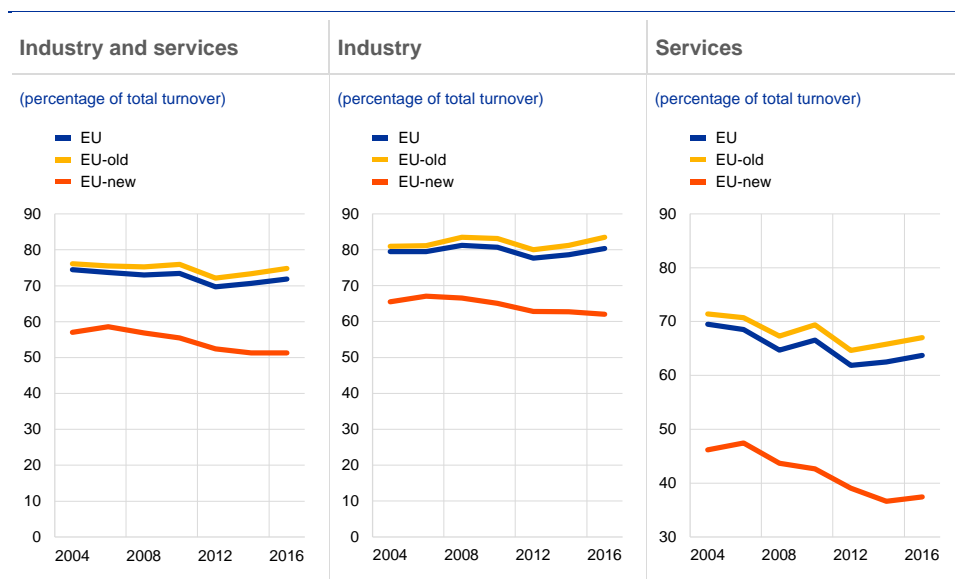
Source: Eurostat (CIS).
Note: Weighted average of EU countries with data availability for 2014-16.

Technology diffusion, measured by the technology content of European exports and imports, shows a gradual rise since 2007 (Chart A.6.3). The difference between EU-old and EU-new economies narrowed during this period but is still significant with respect to high-tech exports. Consistently with the view that the EU-new economies are catching up on the back of rapid technology adoption facilitated by their involvement in international trade, the share of high-tech imports into the region is significantly higher than that of high-tech exports. The share of high-tech imports and exports in EU-old countries is similar and stands at about 14% of total trade.

Chart A.6.3

High-tech trade, imports (left panel) and exports (right panel)

Imports	Exports
(percentage of value of total trade)	(percentage of value of total trade)
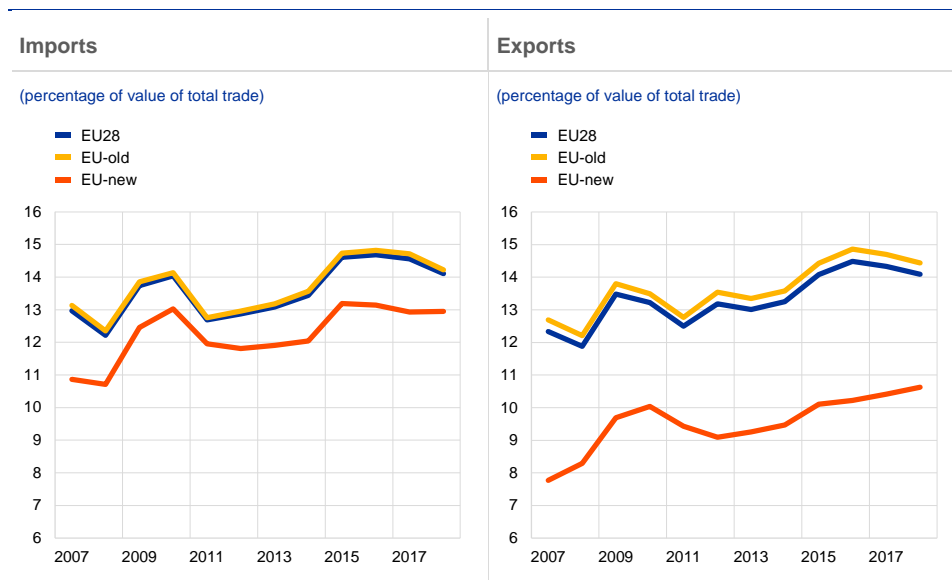
Source: European Commission.
Note: Intra and extra-EU trade, weighted averages of all EU countries.

A.6.2 Analysis of technology creation and diffusion using firm-level data

Firm-level data is taken from two sources: ORBIS and iBACH. ORBIS is a database from Bureau Van Dijk and contains accounting information from private companies worldwide. iBACH, from the Bank for the Accounts of Companies Harmonized (BACH) database, is a European Commission initiative. It includes detailed balance sheet information and revenues for non-financial European enterprises. These two sources were merged, and the final dataset includes firms with at least one employee (excluding self-employed) from Belgium, France, Germany, Italy, Spain and Portugal for the period 2005 to 2017.

As mentioned by Kalemli-Özcan et al. (2015), ORBIS has limited coverage, missing information and poor representativeness as regards small and young firms, and regarding some services sectors. To work around this, we used the cleaning procedures explained by the authors, combined with additional cleaning steps as given in Gal (2013). Variables that include implausible values, for example a negative number of employees or assets, were replaced with missing values. In addition, records with missing information on the number of employees, wages, sales or assets were removed. To avoid double-counting of data reported by the parent company and its subsidiaries, we considered only corporations with unconsolidated accounts. Nominal variables were deflated, using industry-level PPP conversions from OECD Structural Analysis (STAN) and EU KLEMS databases, to allow values to be compared over time and across countries (Gal, 2013).

The merging of the ORBIS and iBACH datasets is based on firms' tax-identification number. This enables duplicates to be removed, with priority given to the data source with a higher degree of completeness. From this merged dataset, firms other than corporations or with a legal status of self-employed, or both, were eliminated. To account for outliers, we removed the 1% and 5% upper and lower tails for labour productivity and TFP levels and growth rates, respectively. The final dataset includes a total of 0.6 million active firms for 2005, rising to 1.5 million in 2017.[130]

To overcome sample biases in size and sector distribution, we used resampling weights constructed on the basis of the number of firms by size class (as defined by the number of employees), industry, country and year. We define the weight w_{jt} for firm j at year t as the ratio between the total number of firms F_{cist}^{BDS} for country c, industry i, size-class s and year t as in the structural business statistics from Eurostat and the number of active firms present within our merged dataset in the same cell, F_{cist}. Formally, $w_{jt} = F_{cist}^{BDS}/F_{cist}$, which will always be greater than or equal to one.

Table A.6.1 shows the impact of weights on the representativeness of the sample by size class. The table shows the dataset without ("micro raw") and with ("micro weighted") the resampling weights and compares these with the population ("Eurostat").

Table A.6.1

Distribution of firms by size at ORBIS-iBACH (2017)

	Less than 10			10 to 20			20 to 50			50 to 250		
	Euro-stat	Micro raw	Micro weighted	Euro-stat	Micro raw	Micro weighted	Euro-stat	Micro raw	Micro weighted	Euro-stat	Micro raw	Micro weighted
Belgium	94.7	96.9	94.6	2.9	2	2.9	1.6	1	1.6	0.7	0.2	0.7
Germany	82	20.4	62.2	10.1	11.9	4.2	5	22.8	5	2.4	35.9	20
Spain	94.6	97.7	94.6	3.1	1.6	3.1	1.6	0.6	1.6	0.6	0.1	0.6
France	95.1	67.6	95.1	2.6	16.9	2.6	1.6	12	1.6	0.6	3.3	0.7
Italy	94.8	94.1	94.6	3.3	4.4	3.4	1.3	1.3	1.3	0.5	0.3	0.5
Portugal	95.3	97.7	92.3	2.6	1.7	4.1	1.4	0.5	2.3	0.6	0.1	1

Sources: Own calculations with ORBIS-iBACH and Eurostat's business demography statistics.

TFP estimation follows Levinsohn and Petrin's (2003) methodology with Ackerberg, Caves and Frazer's (2015) correction using the value-added approach. The production function is estimated by country and 2-digit industry level (pooling all firms with positive value added). Chart A.6.4 compares the resulting weighted average TFP growth rates in the sample with that in the macro data (AMECO and EU KLEMS).

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[130] For Spain, France, Italy and Portugal – and to a limited extent Belgium – the database provides information on a significant proportion of the firms in their respective company population. For Germany, on the other hand, only a relatively small number of large companies listed in the ORBIS database are covered, as Germany does not take part in the compilation of the iBACH database, which forms the basis of the data for the other countries.

Chart A.6.4

Macroeconomic TFP growth in Europe (2005-17) based on three datasets

(y-axis: average annual TFP growth; percentages)

■ EU12 (EU KLEMS)
■ EA (AMECO)
■ 6 EA countries (iBACH-Orbis)
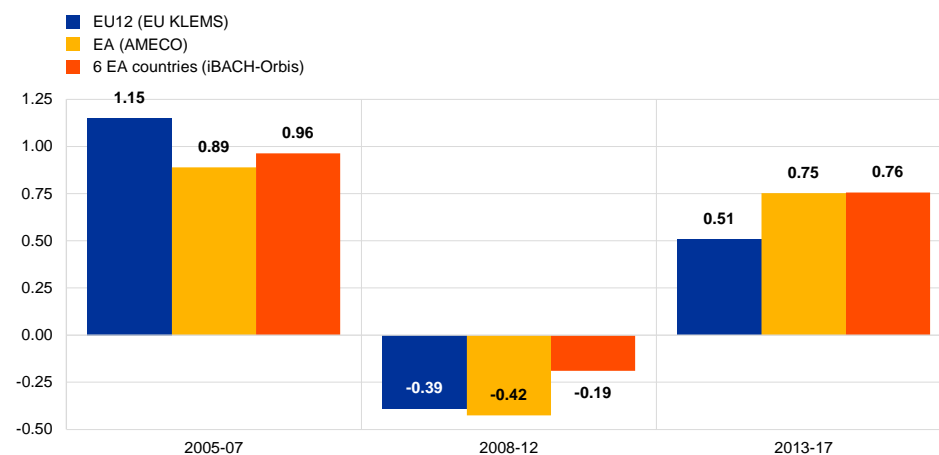
Sources: EU KLEMS, AMECO and ECB iBACH-Orbis database and own calculations.
Notes: The figure shows average annual macroeconomic TFP growth rates. For the EU12 and EA the TFP growth rates based on national accounts data are given. The macroeconomic TFP growth rate, which is based on the iBACH-Orbis data, is derived as the employment-weighted average firm-specific growth rate.

In line with other studies, we flagged frontier and laggard firms by pooling all firms across the six countries and ranked them according to their TFP level. Frontier firms were defined as the euro area top 5% TFP firms in a given sector, narrowly defined at the 4-digit level.[131] [132] Laggard firms, in turn, were approximated by the median firm in the sector from the pooled sample.

A.6.3   Characteristics of frontier and laggard firms in the euro area

Table A.6.2 presents summary statistics for frontier and non-frontier firms in manufacturing and services.

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[131] It should be noted that the makeup of the group of frontier firms can change over time. This is in the light of fluctuations at the top: some firms may become highly productive and advance to the technology frontier, while other firms may fall behind.

[132] Since the dataset includes only European firms, these represent the European technology frontier. Other studies examine the importance of global (e.g., Andrews et al. 2015, 2019 or Bahar 2018) or national (e.g., De Mulder and Godefroid, 2018; Lotti and Sette, 2019; Cette et al., 2018; Heuvelen et al., 2018; Le Mouel and Schiersch, 2020; Decker et al., 2016) productivity frontiers.

Table A.6.2

Characteristics of European frontier and non-frontier firms in manufacturing and services

	Manufacturing				Services			
	Frontier firms		Non-frontier firms		Frontier firms		Non-frontier firms	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
TFP growth (%)	2.7	2.9	0.5	0.6	2.6	2.6	0.4	0.5
TFP level	1.8	1.7	1.0	1.0	2.3	1.9	1.0	1.0
Employment (L)	33.6	10.7	5.7	6.0	9.7	5.6	3.5	3.0
Tangible capital/L	47,101	33,777	21,010	14,884	489,643	32,198	41,555	9,360
Intangible capital/L	13,598	5,264	435	142	15,945	8,100	2,435	38
Tangible capital / total capital	0.83	0.87	0.98	1.00	0.77	0.83	0.97	1.00
Profits	1,607,560	222,658	23,559	15,000	339,160	120,868	9,825	10,210
Debt / equity	10.3	6.6	2.4	1.9	52.8	7.7	1.9	1.7
Age (years)	15.3	14.3	14.4	14.0	13.3	11.5	11.3	11

Source: ECB iBACH-Orbis Database and own calculations.
Note: For each of the variables the mean and the median value of frontier or non-frontier firms is given.

Chart A.6.5

Relationship between frontier firm age and frontier TFP growth
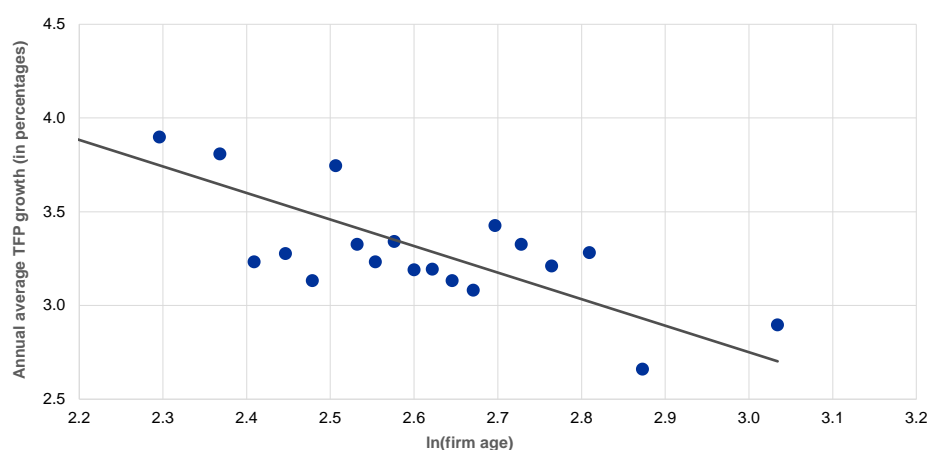
Sources: ECB iBACH-Orbis database and own calculations.
Notes: The figure shows the relationship between the log (average age) of frontier firms and their TFP growth rates when controlling for sector-specific and year-specific fixed effects. A "binned scatterplot" is shown. Only the years 2005-07 and 2013-17 are included.

Annex 7: Meta-analysis

A.7.1   Data and meta-analysis methodology

The goal of meta-analysis is to estimate the "true" effect of misallocation on aggregate TFP. If all empirical studies were equally precise and unbiased, we could simply compute the unweighted mean of effects. For our sample, the unweighted average TFP loss resulting from resource misallocation would be quite substantial and close to 50% (standard error is 1.5%). However, estimated TFP effects vary widely and depend largely on a given study's characteristics. Hence, when reviewing the empirical literature those study characteristics have to be accounted for. The TFP loss resulting from this exercise is what we call the "true" TFP effect of misallocation.

The majority of the 58 studies report multiple estimates. However, estimates from the same study are likely to be correlated. We can view the data as a highly unbalanced panel dataset with the number of cross-section units equal to the number of primary studies. We take into account intra-study correlation of reported effect size by a random effects panel data model. We assume that due to unobserved heterogeneity, each primary study has its own effect size, which by itself is a random draw of an underlying distribution. The generalised least squares estimate of its population mean is equal to 39.4% (standard error is 4.2%). Although smaller than the unweighted sample mean, this estimate still indicates that the TFP loss from misallocation could be potentially large.[133]

We use meta-regressions to explain why the estimated TFP loss varies within and between primary studies. We followed as closely as possible the best practices for meta-analysis as described by Nelson and Kennedy (2008). We ran the following regression model to control for the methodological differences across misallocation studies:

$$y_{ij} = \mu + \beta' x_{ij} + \alpha_i + \varepsilon_{ij}$$

where y_{ij} is the jth productivity loss estimate of primary study i, x_{ij} are meta-regressors measuring study characteristics and β' their marginal effects, μ is the overall mean effect size, α_i is a study specific effect and ε_{ij} is an idiosyncratic error term. The meta-regressors explain systematic variation between studies. We distinguish the following potentially relevant study characteristics: (1) benchmark TFP; (2) direct/indirect approach; (3) country; and (4) year of publication.

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[133]   It should be noted, however, that there is an ongoing debate in the literature on (mis)specification of the models underlying such TFP loss calculations (Haltiwanger et al, 2018; Bils et al., 2020).

Annex 8: Entry and exit of firms

A.8.1   Treatment of sample entries and exits

The database used for this analysis is identical to the one used in Section 3.2.2, but the treatment of the data is different: working with entries and exits requires additional adjustments. The reasons vary from country to country, but they mainly lie in the fact that new firms do not submit balance sheet information, or do so only after a delay. Additionally, many firms disappear from the sample only to reappear years later, perhaps because they were reactivated, or because firms experiencing difficulties forget to submit their accounts. Hence, absence from the sample does not necessarily mean that a firm has exited the market. To factor in these possible biases, we took a two-step approach. First, we flagged entries, exits and incumbents for each year. Entries are firms aged 0 or one when they first appeared in the sample and not listed as dissolved or inactive. Exits are firms whose final appearance in the sample was not followed by reactivation in the subsequent 2 years and whose ORBIS status was compatible with an exit (inactive, dissolved etc.). For firms sourced from iBACH, we simply flagged those firms whose final appearance in the sample was not followed by reactivation in the subsequent 2 years. Second, we applied resampling weights such that the share of entries and exits (and therefore of incumbents) by country, industry and year were the same as in the population, as provided by business demography statistics of EUROSTAT. Note that these weights are different from those used in Section 3, where all firms were given similar treatment regardless of their entry/exit/incumbent status. The results of the weighting system are given in the main text and in Chart A.8.1, showing the employment share of entries and exits across countries in the raw and weighted data compared with those provided by EUROSTAT.

Chart A.8.1

Employment share of entries and exits, raw data, weighted sample and population

(percentage of total employment)
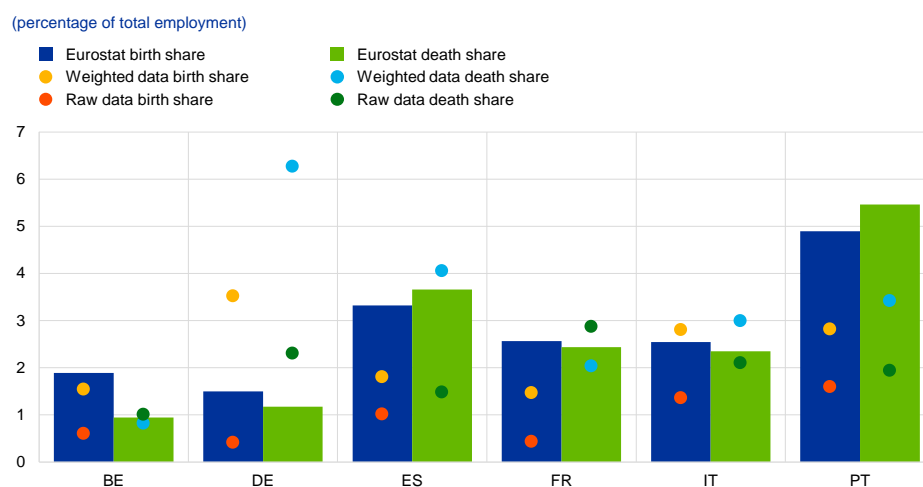
Sources: Own calculations using ORBIS-iBACH data and Eurostat business demography indicators.

A.8.2   Entry and exit rates across industries

Chart A.8.2

Entry and exit rate of corporations, industrial sector
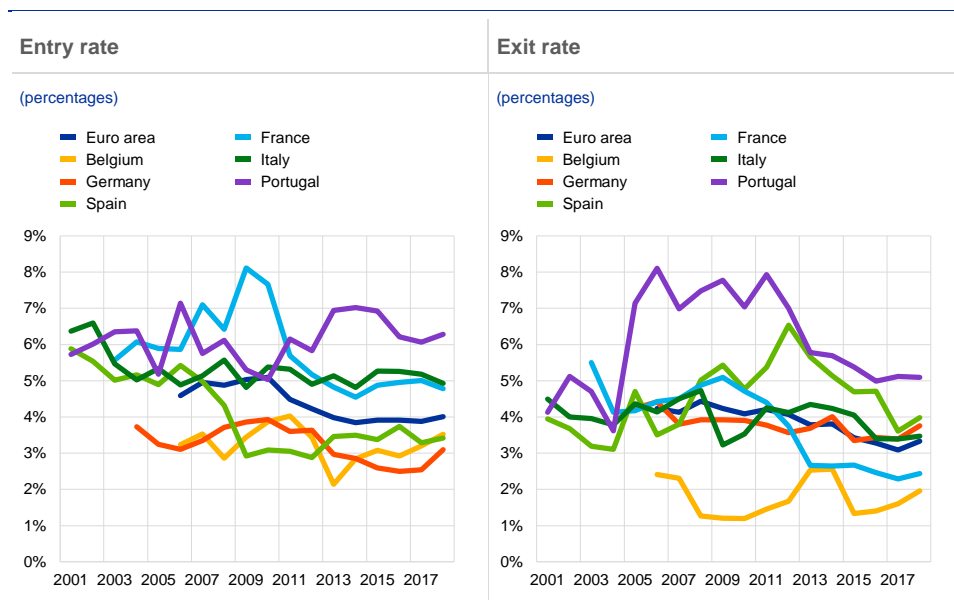
Sources: Own calculations using Eurostat business demography indicators.

Chart A.8.3

Entry and exit rate of corporations, business services sector
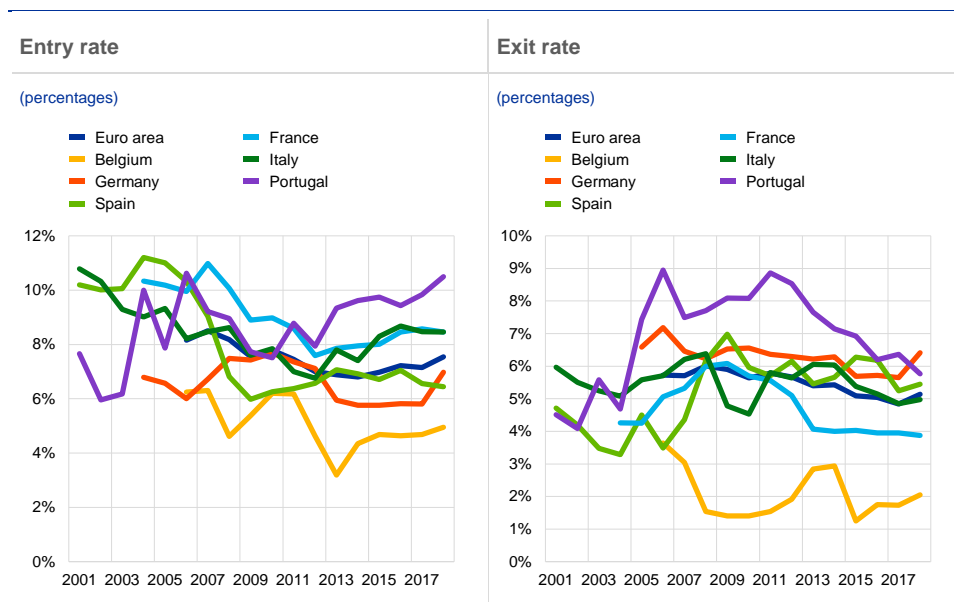
Sources: Own calculations using Eurostat business demography indicators.

Chart A.8.4

Entry and exit rate of corporations, construction sector

Entry rate	Exit rate
(percentages)	(percentages)

Legend (both charts):
- Euro area
- Belgium
- Germany
- Spain
- France
- Italy
- Portugal
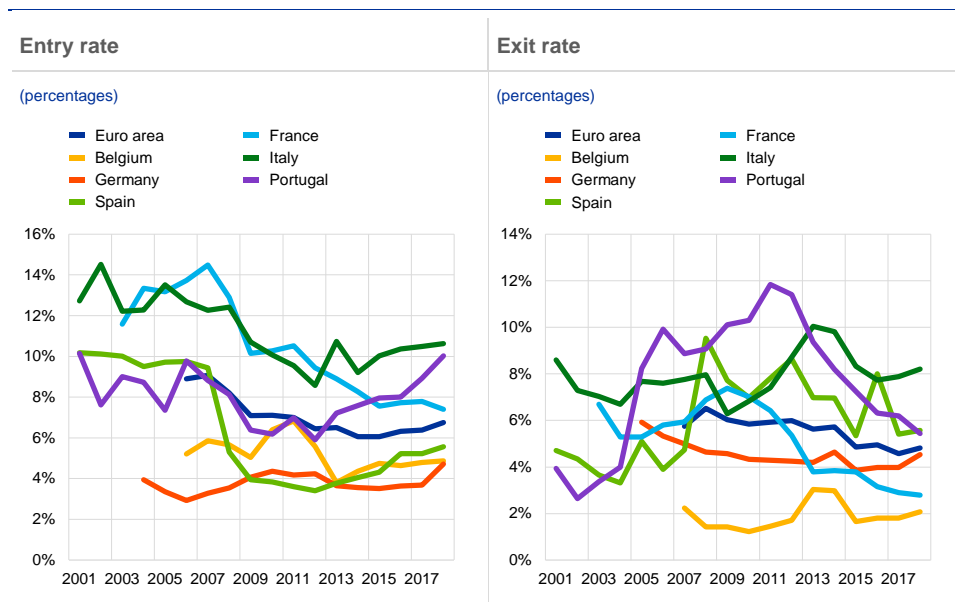
Sources: Own calculations using Eurostat business demography indicators.

Annex 9: Zombie firms

A.9.1   Data details

To ensure that the results were comparable and reliable, the analysis used representative firm-level data for six EU countries in a micro-distributed exercise. The data were taken from financial statement and business register statistics provided by the national data sources in the selected countries: Belgium, Croatia, Italy, the Netherlands, Portugal and Finland (see table below). The sample period varied between countries (Belgium 1998-2018, Croatia 2004-18, Italy 2001-17, Netherlands 2002-17, Portugal 2008-16 and Finland 1999-17). We focused on non-financial private business sector enterprises with at least one employee at the 2-digit sector level (NACE Rev. 2 sectors 10–63 and 68–82). When analysing zombie demographics, the dataset needs to be complete at country level, otherwise the firm death rate cannot be estimated. In many countries, only datasets based on sampling were available. This led to firms being dropped from the data due to sample attrition, so that the death rate could not be accurately estimated.

Table A.9.1

Data sourced and coverage per country

Country	Data source	Sample period	Average number firms/year
Belgium	National Bank of Belgium Central Balance Sheet Office	1998-2018	73,000
Croatia	Financial Agency (fina)	2004–18	17,000
Finland	Statistics Finland	1999-17	64,000
Italy	Cerved Centrale dei Bilanci, Istituto Nazionale della Previdenza Sociale (INPS)	2001-17	152,000
Netherlands	Statistics Netherlands	2002-17	66,000
Portugal	Central Balance Sheet Database	2006-17	104,000

A.9.2   Robustness of results to the chosen zombie definition

Chart A.9.1 shows the incidence of zombie firms over time in Italy and Finland using EBIT and EBITDA respectively to define a zombie. To exclude start-ups and young firms from the sample, only firms that had been active for at least ten years were considered.

Chart A.9.1

Incidence of zombie firms in Italy and Finland as defined using EBIT and EBITDA
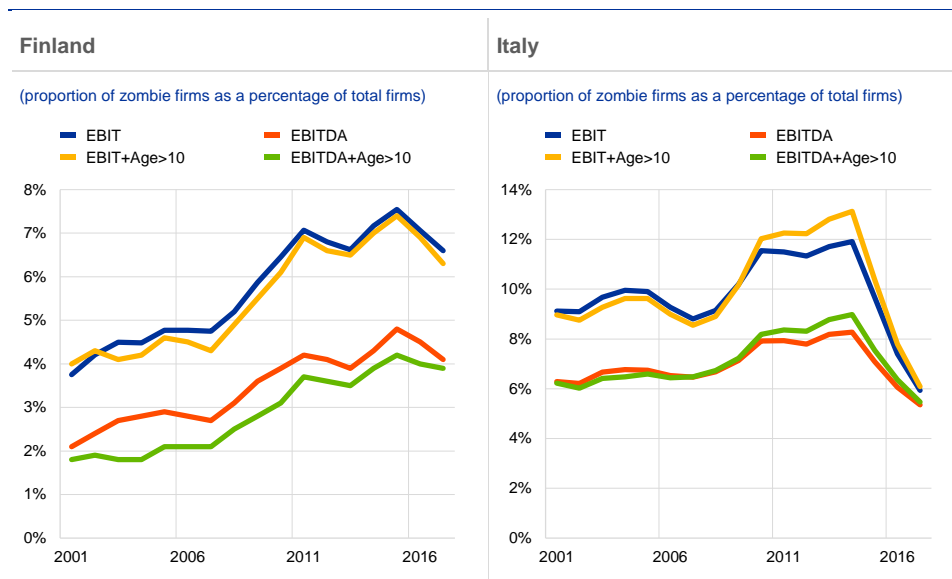
Sources: Cerved Centrale dei Bilanci, Istituto Nazionale della Previdenza Sociale, Statistics Finland and authors' calculations.
Notes: Zombies are defined as firms for which the ratio of EBIT (or EBITDA) to interest paid + financial charges is less than one (EBIT/(interest+financial charges)<1) for three consecutive years. Manufacturing includes NACE Rev. 2 sectors 10-33 and private services includes sectors 45-63 and 69-82.

A.9.3   Zombie dynamics in Germany

The analysis for Germany used firm-level data from Deutsche Bundesbank's Financial Statements Data Pool to assess the quantitative importance of zombies in the low-interest-rate environment. Zombie firms are defined as firms whose operating and investment income over interest and similar expenses is less than one in the reporting year and the two preceding years. Results suggest that the share of zombie firms has decreased in recent years. Zombies accounted for some 7.3% of all firms in 2007, a figure that fell to around 6% in 2017; this was significantly lower in comparison with earlier years, when interest rates were much higher.

Chart A.9.2

Share of zombie firms in Germany

(as a percentage of all non-financial firms)

■ Share of firms
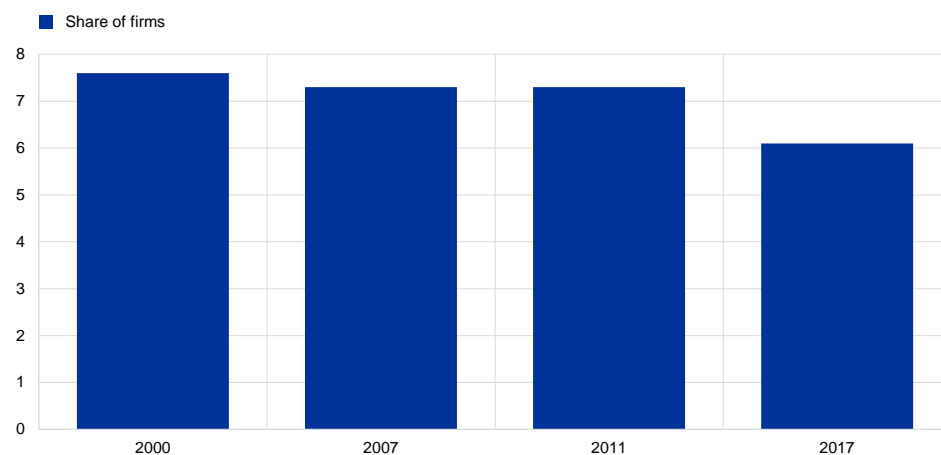
Source: Deutsche Bundesbank.
Note: Zombie firms are defined as firms whose operating and investment income over interest and similar expenses is less than one in the reporting year and the two preceding years.

A.9.4 Zombie flows: the pool size effect

In Chart A.9.3 the flows are presented as proportions of all firms, instead of proportions of the group of departure as in the main text.

Chart A.9.3

The "pool size effect": zombie entries and exits as a percentage of all firms

(percentage of all firms)
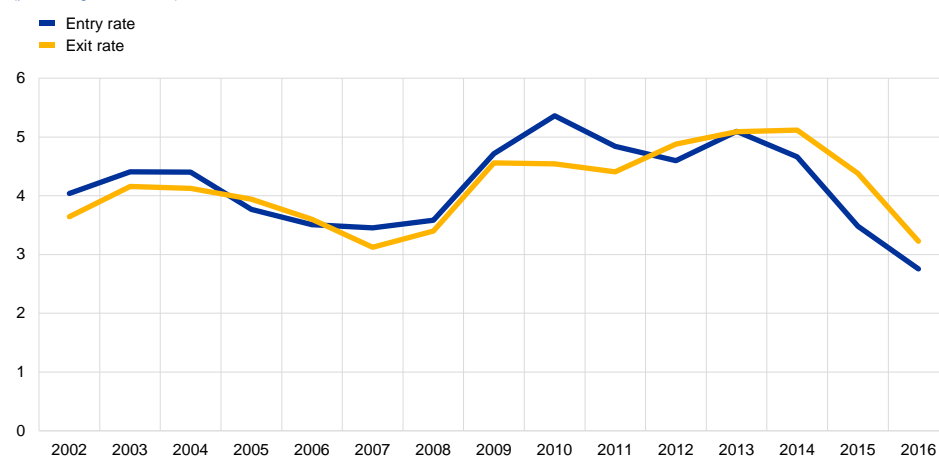
■ Entry rate
■ Exit rate

Sources: Central Balance Sheet Database, Cerved Centrale dei Bilanci, Istituto Nazionale della Previdenza Sociale, National Bank of Belgium Central Balance Sheet Office, Statistics Finland, Statistics Netherlands and authors' calculations.

If both flows are presented as percentages of all firms, the entry rate behaves in a qualitatively similar way as in Chart 33, rising after the financial crisis and then falling in the most recent period. The zombie exit rate, however, seems to rise and fall with a lag, closely mirroring the entry rate. This rise and fall in the exit rate in proportion to

all firms reflects a "pool size" effect: when the zombie pool becomes larger/smaller in a downturn/upswing, zombie exits relative to the firm population increase/decline even though the exit rate as a proportion of zombies remains constant (and may even decline).

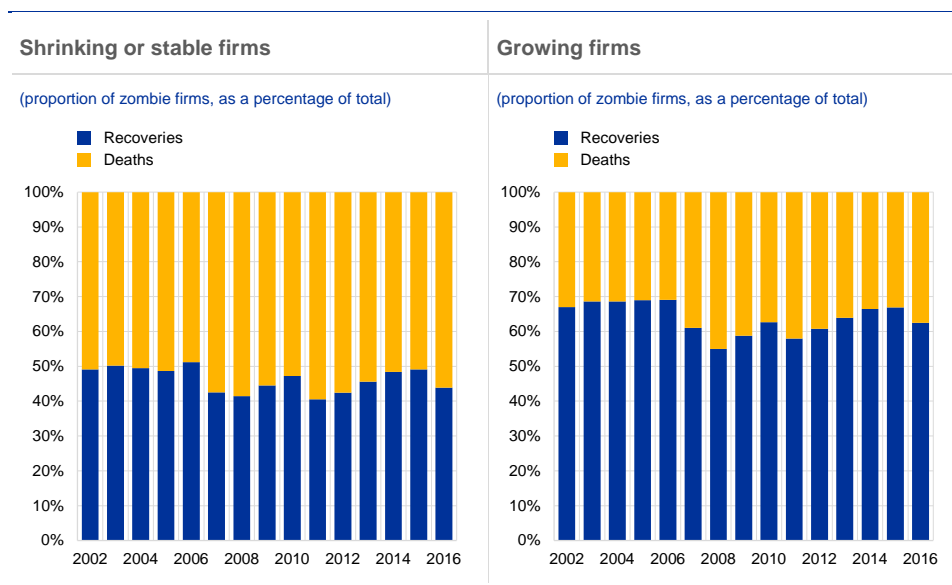## A.9.5 Share of zombies exiting to death or financial recovery

Chart A.9.4
Zombie exits to recovery and death according to firm growth – weighted average for all countries (Croatia, Italy, Netherlands, Finland)

Shrinking or stable firms	Growing firms
(proportion of zombie firms, as a percentage of total)	(proportion of zombie firms, as a percentage of total)

Sources: Central Balance Sheet Database, Cerved Centrale dei Bilanci, Financial Agency (Fina), Istituto Nazionale della Previdenza Sociale, National Bank of Belgium Central Balance Sheet Office, Statistics Finland, Statistics Netherlands and authors' calculations.
Notes: Zombies are defined as firms for which the ratio of EBIT to interest paid + financial charges is less than one (EBIT/(interest+financial charges)<1) for three consecutive years. Manufacturing includes NACE Rev. 2 sectors 10-33 and private services includes sectors 45-63 and 69-82.

Annex 10: Monetary policy and productivity

A.10.1 Monetary policy and capital misallocation in the euro area

A.10.1.1 Data sources and main variables

EU KLEMS Release 2019 provides detailed data for the 28 EU Member States as well as various country aggregates, and data for Japan and the United States, for the period 1995-2017 (although coverage differs between countries). We used data for Spain, Italy and Portugal, retaining only those years that could be matched to monetary policy shock data, that is from 2000 to 2016. Capital, both for stocks (K) and investment (XK), is defined as the sum of machines, equipment and computers.

iBACH contains micro-level data from the firm-level BACH database. It features detailed balance sheet and revenue data for Belgium, Spain, France, Italy, Portugal and Slovakia. However, coverage and representativeness varies from country to country. For this reason, we only used data for Italy and Portugal, which have better coverage of the full population of firms. For Spain we used the Microdatos de la Central de Balances (MCB) dataset, since it has much better coverage (see below) for the years 2003 to 2017. We retained only the years we could match to monetary policy shock data, that is from 2000 to 2016. We removed firms from the mining, financial, insurance and public administration sectors, and also eliminated firms reporting negative capital or negative value added. The resulting data were used to compute our misallocation measure: the weighted average of industry-level dispersion of MRPK (see below for more details).

MCB is a very detailed micro dataset available from the Banco de España for the years 1996 to 2017. The data are taken from the annual accounts that firms submit to the Commercial Registry,[134] which are then harvested and processed by the Banco de España. MCB's primary advantage is that, with nearly one million observations per year, it covers virtually all Spanish firms.[135] As with the iBACH data, we retained only the years we could match to monetary policy shock data, that is, from 2000 to 2016. We again removed firms from the mining, financial, insurance and public administration sectors, and also eliminated firms reporting negative capital or negative value added. Finally, we winsorise capital investment ratios by year at the 1% and 99% percentile.

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[134] In Spain, it is mandatory for all firms to submit their annual accounts (balance sheet, income statements and annual reports) to the commercial registry.

[135] For more detailed information about this dataset, see Almunia et al. (2018).

A.10.1.2 Main variables

- **Capital** (MCB and iBACH): tangible assets (K)

- **MRPK** (MCB and iBACH): we define this variable in logs, i.e.

$$MRPK = \ln\left(\frac{Value\ added}{K}\right)$$

- **Investment** (MCB): Change in the stock of capital, i.e. $XK = K_t - K_{t-1}$

- **Investment rate** (MCB):

$$xk = \frac{XK}{K} \approx \ln(K_t) - \ln(K_{t-1})$$

- **Age** (MCB): Computed as the difference between current year and year of incorporation. Negative values and observations that are more than 250 years old are set as missing values.

- **Sales growth** (MCB): Let Y_t be the deflated sales of firm at year t. Then, sales growth is computed as

$$rev\_g_t = \frac{Y_t - Y_{t-1}}{Y_{t-1}} \approx \ln(Y_t) - \ln(Y_{t-1})$$

- **Leverage** (MCB): Leverage is computed as total debt divided by total assets

$$leverage_t = \frac{ST\ debt + LT\ debt}{A_t}$$

- **Financial Assets** (MCB): Includes both short-term and long-term financial assets

$$FA_t = ST\ financial\ invetsment + trade\ receivables + inventories\ + cash$$

- **Financial Liabilities** (MCB): Includes both short and long-term liabilities

$$FL_t = ST\ debt + trade\ payables + LT\ debt.$$

- **Net Financial Assets** (MCB): $NFA_t = \ln(FA_t) - \ln(FL_t)$.

- **Markups** (MCB): markups are estimated following the De Loecker and Warzynski (2012) methodology. For more details about estimating markups with this dataset, see García-Perea, Lacuesta, and Roldan (2020).

Aggregate dynamic regressions. For the regressions using aggregate data, we follow Jordà (2005) and estimate the following regression

$$y_{t+h} - y_{t-1} = \gamma_0^h + \beta^h \epsilon_t^{MP} + \gamma_1^h \epsilon_{t-1}^{MP} + \gamma_2^h (y_{t-1} - y_{t-2}) + \phi_t + u_t^h \tag{E2.1}$$

In this regression, y_t is our variable of interest at the aggregate level (aggregate investment, weighted average of industry variance of MRPK). The monetary policy shock ϵ_t^{MP} comes from Jarocinski and Karadi (2020), who identify monetary policy shocks via high-frequency surprises and sign restrictions. The time frequency of the data is annual, so monthly monetary policy shocks are aggregated at the year level. ϕ_t is output gap, controlling for the aggregate conditions of the economy.

Firm-level dynamic regressions. For regressions using firm level data, we use an adaptation of local projections:

$$
\begin{aligned}
y_{it+h} - y_{it-1} = \gamma_0^h + \beta^h \epsilon_t^{MP} * MRPK_{it-1} + \gamma_1^h MRPK_{it-1} + \gamma_2^h (y_{t-1} - y_{t-2}) \\
+ \psi \mathbb{Z}_{t-1} + u_t^h
\end{aligned} \tag{E2.2}
$$

In this regression, y_t is the firm-level investment ratio. The monetary policy shock ϵ_t^{MP} is taken from Jarocinski and Karadi (2020). The time frequency of the data is annual, so monthly monetary policy shocks are aggregated at the year level. Z_{t-1} is a set of firm level controls (sales growth and leverage). This regression is estimated using firm and year fixed effects.

Static impact of monetary policy on misallocation. To understand the effect of a monetary policy shock at impact, the authors used the following regressions, where y_{it} is the firm-level investment rate. The monetary policy shock ϵ_t^{MP} comes from Jarocinski and Karadi (2020). The time frequency of the data is annual, so monthly monetary policy shocks are aggregated at the year level. Z_{t-1} is a set of firm level controls (sales growth, total assets and leverage). This regression is estimated using firm and year fixed effects

$$y_{it} = \gamma_0^h + \beta_1 \epsilon_t^{MP} + \psi \mathbb{Z}_{t-1} + u_{it} \tag{E2.3}$$

$$y_{it} = \gamma_0^h + \beta_1 \epsilon_t^{MP} MRPK_{it-1} + \beta_2 MRPK_{it-1} + \psi \mathbb{Z}_{t-1} + u_{it} \tag{E2.4}$$

Heterogeneity of the impact. To explore the mechanisms by which lower interest rates decrease misallocation, we checked the plausibility of financial frictions. To do this, we looked at the heterogeneity of impact of the monetary policy shock based on firm characteristics (where x_{it} refers to age, net financial assets or markups), and ran the following regression:

$$
\begin{aligned}
y_{it} = y_0^h + \beta_1 \epsilon_t^{MP} MRPK_{it} x_{it-1} + \beta_2 \epsilon_t^{MP} MRPK_{it-1} + \beta_3 \epsilon_t^{MP} x_{it-1} + \beta_4 MRPK_{it-1} \\
+ \beta_5 x_{it-1} + \psi \mathbb{Z}_{t-1} + u_{it}
\end{aligned} \tag{E2.5}
$$

Table A.10.1

Output from regressions E2.2 and E2.3

	(1) Investment rate	(2) Investment rate
$\epsilon_{t^{MP}}$	0.01*** (0.003)	
$\epsilon_{t^{MP}} \times MRPK_{t-1}$		0.013*** (0.002)
$MRPK_{t-1}$		0.052*** (0.076)
Observations	1,215,424	1,220,376
R-squared	0.4	0.41
Year FE	No	Yes
Firm FE	Yes	Yes
Z controls	Yes	Yes

Notes: Robust standard errors in parentheses. ***p<0.01, **p<0.05, *p<0.1. Data from MCB (see Appendix). y_t is firm-level investment rate and ϵ_t^{MP} is the expansionary monetary policy shock. Z_{t-1} is a set of firm-level controls (sales growth, total assets and leverage). This regression is estimated using firm and year fixed effects.

Table A.10.2

Output of regression E2.5

	y_t: Investment rate					
	(1) x_t: ln(Age)	(2) x_t: ln(Age)	(3) x_t: NFA	(4) x_t: NFA	(5) x_t: ln(Mark- up)	(6) x_t: ln(Mark- up)
$\epsilon_{t^{MP}} \times MRPK_{t-1} \times x_{t-1}$		-0.008 (0.003)		-0.004*** (0.001)		-0.008** (0.004)
$\epsilon_{t^{MP}} \times MRPK_{t-1}$		0.03*** (0.007)		0.009*** (0.002)		0.016*** (0.004)
$\epsilon_{t^{MP}} \times x_{t-1}$	-0.001 (0.004)	-0.002 (0.004)	0.012*** (0.002)	0.003 (0.003)	-0.015*** (0.005)	-0.010** (0.005)
$MRPK_{t-1}$		0.053*** (0.000)		0.05*** (0.000)		0.09*** (0.001)
x_{t-1}	-0.03*** (0.002)	-0.063*** (0.002)	0.027*** (0.000)	0.018*** (0.000)	-0.015*** (0.001)	-0.013*** (0.001)
Observations	1,220,376	1,220,376	1,215,754	1,215,754	772,760	772,760
R-squared	0.4	0.41	0.4	0.41	0.4	0.41
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Z controls	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Robust standard errors in parenthesis. ***p<0.01, **p<0.05, *p<0.1. Data from MCB (see Appendix). y_{t-1} is firm-level investment rate and ϵ_t^{MP} is the expansionary monetary policy shock. Z_{t-1} is a set of firm-level controls (sales growth, total assets and leverage). This regression is estimated using firm and year fixed effects. The first two columns use as regressor X_t age, columns (3) and (4) use net financial assets as regressors, and columns (5) and (6) use markups.

A.10.2 Does firm survey information point to credit misallocation?

A.10.2.1 Dataset and variable definitions

The analysis uses a dataset that merges survey-based data derived from the ECB's SAFE with balance sheet information from Bureau van Dijk's ORBIS. SAFE gathers information about access to finance by non-financial enterprises in the European Union. It is an ongoing semi-annual survey that has been conducted on behalf of the European Commission and the ECB since 2009.[136] Between 8,000 and 15,000 firms are interviewed in each round. Our analysis is based on firms from 11 European countries (Belgium, Germany, Ireland, Greece, Spain, France, Italy, Netherlands, Austria, Portugal and Finland) observed from round three (second part of 2010) until round 22 (March 2020). The survey responses of firms are supplemented with detailed balance sheet and profit and loss information available from ORBIS for the years 2008 to 2018. This combined dataset has two major advantages: i) it enables us to retrieve harmonised and homogeneous information on several aspects of financial vulnerability directly reported by firms as well as constructed from their financial statements over time; and ii) it allows us to compute productivity at firm level. The combined dataset includes some 33,000 firms for the period 2010–18.

Definition of the variable of interest and empirical definition

The information in the survey is qualitative. Firms are asked if a specific variable has "deteriorated, stayed the same or improved" (scored as -1/0/1). In the empirical analysis, these two scores are collapsed into two for each variable, according to the following definition:

$$x_i = 1 \ if \ x_i = 1$$
$$= 0 \ if \ x_i \neq 1$$

where x_i is equal to one if firms report an improvement and zero if they report a deterioration or no change for a given variable. The empirical model is as follows:

$$Prob(access \ to \ finance_{it})$$
$$= \beta_0 W_{it} + \beta_1 W_{it} \times lending \ conditions_{it} + \beta_2 lending \ conditions_{it}$$
$$+ \beta_3 X_{it} + \beta_4 dummies_{it} + u_{it}$$

The model is estimated using a logit specification where the dependent variable access to finance is the availability of bank loans at firm level (Q9 in the survey); lending conditions are a set of variables that summarise the terms and conditions applied to bank loans (Q10). For the SAFE, firms report on: 1) interest rates, 2) other costs of financing (charges, fees and commissions), 3) available size of loans,

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[136] For an overview of the methodology followed when setting up the survey, see ECB (2020).

4) available maturity, 5) collateral requirements and 6) other requirements (guarantees, loan covenants and information requirements). All these variables are equal to 1 if lending conditions have improved.

W_{it} is the set of indicators used to define a firm's financial weakness. Five different indicators are considered: one derived from the survey replies (vulnerable index), two from balance sheets (weak firms and Altman Z-score) and two related to productivity, also constructed using financial statement data.

The indicators are defined as follows:

Vulnerable firms: The SAFE includes a very strict indicator of vulnerable firms (ECB, 2018). These are firms that have simultaneously reported lower turnover, decreasing profits, higher interest expenses and higher or unchanged debt-to-total assets in the last six months; the variable is a dummy equal to one if the firm is vulnerable.

Zombie firms: As elsewhere, this indicator is equal to one if the interest coverage ratio (defined as the ratio of interest expenses to operating profits) is less than one for three consecutive years.

Altman Z-score: this indicator is equal to one for firms with Z-score values of less than 1.8. The Z-score is widely used to predict the probability that a firm will go into bankruptcy within two years. It is an easy-to-calculate control measure for firms' financial distress. The formula used in the analysis is the one calculated for private firms (Altman and Sabato, 2007):

$$Z = 0.717X1 + 0.842X2 + 3.107X3 + 0.420X4 + 0.998X5.$$

X1 = working capital / total assets

X2 = retained earnings / total assets

X3 = earnings before interest and taxes / total assets

X4 = equity / total liabilities

X5 = sales / total assets

Low-productivity firms I: the first dummy is equal to one if a firm is in the bottom 10% of the country/sector/year distribution of productivity, where productivity is defined as real value added or turnover per employee;

Low-productivity firms II: the second dummy is based on the Solow residual (using median sector input shares as elasticities) and takes the value one if the productivity of the firm is in the bottom 10% of the country/sector/year distribution.

The empirical specification additionally controls for firm characteristics, X_{it}, which refers to ownership (family-owned), operational autonomy status and firm size as well as the primary sector (industry) in which the firm operates. As the model is based on perceptions/opinions of respondents, we acknowledge that these may be

"tainted" by the macro-environment at the time of the interview. We thus introduce interactions of country (c) and time dummies corresponding to each SAFE round, while u_i is the error term.

The coefficients of direct interest as regards the economic inference are those related to W, and to the interactions $W_{it} \times lending\ conditions_t$.

Table A.10.3 shows the marginal effects for the empirical specifications where improvements in the availability of bank loans is regressed on each indicator of firms' financial weakness and the other variables specified above.[137]

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[137] For an additional robustness check, we also ran an empirical check that included all the different measures of financial weakness taken together (but with only one measure of productivity). The results (not reported) confirm the analysis reported in Table A.10.3, which was conducted using the indicators on an individual basis.

Table A.10.3

Availability of bank loans – weak firms and terms and conditions

(marginal effects)

	1 Vulnerable firms	2 Zombie firms	3 Altman Z score	4 Ln Lprod	5 TFP
Vulnerable firms index	-0.114*** (0.019)				
Zombie firms index		-0.077*** (0.022)			
Altman Z score <1.8			-0.023** (0.011)		
d_p10_lnlprod_turnover				0.009 (0.015)	
d_p10_lnTFP_CS					-0.009 (0.015)
Terms and conditions					
Decreased interest rates	0.127*** (0.008)	0.124*** (0.010)	0.125*** (0.010)	0.136*** (0.009)	0.131*** (0.009)
Decreased cost of financing	0.090*** (0.013)	0.107*** (0.015)	0.081*** (0.016)	0.087*** (0.013)	0.088*** (0.013)
Increased size loan	0.186*** (0.008)	0.184*** (0.010)	0.180*** (0.010)	0.179*** (0.008)	0.178*** (0.008)
Increased maturity	0.073*** (0.012)	0.086*** (0.015)	0.071*** (0.015)	0.085*** (0.013)	0.080*** (0.013)
Decreased collateral	0.165*** (0.019)	0.164*** (0.022)	0.181*** (0.023)	0.179*** (0.020)	0.179*** (0.020)
Decreased other T&C	0.075*** (0.020)	0.049** (0.024)	0.095*** (0.024)	0.067*** (0.020)	0.079*** (0.020)
Interactions weak firms with:					
Decreased interest rates	0.019 (0.038)	0.087** (0.036)	0.018 (0.017)	-0.037 (0.025)	0.000 (0.025)
Decreased cost of financing	-0.049 (0.060)	-0.049 (0.055)	0.033 (0.026)	0.032 (0.043)	0.022 (0.039)
Increased size loan	-0.066** (0.033)	0.069 (0.042)	0.005 (0.017)	0.026 (0.026)	0.021 (0.025)
Increased maturity	0.052 (0.042)	-0.009 (0.056)	0.014 (0.025)	-0.070** (0.033)	-0.026 (0.034)
Decreased collateral	-0.109* (0.062)	0.050 (0.072)	-0.067 (0.041)	-0.128** (0.061)	-0.104* (0.055)
Decreased other T&C	-0.020 (0.062)	0.010 (0.067)	-0.072* (0.040)	0.065 (0.069)	-0.017 (0.061)
Observations	28,578	18,910	28,584	28,584	28,584
Firm characteristics	Yes	Yes	Yes	Yes	Yes
Sector dummies	Yes	Yes	Yes	Yes	Yes
Country X Time FE	Yes	Yes	Yes	Yes	Yes
VCE_Cluster	Robust	Robust	Robust	Robust	Robust

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

Table A.10.4

Availability of bank loans – weak firms and terms and conditions by size class

Micro-small firms

(marginal effects)

	1 Vulnerable	2 Zombie	3 AltmanZ score	4 Ln Lprod	5 Ln TFP
Vulnerable firms index	-0.101*** (0.019)				
Zombie firms index		-0.035* (0.021)			
Altman Z score <1.8			-0.018* (0.010)		
d_p10_lnlprod_turnover				-0.023 (0.015)	
d_p10_lnTFP_CS					-0.025* (0.015)
Interactions weak firms with:					
Decreased interest rates	0.015 (0.036)	0.015 (0.037)	0.011 (0.017)	-0.018 (0.026)	0.000 (0.023)
Decreased cost of financing	-0.054 (0.072)	-0.059 (0.060)	-0.001 (0.028)	0.019 (0.051)	-0.000 (0.040)
Increased size loan	-0.095*** (0.032)	-0.021 (0.039)	-0.011 (0.018)	0.022 (0.025)	-0.003 (0.024)
Increased maturity	0.033 (0.042)	-0.091* (0.047)	-0.055** (0.025)	-0.010 (0.033)	-0.006 (0.031)
Decreased collateral	-0.025 (0.068)	-0.019 (0.085)	0.074** (0.037)	-0.021 (0.053)	0.075 (0.050)
Decreased other T&C	-0.057 (0.071)	0.057 (0.080)	-0.10*** (0.037)	0.020 (0.052)	-0.12** (0.050)
Observations	16,253	9,300	16,257	16,257	16,257
Firm characteristics	Yes	Yes	Yes	Yes	Yes
Sector dummies	Yes	Yes	Yes	Yes	Yes
Country X Industry FE	Yes	Yes	Yes	Yes	Yes
VCE_Cluster	Robust	Robust	Robust	Robust	Robust

Medium-large firms

(marginal effects)

	6 Vulnerable	7 Zombie	8 Altman Z score	9 Ln Lprod	10 Ln TFP
Vulnerable firms index	-0.125*** (0.038)				
Zombie firms index		-0.100*** (0.033)			
Altman Z score <1.8			-0.026 (0.019)		
d_p10_lnlprod_turnover				0.033 (0.025)	
d_p10_lnTFP_CS					0.004 (0.024)
Interactions weak firms with:					
Decreased interest rates	0.015 (0.069)	0.113** (0.051)	0.019 (0.026)	-0.046 (0.037)	-0.003 (0.037)
Decreased cost of financing	-0.058 (0.098)	-0.064 (0.071)	0.051 (0.039)	0.048 (0.059)	0.036 (0.054)
Increased size loan	-0.022 (0.060)	0.109* (0.059)	0.020 (0.027)	0.027 (0.040)	0.036 (0.038)
Increased maturity	0.086 (0.076)	0.020 (0.077)	0.051 (0.038)	-0.114** (0.050)	-0.041 (0.053)
Decreased collateral	-0.232** (0.107)	0.080 (0.107)	-0.164*** (0.063)	-0.227** (0.090)	-0.213*** (0.082)
Decreased other T&C	0.022 (0.107)	-0.007 (0.096)	-0.048 (0.068)	0.114 (0.116)	0.069 (0.096)
Observations	12,131	9,389	12,133	12,133	12,133
Firm characteristics	Yes	Yes	Yes	Yes	Yes
Sector dummies	Yes	Yes	Yes	Yes	Yes
Country X Industry FE	Yes	Yes	Yes	Yes	Yes
VCE_Cluster	Robust	Robust	Robust	Robust	Robust

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

A.10.3 Micro-distributed analysis of zombie firm demographics for five euro-area countries

To gauge the impact of interest rates on the entry to and exit from distress, a discrete-time proportional hazard duration model was used, where the discrete interval hazard rate followed a complementary log-log distribution. The model controlled for firm-level characteristics, sector and time fixed effects and included the corporate lending rate in the regressors. To identify causality, we tested whether the cost of financing had a distinct effect on firms operating in sectors less reliant on external financing, as proposed by Rajan and Zingales (1998). External financial reliance is measured by the sector-median share of bank loans to total debt as in Inklaar & Kloetter (2008). The model is run separately for entry into distress, exit from distress, and also for exit to recovery and exit from the market.

Table A.10.5

Impact of interest rates on inflows and outflows from "zombieness"

	Belgium	Finland	Italy	Netherlands	Portugal
Dependent variable	**DV: Exit from distress**				
Corporate interest rate	-0.058*** (-2.922)	-0.006 (-0.351)	-0.078*** (-7.300)	-0.117*** (-3.560)	-0.0414*** (-3.554)
Debt share	0.353** (1.964)	0.183 (1.317)	-0.804*** (-3.156)	-0.461*** (-4.983)	6.179*** (16.86)
Corporate interest rate *Debt share	-0.0874* (-1.797)	-0.0162 (-0.376)	0.197*** (3.212)	0.115*** (5.044)	-1.675*** (-18.69)
Observations	98,053	45,014	165,423	59,831	84,207
Dependent variable	**DV: Exit from distress to recovery**				
Corporate interest rate	-0.110*** (-4.871)	-0.075*** (-3.609)	-0.107*** (-7.951)	-0.0652 (-1.606)	0.0228 (1.496)
Debt share	0.400* (1.956)	0.527*** (2.980)	-0.403 (-1.268)	-0.002 (-0.018)	-1.004** (-2.294)
Corporate interest rate *Debt share	-0.113** (-2.061)	-0.116** (-2.158)	0.092 (1.225)	0.002 (0.0807)	0.175* (1.802)
Observations	98,053	45,014	165,423	59,831	84,207
Dependent variable	**DV: Exit from distress to out of market**				
Corporate interest rate	0.0960** (2.387)	0.174*** (5.769)	0.00211 (0.121)	-0.0824* (-1.706)	-0.0964*** (-5.169)
Debt share	-0.200 (-0.541)	-0.285 (-1.241)	-1.203*** (-2.871)	-0.845*** (-6.058)	15.62*** (24.59)
Corporate interest rate *Debt share	0.0682 (0.665)	0.125* (1.687)	0.291*** (2.898)	0.211*** (6.431)	-4.241*** (-24.89)
Observations	98,053	45,014	165,423	59,831	84,207
Dependent variable	**DV: Entry in distress**				
Corporate interest rate	2.161*** (101.4)	0.962*** (56.54)	0.925*** (93.15)	2.810*** (62.53)	1.609*** (117.9)
Debt share	0.857*** (5.415)	2.777*** (21.60)	12.67*** (53.39)	0.566*** (5.911)	-0.294 (-0.711)
Corporate interest rate *Debt share	-0.0962** (-2.103)	-0.711*** (-17.56)	-2.560*** (-45.17)	-0.135*** (-4.940)	-0.616*** (-7.060)
Observations	95,552	45,014	162,951	59,831	84,416

Notes: Discrete-time proportional hazard duration model where the discrete interval follows a complementary log-log distribution.
Controls not reported include labour productivity, firm size (employment), capital intensity, dummies for durations and zombie cohorts.
Clustered standard errors by firm. *** p<0.01, ** p<0.05, * p<0.1.