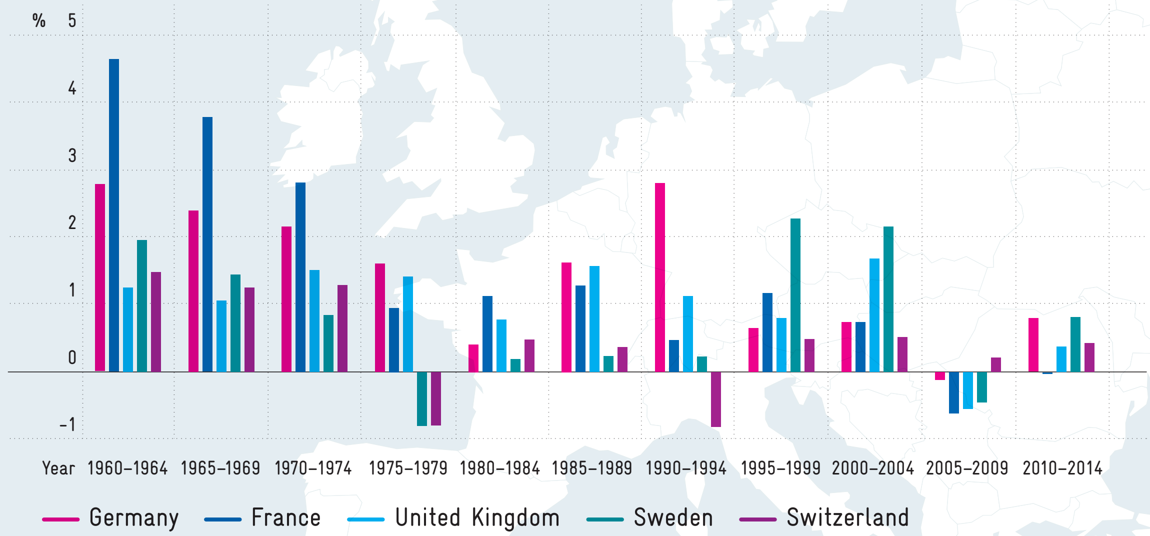
B 1 Long-term developments of productivity and innovation

Download data

The pace of growth of macroeconomic productivity indicators has slowed in many developed economies. Parallel to this, some indicators, e.g. the innovator rate, suggest a decline or focusing in innovation activities.

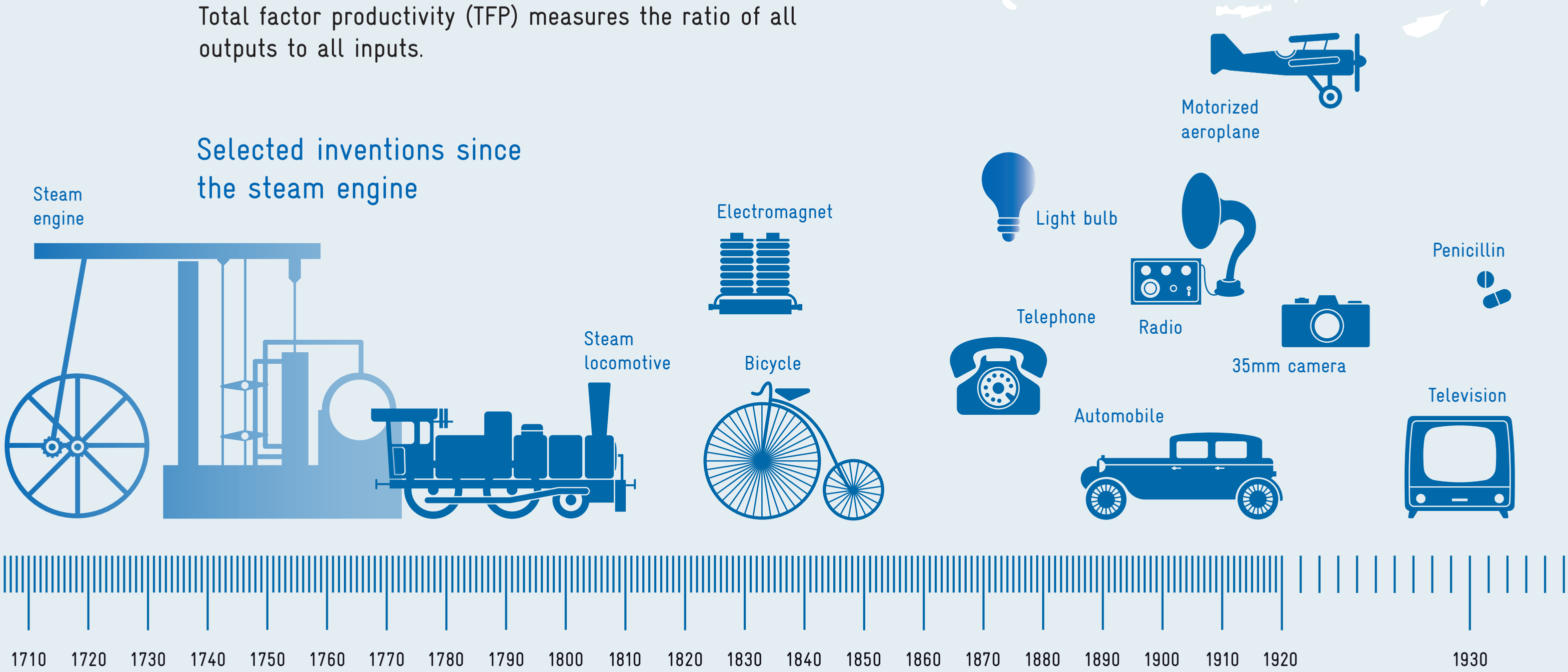
International comparison of TFP growth rates as percentages



Productivity

Total factor productivity (TFP) measures the ratio of all outputs to all inputs.

Selected inventions since the steam engine

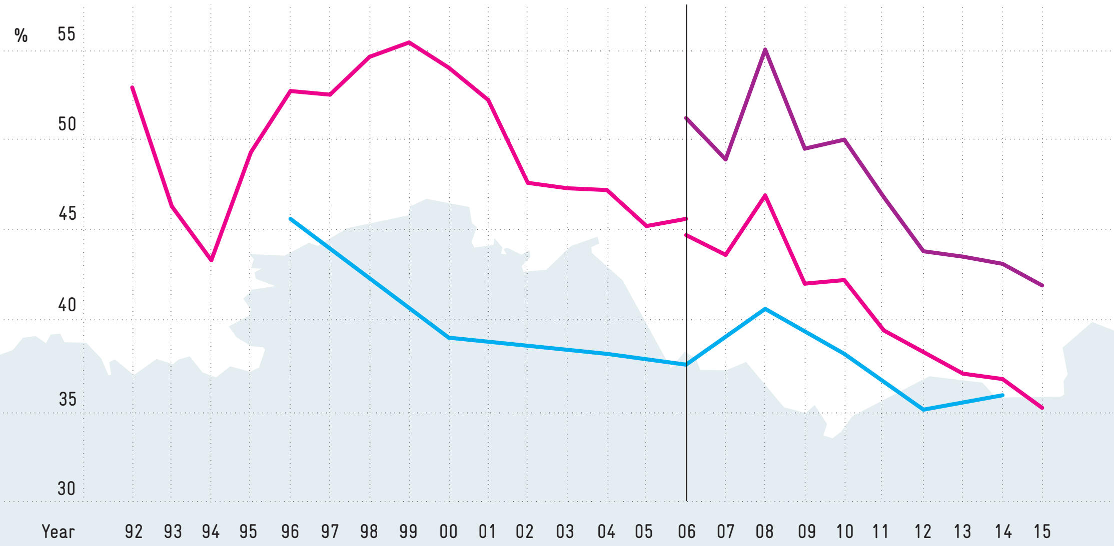


Source: Penn World Table 9.0. Cf. Peters et al. (2018). Own calculations.

Innovator rate

The innovator rate is the percentage of companies that have introduced at least one product or process innovation within a three-year reference period.

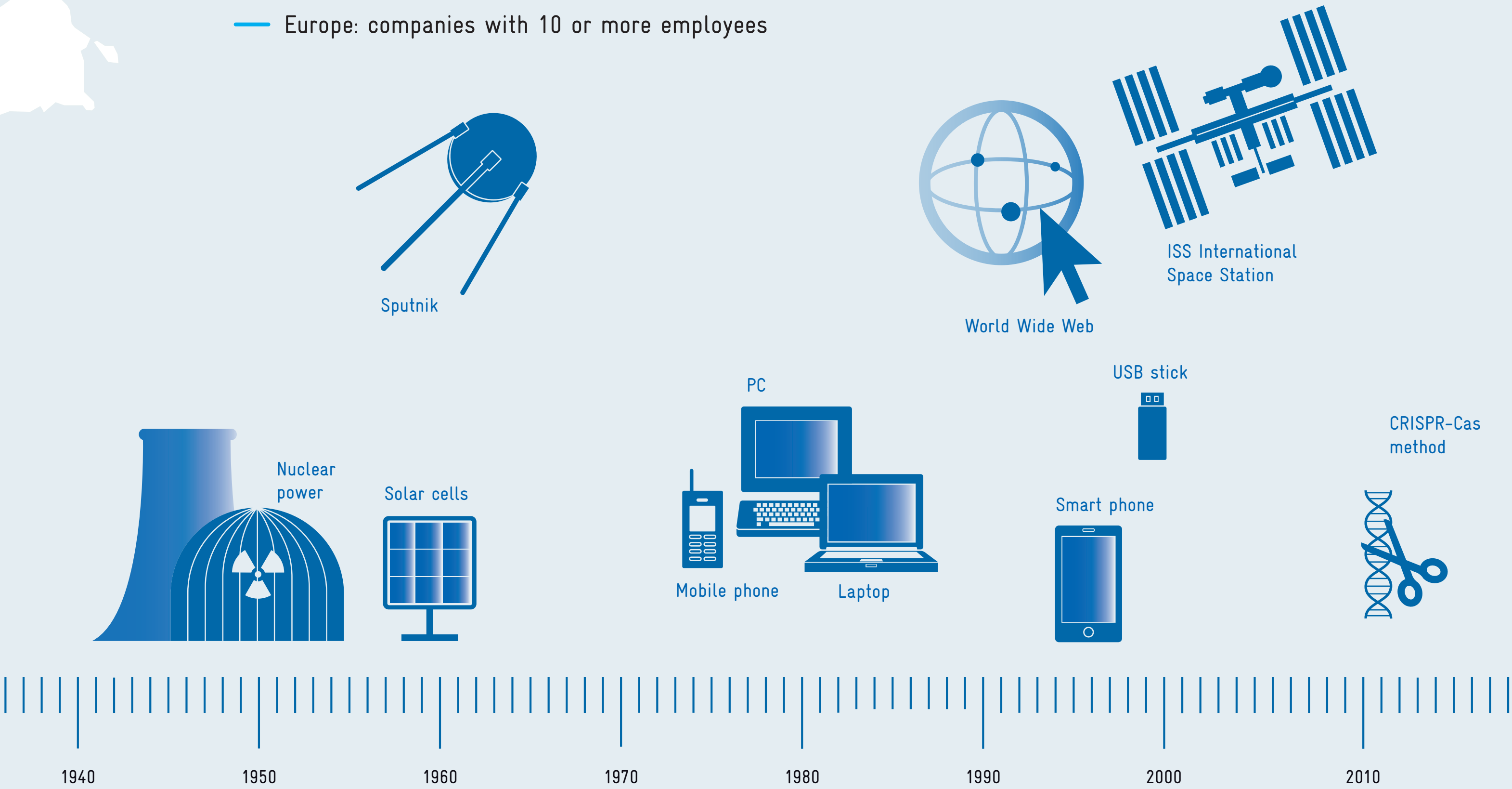
Development of the innovator rate in Germany and Europe as percentages



Germany: companies with 5 or more employees
2006: break in the time series following a change in the WZ reference base.

Germany: companies with 10 or more employees

Europe: companies with 10 or more employees



Source: Mannheim Innovation Panel and Eurostat, Community Innovation Surveys. Calculations by ZEW (Centre for European Economic Research).

B 1 Long-term developments of productivity and innovation

B 1-1 Introduction

B

An economy's productivity is an important determinant of the development of its income and prosperity. In general terms, productivity measures the ratio of all outputs (goods and services) to inputs (factors of production) – for example, how much work is required in a year to produce a certain amount of goods. Productivity and prosperity have grown worldwide almost continuously since the Industrial Revolution. However, it has been observed for several decades, and especially since the mid-1990s, that this growth has slowed down.[149] This observation seems surprising in view of the advancing digitalization and networking of the global economy and the productivity gains this is expected to generate. It is discussed under the term 'productivity growth slowdown' and is regarded as a cause for concern by many.

The growth of overall economic productivity is highly dependent on innovation. Process innovations reduce production costs by making more efficient use of input factors, while product innovations raise the quality of the output or lead to entirely new products and services.[150]

Some indicators suggest that an innovation slowdown is also taking place in Germany and most other European industrial countries[151] parallel to the decline in productivity growth. In this chapter, the Commission of Experts discusses possible causes of these phenomena. It comes to the conclusion that the observed decline in the innovator rate could be interpreted as a concentration of innovation activities among a shrinking proportion of economic actors. Alongside other reasons, the resulting less broad-based generation and use of innovations could have led to a lower rate of productivity growth.

Slowdown in productivity growth as a worldwide phenomenon B 1-2

The prosperity of a society is often measured in a simplified fashion on the basis of its economic performance. Weak productivity growth in the economy as a whole, let alone an ongoing slowdown in productivity growth, is seen as a threat to rising prosperity.

The productivity of a country, industry or company can be measured in different ways.[152] The concept of Total Factor Productivity (TFP) has become established as the most important statistical tool for measuring it. Box B 1-1 explains technical details of TFP and its changes as a measure of the contributions that innovation makes to growth.

Figure B 1-2 illustrates the development of TFP from 1960 to 2014 in five-year averages in China, France, Germany, Japan, South Korea, Sweden, Switzerland, the United Kingdom and the USA. Over this long period, a trend towards a slowdown in productivity growth can be observed in many of the economies examined – for example in France, Switzerland and Sweden. In some countries, an intermediate increase in TFP growth up until around 2004 was followed by a renewed decline in growth – especially in the USA,[153] the United Kingdom and Japan. This decline in TFP growth has also been measurable in China in recent years.

Figure B 1-2 also shows the development of TFP[154] in Germany from 1960 to 2014 in five-year averages.[155] Here, a negative trend in TFP development since 1960 emerges over the long term. The annual growth rate of TFP fell from an average of 2.8 percent in the period from 1960 to 1964 to an average of 0.8 percent between 2010 and 2014. The effects of German Reunification[156] are clearly visible, as is the financial and economic crisis of 2007/2008.

Box B 1-1

Total Factor Productivity (TFP)

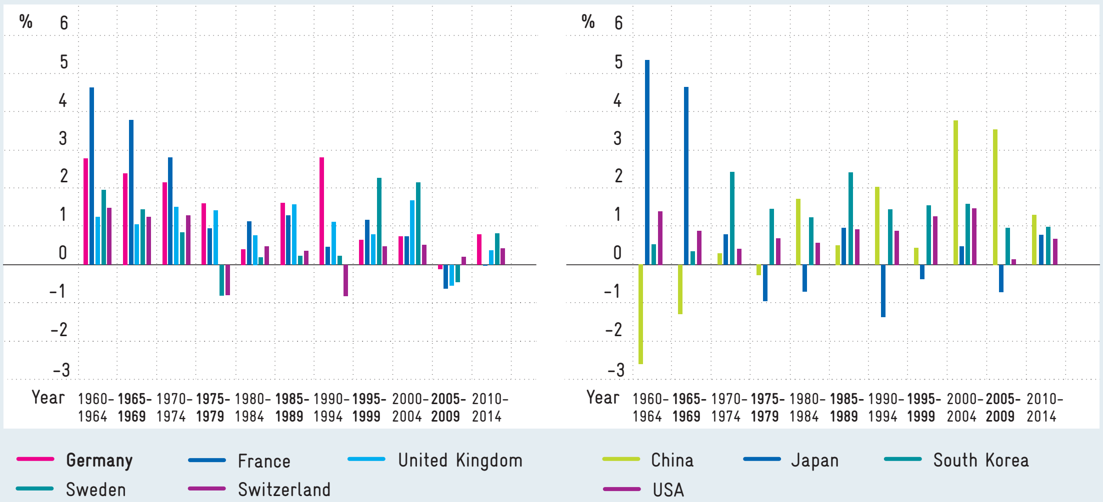
Total Factor Productivity is the most widespread measure of productivity; it relates overall economic output to a weighted combination of input factors (especially labour input, physical and intangible production capital, and energy).[157] The growth rates of the outputs and inputs are observed in order to determine the TFP growth rate. TFP growth in the observed economy is calculated from the difference between these growth rates.[158] Accordingly, TFP growth measures the part of output growth that cannot be directly explained by the use of the known input factors: in other words the unexplained part that is 'left over'.[159]

TFP growth can be an indication of a more efficient use of input factors and is often used as a measure of technical progress.[160] TFP is frequently interpreted as a further input and associated with an economy's knowledge base, which, like other input factors, changes over time. Labour productivity or other partial productivities – where total output is compared to a single input factor – are often used as additional measures of productivity. However, they only partially depict the production process, so that their informative content is significantly inferior to TFP.

Fig. B 1-2

Download data

International comparison of annual TFP growth rates as percentages



Total factor productivity (TFP) measures the ratio of all outputs to all inputs.
Shown as five-year averages.
Source: Penn World Table 9.0. Cf. Peters et al. (2018). Own calculations.

Disaggregated sectoral observations can provide further insights into productivity development. In view of the possibility that delays in the diffusion of IC technologies might be one reason for declining TFP growth, the recent development of ICT-intensive and ICT-producing industries in Germany is of particular interest. Box B 1-3 traces productivity growth in these industries between 1991 and 2013.

Innovation and productivity

B 1–3

Innovation is an important determinant of productivity growth.[161] The evolution over time of such indicators as start-up rates, innovator rates, research productivities and patent developments is therefore of particular interest for R&I policy.

Box B 1-3

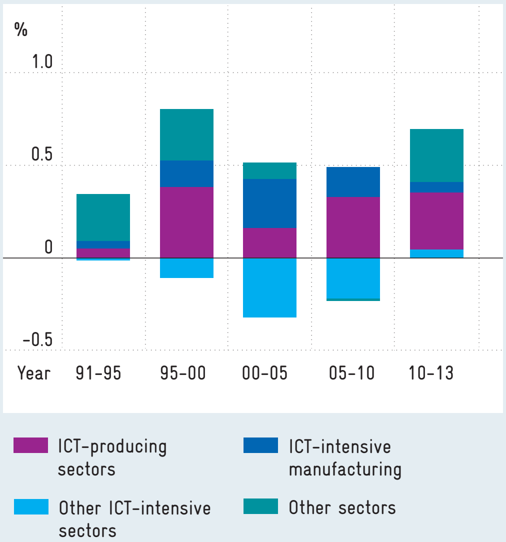
Download data

Productivity growth in ICT-using and ICT-producing sectors of the economy

A recent study takes a separate look at the contributions made to TFP growth in Germany by ICT-producing, ICT-intensive and other industries since 1991 (i.e. after Reunification).[162] Industries are considered ICT-intensive if they use a relatively large amount of ICT capital, but do not produce ICT themselves. The figure shows the average annual TFP growth contributions over five periods between 1991 and 2013.

The ICT-producing industries in Germany were thus responsible for about half of total TFP growth since 2005, although they only contributed less than 5 percent of the economy's gross value added. By contrast, TFP growth was recently weak in the ICT-intensive industries (manufacturing and the other ICT-intensive industries) – and their contributions to growth were even negative between 2000 and 2010. This difference in the productivity change between producers and users of ICT suggests a delay in the diffusion of new IC technologies.

Average annual TFP growth contributions in Germany as percentage points



Source: BEA and ifo. Presentation based on Elstner et al. (2016: 7).

Start-up rates and innovator rates declining

The start-up rate, i.e. the number of start-up businesses as a percentage of the total number of companies, is low in Germany by international comparison.[163] Furthermore, start-up rates in the knowledge-based economy[164] have been declining for years.[165] Figure C 5-2 (p. 109) illustrates this development. This is a cause for concern since innovative products, processes and business models are frequently developed and implemented especially in new companies. Moreover, start-ups secure the creation of jobs by generating local value added.

The innovator rate is defined as the number of companies with product and process innovations as a percentage of all companies.[166] Since the early 1990s, the so-called Oslo Manual published by the OECD and Eurostat has provided a conceptual framework – and the Community Innovation Surveys (CIS) an empirical basis – for comparing innovator rates internationally.[167] Marketing and organizational innovations are not taken into account; this is not a problem since new digital business models, for example, are usually reported as product innovations and not as marketing and organizational innovations.[168]

The development of the innovator rate in Germany since 1992 on the basis of national statistics (i.e. in companies with five employees or more and including additional service industries) has been characterized by an almost continuous decline – from just under 56 percent in 1999 to 35 percent in 2015 (cf. figure B 1-4).[169] The trend is the same for the period from 2006 to 2015 according to the CIS definition (companies with ten employees or more, fewer service industries) at an innovator rate that is about 6 to 8 percentage points higher.

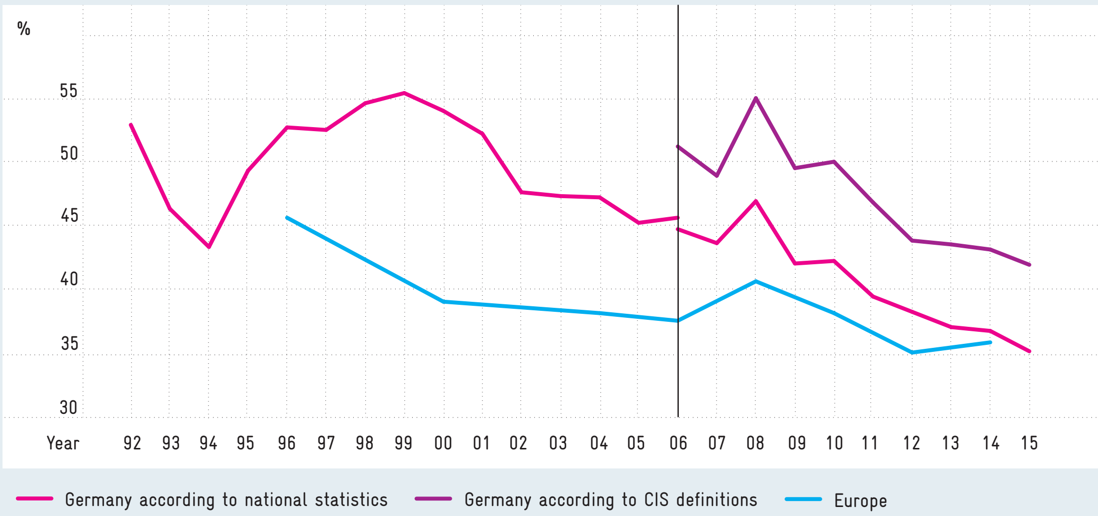
The trend towards declining innovator rates can be observed in the majority of EU countries examined by the CIS (cf. figure B 1-4). For example, the innovator rate fell from 46 percent in 1996 to 36 percent in 2014 in the European countries for which figures have been available since the second CIS survey (reference period 1992 to 1996)[170] – in the sectors included in the CIS (manufacturing, wholesale trade, transport, financial services, IT services, engineering offices).[171]

The decline in the innovator rate could be interpreted as innovation activity focusing on a decreasing percentage of companies. This development might

Fig. B 1-4

Download data

Development of the innovator rate in Germany and Europe as percentages



Reference basis according to national statistics: 1992–2006: divisions 10–37, 51, 60–64, 65–67, 72–74, 90 of 2003 WZ classification; 2006–2015: divisions 5–39, 46, 49–53, 58–66, 69–74, 78–82 of 2008 WZ classification. Companies with five or more employees. 2006: break in time series. Reference basis according to CIS definitions: divisions 5–39, 46, 49–53, 58–66, 71–73 of 2008 WZ classification. Companies with 10 or more employees. The data for Europe relate to the following countries: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, United Kingdom.
Sources: Mannheim Innovation Panel and Eurostat, Community Innovation Surveys. Calculations by ZEW (Centre for European Economic Research).

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– but need not necessarily – involve a decline in the absolute number of innovations.

Development of research productivity and patent intensity not unequivocal

Another indicator that is currently the subject of much discussion is known as research productivity. It relates TFP growth to the number of researchers who provoke the growth via their knowledge production.

A recent study in the USA suggests a marked decline in research productivity of about 5 percent per annum.[172] One important criticism of the study looks at the way it measures research input, in particular the effective number of researchers in the years before 1960, when there was no uniform definition of R&D activities.[173] Another point of criticism is the measurement of research output: the growth rate of TFP is used as a measure of the number of new ideas.[174] This indicator is subject to a whole series of influencing factors, such as the quality of the traditional input factors – labour and capital – that are used. If this quality improves over time, there will be a decline in TFP, its growth and thus also the level of research productivity that is measured.[175] Another problem with this approach is that TFP growth alone is related to the research input. Other variables that can also influence the level of TFP growth are not taken into account, nor is their influence controlled for.[176]

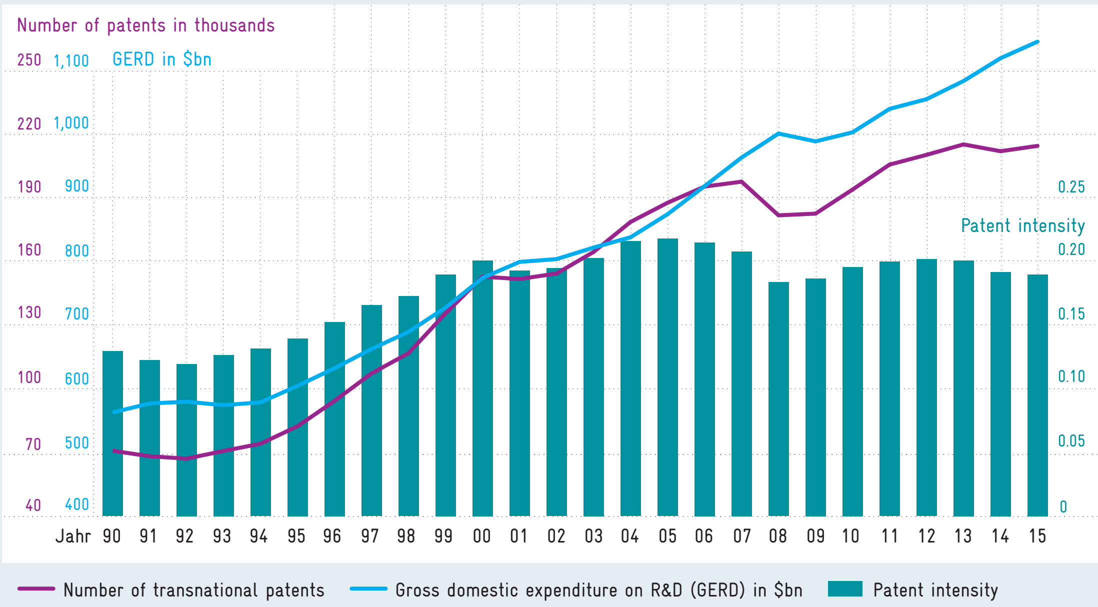
However, patents can also be used as a direct measure of new ideas. They are an important indicator of the potential exploitation of new ideas on the market. Transnational patent applications[177] have been stagnating both in Germany and in other major European economies since the international financial and economic crisis (cf. figure C 6-1). By contrast, particularly China, Japan and the USA have seen high rates of growth in patent applications, as shown in figure C 6-1 (left).

Average patent intensity – measured here as the ratio of transnational patent applications to GERD (Gross Domestic Expenditure on Research and Development, which is also an indicator of research productivity) – has declined slightly in the OECD countries since 2005.[178] Figure B 1-5 shows that the number of patent applications has been stagnating since then, while R&D expenditures continue to grow.

Fig. B1-5

Download data

Development of patent intensity in the OECD



GERD: Gross Domestic Expenditure on Research and Development.
GERD in $bn: constant prices and purchasing-power parity.
Transnational patents: fractional counting.
Sources: OECD, Main Science and Technology Indicators, and EPO, PATSTAT. Calculations by Fraunhofer ISI.

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Various factors may have played a role here. One possible cause might be an increase in technological complexity, with the result that more effort would be required to achieve patentable research results. Economic structural change – moving towards sectors that are more R&D-intensive and towards fewer patentable innovations – could also have contributed to the decline in patent intensity.

The Commission of Experts believes that the development of patent applications and patent intensity offers little evidence of a marked decline in the generation of new ideas or, as a result, in innovation activity. The falling innovator rate is therefore more likely to be a result of innovation activities becoming concentrated among fewer and fewer actors.

B 1-4 Possible causes of slower productivity growth

In the following, the Commission of Experts discusses possible causes of the phenomena described.[179]

Measurement problems in the context of digitalization

Identifying a declining productivity growth rate initially depends decisively on correct measurements of macroeconomic growth and productivity. It is often argued that certain measurement problems have increased in the course of digitalization.[180] Box B 1-6 looks into this assertion. In the Commission of Experts' assessment, however, the decline in productivity growth is not due solely to measurement problems. Although declines in growth are distinctly lower when the estimates are adjusted for any measurement errors, there is always a statistically and economically significant amount left over.

Delayed diffusion – the view of the 'technology optimists'

There is no doubt that developed economies are currently experiencing a phase of intense technological dynamics – especially with regard to the digital transformation. Seen from this angle, the observed slowdown in productivity growth is an astonishing phenomenon at first sight. New technologies such as artificial intelligence should hold great potential for innovation, and this should also be reflected in higher productivity.[181] The situation is therefore sometimes referred to as the productivity paradox or the productivity puzzle.[182]

Some studies argue in this context that the slowdown in productivity growth is most likely to be a temporary phenomenon.[183] It is claimed that particularly the use of digital technologies in production is still in its infancy, but could generate far-reaching development leaps and associated productivity gains in the future (cf. box B 1-1). The fact that future productivity gains are still outstanding could be due to various factors acting as obstacles to adoption:[184]

1. Lack of complementary human capital: There are indications that a lack of IT skills among employees can lead to IT systems and IT applications being introduced less frequently or used less intensively.[185] At the same time, recent analyses show that a considerable proportion of the workforce who have to use ICT applications in their work do not have the ICT skills needed to apply these technologies effectively.[186] In addition, there is a consensus in the literature that knowledge and skills complementary to ICT, such as problem-solving skills, have become more important.[187]

   However, there are no conclusive findings on whether a lack of IT skills can explain the slowdown in productivity growth (at least in certain countries).[188] A lack of IT skills in companies can arise from recruitment problems or a lack of further-training activities. The Commission of Experts addresses these two topics in its chapter A 4 on Digital Education.

2. Other lacking input factors that have a complementary effect: A lack of investment in the necessary infrastructure or complementary inputs could be an obvious reason for a slowdown in productivity growth.[189] The digital transformation depends to a large extent on the availability of a powerful broadband infrastructure in order to ensure the use of large-volume data-based IT services. Against this background, the Commission of Experts has repeatedly urged a forward-looking expansion of the infrastructure and called for ambitious targets.[190]

   A lack of absorptive capacity is closely linked to a lack of complementary inputs (e.g. because of outdated methods and (IT) tools). When well-established work processes in the economy need to be adapted and geared to new technological opportunities, requiring a lot of effort, companies often face high adoption costs. In this context, various studies have focused specifically on organizational learning processes and the importance of absorptive capacity in companies.[191] Accordingly, the productivity impact of external knowledge, for example, is all the greater, the more the company performs its own R&D, thus building up absorptive capacity.[192]

3. Regulatory barriers: Finally, political and institutional framework conditions also exert an influence on productivity growth. The Commission of Experts recently called for the creation of a future-oriented legal framework for the digital economy.[193] Internet-based technologies require new or adapted legal norms, e.g. in the fields of copyright, data protection and consumer protection.

The argument of delayed diffusion and underlying adoption barriers finds support in a current study conducted on behalf of the OECD.[194] It explores the evolution over time of global productivity indicators, differentiated according to companies with varying degrees of technological development. It finds that productivity is growing in companies close to the technological frontier (frontier companies), while the gap between them and already less productive enterprises (laggard companies) continues to grow.[195] According to the study, this structure primarily reflects technological progress and its diffusion in general, but is also closely linked to the observation of growing market power (see the section on the role of growing market concentration in productivity growth and innovation).

The Commission of Experts regards delayed diffusion as an important reason for the observed decline in productivity growth.

Depleted technological potential – the view of the 'technology pessimists'

Several studies argue that the low level of productivity growth, coupled with a simultaneous high level of expenditure on research, is an indication of decreasing or depleting technological potential

Box B 1-6

B

Measurement problems in the context of digitalization

Measuring changes in growth and productivity in the context of the national accounts (NA) is problematic (cf. box B 1-1). Measurement problems, which can be conceptual or empirical, can occur when collecting data on these variables.

From the conceptual point of view, for example, covering many of the technologies that have diffused quickly in the last decade (smart phones, social networks, digital media services, etc.) is problematic. This is because, although consumers spend a lot of time using them, this hardly causes them any further monetary costs. If not only the direct expenditure on the acquisition and use of these products is taken into account, but also the time spent using them, they seem to generate substantially more benefit than is expressed by their price. Indicators such as gross domestic product (GDP) cannot adequately measure this 'consumer surplus' even conceptually – a known weakness of NA. Discussions on whether GDP can be a suitable measure of welfare in an economy have therefore gained additional momentum in the course of digitalization.[196]

From the empirical point of view, data collection in the NA context becomes increasingly difficult in information- and knowledge-based economies, especially with regard to determining real GDP on the basis of price adjustments (so-called deflation). For several years, chain indices have been used in this context in accordance with international conventions and binding European regulations[197] using an annually changing price basis (previous year's price basis).[198] The deflation of ICT inputs and outputs in the service sector proves to be particularly problematic, since the price indices must also take quality improvements into account. This is often very difficult, since digitalization leads to an acceleration of both product and service innovations,[199] and substitution effects occur. This can have the consequence that, due to insufficient price deflators, growth and productivity changes are not properly recorded, especially in the case of digital products and services, leading to corresponding distortions.

These conceptual and empirical measurement problems might increase over time with the increasing diffusion of ICT. However, recent studies have come to the conclusion that the recent decline in productivity growth is not only due to measurement problems in the context of digitalization.[200] Although the majority of studies focus on productivity development in the USA, there is also evidence to suggest that declining productivity growth can be found simultaneously in at least two dozen other developed economies.[201] In this context, the respective extent to which productivity development is slowing within these countries is evidently not linked to the relative size of the local ICT industry and does not depend on whether ICT intensity is measured via consumption or production.

Various adjustments of GDP growth to take into account the effects of a distorted measurement of digital goods and products suggest that, if measurement errors were exclusively responsible for the slower productivity growth, and if its cause lay in ICT industries, then the real turnover of these industries should have been five times higher.[202] The productivity of labour in these industries would have had to increase by more than 360 percent in eleven years. Changing the conceptual approach – e.g. making the purchase and use of an internet connection a possible metric of the gains generated by new digital technologies – shows that this adjustment is not sufficient to offset the reduction in economic growth caused by the slowdown in productivity growth.[203] Even the largest (and most unrealistic) estimate – which generously prices-in the time that people spend online – would only account for a third of the supposedly underestimated growth.

('low-hanging fruits have already been picked') and thus of decreasing research productivity.[204]

Depleting technological potential could, on the one hand, only be used by companies at increasing expense; on the other, it would also generate smaller increases in productivity. Both of these could lead to falling long-term gains from innovations and to companies withdrawing from innovation activities. However, it was already argued in section B 1-3 that little empirical evidence can be found of depleted technological potential, as measured by a decrease in the number of new ideas (via patents).

Accordingly, the Commission of Experts attaches little importance to the argument that technological potential is becoming depleted on a broad front. In order to safeguard against potentials becoming depleted, one could consider strengthening basic research and emphasizing the transfer of knowledge and findings from basic research (in terms of spillover effects).[205]

The role of increasing market concentration in productivity growth and innovation

So-called markups, i.e. the margin a company can add to its marginal costs of production, are a measure of market concentration and market power. The more market power a company has, the larger these markups can be. A recent study conducted in the USA[206] argues that markups have risen continuously since about 1980. According to the authors, no decline in productivity growth would be measurable if growing market power were taken into account when calculating growth throughout the economy.

Innovations are a possible explanation of market power and its changes. If they are protected by a patent, then the resulting (temporary) market power is an important positive incentive for innovative activity. Furthermore, technological complexity that is growing as a result of innovations may make it easier for companies to secure their market position and their competitive edge even without patents – especially because it becomes increasingly cost-intensive for potential competitors to catch up technologically. In the same way, an increase in so-called strategic patenting[207] makes it possible to build high barriers to market entry vis-à-vis potential competitors.

Market-concentration processes are typical of mature markets and industries.[208] Accordingly, fewer (innovative) start-ups or other innovation-driven market entries will be observed here. In the course of this development, innovative activity becomes concentrated on fewer and fewer companies. In addition, in line with industry and technology life-cycle theory,[209] there is a tendency among the established companies to hold back more and more in the field of product and process innovations.

A phenomenon that is currently the subject of intense discussion is the rapidly growing market concentration that can be caused by 'superstar effects'[210] in younger industries and markets. Technology leaders or first movers can gain very high market shares for themselves ('winner-takes-it-all') as a result of network effects, which are particularly common in digital markets.[211] Here, too, there is a trend towards a concentration of innovation activities on a few companies and an associated creation of entry barriers to markets and technologies. The existence of market concentration due to network externalities can also increase the incentive for company founders to seek a quick sale of their company to market leaders, rather than relying on the growth of their own company.

Another reason for the growing market concentration may also be that suitable competitive framework conditions have not been created in time and undesirable developments of increasing concentration have not been sufficiently counteracted.

The Commission of Experts also regards the growing market concentration as an indication of the concentration of innovation activities on the one hand, and a reason for a declining start-up rate on the other.

Assessments B 1–5

The Commission of Experts has come to the assessment that the decline of productivity growth that can be observed in Germany and many other OECD countries cannot be attributed to a single cause. Rather, this development has been induced by several of the effects described in this chapter.

If, on the one hand, there are not yet any applications for radical innovations and, on the other hand, new technologies only diffuse slowly due to their complexity or a lack of complementary inputs

– above all skilled employees – this is reflected negatively in productivity figures. The recent wave of digital transformation has not contributed to productivity growth to the expected extent either. However, the Commission of Experts points out that also in past cases of radical innovations, the productivity development measured at the time did not lead to good forecasts of future developments.[212] In this sense, the currently observed phenomena should be assessed cautiously by political decision-makers. Even so, action should be taken against delayed diffusion, particularly in the field of digital technologies.

The Commission of Experts is fundamentally optimistic that there is no need to fear a general depletion of technological potential. Rather, established companies in mature industries are often slow to make the transition to new technologies, even if it could result in more favourable growth developments in the long term. The example of alternative drive technologies in the automotive industry illustrates how difficult business decision-makers, who are generally used to acting relatively quickly, find it to accept a far-reaching technological change – especially when industry-specific productivity indicators are positive, yet contrary to overall economic trends.[213]

Ongoing market concentration in different industries and the concentration of innovation activities among fewer and fewer actors suggest that established companies are successfully building entry barriers based on increasingly complex technologies. The resulting uncertainty about the competitiveness and profitability of new firms could be one reason for declining start-up and innovator rates. R&I policy should focus its attention on the entry barriers and innovation obstacles that are responsible for this, especially those standing in the way of radical innovations. As a first step, innovation-inhibiting regulations should be reduced and market access made easier for new players.

B 1-6 Recommendations

Ensuring long-term productivity growth requires the use of radical innovations and, in particular, their rapid diffusion. Due to its power to design the regulatory environment, the Federal Government has important influence here, which it should use. The Commission of Experts considers the following aspects essential:

- Basic research is an important source of radical innovations and should be strengthened. It should not be neglected in favour of applied research, even when the latter promises short-term contributions to innovation and growth. The key prerequisite for innovative effects is the transfer of knowledge and findings from basic research to economic application. In its last report, the Commission of Experts made detailed recommendations on both of these fields, i.e. on the science system and on transfer.[214]
- Innovations can only have a broad impact on productivity if they find widespread application. It is therefore important to take appropriate measures to support the diffusion of radical innovations and their follow-on innovations. This currently applies in particular to the digital transformation, which is yet to be universally implemented (cf. chapter B 3).
- The regulatory environment must ensure that economic actors can make agile use of new technological opportunities, and generate and market radical innovations. This requires a suitable regulatory framework, e.g. in competition law, to give new actors barrier-free market access and prevent the emergence of dominant companies; such conditions are also needed in the financial sector to support the founding and growth of innovative young companies.
- The empirical and methodological problems of measuring growth, productivity and innovation complicate the ongoing assessment of the R&I system and the development of appropriate policy measures. The Commission of Experts expressly welcomes the 'Research project for the further development of sets of indicators for research and innovation' launched by the Federal Ministry of Education and Research (BMBF).[215] It recommends drafting concrete metrics to improve ways of measuring the development of growth, productivity and innovation with the involvement of the relevant actors (Federal Statistical Office, Bundesbank, etc.).