The slowdown in euro area productivity growth

Economic growth and prosperity are largely determined by developments in labour productivity. It is therefore unsurprising that the long-observed slackening of productivity gains in many advanced economies has come to the fore of the economic policy debate. In the euro area, too, productivity growth has slowed markedly over the past 20 years, albeit with some pronounced differences between Member States.

On the one hand, the steep economic losses induced by the global financial and economic crisis and the subsequent sovereign debt crisis likely affected productivity growth not only in the short term. Beyond this, however, there are also clear signs of structural influences. Growth in total factor productivity – a key driver of labour productivity – had already declined in large swathes of the euro area prior to the onset of the global financial crisis. This can be attributed, amongst other things, to a decline in entrepreneurial innovation and adoption activities in some sectors of the economy and decreasing allocative efficiency. Continued demographic change is likely to have contributed to this. Other possible explanatory factors include the institutional and regulatory frameworks in place. The relative loss of importance of the industrial sector, which was accompanied by a shift in labour input to economic sectors with comparatively low productivity growth, also slowed overall output growth. Increased productivity gains in some service sectors were unable to offset this.

The ageing of the population and reduced labour force growth could continue to dampen labour productivity growth in the future. At present, it is difficult to assess what impact the coronavirus pandemic will have on productivity developments. The macroeconomic turmoil triggered by the pandemic is likely to weigh on future labour productivity growth. The extent to which the exceptional challenges presented by the current crisis will lead to a wave of innovation that counteracts such burdens remains to be seen.

Labour productivity developments in the euro area and the Member States

Productivity as a key economic metric

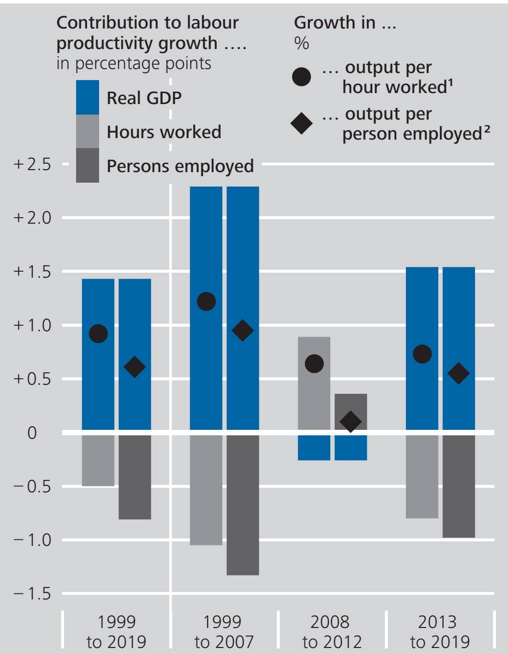
Recently, the focus has mainly been on current economic developments on account of the coronavirus pandemic. However, the long-observed trend of slowing labour productivity growth in a great number of advanced economies remains a core economic policy issue. Labour productivity, defined as the ratio of output to labour input, is a key measure of economic efficiency.[1] Trend developments in labour productivity are an indicator of economies' growth potential. Owing to its close link to per capita income, labour productivity is often also interpreted as a measure of prosperity.

Measuring labour productivity using different labour input metrics

The output measure typically used for the calculation of labour productivity is the price-adjusted gross domestic product (GDP) or real value added, while labour input is determined based on the number of hours worked or the number of persons employed. The number of hours worked is considered to be the more precise measure of labour input, as both trend changes in average hours worked as well as temporary reductions in hours worked or absences are taken into account.

Labour productivity growth in the euro area

Average annual change



Sources: Eurostat and Bundesbank calculations. **1** Labour productivity measured as the ratio of real GDP to the number of hours worked. **2** Labour productivity measured as the ratio of real GDP to the number of persons employed.

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Slowdown in euro area productivity growth

For the euro area as a whole, a marked slowdown in productivity growth can be observed between 1999 and 2019, irrespective of the labour input measure used. Greater differences between the two metrics become apparent during the global financial and economic crisis as well as the subsequent sovereign debt crisis. Between 2008 and 2012, the number of hours worked fell more sharply than the number of persons employed.[2] Growth of output per hour during this period was accordingly markedly higher than that of output per person employed.

Heterogeneous labour productivity developments in the euro area countries

A look at the euro area as a whole conceals what are, in some instances, considerable variations between the Member States. For instance, labour productivity in Estonia, Ireland, Latvia, Lithuania, Slovakia and Slovenia increased significantly more strongly on average between 1999 and 2019 than the euro area average. While the above-average rise in labour productivity in central and eastern European Member States is to be viewed against the backdrop of the ongoing convergence process, the statistical data on labour productivity in Ireland over the past few years have been strongly influenced by the recording of multinational enterprises' business activities.[3] By contrast, labour productivity in the five largest euro area countries increased much more moderately. While labour productivity growth in Germany, France and the Netherlands rose on average by about 1% per year, the development of prod-

1 It follows from the definition above that labour productivity growth can be approximated by the difference between the rates of growth of output and labour input.
2 This was due, amongst other things, to the hoarding of labour, which was exacerbated by short-time work schemes. See also Deutsche Bundesbank (2015).
3 See also Deutsche Bundesbank (2018, 2019b).

Average annual labour productivity growth

Average annual percentage change

Country	Real GDP per person employed				Real GDP per hour worked			
	Total period 1999 to 2019	1999 to 2007	2008 to 2012	2013 to 2019	Total period 1999 to 2019	1999 to 2007	2008 to 2012	2013 to 2019
Euro area[1]	0.6	0.9	0.1	0.6	0.9	1.2	0.6	0.7
Austria	0.7	1.5	− 0.3	0.3	1.2	2.0	0.6	0.6
Belgium	0.8	1.4	− 0.1	0.5	0.8	1.3	0.0	0.6
Cyprus	0.8	1.7	− 0.1	0.3	1.1	2.0	0.1	0.6
Estonia[2]	3.3	6.3	0.0	1.9	3.5	6.1	1.2	2.6
Finland	0.8	2.1	− 1.0	0.5	1.2	2.5	− 0.5	0.8
France	0.8	1.1	0.2	0.6	1.0	1.5	0.2	0.9
Germany	0.6	1.1	− 0.1	0.5	1.0	1.4	0.5	0.7
Greece	0.1	2.7	− 3.6	− 0.5	0.3	2.7	− 3.4	0.0
Ireland	3.1	2.4	1.7	5.1	3.6	2.9	3.1	4.8
Italy	− 0.2	0.1	− 1.0	0.0	0.2	0.4	0.0	0.2
Latvia	4.0	6.8	1.5	2.2	4.3	7.5	0.9	2.8
Lithuania	4.2	6.9	2.0	2.3	4.0	6.1	2.5	2.3
Luxembourg	0.1	1.2	− 2.3	0.5	0.4	1.4	− 1.6	0.5
Malta[3]	1.0	1.3	0.5	1.0	1.7	1.8	1.8	1.4
Netherlands	0.7	1.3	− 0.1	0.6	0.9	1.7	0.2	0.3
Portugal	0.9	1.3	0.6	0.6	1.0	1.4	1.1	0.3
Slovakia	2.9	4.7	1.8	1.3	3.2	4.9	1.8	2.1
Slovenia	1.7	3.3	− 0.2	1.2	2.1	3.8	− 0.1	1.6
Spain	0.6	0.0	1.7	0.5	0.7	0.3	1.7	0.6
Other advanced economies								
Canada	0.8	1.1	0.4	0.6	1.1	1.5	0.6	0.9
Japan[4]	0.7	1.4	0.2	0.2	0.7	1.1	0.2	0.5
United Kingdom	0.9	1.8	− 0.2	0.5	1.0	2.1	0.0	0.4
United States[5]	1.4	1.8	1.2	0.9	1.6	2.3	1.4	0.7

Sources: Eurostat and Bundesbank calculations. **1** 19 countries as of 2015. **2** Data for productivity based on the number of hours worked in Estonia available from 2001. **3** Data for labour productivity in Malta available from 2001. **4** Data for labour productivity in Japan available up to 2018. **5** Data for labour productivity in the United States available up to 2018.

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uctivity was considerably lower in Spain. In Italy, labour productivity growth virtually stagnated.

Moderate productivity growth prior to the global financial and economic crisis …

Looking at individual sub-periods, productivity growth before the global financial and economic crisis was larger in most euro area countries than in later years. In the pre-crisis period, labour productivity expanded particularly strongly in the Baltic States. Productivity gains in Italy and Spain, by contrast, were strikingly small.

… was followed a broad-based slump

In the wake of both the global financial and economic crisis and the subsequent sovereign debt crisis, productivity growth in most euro area countries collapsed. In several euro area countries, labour productivity even declined. Spain represents an exception in this respect. As a result of the disproportionately large reduction in labour input, hourly labour productivity growth there increased more than fivefold during the crisis period.[4]

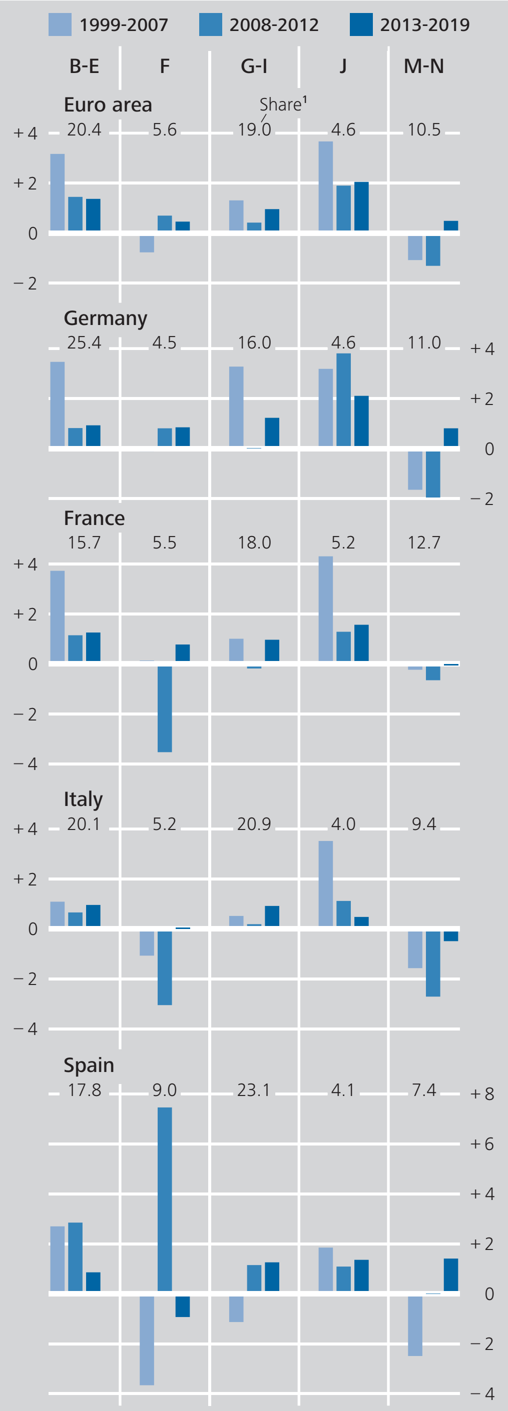
Economic recovery amid subdued productivity growth

Productivity growth picked up again in subsequent years, but in most euro area countries it fell short of its pre-crisis rates. Spain was again

4 See also Deutsche Bundesbank (2016). A similar phenomenon can be seen in Ireland, where average labour productivity growth also increased during the crisis years.

Labour productivity growth in selected economic sectors and sector groups*

Average annual percentage change



Sources: Eurostat and Bundesbank calculations. * Sector classification according to NACE. **B-E:** mining and quarrying; manufacturing; electricity, gas, steam and air conditioning supply; and water supply; sewerage, waste management and remediation activities; **F:** construction; **G-I:** wholesale and retail trade; repair of motor vehicles and motorcycles; transportation and storage and accommodation and food service activities; **J:** information and communication; **M-N:** professional, scientific and technical activities and administrative and support service activities. **1** Sector or sector group's average percentage share in aggregate nominal gross value added over the observation period 1999 to 2019.

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a notable exception, with GDP rising at an above-average rate during the recovery period, whilst employment growth remained subdued. In the other countries hit hard by the crisis, however, productivity gains remained clearly below the euro area average. Labour productivity increased only marginally in Italy and continued to decline in Greece despite a certain degree of economic recovery.

Difficult to gauge impact of the coronavirus pandemic on productivity growth

At present, it is difficult to assess how the current coronavirus pandemic will affect trend labour productivity growth. At the current end of the data, the reduction of labour input during the crisis, coupled with simultaneous efforts to maintain employment, result in significant differences between the development of the growth rates of output per hour and output per person employed. Alongside these short-term effects, however, longer-term impacts are to be expected (for more on this, see the box on pp. 36 f.).

Slowdown in productivity growth in manufacturing

The flattening of productivity growth between 1999 and 2019 was observed in several economic sectors.[5] It was particularly pronounced in manufacturing, especially in Germany and France. The manufacturing sector had previously been characterised by above-average productivity gains, which also had a marked impact on average productivity growth owing to the importance of this sector. A similarly strong slowdown was observed in the communication and information sectors. However, productivity growth here, as in manufacturing, was still above average over the period under review.

Marked regional differences in services sector and construction industry, in some cases

In other services sectors, by contrast, productivity growth was rather subdued over the whole observation period. This was particularly true for the provision of professional, scientific, technical, administration and support service

5 The sectoral analysis is based on the Statistical classification of economic activities in the European Community (Nomenclature générale des activités économiques dans les Communautés européennes (NACE)), Rev. 2.

activities.[6] Productivity growth in this area accelerated only recently, particularly in Germany and Spain. In wholesale and retail trade, transportation and storage, and accommodation and food service activities, too, euro area labour productivity increased only slowly for the most part following the introduction of the single currency. In the construction sector, productivity was subject to what were, in some cases, considerable fluctuations. In Italy and France, it outright collapsed between 2008 and 2012. Between 2013 and 2019, output in the affected countries recovered perceptibly, but productivity growth remained subdued. In Spain, by contrast, the sharp contraction in construction output during the crisis was accompanied by an even greater reduction in the use of mostly low-productivity workers, resulting in a significant increase in average labour productivity growth. Productivity has since fallen once again somewhat.[7]

Weakened productivity momentum outside the euro area, too

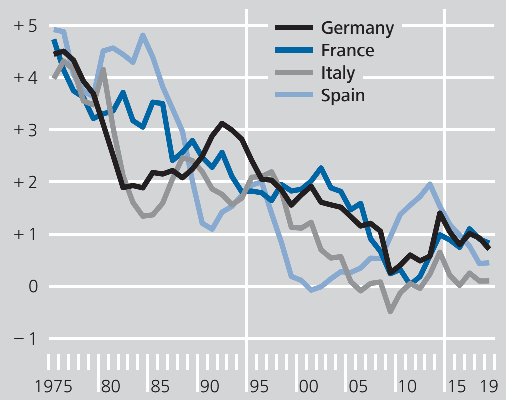
A comparison with other advanced economies shows that subdued productivity developments since 2013 are not a specific feature of the euro area. In the United States, average growth of output per hour was only around one-third of its pre-crisis average; in the United Kingdom, it stood at only one-fifth. Productivity growth also decelerated markedly in Canada and Japan. Meanwhile, the decline in the euro area was comparatively moderate; hourly productivity growth here between 2013 and 2019 did not differ markedly from that in other advanced economies. By contrast, hourly productivity growth in the euro area had been below average before the onset of the financial crisis.

Diminished productivity growth in the four large euro area countries even prior to the financial crisis

Both cyclical and structural factors may provide possible explanations for the subdued productivity dynamics. It is conceivable that severe recessions, as seen during the global financial and economic crisis and the subsequent sovereign debt crisis, could affect productivity gains in the longer term by weakening the development and adoption of innovations, or disrupt the allocation of production factors (see also the box on pp. 28 f.).[8] However, data for the past four decades show that the slowdown in productivity growth started prior to the global financial and economic crisis, at least in the four largest euro area countries. This finding contradicts a purely cyclical explanation of declining productivity growth and also points to structural causes.

Labour productivity growth in selected euro area countries since 1975

%, five-year moving average of annual growth rates



Sources: OECD and Bundesbank calculations.
Deutsche Bundesbank

Explanatory approaches to the slowdown in labour productivity growth

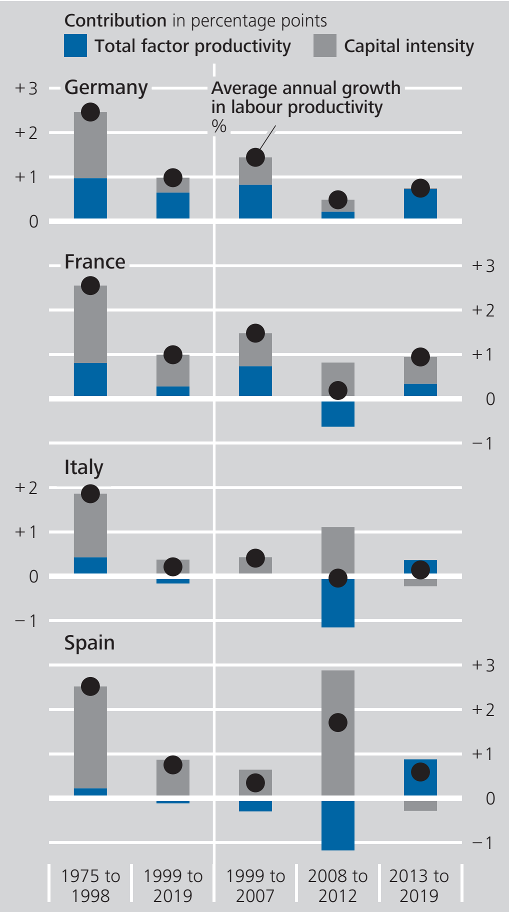
Key drivers of labour productivity

Productivity slowdown, according to growth decomposition …

Growth accounting is one way to study labour productivity developments in greater detail. Most commonly, the change in labour productivity is decomposed into the contributions of

6 It should, however, be borne in mind that measuring labour productivity in the services sector sometimes presents a challenge, for instance, when taking into account quality improvements.
7 A clear shift away from building construction, which has declined particularly sharply, towards civil engineering, where per capita value added is just over 40% higher, also contributed to the considerable increase in labour productivity seen in the Spanish construction sector since 2008. See Deutsche Bundesbank (2014).
8 See, inter alia, Comin and Gertler (2006), Liu and Wang (2014), and Anzoategui et al. (2019).

Contributions of capital intensity and total factor productivity to labour productivity growth*



Sources: European Commission (AMECO database) and Bundesbank calculations. * Capital intensity defined as the ratio of the capital stock to the number of hours worked. Labour productivity measured as the ratio of real GDP to the total number of hours worked.
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capital intensity, which is defined as the ratio of the capital stock to labour input, and total factor productivity (TFP).[9] The TFP contribution is measured as a residual. It captures the part of productivity growth that cannot be attributed to changes in the factor inputs, serving as a yardstick for the increased efficiency of production processes.[10] The long-term development of TFP is sometimes also seen as an indicator of disembodied technological progress. In the short term, though, it is difficult to make such an interpretation. Even in the case of severe economic downturns, decreases in technological progress can, if at all, only be regarded to a very limited extent as a plausible explanation for calculated TFP declines. Furthermore, due to its residual character, the contribution of TFP can also pick up other influences on labour productivity. Against this background, there is good reason to interpret TFP more broadly and to view it as a metric of production efficiency.[11]

… due to declining TFP growth …

According to the growth accounting exercise, TFP growth in the four largest euro area economies has lost significant momentum over the past 45 years. An examination of individual subperiods shows that the average TFP development between 1999 and 2019 was considerably burdened by the crisis years between 2008 and 2012. In Germany and France, however, the TFP growth rate also remained under its average of the pre-crisis period in the subsequent recovery phase. In Italy, TFP growth provided no stimulus even prior to the outbreak of the global financial crisis, whilst in Spain, TFP even decelerated. Recently, however, TFP has risen in Spain in particular. Nevertheless, according to the calculations, production efficiency overall has also been lower in Italy and Spain in the past 20 years than before the turn of the millennium. Although the declining TFP growth rates in the four largest euro area countries heavily influence the development of the euro area as a whole simply by virtue of their aggregate economic output, a similar pattern can also be identified in a host of other euro area economies.[12]

… and reduced capital intensity contributions

The contributions of capital intensity to labour productivity growth in the four largest euro area countries were far lower in the period following the establishment of the monetary union than they had been in the preceding 25

9 The growth accounting approach is based on several assumptions. For instance, it is typically assumed that the relationship between output and the effective factor input can be depicted using a Cobb Douglas production function with constant returns to scale. Furthermore, it is assumed for the sake of simplicity that perfect competition exists in the goods and factor markets. See also Solow (1957).
10 See also Comin (2008).
11 See Hulten (2001).
12 A fall in TFP growth was also apparent in this period in Austria, the Netherlands and Belgium. Together with the four largest euro area countries, these countries account for approximately 90% of economic output in the euro area.

years. Subdued investment and increased labour input were key factors in this development.[13] Between 2013 and 2019, the growth contributions of capital intensity contracted once more.

TFP measurement influenced by factors such as quality of work, capacity utilisation …

Standard growth accounting provides initial information about the main driving forces behind the slowdown in productivity growth. However, the results cannot be interpreted without acknowledging certain caveats. This applies in particular to the TFP contributions. Due to their residual character, they can be biased if the actual factor inputs are not accurately measured. Thus far, for example, neither changes in the quality of the factor labour or fluctuations in the degree of utilisation of labour and capital have been taken into account.[14] However, further analyses that control for these important factors confirm the finding of decreasing TFP growth, at least for the period since the establishment of monetary union (see also the box on pp.22 ff.).[15]

… and embodied technology

Moreover, traditional growth accounting typically does not take into account the fact that technological progress can be embodied and, for example, only be released through investment in new equipment. This applies to a large extent to information and communication technologies.[16] The contribution of capital-embodied technological progress to labour productivity growth can be determined with a model-based analysis. Here, too, the larger euro area economies display declining growth rates. This supports the hypothesis of a structurally driven slowdown in productivity growth (see also the box on pp. 25 ff.).

Determinants of total factor productivity at the corporate level

With regard to the importance of total factor productivity for labour productivity, the question arises as to the underlying explanatory factors for the slowdown in TFP growth in large parts of the euro area. A key determinant of the overall TFP path is the development of TFP at the enterprise level,[17] which is a function of enterprises' power to innovate and adopt new technologies. The former measures an enterprise's ability to develop new products and processes, while the latter assesses how well enterprises are able to integrate new technology into their production processes. Enterprises' innovation and adoption abilities have recently become a focal point.[18]

Macroeconomic productivity development shaped by enterprises' ability to innovate and adopt

No evidence of a general decline in innovative power but rather of a shift toward services

Own analyses of corporate data selected from a group of euro area countries[19] suggest that the previously above-average TFP growth of highly productive enterprises in the manufacturing sector slowed significantly (for more details, see the box on pp. 28 f.). By contrast, the innovative power of service providers with the highest TFP level even seems to have increased over time, in spite of burdens resulting from the global financial crisis and the subsequent sovereign debt crisis. Thus, although there is no evidence of a general lack of innovation at the enterprise level, there are indications of a shift in innovation toward services.

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13 See also Deutsche Bundesbank (2016). The temporary increase in the contribution of capital intensity to hourly labour productivity growth in Italy and Spain during the global financial and economic crisis and the subsequent sovereign debt crisis was the arithmetical effect of the considerable decline in labour input during this period.
14 For example, actual labour input may differ between employed persons working the same number of hours on account of their training, professional experience and other individual characteristics. For more information on quality adjustments to the factor labour and the difficulties entailed, see, inter alia: OECD (2001).
15 Further measurement problems arise in the price adjustment of inputs and outputs as well as the recording of capital input, particularly in the case of intangible goods (see OECD (2001) and Deutsche Bundesbank (2002)). The assumptions of constant returns to scale and perfect competition are also gross simplifications (see Hulten (2001, 2010)).
16 See, inter alia, Solow (1960), Greenwood et al. (1997), Sakellaris and Wilson (2004) and Hulten (2010).
17 See also Syverson (2011).
18 See, inter alia, Andrews et al. (2015, 2019) and OECD (2015).
19 The analysis is based on data for Germany, Spain, France, Italy, Belgium and Portugal for the period 2004-2017.

Measuring total factor productivity in the euro area

Total factor productivity (TFP) captures the fraction of output that cannot be explained by the amount of production factors. It is thus a key indicator for the efficiency of production processes.[1] However, TFP is not directly observable and, therefore, has to be estimated. A common approach is to capture TFP developments by decomposing output growth into the contributions of the primary production factors, i.e. labour and capital, as well as a residual component.[2] The latter, also known as the Solow residual, is interpreted as a measure of TFP growth.

One key challenge for the determination of TFP developments lies in precise measurement of the used production factors.[3] For example, idle assets or not fully utilised employees can cause an overestimation of factor inputs and thereby an underestimation of TFP growth. As the rate of capacity utilisation is typically procyclical, this might particularly bias the measurement of TFP in boom and bust phases.

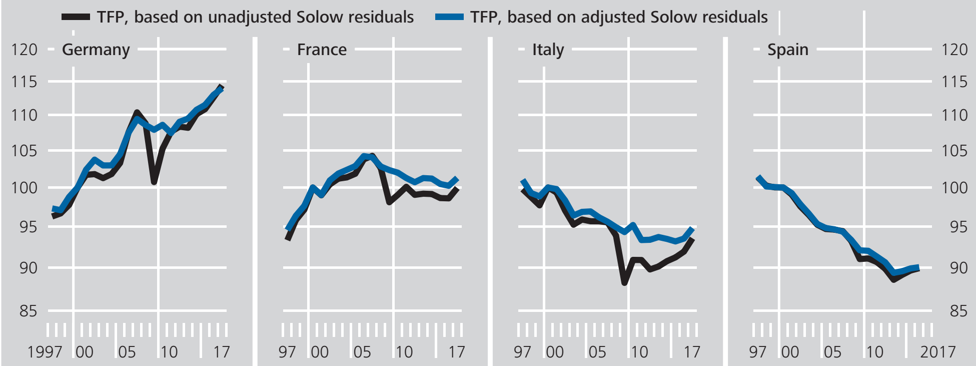
By incorporating an indicator for the degree of capacity utilisation, it is possible to better account for the actual use of production factors and, as a result, to measure TFP growth more accurately.[4] One such indicator can be found in the European Commission's business and consumer surveys.[5]

Not least in order to make full use of the available information, the growth decompositions are conducted at the sectoral level.[6] The Solow residual in each economic sector is calculated as the difference between the growth rate of price-adjusted gross value added and the growth rates of capital and (quality-adjusted) labour input weighted by the respective production elasticities.[7] The Solow residuals are then regressed in a panel on the percentage change in the economic sectors' average rates of capacity utilisation and sector-specific indicator variables.[8] Utilisation-adjusted TFP growth of an economic sector

1 See Comin (2008).
2 See Solow (1957). The decomposition is based on a Cobb-Douglas production function with constant returns to scale, which characterises output as a function of the capital and labour inputs (weighted by the production elasticities) as well as TFP. Assuming perfect competition on the factor and product markets, cost minimisation by firms implies that the production factors are remunerated according to their marginal products. The production elasticity of labour can therefore be determined by the ratio of the wage bill to gross value added, while the elasticity of capital is equal to one minus the elasticity of labour. See Deutsche Bundesbank (2012) and Hulten (2010).
3 This is only one possible bias. Distortions in the measurement of TFP can also result, inter alia, from disregarding factor-embodied technological progress or imperfect competition. See Hulten (2001, 2010) and Baqaee and Farhi (2020).
4 See Comin et al. (2020).
5 For the big euro area countries, quarterly data on the degree of capacity utilisation are available from the first quarter of 1985 onwards for the manufacturing sector and from the third quarter of 2011 onwards for the services sectors (Italy from the third quarter of 2010 onwards). See European Commission (2020).
6 The data were taken from the EU KLEMS database (https://euklems.eu/).
7 In the EU KLEMS data, labour input is weighted, inter alia, by the average educational attainment and age of the persons employed in the respective economic sector in order to incorporate the characteristics of the production factor. Capital services are based on the capital stock weighted by the user cost of capital. See EU KLEMS (2019). In order to account for the dynamics of the production elasticities, these are calculated as the average of the current and previous year.
8 The methodology follows the approach outlined by Basu et al. (2006) for the United States. Comin et al. (2020) use a similar approach to determine TFP measures for selected euro area countries. For the years prior to 2011 (for Italy prior to 2010), the capacity measures for the services sectors are extended backwards by using the growth rate of average capacity utilisation in the manufacturing sector (see Comin et al. (2020)). Due to a lack of data availability, the average capacity utilisation for the manufacturing sector is also used for the construction, trade as well as energy and water supply sectors. Survey data from the ifo Institute and the National Institute of Statistics and Economic Studies *(Institut national de la statistique et des études économiques)* are used for the German and French construction sectors, respectively.

Total factor productivity* in selected euro area countries between 1997 and 2017

2000 = 100, log scale



Sources: EU KLEMS, European Commission and Bundesbank calculations. * Unadjusted total factor productivity (TFP) was calculated using a prototypical Solow decomposition. Survey data on capacity utilisation were used in an econometric model to adjust TFP for changes in the rate of capacity utilisation.

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is then computed as the difference between the Solow residual and the estimated impact of changes in capacity utilisation.[9]

Since changes in capacity utilisation can, in turn, be triggered by exogenous changes in TFP, an instrumental variables approach is used for the estimation. The approach requires variables that are correlated with capacity utilisation, but not with TFP growth. The following structural shock series that were obtained in separate analyses prove suitable: an international oil price shock, an international financial market shock and macroeconomic uncertainty shocks.[10] Finally, aggregate TFP growth is derived by aggregating the adjusted TFP growth rates of the various economic sectors, weighted by gross value added shares.[11]

The calculations were performed for each of the four major Member States using data for 19 economic sectors.[12] To account for differences in the effect of capacity utilisation across different areas of the economy, the economic sectors were divided into three groups (durable manufacturing, non-durable manufacturing, and other economic sectors, in particular services). The panel estimations were conducted separately for each group.

While the time series of the unadjusted and adjusted TFP measures show similar trends, they can differ significantly in the short term. This is especially true for the years during the global financial and economic crisis. Whilst, according to the standard Solow decomposition, TFP contracts sharply in most countries during this period, the adjusted measure shows no or only a comparatively moderate decline.[13] Temporary

9 Capacity utilisation is only taken into account if the estimated coefficient is significant at the 90% level.
10 The oil price shock is calculated on the basis of movements in the Brent oil price (see Basu et al. (2006)). The uncertainty shocks stem from structural macroeconomic models (see Jurado et al. (2015) and Meinen and Röhe (2017)). The financial market shock is based on the indicator introduced by Gilchrist and Zakrajšek (2012) for the non-predictable component of risk premia on US corporate bonds. Statistical tests certify that the instruments are sufficiently correlated with the capacity utilisation of the sectors provided in the surveys.
11 See Hulten (1978).
12 The estimation period spans from 1997 to 2017 (Spain: 1997 to 2016). The models comprise sections D-E, F, G, H, I, J, K, M-N, R-S of the Statistical classification of economic activities in the European Community (NACE) as well as NACE divisions C10-C12, C13-C15, C16-C18, C20-C21, C22-C23, C24-C25, C26-C27, C28, C29-C30 and C31-C33 of the manufacturing sector.
13 This can also be observed, inter alia, in Austria, the Netherlands and Belgium.

reductions in typical, unadjusted TFP indicators can therefore often be explained by changes in capacity utilisation and, consequently, do not represent efficiency declines.

Over the longer term, the estimations confirm the findings from macroeconomic growth decompositions which are based on aggregate data (see also the remarks on pp. 19 ff.). In Germany, a slowdown in TFP growth is apparent following the global financial and economic crisis, whilst in France, TFP even stagnated. The picture is somewhat different for Italy and Spain. Following a continuous decline over most of the observation period, TFP improved for the first time in these countries before the onset of the current economic downturn.

Signs of enterprises' waning ability to adopt new technologies also apparent

With regard to enterprises' ability to adopt new technologies, there have been indications of a growing discrepancy between the TFP growth of highly productive enterprises and that of other enterprises since the global financial and economic crisis. The manufacturing sector is showing a similar development, although the differences between the groups of enterprises are noticeably smaller than those seen for services. Overall, the empirical analysis thus provides a differentiated picture of the reasons behind a flattening-out of TFP growth.

Reduced capacity to innovate and adopt new technologies may have both cyclical and structural causes

A decline in an enterprise's capacity for innovation and technology adoption can have a variety of causes. In addition to cyclical influences – in the form of severe recessions, for example – these include structural impediments such as a lack of quality in the institutional environment,[20] rigidities in the labour and product markets,[21] an increasing market concentration[22] or a lack of availability of (specific) human capital.[23] Thus, the considerable economic turmoil in the wake of the global financial and economic crisis and the subsequent sovereign debt crisis are just one possible cause of the slowdown in innovation capabilities and diffusion in the euro area countries. For example, there are also indications in the euro area of a clear need for reform in the institutional and regulatory frameworks, in some cases.[24] Added to this is the skills mismatch observed in the euro area labour market,[25] which is likely to become increasingly important in view of the ongoing demographic change (see also the remarks on pp. 33 ff.).

20 See, inter alia, Parente and Prescott (2000), Manca (2010) and Mokyr (2018).
21 See, inter alia, Andrews et al. (2019).
22 See, inter alia, Autor et al. (2020).
23 See, inter alia, Bartel and Lichtenberg (1987), Abowd et al. (2005) and Berlingieri et al. (2020).
24 See, inter alia, Deutsche Bundesbank (2019a).
25 See European Centre for the Development of Vocational Training (2015, 2019).

Capital-embodied technological progress and its importance for labour productivity: a DSGE analysis

Not least in view of the role played by information and communication technology (ICT), a range of studies has emphasised the importance of capital-embodied technological progress for the economy as a whole.[1] This specific form of technological change requires capital investment to become effective, and it impacts labour productivity, inter alia, by improving the quality of the capital stock.[2] Investment by firms in new, more powerful computer equipment is commonly cited as an example of capital-embodied technological progress enhancing productivity. Standard growth accounting approaches, which are based solely on disembodied technological progress, ignore these relationships.[3]

Dynamic stochastic general equilibrium (DSGE) models[4] are one way to grasp the macroeconomic role of capital-embodied technological progress.[5] This framework can also be used to estimate its contribution to trend labour productivity growth.[6]

To illustrate the approach, this box analyses labour productivity growth in the three largest euro area countries and the United States based on a DSGE model with different types of capital. In order to evaluate the extent to which capital-embodied technological progress specifically in the field of ICT contributes to labour productivity growth, we divide the capital stock (excluding structures) into two types of capital: ICT capital, which comprises information and communication technology plus software and databases, and other assets (non-ICT capital).[7]

In the model, the total contribution of capital-embodied technological change is equal to the weighted sum of the technological progress associated with each of these types of capital.[8] Capital-specific technological progress can be measured by the development of the ratio of consumption goods prices to investment goods prices.[9] The idea here is that investment-specific innovations will lower the price of investment goods relative to that of consumption goods.[10] The resulting increase in demand for investment goods is ultimately what enables technological progress to have its productivity-enhancing effect. However, the importance of capital-embodied technological progress of a specific capital type for labour productivity growth is also determined by its relative weight in the production process. Assuming a Cobb-Douglas production function with constant returns

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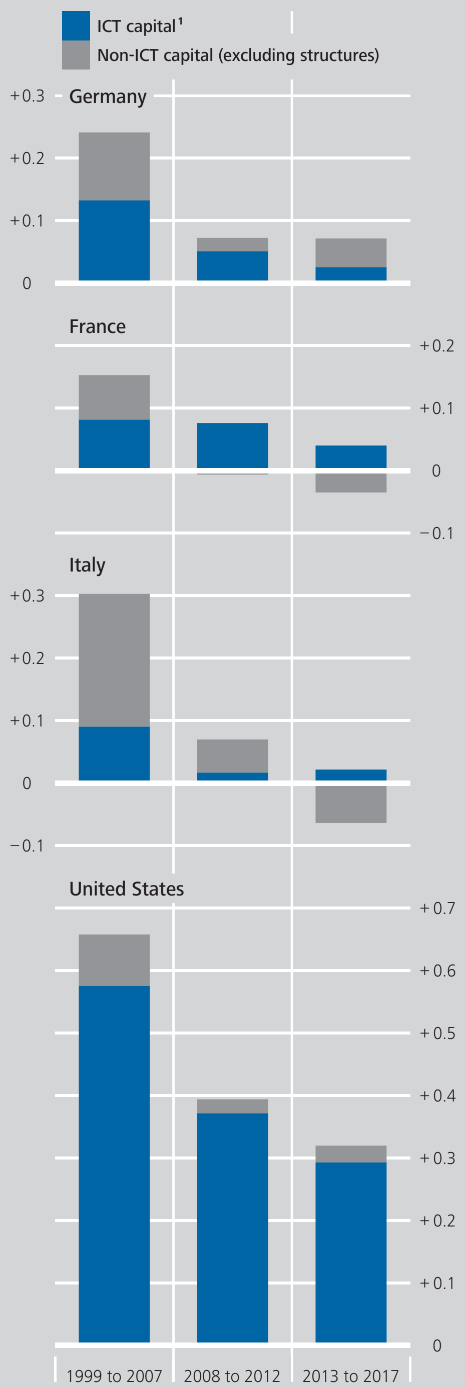
1 See, inter alia, Solow (1960), Greenwood et al. (1997), Hercowitz (1998), Cooper et al. (1999) and Greenwood and Jovanovic (2001).
2 The terms "capital-embodied technological progress" and "investment-specific technological progress" are therefore often used interchangeably in the literature.
3 See Solow (1957).
4 A typical feature of this model class is the way it seeks to explain macroeconomic relationships and developments based on the individual optimal decisions of rational economic agents. More specifically, it assumes that economic agents do not make any systematic errors when forming their expectations and that they make optimum use of all the information available to them. In this sense, they behave "rationally". This model framework is presented in detail, inter alia, in Christiano et al. (2018).
5 See, inter alia, Justiniano et al. (2011), Schmitt-Grohé and Uribe (2012) and Díaz and Franjo (2016).
6 See, inter alia, Greenwood et al. (1997), Bakhshi and Larsen (2005) and Rodríguez-López and Torres (2012).
7 The analysis for the three euro area countries is based on data from the EU KLEMS database on the capital stock, depreciation rates, the labour income share and labour productivity. These data are available over the period 1999 to 2017. For the United States, meanwhile, the relevant data are sourced from the US Bureau of Economic Analysis (national income and product accounts and fixed assets accounts) and the US Bureau of Labor Statistics.
8 The assumption here is that exogenous capital-embodied technological progress can be described by a stochastic trend. See also Schmitt-Grohé and Uribe (2011).
9 The model assumes that there is a linear relationship between the relative price and capital-embodied technological progress. Empirical evidence suggesting that such a relationship exists can be found, inter alia, in Schmitt-Grohé and Uribe (2011).
10 See Greenwood et al. (1997), Fisher (1999) and Pakko (2002).

Contributions of capital-embodied technological progress to average annual labour productivity growth in selected countries*

Percentage points



Sources: EU KLEMS, Haver Analytics and Bundesbank calculations. * Contributions of capital-embodied technological progress, broken down by type of capital, to the average annual (aggregate) growth rate of labour productivity (real GDP per hour worked). Computed from a dynamic stochastic general equilibrium model. **1** Investment capital in the areas information and communication technology, software and databases.

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to scale, the weight is given by the ratio of the respective capital income to total labour income.[11,12] This allows both technological progress and its relative importance for aggregate productivity to be derived in a model-consistent manner from macroeconomic data. In traditional growth accounting approaches, by contrast, the contribution of (disembodied) technological progress to labour productivity growth is typically measured as a residual. This might lead to considerable mismeasurement of technological progress (see also the box on pp. 22 ff.).[13]

However, the approach outlined above relies on a number of simplifying assumptions. These include, in addition to the basic principles of the standard neoclassical model, the assumption of a closed economy and of labour being a homogenous production factor.[14,15] The model furthermore presumes that there is a direct inverse relationship between capital-embodied technological progress and the respective relative price of ICT and non-ICT investment goods. This requires that the prices of investment goods are accurately captured in the official statistics.[16]

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11 One particular feature of the model specification chosen here is the assumption of time-varying production elasticities. Therefore, unlike in the prototypical approach, there is no need to confine the analysis to an assessment of long-term equilibria (where it is standard practice to assume constant parameters as production elasticities that are calibrated to average values). Instead, changes in capital and labour income shares can be taken into account. In the above DSGE approach, exogenous stochastic shocks are assumed to capture the time-varying production elasticities. See Young (2004), Ríos-Rull and Santaeulàlia-Llopis (2010) and Lansing (2015).
12 See Eden and Gaggl (2018).
13 See also Greenwood and Krusell (2007).
14 For a critical discussion of these assumptions, see, inter alia, Chen and Wemy (2015).
15 The impact of capital goods imports on investment-specific technological progress is discussed, inter alia, in Cavallo and Landry (2010).
16 In this regard, the literature notes that in the field of ICT especially, insufficient attention has been given to adjustments for changes in quality, which can lead to a mismeasurement of technological progress. See, inter alia, Byrne et al. (2017).

Model-based growth accounting shows that the contributions of capital-embodied progress in ICT to aggregate labour productivity growth turned out to be smaller in all countries under observation during the post-crisis period compared to the time before the global financial and economic crisis. In this context, it is noteworthy that ICT-specific technological progress had a comparatively low relative weight for labour productivity over the entire observation period.[17] This suggests that the at times fairly large ICT-specific growth contributions to labour productivity, particularly in the 1999-2007 sub-period, can be attributed to exceptionally strong growth rates of capital-embodied technological progress. This is particularly the case for the United States.[18]

Non-ICT-specific technological progress evolved in a similar way over time, its contribution to labour productivity growth likewise decreasing markedly and even changing signs in part in recent years.

Taken as a whole, all countries considered saw the growth contributions of capital-embodied technological progress decline in the post-crisis period relative to the preceding era. This outcome is consistent with the finding that TFP dynamics have been receding, as outlined by traditional growth accounting exercises (see the remarks on this topic on pp. 19 ff.).[19]

17 Average ICT capital income shares range between 2% (Italy) and 5% (United States) over the total observation period. By contrast, capital income shares for non-ICT assets vary from 10% in the United States to 19% in France.
18 The United States records significantly higher contributions of ICT-specific technological progress to labour productivity growth than the three euro area countries over all periods under observation. This finding is consistent with the results of other empirical studies. See, inter alia, van Ark et al. (2003) and Cette et al. (2015).
19 See Cette et al. (2016).

The role of factor allocation and business dynamism in the development of total factor productivity

TFP growth also influenced by factor allocation between enterprises

In addition to within-firm dynamics, the distribution of production factors, such as labour and capital, across enterprises plays an important role in aggregate productivity growth. The reallocation of production factors from relatively low-productivity enterprises to high-productivity enterprises is a key driver of aggregate TFP growth.[26] By contrast, systematic misallocations reduce aggregate production efficiency.

Increasing dispersion of marginal revenue products within economic sectors …

A comparison of the marginal revenue products of capital and labour across enterprises within an industry provides an important indication of whether production factors have been misallocated. The marginal revenue product shows how revenue would change if an enterprise raised its factor input marginally. Diverging marginal revenue products within an industry suggest that value added can be pushed up by decreasing (increasing) the input of production factors in enterprises with a relatively low (high) marginal revenue product. In case of an efficient allocation, the marginal revenue products of enterprises in an industry should be similar to each other.[27]

… points to increasing misallocation in the euro area

Corporate data provide an opportunity to examine the development of marginal revenue products. For the euro area, however, limited data availability across countries and sectors

26 See, inter alia, Foster et al. (2001, 2006), Bartelsman et al. (2013) and Restuccia and Rogerson (2017).
27 In macroeconomic models, the marginal revenue products of enterprises in an industry are, under certain assumptions, identical in a first-best scenario. These models assume, in particular, identical production functions of the Cobb-Douglas type as well as perfect price adjustments to changes in demand. See Hsieh and Klenow (2009) and Restuccia and Rogerson (2017).

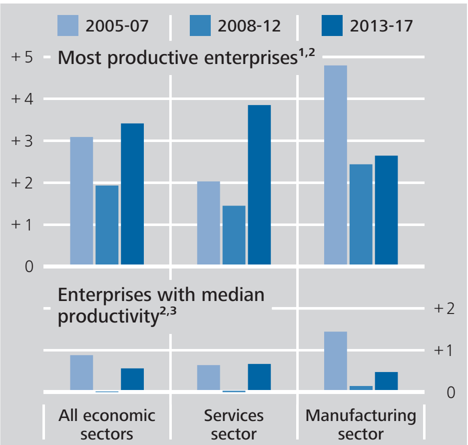
Developments in innovation activity and productivity growth in Europe

In recent years, the advanced economies have seen a marked decline in productivity growth. "Techno-pessimists" attribute this to a slowdown in technological progress, i.e. a general low level of innovation.[1] From the point of view of "techno-optimists", however, technological progress is generally still intact. In their opinion, weak productivity growth is more a result of mismeasurement, allocation inefficiencies, and a reduced diffusion of innovation.[2]

The question of the extent to which weak productivity growth in Europe stems more from a low level of innovation or more from reduced diffusion can be investigated using a dataset covering enterprises from six euro area countries (Belgium, France, Germany, Italy, Portugal and Spain); this data can be used to calculate growth rates in total factor productivity (TFP) for each enterprise and each year.[3] The findings are inconsistent: while TFP growth among highly productive enterprises[4] – interpreted here as a measure of innovative power – actually appears to have increased recently in the services sector, it declined in the manufacturing sector. According to the calculations, productivity growth among the leading enterprises in the high-technology segments of the manufacturing sector in particular – such as pharmaceuticals, mechanical engineering and IT hardware – has fallen distinctly over time.[5] One reason for this may have been waning business dynamics (as measured by rates of market entry and exit). At the very least, this is suggested by the relatively high and sharply increasing average age of the leading enterprises in

Average annual TFP growth rates for enterprises at and behind the technology frontier

%



Sources: iBACH (micro Bank for the Accounts of Companies Harmonized), ECCBSO (European Committee of Central Balance-Sheet Data Offices), Orbis (Bureau van Dijk), and ECB and Bundesbank calculations. **1** Weighted sum of the average annual growth rates in total factor productivity (TFP) of the most productive 5% of enterprises in each industry (NACE level 4). **2** The weighted aggregate across industries is calculated using the average number of employees in each industry during the period from 2005 to 2017. **3** Weighted sum of the TFP growth rates of those enterprises with the median TFP level in each industry (NACE level 4).

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1 See Gordon (2016) and Bloom et al. (2020a).
2 See Brynjolfsson and McAfee (2014), van Ark (2016) and OECD (2015).
3 The analysis is based on the iBACH database (micro Bank for the Accounts of Companies Harmonized) processed by the ECB and expanded to include data from the Orbis database (Bureau van Dijk). This database contains annual balance sheet data from a multitude of non-financial enterprises from the six aforementioned countries. The database provides information on a considerable portion of the relevant enterprises in France, Italy, Portugal, Spain and, to a limited extent, in Belgium. Germany is represented only by a comparatively small number of large enterprises, which are included in the Orbis database. Annual and enterprise-specific TFP levels and growth rates were calculated using an estimated production function. The dataset covers the period from 2005 to 2017 as well as the following NACE sections: C (excluding C12 and C19), F, G, H (excluding H51), I, J, L, M (excluding M75) and N (excluding N78 and N82).
4 For each year, the most productive enterprises are defined as the 5% of enterprises with the highest TFP level in a given industry (NACE level 4) in that year.
5 The segments of the manufacturing sector are divided into those with relatively intensive usage of high technology and those with comparatively limited usage of high technology on the basis of the corresponding Eurostat classification. The group of high-technology industries includes NACE divisions C20, C21, C26, and C27 to C30.

this subgroup.[6] On the whole, however, the enterprise data provide no indication of a general low level of innovation.[7]

With regard to TFP growth among less productive enterprises,[8] which comprise the majority of enterprises in every sector, the findings are similarly complex. In this case, too, the TFP growth of enterprises in the manufacturing sector appears to have declined noticeably. By contrast, TFP growth in the services sector stagnated despite heightened innovation activity among the leading enterprises. As a result, the gap in productivity between highly productive and less productive service providers widened considerably, which may be interpreted as a sign of a reduced diffusion of technology.[9]

There are a number of possible explanations for the decline in technology diffusion observed in some sectors. For instance, the nature of technological progress over recent years, often characterised by the use of digital technologies and intangible capital, may have made it more difficult to close productivity gaps.[10] In addition, a general rise in market power – not necessarily induced by technology – may have reduced incentives to adapt technologies or innovate.[11] In Europe, however, there is very little evidence to suggest a broadly based increase in market concentration and market power.[12] Ultimately, even if there are incentives to adapt innovations, it is likely that, in many cases, enterprises simply lack the corresponding complementary resources required to do so (such as well-trained and skilled workers or a specific infrastructure).[13]

In summary, the results of the enterprise data analysis suggest that there are multifaceted reasons for weak macroeconomic productivity. They do not provide any indication of a general low level of innovation. The findings suggest that the leading, highly productive enterprises should be given sufficient scope to develop their growth potential, at least to the extent that this does not excessively subdue their incentives to innovate or third parties' incentives to imitate. Less successful competitors should not be prevented from exiting the market and the subsequent reallocation of resources should not be obstructed. Such an approach would most likely boost macroeconomic productivity growth.

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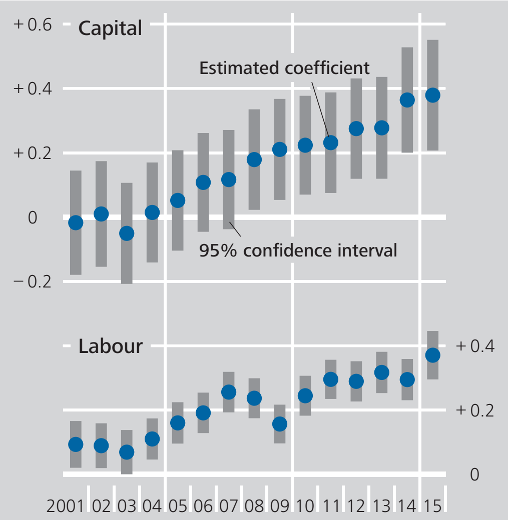
6 In the subgroup of industries that utilise high technology less intensively, the average age of enterprises at the technology frontier (known as "frontier firms") rose by just over 1 year from 14 years (in the period from 2006 to 2007) to around 15¼ years (in the period from 2013 to 2017). For industries characterised by greater usage of high technology, this figure rose by around 5½ years to just under 19 years during the same period.
7 Here, it also cannot be ruled out that, especially during phases of cyclical upturn and downturn, TFP growth is captured only imprecisely (for more information, see the box entitled "Measuring total factor productivity in the euro area").
8 In this context, the productivity growth of this group is approximated based on the TFP growth of the enterprise with the median TFP level in each year and each industry (NACE level 4).
9 A number of studies have reached similar overall conclusions for the services sector in particular. See Andrews et al. (2015, 2019), Lotti and Sette (2019), Cette et al. (2018) and Decker et al. (2016).
10 In this vein, it is argued that the rising use of digital technologies and intangible capital, which is often associated with high fixed costs and network effects, also leads to increasing economies of scale. See Haskel and Westlake (2018), Aghion et al. (2020) and De Ridder (2020). Such economies of scale cannot be replicated at will. Increasing economies of scale could also result in "superstar effects" (see Autor et al. (2020)): especially in less mature sectors, market leaders may use economies of scale to capture large market shares within very short periods of time, thus leading to rising market concentration and market power. This may reduce the incentives to invest in innovation and adapting technologies, which would ultimately have a dampening effect on productivity growth. See Aghion et al. (2020), De Ridder (2020) and Le Mouel and Schiersch (2020).
11 For example, multiple studies suggest a broadly based increase in market power for the United States in particular over the past few years. See De Loecker et al. (2020).
12 See Deutsche Bundesbank (2017), OECD (2018) and Gutierrez and Philippon (2020).
13 In particular, there may be a lack of sufficient human capital (see Berlingieri et al. (2020)). This applies especially with regard to digital technologies that require employees with relevant IT skills in order to be utilised successfully. See Autor et al. (2003) and OECD (2016).

Estimated changes in the dispersion of marginal revenue products of capital and labour in the euro area*



Sources: CompNet and Bundesbank calculations. * Changes in the average dispersion of (standardised) marginal revenue products within selected economic sectors compared with the base year 2000, derived from a panel model with indicator variables for countries, sectors and years. The estimations include data from 11 euro area countries (Belgium, Finland, France, Germany, Italy, Lithuania, the Netherlands, Portugal, Slovakia, Slovenia and Spain) and 57 NACE divisions from sections C, F, G, H, I, J, L, M and N.

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complicates this analysis.[28] Nonetheless, by using a panel model with indicator variables for industries, countries and years, it is possible to estimate how the dispersion of marginal revenue products has changed on average across economic industries.[29] The estimated coefficients of the annual indicators reflect how the dispersion has changed on average across all industries and countries over time. They show that the dispersion of marginal revenue products has increased since the mid-2000s, and that this rise accelerated again slightly at the end of the estimation horizon.[30] Moreover, this fairly continuous development suggests that these are not purely cyclical phenomena. Rather, allocation efficiency within euro area industries appears to have deteriorated structurally, which is likely to have contributed to the slowdown in euro area productivity growth.[31]

Role of business dynamism in productivity growth

Changes in business dynamism are one possible explanation for the declining allocation efficiency between enterprises. For instance, a number of studies stress the importance of enterprise births and deaths for reallocation processes and productivity growth.[32] Schumpeterian growth models, in which the entry of young innovative firms into the market increases the degree of competition and the pressure for competitors to innovate, thus leading to the exit of less profitable producers ("creative destruction"), also indicate a link between business dynamism and productivity growth.[33]

Data on enterprise births and deaths in the euro area …

Owing in particular to the limited availability of data, a panel model is estimated to answer the question of how business dynamism has developed in the euro area.[34] Country-specific sectoral market entry and exit rates are regressed on a constant and indicator variables

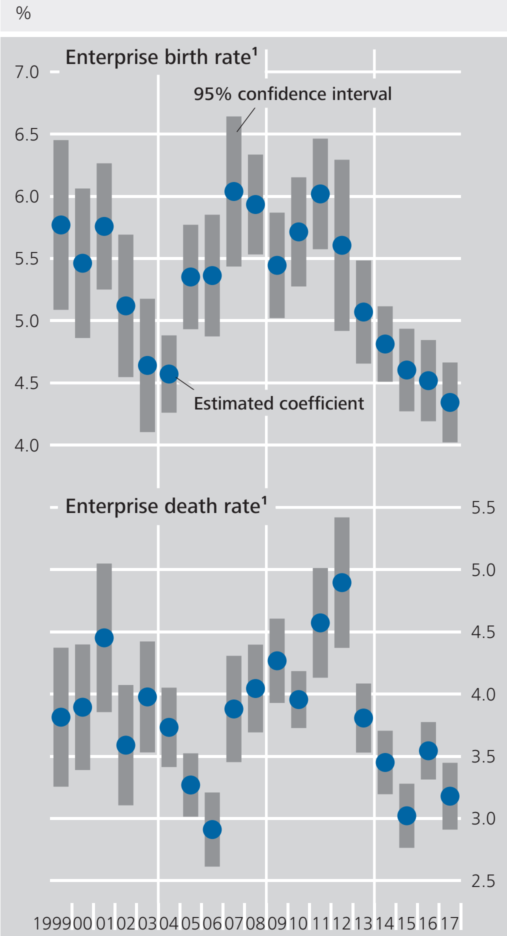
28 Data on marginal revenue products are taken from the CompNet database (www.comp-net.org). An enterprise's marginal revenue product is calculated as a product of the production elasticity of labour or capital and the ratio of revenue to labour or capital input, assuming a Cobb-Douglas production function and perfect competition. The dispersion is calculated as the standard deviation of the marginal revenue products across enterprises within an industry, with these being normalised at the industry level (see Kehrig (2011)).
29 The estimates include data from eleven euro area countries and 57 industries for the years 2000 to 2015. The latter belong to the following NACE sections: "manufacturing" (C), "construction" (F), "wholesale and retail trade; repair of motor vehicles and motorcycles" (G), "accommodation and food service activities" (I), "information and communication" (J), "transportation and storage" (H), "real estate activities" (L), "professional, scientific and technical activities" and "administrative and support service activities" (M-N). The data situation varies considerably across countries. For example, only data for NACE section C are available for Germany. See CompNet (2020).
30 It should be noted that estimation uncertainty is higher due to a smaller number of observations for the dispersion of the marginal revenue product of capital.
31 The finding is consistent with indications that misallocations have increased in southern European countries (Gopinath et al. (2017)) and selected OECD countries (Corrado et al. (2019)). When interpreting the results, it should be borne in mind that an aggregate analysis may mask potential differences between countries.
32 See, inter alia, Foster et al. (2001, 2006, 2008), Lentz and Mortensen (2008) and Decker et al. (2017).
33 See, inter alia, Schumpeter (1934), Nelson (1981), Aghion and Howitt (1992), Caballero and Hammour (1996) and Aghion et al. (2014).
34 The inclusion of cross-sectional information in the form of sectoral data on enterprise births and deaths provides an opportunity to shed light on the development of business dynamism in the euro area, despite a limited time series dimension and existing data gaps.

for countries, years and sectors.[35,36] The changes in the annual enterprise birth and death rates in the euro area are then derived from the estimated coefficients of the time indicators.[37] The data cover 19 euro area countries, each with nine economic sectors,[38] for the years 1999 to 2017.

… tend to show slowing business dynamism

There are signs that business dynamism in the euro area has undergone a slowing trend. However, developments have not been steady and the estimates are subject to considerable uncertainty. The development between 2013 and 2017 is particularly striking. Despite the broad-based economic upturn over this period, the rates of enterprise births and deaths declined markedly. As the economic situation was favourable overall, one would normally have expected a rise in enterprise births.[39] A possible explanation for this development is the similarly unusual marked decline in the market exit rate. If fewer firms exit the market, this can impede the entry of potential candidates, as competition for sales markets and scarce production factors is then greater.[40] The question therefore arises as to whether the extended policy measures implemented during this period were beneficial to established enterprises in particular and could have thus dampened business dynamism.

Estimated enterprise birth and death rates in the euro area*



Sources: Eurostat and Bundesbank calculations. * Estimated birth and death rates for enterprises with at least one employee. The underlying panel estimations include data for all 19 euro area countries and the following nine economic sectors or sector groups according to NACE Rev. 2: B, C, D-E, F, G, I, J and H, K and L-N. **1** Number of enterprise births or deaths relative to the total number of active enterprises in the respective year.
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Structural change as a possible cause of flattening productivity growth

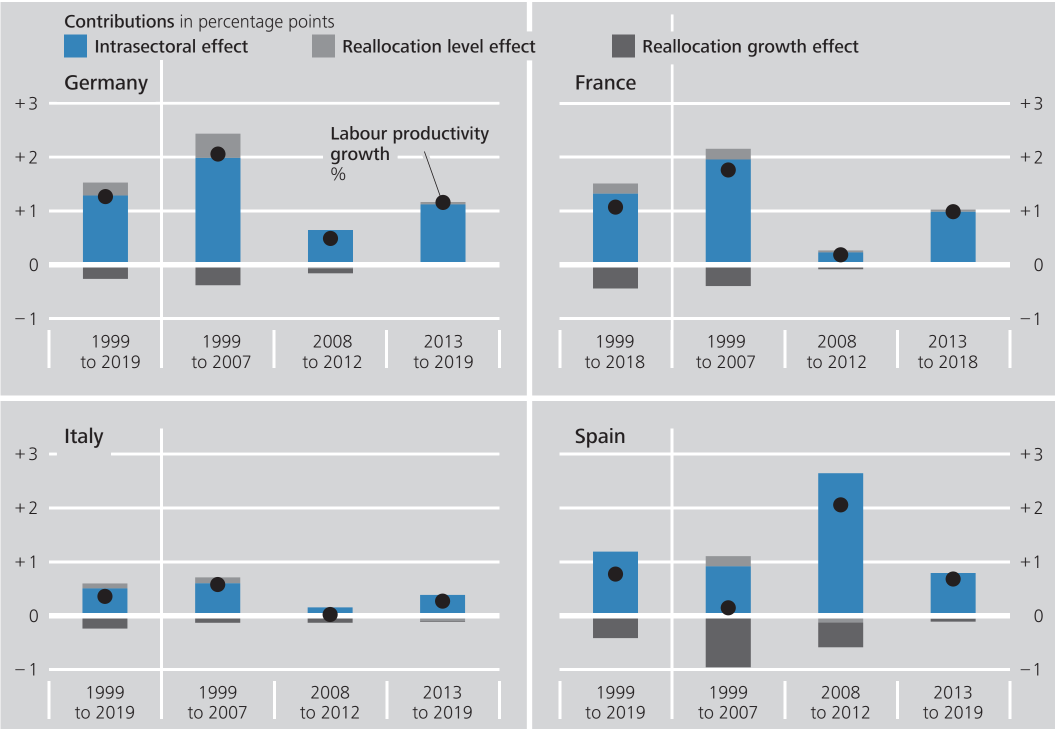
Impact of reallocation of labour input between economic sectors on aggregate productivity growth

Productivity-dampening effects can also emerge from the changing economic structure and the associated intersectoral shifts in production factors. One prominent hypothesis in this context is that the share of employees in

35 The birth rate (death rate) is defined as the ratio of the number of enterprise births (enterprise deaths) to the total number of active enterprises in the respective year. The analysis only considers enterprises with at least one employee in order to ensure better comparability across countries. See Eurostat (2007).
36 The country data on enterprise demographics reported by Eurostat only go back to 1997, with data availability varying across member countries. In addition to fundamental differences regarding when data were first recorded, the country data are incomplete in some cases. Furthermore, a conceptual revision of the statistical classification of economic activities in the European Community (NACE) makes it more difficult to examine business dynamism over time. The updated version of statistics relating to economic activities (NACE Rev. 2) has been applicable since 1 January 2008. See Eurostat (2008).
37 Average enterprise birth and death rates over time are calculated from the estimated coefficients of the country and sector indicators.
38 The economic activities covered include NACE sections C, F, G, I, J and H, and L to N, as well as the sections “mining and quarrying” (B), “electricity, gas, steam and air conditioning supply” and “water supply; sewerage, waste management and remediation activities” (D-E) and “financial and insurance services” excluding holding companies (K, excluding NACE group 642).
39 See also Koellinger and Thurik (2012), Lee and Mukoyama (2015) and Tian (2018).
40 See also Caballero et al. (2008) and Acharya et al. (2019).

Contributions to labour productivity growth in selected euro area countries*

Average annual change



Sources: Eurostat and Bundesbank calculations. * Contributions to growth in labour productivity (real gross value added per hour worked) in the market sector, which comprises NACE sections A, B-E, F, G-I, J, K, M-N and R-S.

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the workforce working in economic sectors with comparatively low productivity growth increases on account of consumer preferences.[41] This curbs overall productivity growth even without changes in productivity or its growth rate in individual enterprises or sectors.[42] The significance of this reallocation effect can be illustrated by breaking down productivity growth into three sub-components. A "reallocation level effect" captures the contribution to aggregate productivity growth that results from a shift in labour input between sectors with different productivity levels. A "reallocation growth effect" measures the impact of a shift in working hours between sectors with different productivity growth rates. In addition, there is an "intrasectoral effect", which is calculated as the weighted sum of productivity growth in the economic sectors under consideration and which reflects, amongst other things, sector-specific TFP growth.[43] When viewed in isolation, the reallocation growth effect causes aggregate hourly productivity to rise when labour input increases (decreases) in areas with positive (negative) productivity growth. The reallocation level effect makes a positive contribution to labour productivity growth if hours worked are increased (reduced) in sectors with a comparatively high (low) hourly productivity relative to aggregate labour productivity.[44] Consequently, factor reallocation across economic activities can help to increase aggregate labour

41 For example, consumers do not want to give up services provided by sectors with low productivity growth, and even increase their demand for such services.
42 See Baumol (1967) and Baumol et al. (1985).
43 The literature contains various methods of decomposing labour productivity growth in this manner. In order to avoid distortions that may arise when adding chained volume data, the "generalised exactly additive decomposition" (GEAD) method was used to break down hourly productivity. A detailed description of the method can be found in Tang and Wang (2004) and Dumagan (2013).
44 In the context of this kind of labour productivity decomposition, some simplifying assumptions are typically made, including the fact that no differences in the quality of the labour input are taken into account.

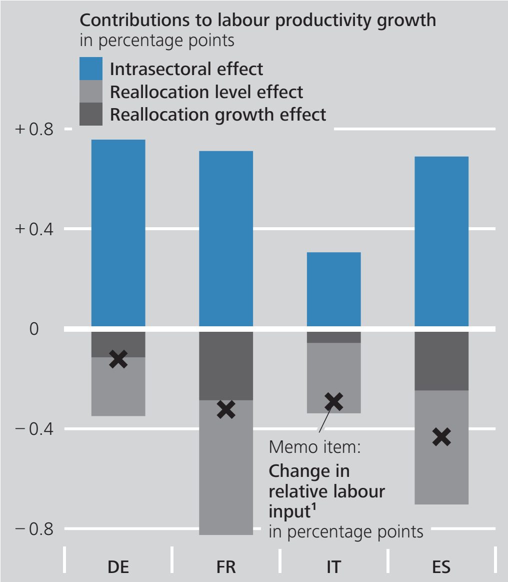
productivity even if sectoral productivity growth is stagnant.[45]

Decomposition of aggregate productivity growth shows industry's relative loss of importance

A corresponding decomposition for the four largest euro area economies shows that, on average, productivity growth over the years 1999 to 2019 was driven mainly by the intrasectoral effect.[46] Nevertheless, reallocation effects in countries where the intrasectoral effect is relatively small can have a noticeable impact on aggregate productivity growth. However, it can be seen that the direction of impact of the two reallocation effects is often divergent. For instance, the reallocation level effect was mostly positive on average across all of the sectors under consideration (labour input shifted on average to sectors with above-average productivity), while the reallocation growth effect was negative (labour input shifted on average to sectors with below-average productivity growth).[47] The latter was mainly driven by the relative loss of importance of the industrial sector. The negative impact of the reallocation growth effect was particularly strong in the pre-crisis period from 1999 to 2007. Nevertheless, in France, Italy and Spain a productivity-dampening effect – albeit only marginal at times – caused by shifts in the number of hours worked to economic sectors with comparatively weak productivity growth can also be seen in the economic recovery period from 2013 to 2019.

Contributions of the industrial sectors to aggregate labour productivity growth between 1999 and 2019*

Average annual change



Sources: Eurostat and Bundesbank calculations. * Contributions of the industrial sectors (NACE sections B-E) to average growth in labour productivity (real gross value added per hour worked) in the market sector (NACE sections A, B-E, F, G-I, J, K, M-N and R-S). Data for France up to 2018. 1 Relative labour input reflects the share of hours worked in the industrial sectors.

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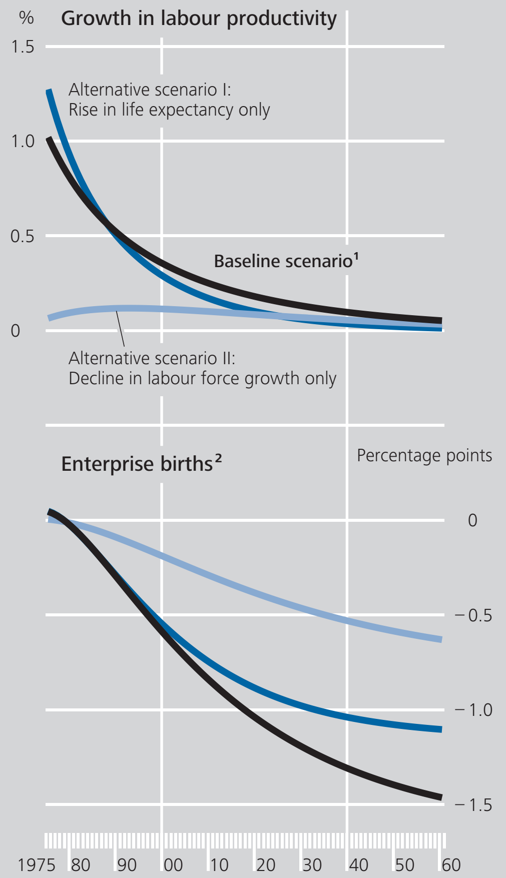
The impact of demographic change

Ageing population has direct impact on productivity

Demographic change is another structural factor with a potential impact on labour productivity. The progressive ageing of the population can dampen productivity growth in a number of ways. First, there are indications that individual productivity varies across age groups and tends to decline at an older age.[48] There is also growing evidence that societal ageing reduces innovation and technology adoption.[49]

45 Alongside changes in labour input, sectoral relative price changes can also influence the contributions of reallocation effects in the GEAD decomposition. Although these price effects can be isolated by modifying the GEAD method, this comes at the cost of giving up an isolated assessment of the two reallocation effects; see Diewert (2015). It is evident, however, that the price effects have a negligible impact on the results of the analysis carried out here.
46 Only the following NACE sections are considered here: A (agriculture, forestry and fishing), B-E, F, G-I, J, K, M-N and R-S (arts, entertainment and recreation and other service activities). The reasons for this selection include the partial absence of market prices in public services data and, with regard to the aim of measuring efficiency, a distorting effect in the case of real estate activities. In the case of the latter, total rents from real estate including the use of owner-occupied dwellings are recorded. See also Institute for the World Economy (2017).
47 In the four euro area countries considered in the analysis, the positive reallocation level effect between 1999 and 2019 is due, in particular, to a relative increase in labour input in "professional, scientific and technical activities" and "administrative and support service activities" (NACE sections M and N). Although these areas showed below-average productivity growth over the period under review, their level of productivity was above average.
48 See Feyrer (2007), Jones (2010), Aiyar et al. (2016) and Maestas et al. (2016).
49 Empirical studies suggest that an ageing population negatively affects the number of patent applications (Aksoy et al. (2019)), enterprise births (Ouimet and Zarutskie (2014)) and the ability to adopt new technologies (Weinberg (2004) and Skirbekk (2004)).

Effects of demographic change on labour productivity and enterprise births



Sources: Bundesbank calculations based on Röhe and Stähler (2020). **1** The baseline scenario shows the combined effect of rising life expectancy and a decline in the growth rate of the labour force on labour productivity growth and the entry rate of enterprises in an OLG-DSGE model. The simulation period spans from 1970 to 2060. The model is calibrated for the United States. **2** Deviation from the state with constant population growth and unchanged life expectancy.

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Other possible transmission channels of demographic change

Furthermore, it is conceivable that societal ageing, as a result of declining growth of the labour force and rising life expectancy, may also influence TFP growth through its impact on market dynamics. A dynamic general equilibrium model with overlapping generations as well as endogenous market entry and exit of enterprises demonstrates this.[50] In this model, ageing reduces fluctuations in the number of enterprises.[51] This is due, in particular, to the savings decisions prompted by higher life expectancy, which depress the real interest rate.[52] As a result, incumbent enterprises find it easier to refinance their fixed assets, with the result that fewer enterprises close. This creates a competitive disadvantage for potential market entry candidates, which is reflected in a decline in the birth rate of enterprises in the long term. Business dynamism, however, is an important driver of TFP growth. The model framework also illustrates that societal ageing can dampen labour productivity growth over time, even without having a direct impact on TFP.[53]

Empirical analyses of euro area based on a vector autoregressive model …

In order to empirically examine the impact of demographic change on productivity growth in the euro area, a vector autoregressive model with a panel structure is estimated. In this model, important macroeconomic variables for a number of Member States are regressed on their own lagged values and exogenous variables. The dependent variables comprise year-on-year labour productivity growth, the saving and investment ratio, the short-term real interest rate and the inflation rate. The exogenous variables are demographic indicators: the shares of the population that are categorised as young (below 20), middle aged (aged 20 to 64) and elderly (aged 65 and above).[54] Because of the data's cross-sectional dimension, the model can also take advantage of variations in the ageing process across Member States to identify the effect of demographic changes on endogenous variables. The panel model com-

50 A detailed description of the model, calibrated for the United States, can be found in Röhe and Stähler (2020).
51 This finding is consistent with studies that see ageing as a key factor in the decline in business dynamism in the United States. See Pugsley and Sahin (2019), Hopenhayn et al. (2018) and Karahan et al. (2019).
52 See also Carvalho et al. (2016) as well as Kara and von Thadden (2016).
53 For example, although a higher life expectancy leads to a clear rise in capital intensity – assuming a prototypical production function – its growth rate declines steadily over time, which is reflected in a slowdown in labour productivity growth.
54 See Aksoy et al. (2019). The estimating equation $Y_{it} = a_i + AY_{it-1} + DW_{it} + \varepsilon_{it}$, where Y_{it} encompasses the dependent variables and W_{it} the age structure of country i in year t (a_i and ε_{it} are a country-specific constant and a residual). To avoid exact linear dependencies, the differences between the share of the population classed as young and middle aged to the share of the population classed as elderly are entered as exogenous variables. The influences of the individual age groups can then be derived from the estimated coefficients. Vector W_{it} also includes lagged values of an international oil price.

Projected change in population shares and labour productivity growth

%

Population share	Euro area 2017	Euro area Δ 2030[1]	Germany 2017	Germany Δ 2030[1]	France 2017	France Δ 2030[1]	Italy 2017	Italy Δ 2030[1]	Spain 2017	Spain Δ 2030[1]
Below 20	20.3	– 1.4	18.5	0.4	24.0	– 1.9	18.2	– 2.4	19.4	– 2.4
Aged 20 to 64	59.3	– 3.7	60.1	– 5.2	56.3	– 2.6	59.3	– 3.0	61.4	– 3.5
Aged 65 and above	20.4	5.1	21.4	4.8	19.7	4.5	22.5	5.4	19.1	5.9
Δ LP growth[2]	– 1.4		– 1.2		– 1.3		– 1.6		– 1.8	
90% confidence bands	(– 2.2; – 0.7)		(– 2.0; – 0.4)		(– 2.0; – 0.7)		(– 2.4; – 0.9)		(– 2.6; – 1.0)	

Source: UN World Population Prospects and Bundesbank calculations. **1** Projected change in the respective population share between 2017 and 2030 (in percentage points). **2** Estimated change in growth rate of labour productivity (real GDP per hour worked) caused by the projected change in the age structure between 2017 and 2030 (in percentage points).

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prises 17 euro area Member States and is estimated over the period from 1971 to 2017.[55]

… suggest a distinct negative impact of ageing on labour productivity growth …

As demographic variables typically only change slowly over time, the analysis focuses on long-term relationships, which can be derived from the estimated coefficients of the panel model.[56] This analysis suggests that an increase in the share of the elderly population – with a concurrent fall in the young and middle-aged population shares – is likely to have dampened labour productivity growth in the euro area countries. Between 2007 and 2017, for example, the share of the population aged over 65 in the euro area increased by around 2.5 percentage points. According to the estimation, overall productivity growth in the euro area would have been around 0.8 percentage point higher during this period if the age structure had remained unchanged.

… and also indicate that productivity growth will be dampened going forward

United Nations projections suggest that the percentage of the euro area population aged over 65 years will rise even more sharply in the future. Between 2017 and 2030, their share is expected to increase from around 20% to more than 25%. According to the estimates, this would depress euro area productivity growth by a total of 1.4 percentage points over this period. On average, this corresponds to a decline of just over 0.1 percentage point per year.

The picture is similar for the euro area's four major economies. However, productivity growth in Italy and Spain would, in fact, decline somewhat more sharply, as the ageing process is forecasted to be more rapid there. When interpreting the projections, it should, however, be noted, that the estimation results (as well as the population forecasts) are subject to uncertainty. Moreover, no account is taken of potential factors that could counteract the adverse effects of ageing. And finally, the calculations are based on the simplifying assumption that changes in the age structure have the same impact on productivity trends in all the countries included in the analysis.

Conclusion and outlook

Slowdown in productivity growth in the euro area attributable to cyclical as well as structural factors

Growth in labour productivity in the euro area has slowed significantly over the past 20 years. This slowdown was broad based across the Member States and was evident in numerous sectors of the economy. It can be attributed, amongst other things, to a reduction in the

55 The estimate covers all Member States except Luxembourg and Malta. Due to data availability, the length of the time series used varies across countries.
56 The long-term impact of the demographic variables is derived from the long-term equilibrium of the model. This results from a combination of the coefficient matrices: $(I-A)^{-1}D$. See Aksoy et al. (2019).

Possible impact of the coronavirus pandemic on productivity growth in the euro area

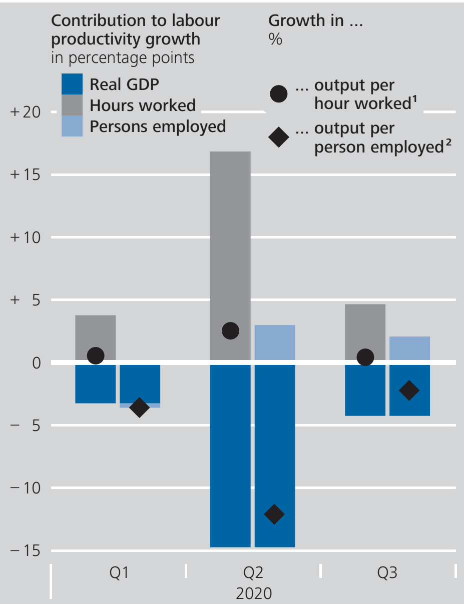
In the light of the current severe economic crisis and its specific nature, the question arises as to the implications for euro area productivity growth. In the short term, both the pandemic-induced constraints on production and also its recovery are having a direct impact on labour productivity. In this context, it is of significance that governments' efforts are currently aimed at safeguarding as many jobs as possible. One instrument in this respect is government-assisted short-time work. As a consequence, output per person employed in the euro area initially fell significantly before recovering again.

The development of output per hour worked was more remarkable. It rose sharply at times, as it already had done in some countries during the global financial and economic crisis. Compositional effects are likely to have played a role in this, as the containment measures mainly affected sectors with below-average labour productivity. This probably obscured possible productivity-reducing effects caused by abrupt, pandemic-related changes in working methods, such as the switch to teleworking.[1] The temporary closure of child daycare facilities and schools presumably has also affected not only labour supply but also labour productivity.[2]

Beyond these short-term impacts, longer-term effects need to be taken into account. For example, despite the massive economic and monetary policy interventions, investment activity suffered significantly, also owing to the temporarily steep rise in uncertainty.[3] If the decline in investment is not compensated for sufficiently fast, it is likely to weigh on enterprises' innovation performance and technology adoption, and therefore hamper productivity growth. Beyond this, reduced investment activity impedes labour productivity via its negative impact on capital intensity. These factors may possibly be countered by productivity increases induced by the pandemic. The crisis forced enterprises and employees to try new ways of working. Some of the lessons learned could also be useful in the future.[4] Examples include more flexible working models and virtual conference formats. In general, there are signs of a boost to digitalisation.

Labour productivity growth in the euro area in 2020

Year-on-year percentage change



Sources: Eurostat and Bundesbank calculations. **1** Labour productivity measured as the ratio of real GDP to the number of hours worked. **2** Labour productivity measured as the ratio of real GDP to the number of persons employed.
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1 See Bloom et al. (2015) and Bloom (2020).
2 In addition, there may possibly be longer-term implications for productivity as a result of a deterioration in the quality of school education. See also Fuchs-Schündeln et al. (2020).
3 See Baker et al. (2020).
4 See also European Central Bank (2020).

Without extensive government assistance, many enterprises would probably have had to exit from the market owing to the massive slump in some sectors. Even the assistance measures will probably not be able to entirely prevent this in the longer term. This, too, may influence productivity growth. If mainly low-productivity enterprises or economic sectors are affected by closures, this may have a positive impact on average productivity.[5] However, if the freed-up production factors are not, or only insufficiently, absorbed, this will weigh on macroeconomic developments. Moreover, market concentration may increase, with potentially adverse effects on competition and productivity gains.

To sum up, the pandemic may influence future productivity growth via multiple channels. Although the severe macroeconomic disruptions are likely to weigh on productivity growth, the overall effect is difficult to gauge. Specifically, it remains to be seen to what extent a crisis-induced boost to innovation – in the form of increased digitalisation, for example – will impact on future productivity growth.

5 See Bloom et al. (2020b).

growth rates of total factor productivity. Analyses of the underlying driving forces point to cyclical influences as well as, in particular, structural factors. For some sectors of the economy, there are indications to suggest that enterprises' ability to innovate and adopt may have diminished. Moreover, inefficiencies in the allocation of production factors appear increasingly to have contributed to the slowdown in productivity growth. Alongside the institutional and regulatory framework, demographic change is another possible structural factor. As a society ages, enterprises' ability to innovate and adopt may be impaired. The decline in labour force growth and the increase in life expectancy can also affect business dynamics and, via this channel, also impede aggregate TFP growth. An empirical analysis for the euro area suggests that demographic change has indeed dampened productivity growth.

Outlook

The continued ageing of the euro area's population could continue to dampen productivity growth in the future. Moreover, the observed slowdown in the pace of reforms in the euro area suggests that economic policy will not provide any decisive stimulus for productivity growth. At present, it is difficult to assess what impact the coronavirus pandemic will have on developments in productivity. The macroeconomic turmoil triggered by the pandemic is likely to weigh on future labour productivity growth. The extent to which this can be counteracted by a wave of innovation in response to the exceptional challenges presented by the crisis remains to be seen.

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