GERMAN COUNCIL of Economic Experts

STRENGTHENING POTENTIAL GROWTH THROUGH CAPITAL FORMATION

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STRENGTHENING POTENTIAL GROWTH THROUGH CAPITAL FORMATION

KEY MESSAGES

↘ Rising labour shortages are increasingly hindering the growth prospects of the German economy. Not all sectors of the economy are equally affected, and individual sectors can compensate for this effect to varying degrees.

↘ Capital formation and new general purpose technologies such as AI can sustain growth, while diversification of global value chains can increase resilience.

↘ Skilled immigration and stronger employment incentives as well as the substitution of labour by new capital goods can mitigate the growth-dampening effects of the declining volume of labour.

SUMMARY

The **real growth rate of potential output in the German economy** has fallen drastically in recent decades, from an average of about 2.5 % in the 1970s to 0.5 % in 2022. The **declining volume of labour in** Germany is **likely to significantly dampen the growth of potential output in future. Capital services and total factor productivity** (TFP) are **also** unlikely to provide **much growth impetus** unless conditions change. However, in **times of urgent transformation imperatives**, the **expansion of potential output** is **particularly important** for the German economy. The **challenges facing the individual sectors of the economy** differ significantly. In particular, capital intensity and opportunities to replace labour with capital vary widely between economic sectors.

Capital formation **can** help **accelerate technical progress** and **compensate for** the **declining volume of labour**. For example, TFP can be increased by investment in machines and tools or automation systems as well as in intangible capital. In addition, labour shortages can be compensated by artificial intelligence (AI) and the use of robots. Suitable framework conditions, e.g. efficient digital administration, should **support** the **rapid penetration of the German economy by new general purpose technologies** such as AI. In the medium to long term, the **improvement of school education** and strengthening of **universities** can act as **drivers** for increasing TFP. **In** addition, **immigration into the labour market** and **stronger employment incentives** can compensate for the declining labour force.

An **efficient allocation of production factors** is crucial for the growth of potential output. If the productivity of green capital goods is already similar to that of capital powered by fossil fuels, early transformation investments offer benefits. In the course of decarbonisation, this would be particularly effective in energy-intensive industries and the energy sector. Capital formation in assets and intangibles **can be encouraged** through **tax incentives** and **reliable regulatory frameworks**, e.g. in the context of CO_2 pricing. In addition, **greater diversification** of foreign direct investment can help efficiently exploit the benefits of the **international division of labour**, while simultaneously increasing the German economy's **resilience** to geopolitical changes.

I. INTRODUCTION

74. Discussions about Germany's growth opportunities are often based on short-term forecasts. However, the development of the **potential output** of the economy as a whole is of relevance to the **medium- and long-term opportunities for growth**. ↘ BACKGROUND INFO 2 ↘ ITEMS 99 FF. The potential output of an economy is the production quantity of goods and services that is achievable assuming normal capacity utilisation ↘ GLOSSARY of all available production factors. The development of potential output characterises an economy's long-term growth path. The more potential output grows, the greater the scope for distribution in an economy – both for the distribution of output between consumption and investment activity ↘ ITEMS 109 FF. and for the (re-)distribution of income within the population. ↘ ITEMS 285 FF. In times of urgent transformation imperatives, the expansion of potential output is particularly important for the German economy.

75. Potential output is largely determined by the utilisation of the production factors **capital and labour** as well as the level of technological progress, which is approximated by **total factor productivity** (TFP). ↘ ITEMS 80 FF. In recent years, the GCEE has repeatedly analysed the positive but declining growth of TFP and labour productivity in most advanced economies (GCEE Annual Report 2019 items 140 ff.; GCEE Annual Report 2020 items 483 ff.) and the falling volume of labour in Germany (GCEE Annual Report 2019 items 141 ff.; GCEE Annual Report 2022 items 355 ff.). ↘ ITEM 126 The declining volume of labour is likely to be the greatest structural obstacle to potential output growth in future. In the coming decades, a significant decline in the labour force is to be expected **due to demographic change.** This will have a dampening **effect on the potential output growth.** ↘ ITEMS 106 F. ↘ CHART 42

Against this backdrop, this year's **Productivity Report** uses long-term scenario calculations (projections) ↘ ITEMS 99 FF. and the analysis of firm-level data ↘ ITEMS 127 FF. AND 138 FF. to investigate how capital formation can contribute to increasing potential output growth, compensating for declining labour volumes, increasing TFP growth and advancing the green transformation.

↘ BACKGROUND INFO 2

Background: potential output

Potential output is the production volume that is achieved when all factors of production are utilised at normal capacity. It is not directly observable and has to be estimated using statistical methods. The factors of production taken into account in the model used by the GCEE are labour volume, human capital and capital services (Solow, 1956; Lucas, 1988; Mankiw et al., 1992; Romer, 1994; Galor, 2011). ↘ BOX 10 For growth to occur, the factors of production must be used more efficiently or expanded. Potential growth that is not explained by the accumulation of production factors is attributed to growth in total factor productivity (TFP). TFP growth includes, for example, general productivity gains due to technological progress or improvements in the allocation of capital and labour. TFP is identified in both neoclassical and endogenous growth theory as well as in empirical literature as the most important driver of long-term growth (Solow, 1956; Romer, 1990; Mankiw et al., 1992).

76. **Capital formation** is especially important for increasing potential output growth. Capital formation **is particularly growth-enhancing if it increases TFP** in addition to the capital stock. For example, in the case of capital goods with a service life, there are sometimes considerable productivity differences between old and new assets. This is known as capital-embodied technological change (CETC) and is not fully reflected in the valuation of capital goods (Hulten, 1992; Sakellaris and Wilson, 2004; Jones and Liu, 2022). ↘ ITEMS 139 FF. Capital formation can also increase TFP if more productive companies invest more than less productive companies. This shifts the distribution of factors of production towards more productive companies. Moreover, capital stock today increasingly consists of intangible capital goods such as patents or software. These have a complementary effect on physical capital or labour and, when used more intensively, have a particularly strong positive impact on the productivity of these factors of production (GCEE Annual Report 2019 items 305 ff.; GCEE Annual Report 2020 items 481 ff.). ↘ ITEMS 147 FF. AND 93 In addition, investment decisions are made in Germany and the European Union (EU) against the backdrop of an **increasingly fragmented global economy** (IMF, 2023). ↘ ITEM 97

77. Capital formation is of particular importance in view of the **declining labour volume**, even independently of its positive impact on TFP (Mayer, 2021; Sauer and Wollmershäuser, 2021; Ahlers and Quispe Villalobos, 2022). Firstly, labour can be substituted by capital, for example, through automation and the use of robots or – as will increasingly be the case in the coming years – artificial intelligence (AI). ↘ ITEMS 126 AND 133 This increases labour productivity, as the same potential output is achieved with less labour input. However, these possibilities for substitution vary greatly both between and within individual sectors of the economy. This is due to differences in the maximum capital intensity of production that can be achieved in practice, as well as the fact that the scope for substituting labour with capital has already been used to varying degrees. ↘ ITEMS 132 FF.

78. An important auxiliary condition for the future potential growth of the German economy is the goal of **greenhouse gas neutrality by 2045.** This goal **requires the replacement of fossil fuels with green energy sources and an increase** in the **efficiency of** energy use (GCEE Annual Report 2022 items 325 ff.). Due to differences in the service lives of existing assets and their long use past their imputed service life (Michelsen and Junker, 2023), there are very significant differences in terms of opportunities to increase energy efficiency through capital formation or to switch to other energy sources. ↘ ITEMS 109 FF. In the case of capital goods with long service lives in particular, e.g. non-residential buildings, the early disposal of capital goods powered by fossil fuels is likely to be necessary to achieve greenhouse gas neutrality. ↘ ITEMS 111 FF.

79. In the coming decades, potential output growth could be considerably lower than in the previous decade due to the expected decline in the volume of labour.

However, the GCEE's analyses indicate that this development can be mitigated if economic policy measures are implemented swiftly and decisively. Reforms that **increase incentives for employment are** crucial to any future growth strategy. At the same time, long-term measures to **spur productivity** through technological progress, to compensate for the decline in labour supply through immigration, and to **modernise capital stock through capital formation** are essential. ↘ ITEMS 156 FF.

II. STARTING POINT – GERMANY'S POTENTIAL OUTPUT

80. **The potential output of an economy grows** over time as the **factors of production** – labour, human capital and both intangible and physical capital – are **accumulated** and **put to** increasingly **productive use** (Solow, 1956; Mankiw et al., 1992; Romer, 1994; Acemoglu, 2009; Galor, 2011). ↘ BOX 11

1. Potential growth in decline since 1970

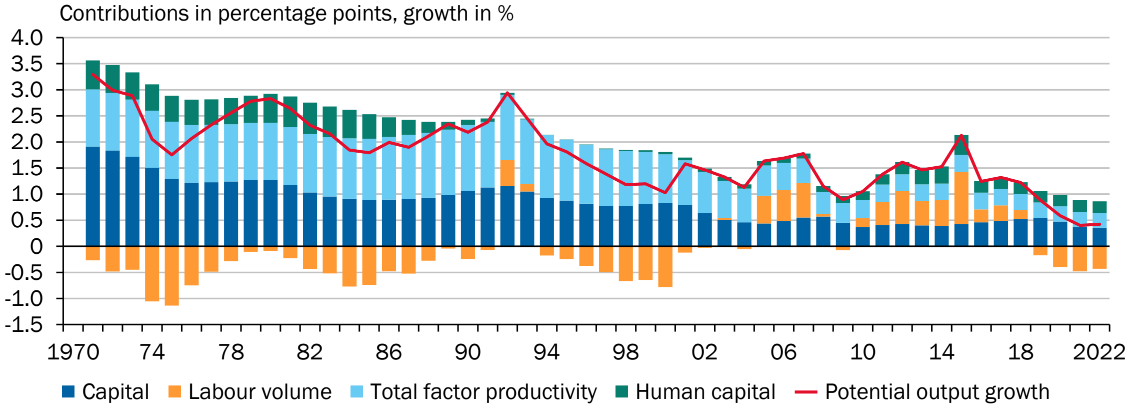
81. According to estimates by the GCEE, the **growth rate of real potential output in the** German economy fell from an average of about 2.5 % in the 1970s to an average of about 1.4 % between 2000 and 2019. Since 2020, it has averaged at about 0.5 % (Ochsner et al., 2023b). ↘ ITEMS 71 AND 99 ↘ CHART 34 Due to strong net immigration in 2022, ↘ ITEM 100 e.g. from Ukraine, the potential output growth rate in 2023 is above its long-term expected trend, at about 0.7 %. ↘ ITEM 99

82. There are several reasons for the **decline in potential output growth** compared to 1970. One major factor is the continuously declining rate of growth in capital stock in Germany since 1970. Since the end of the 1990s, TFP growth has also been declining significantly. In addition, Germany's potential growth has been dampened by negative contributions to growth from the volume of labour since 2019. ↘ CHART 44

83. The most important determinant of potential output growth is overall economic productivity gains due to technological progress (Solow, 1956; Romer, 1990, 1994; Galor, 2011). In the 1970s, potential growth was mainly driven by high TFP growth (about 1.1 % annually). The **decline in contributions to growth from TFP** observed in Germany since the 1990s is particularly problematic in this context. It could point to a declining rate of technological progress or a slower reallocation of production factors from low- to high-productivity companies and sectors. ↘ ITEMS 89, 90, 148 AND 202 FF.

84. In addition to TFP growth, the accumulation of fixed capital has contributed massively to the expansion of potential output since the 1970s. However, the **contribution to potential output growth from capital services** has declined sharply, from 1.5 percentage points in the 1970s to 0.4 percentage points

↘ CHART 34
Growth contributions of components to potential output



Sources: Federal Statistical Office, IAB, OECD, own calculations

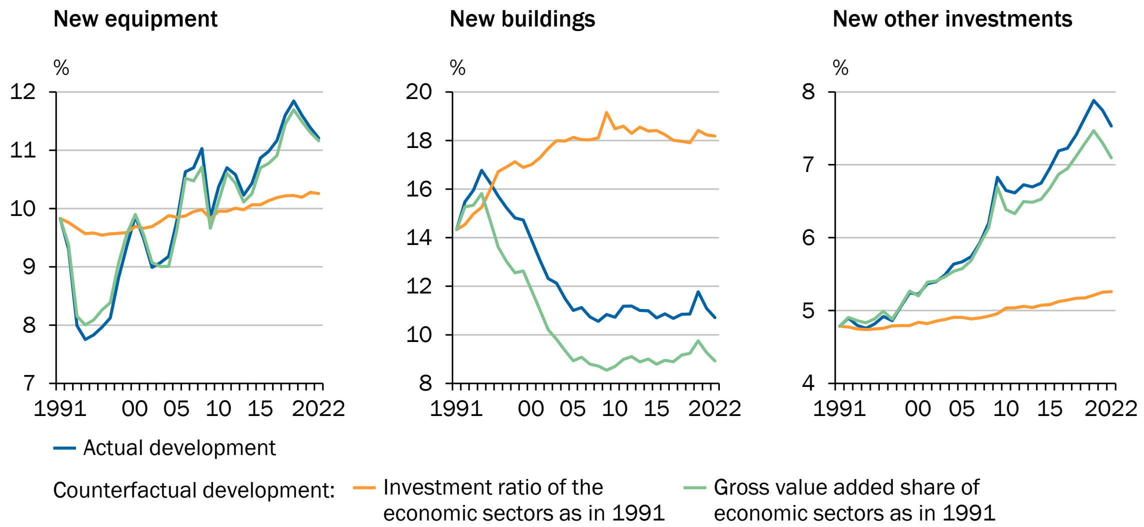
in the past five years. Capital intensity, measured as the ratio of capital services to hours worked, has risen by 412 % since 1970 as capital accumulated and the volume of labour declined. ↘ CHART 43 The **contributions to capital services growth from the various capital goods** were consistently positive in the past, but have been **declining** on average over many years. The **exception** is **other capital**, which largely consists of intellectual property. ↘ ITEMS 93 AND 94 The share of other capital in capital services growth has been rising slowly since 1970 and only declined temporarily after reunification. The contributions to growth from non-residential buildings, such as factories or roads, have been close to zero since the turn of the millennium.

85. Capital services growth is essentially determined by the growth of capital stock and thus by capital formation. The **gross investment rate**, i.e. the ratio of **capital formation** to gross value added, **has developed very differently for the different capital goods in Germany since 1991.** For example, the gross investment rate for new buildings has decreased by approximately 20 % since 1991, while it has increased by approximately 50 % for new other investments. ↘ CHART 35

86. The observed **changes in Germany's aggregate investment ratios** can be divided into changes in the capital goods-specific propensity to invest and changes in the composition of the economy due to structural change. If the investment ratio for each economic sector were to be consistently maintained at the 1991 level and if we were to look only at the actual changes that occurred in the composition of economic sectors, the investment ratio for new buildings in 2022, for example, would be approximately 7.5 percentage points above its recorded level. ↘ CHART 35 This difference is due in particular to the decline in the investment ratio in the service sectors from 20 % in 1991 to 14 % in 2022. In contrast, **structural change** has a **slightly positive effect**. This is because, without the change in the composition of the economic sectors, the investment ratio for new buildings would be 1.8 percentage points below its 2022 level. ↘ CHART 35

↘ ABBILDUNG 35

Investment ratios in gross fixed capital formation[1]



1 – Real gross fixed capital formation in relation to real gross value added. Economic sectors considered: agriculture and forestry, fishing, manufacturing excluding construction, construction, trade, transportation, accomodation and restaurants, information and communication, financial and insurance services, real estate services, business services, public services, education, health, other services. According to the Classification of Economic Activities, 2008 edition (WZ 2008).

Sources: Federal Statistical Office, own calculations

87. In the period from 1970 to 1999, the potential volume of labour (measured in hours) contracted, in turn reducing potential growth by an average of 0.5 percentage points per year. ↘ CHART 34 **From the turn of the millennium to 2019**, however, the **contributions to growth** from the **volume of labour** were largely **positive.** ↘ CHART 44 This is partly due to the sharp decline in the structural unemployment rate ↘ GLOSSARY from 8.4 % in 1999 to 2.4 % in 2023 in the wake of labour market reforms in the early 2000s (Hochmuth et al., 2019). Moreover, OECD data indicates that the labour force participation rate increased from about 65 % to about 70 % during the same period ↘ BOX 11, which also contributed to the expansion of the labour force. ↘ CHART 44 The decline in average hours worked per person in employment counteracts the increase in employment and hinders growth in the volume of labour. Since 2019, the effect of declining hours worked has outweighed the effect of rising labour force participation (which was already high by international standards) and low structural unemployment. Since reunification, the contribution of human capital to potential growth has been positive but small, at a long-term average of 0.2 percentage points annually. ↘ CHART 34

↘ BOX 10

Background: Capital goods, cost of capital utilization and use of capital

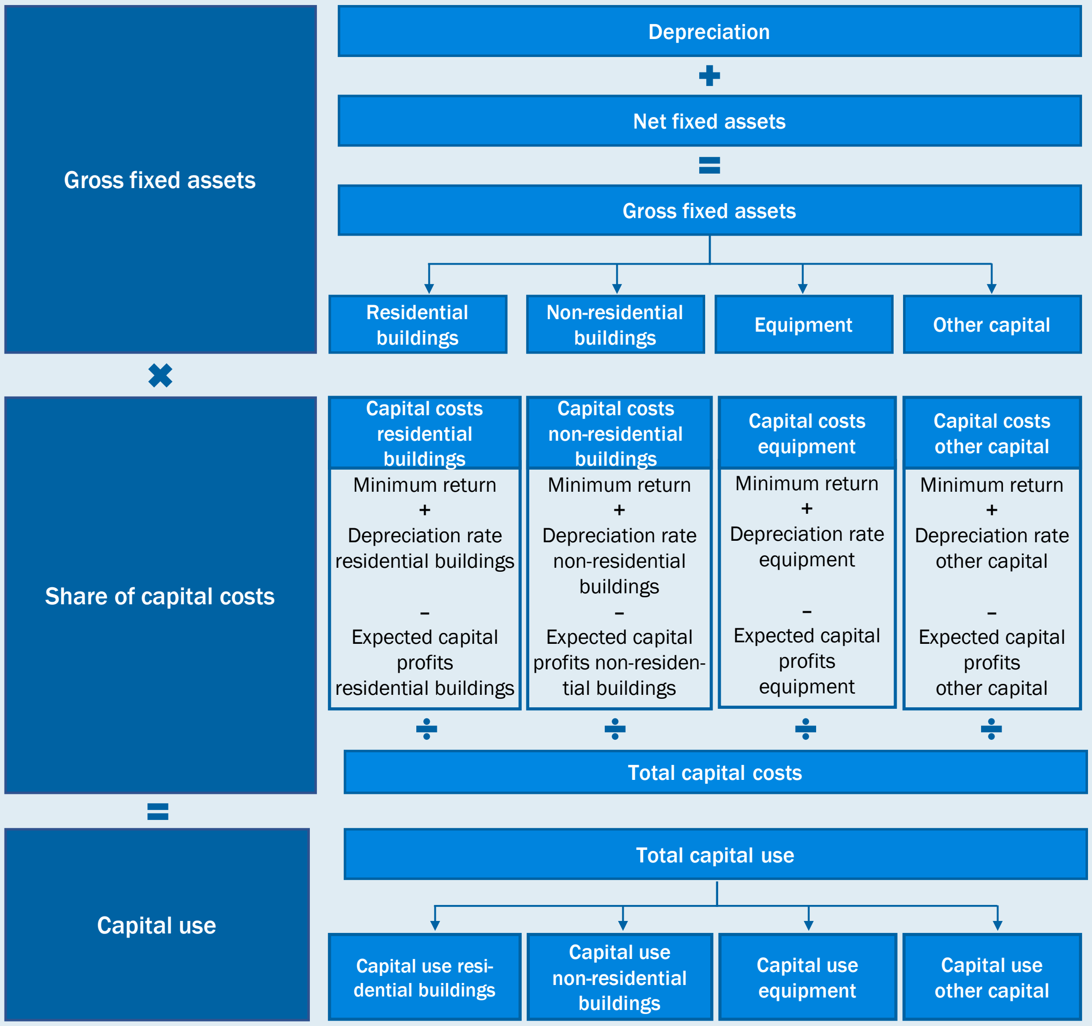
Various concepts are used to measure capital stock and its economic use. The **gross stock of fixed assets** is ideal for measuring productive capital stock. The gross stock of fixed assets is the sum of the replacement values of residential buildings, non-residential buildings, equipment and other capital. Valuation at replacement cost takes into account, at least in part, the differences in quality between the different generations of capital assets. The assets are fully accounted for in the asset portfolio for their intended period of use. When a capital asset is no longer in productive use and is permanently withdrawn from service, the gross fixed assets are reduced accordingly through disposals.

In contrast to the gross stock of fixed assets, the **net stock of fixed assets** is ideal for measuring the economic residual value of capital stock. In contrast to the gross stock of fixed assets, which are derecognised from capital stock at the point when they are finally taken out of service, capital assets are depreciated gradually over the course of their service life. Imputed depreciation takes account of the reduction in value of capital assets due to wear and tear (Gühler and Schmalwasser, 2020). The net stock of fixed assets therefore indicates how much replacement investment that would be needed to keep capital stock constant. The gross and net stocks of fixed assets differ in their significance with regard to the productivity of capital stock. While depreciated assets may still be productive, they may not be as productive as they were at the beginning of their life (Dullien et al., 2019; Grömling et al., 2019). As a result, the actual productive value of capital stock is likely to be overestimated based on the gross stock of fixed assets and underestimated based on the net stock of fixed assets.

To measure the contribution of capital stock to production, the various capital goods can be aggregated using the **capital utilisation cost approach** (Knetsch, 2013). The GCEE uses this

↘ ABBILDUNG 36

Capital goods, capital costs and capital use



Source: own representation

approach to measure capital services in its medium-term projection. ↘ CHART 71 To measure **capital services** in the German economy, an index of gross fixed capital stocks weighted with the respective shares in the cost of capital utilization is constructed, with the index corresponding to the value 100 in 1969. ↘ CHART 43 Following the approach of Knetsch (2013), the cost of capital utilization for each of the four capital goods is calculated as the sum of the minimum return on the capital stock required by the economy as a whole plus the depreciation rate, minus the expected capital gains. While the gross stock of fixed assets indicates the quantity of capital goods that can be productively used, the shares of the individual capital utilization costs in total capital utilization costs (i.e. the sum of the capital utilization costs of all capital goods) indicate the relative marginal productivity of the individual capital good in relation to the productivity of the entire capital stock. Capital services thus take into account both the quantity and the quality of the available capital valued at the relevant current marginal productivity. ↘ CHART 36

2. International comparison of potential output

88. The **potential output growth rate** has been **declining** for decades not only in Germany, but **also in other advanced economies**, such as the US or France. ↘ CHART 37 ↘ BOX 11 For example, the potential growth rate of the US declined from about 3.2 % in 1981 to about 1.6 % in 2022. According to projections by the European Commission, the growth rates of potential output in almost all countries under consideration will lag behind their historical trends until 2027 (European Commission, 2023a).

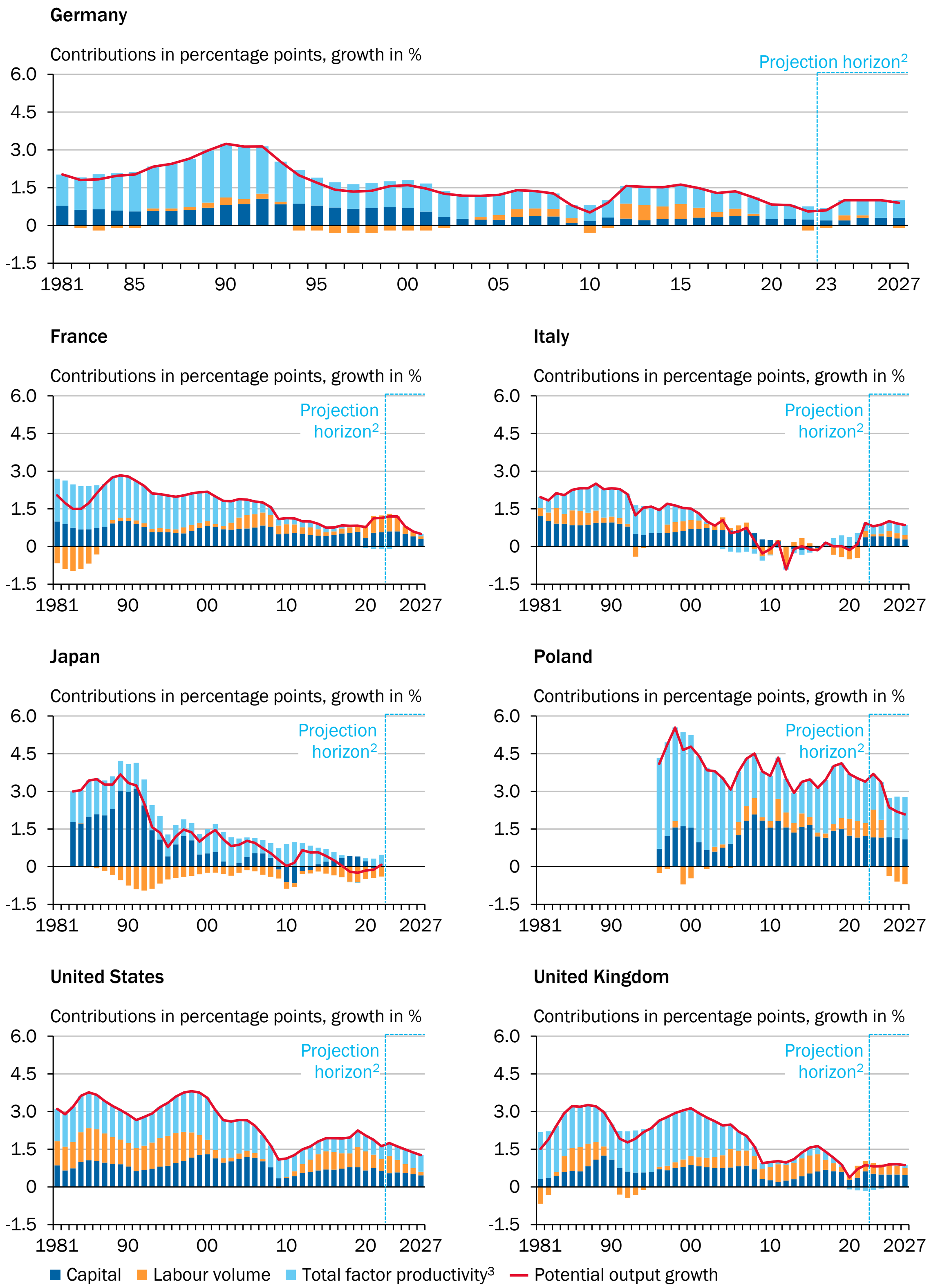
89. **Convergence to a country-specific, positive,** more or less **constant potential output growth rate** is a feature of advanced economic development. This convergence, which is determined in particular by a convergence in the growth of capital stock per capita, is the result of both neoclassical (Ramsey, 1928; Solow, 1956; Koopmans, 1963; Cass, 1965) and more recent (Barro and Sala-i-Martin, 1997; Acemoglu et al., 2006) growth models, as well as many empirical studies (Barro and Sala-i-Martin, 1991; Sala-i-Martin and Sachs, 1991; Barro, 2015).

Recent research indicates that the **potential output growth rate** also declines over time **due to a decrease in the TFP growth rate** (Bloom et al., 2020). ↘ BOX 12 For example, since the mid-1990s, potential growth in Poland has been similarly dynamic to that in Germany during the 1970s and 1980s and has not yet fallen to the current level of more advanced European economies. This suggests that the Polish economy is still in the process of catching up with the economies of Western Europe following the collapse of the Soviet Union. ↘ CHART 37

90. Due to this convergence of capital growth and the slowdown in productivity growth, it is not surprising that **potential output in Germany is** growing at a rate below its high historical level. In contrast to other advanced economies (such as Italy), where potential output growth rates have risen again recently following a significant temporary slowdown, potential growth rates in Germany (and France) are in decline. ↘ ITEM 99 ↘ CHART 37

↘ CHART 37

Potential growth in selected countries according to European Commission estimates[1]



1 – For Japan, Bank of Japan estimates. 2 – From 2023 onwards, projections by the European Commission and the Bank of Japan. 3 – Total factor productivity and human capital.

Sources: Bank of Japan, European Commission, own calculations

The observed **slowdown in TFP growth** is not a specifically German phenomenon, and can also be observed in many other advanced economies. ↘ CHART 37 ↘ BOX 11 In France and the United Kingdom, the contributions to growth from TFP are expected to be around zero by 2027, according to European Commission estimates, whereas the United States can expect TFP increases of between 0.5 and 0.7 percentage points per year in future (European Commission, 2023a). ↘ BOX 12

91. In addition to general productivity growth, **capital accumulation** plays a central role in the growth process (Solow, 1956; Mankiw et al., 1992; Galor, 2011). According to European Commission estimates, contributions to growth from capital in the United Kingdom, France and Italy have fluctuated by an historical average of about 0.5 percentage points since 1981 – a trend similar to that shown by the German economy. In many economies, however, these contributions to potential growth are more significant than in Germany. ↘ CHART 37

92. In contrast to the steady growth of fixed assets, the **contributions to growth from labour** have been **declining** in recent years in many developed economies. This is even the case in the United States and the United Kingdom, which have historically benefited strongly from immigration (Borjas, 1996; Hatton and Price, 1999). In most other industrialised countries, the increasing ageing of the population is leading to sharply declining and even negative contributions to growth from the volume of labour. These developments are particularly pronounced in Japan and Italy. ↘ CHART 37

↘ BOX 11

Background: The GCEE's projection model compared to the model of the Joint Economic Forecast and the European Commission

For its medium-term projection, the GCEE estimates the potential of **labour input**, **human capital** and **physical** as well as **intangible capital and total factor productivity** and aggregates these with a Cobb-Douglas function to arrive at the overall economy's potential output. Human capital has only been taken into account since this GCEE Annual Report, as part of a new method (Ochsner et al., 2023b). The volume of labour is expressed in hours worked by employed persons; human capital is taken into account as the average number of years of training weighted by the marginal return of an additional year of training, and the concept of capital services is constructed as an index of the sum of gross fixed capital stocks weighted with the respective shares in the cost of capital utilization. ↘ BOX 10 Total factor productivity is obtained as the Solow residual of the Cobb-Douglas production function.

The GCEE's new model is used in this Productivity Report for long-term projections up to the year 2070. The end point is obtained by using the current population forecast of the Federal Statistical Office, which extends to the year 2070. This is the first time that the GCEE has quantified the **projection uncertainty** of potential output using Bayesian methods in its projection for the medium and long term in the current GCEE Annual Report (Chan and Jeliazkov, 2009; Ochsner, 2023). Unless explicitly stated otherwise, the reported results always refer to the medians of the estimates and projections. The method used by the GCEE to estimate potential output is based on the **method used by the European Commission and the Joint Economic Forecast;** similar methods are used by the US Congressional Budget Office and the OECD (Havik et al., 2014; Joint Economic Forecast, 2017; Shackleton, 2018; Chalaux and Guillemette, 2019). However, there are **important differences** between the method used by the

European Commission, which also estimates potential output for Germany, ↘ CHART 37 TOP, and the GCEE's method.

The Joint Economic Forecast and the European Commission, unlike the GCEE's new method, both use the **Hodrick-Prescott filter** (HP filter; Hodrick and Prescott, 1997)) to determine the mean values of the trend for most macroeconomic aggregates (with the exception of the structural unemployment rate and TFP). However, the HP filter is known for mechanical instability and thus high susceptibility to revision, especially at the end of the time series (Hamilton, 2018). To avoid this problem, the GCEE now uses a state-space **model** estimated using Bayesian techniques (Chan and Jeliazkov, 2009; Ochsner, 2023). In contrast to the European Commission, the GCEE also uses an **age cohort model** to project forward the labour force participation rate (Breuer and Elstner, 2020; Ochsner et al., 2023b). This helps to better capture how the demographic changes which are currently and foreseeably taking place in Germany are being manifested in the labour market. Furthermore, unlike the Joint Economic Forecast and the European Commission, the GCEE uses the **Perpetual-Inventory Method (PIM)** to determine the disposals and depreciation of individual capital goods. This approach takes heterogeneous useful lives of capital goods into account. With this method, a density function can be used to determine the volume of disposals for each reporting year as the sum of the individual disposals from all relevant investment years. The depreciation results endogenously from this (Schmalwasser and Schidlowski, 2006; Ochsner et al., 2023b).

Unlike the European Commission and the Joint Economic Forecast, the GCEE does **not** use **a stationary trend growth specification for modelling total factor productivity.** The European Commission projects forward the TFP growth g_t with the help of

$$g_t = a(1-b) + bg_{t-1} + e_t$$

where a is a real constant and b lies on the open interval (0, 1) and e_t are normally distributed innovations (Havik et al., 2014; Ochsner et al., 2023b), while the GCEE specifies the following for trend growth in total factor productivity

$$g_t = g_{t-1} + e_t$$

The difference between the two processes is their long-term behaviour. While the first process always returns to its long-term mean a, the future, unconditional expectation of the second process corresponds to its current state. For many quantities that empirically fluctuate around an (approximately) constant mean, the first process is a sufficiently good approximation for the purposes of potential estimation; the second equation is merely another option. However, for processes that are not stationary around the mean, because their position changes greatly over time, for example like total factor productivity, the first specification can lead to strong distortions of the estimated parameters (misspecification) and produce misleading results.

The European Commission uses the first specification to estimate potential TFP growth uniformly for all countries in the European Union. For many European countries, especially those in Eastern Europe that are experiencing an (economic) upturn, for example Poland, the first equation can provide a well-conditioned estimate of TFP trend growth, as TFP growth rates are sufficiently constant for the period under consideration. The first specification can also be helpful for countries with negative TFP growth rates in the meantime, since negative TFP growth rates in the long run are not expectable in economic terms and accordingly are not likely to be the result of a projection. Since the **TFP growth rate in Germany is positive but declining**, and since the rate of decline varies over time, the second specification is better suited to estimate and project the TFP growth rate for Germany. Applying the first specification would instead lead to increasing growth rates from the current level until the level of $a > g_{t-1}$ is reached. This may lead to very high contributions to growth in TFP. ↘ CHART 37 TOP Since Germany had high TFP growth rates in the 1970s and 1980s, which are incorporated into the estimate of a, this potentially leads to a biased estimate that would systematically result in inaccurate prediction of the projected TFP growth rate. For this reason, the GCEE chooses the second specification for TFP growth.

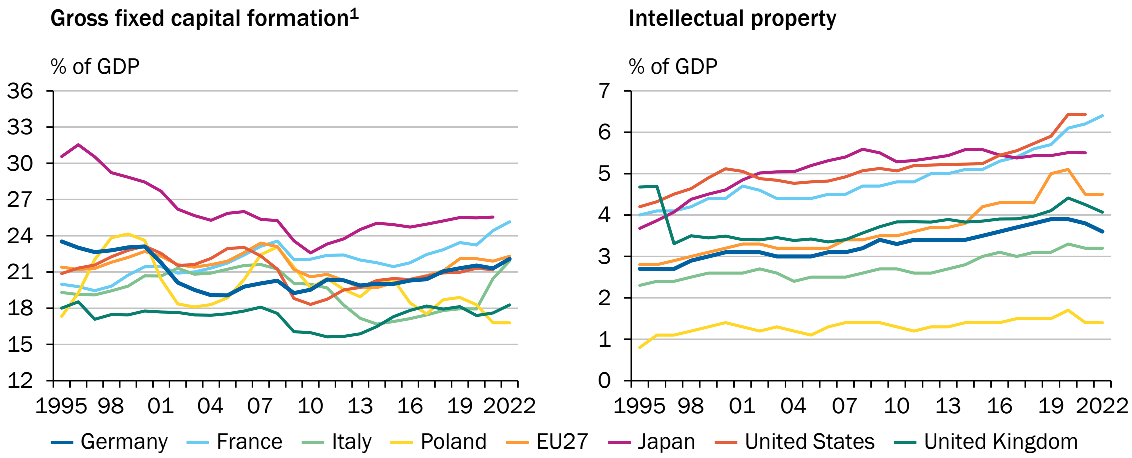
3. International comparison of capital formation

93. Since 1995, **fixed capital formation** in relation to gross domestic product (GDP) has ranged between 16.7 % and 24.8 % of GDP for the **selected countries** with the exception of Japan. ↘ CHART 38 In Germany, this figure ranges between 19.1 % and 23.5 %. Japan invests a consistently higher share of GDP, i.e. 22.6 % to 31.5 %.

Capital formation in intellectual property as a share of GDP has increased slightly since 1995 in all economies examined. Intellectual property accounts for about 99 % of other capital (the remaining share comprising livestock and crops). ↘ CHART 38 There are greater differences between countries in terms of capital formation in intellectual property than in terms of gross fixed capital formation as a whole. While Poland invested only 0.8 % to 1.7 % of GDP in intellectual property, the investment ratio in Japan, the United States and France ranges from 3.7 % to 6.4 %. Germany's investment ratio grew from 2.7 % to 4.0 % from 1995 to 2019 and has since declined slightly to 3.7 % in 2022.

94. **Intellectual property** has **gained in relevance** compared to other capital assets. ↘ CHART 38 ↘ ITEMS 99 AND 105 In Germany, capital formation in intellectual property largely comprises research and development (86 %) and software and databases (11 %). The share of intellectual property in fixed capital formation has increased by 4.9 percentage points between 1995 and 2022 and is currently 16.2 %. In the other countries, a strong increase in the share of intellectual property in fixed capital formation can also be observed over this period. In Poland and Japan, this trend was very pronounced, with a near doubling of the share (GCEE Annual Report 2019 items 306 ff.; GCEE Annual Report 2020 item 564).

↘ CHART 38
Gross fixed capital formation and capital formation in intellectual property for selected countries



1 – Without cultivated biological resources.

Sources: Eurostat, OECD, own calculations

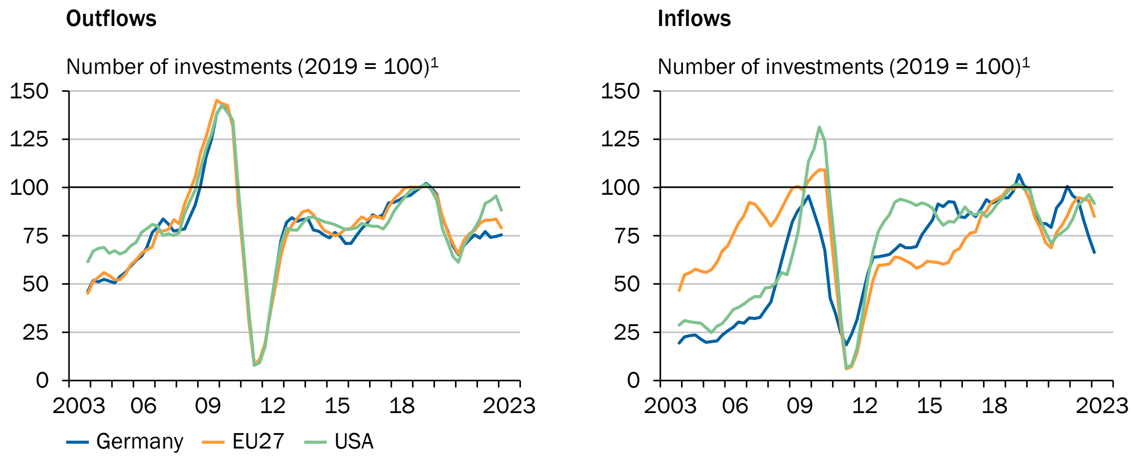
4. Foreign direct investment

95. In addition to capital formation by domestic economic agents, **foreign direct investment (FDI)** is also **significant for the overall economy.** On average from 2010 to 2022, the ratio of annual FDI to gross fixed capital formation was around 12 %, and the share of expansion investments (greenfield FDI) in gross fixed capital formation has been around 4 % (EPSC, 2018; Deutsche Bundesbank, 2023a). Note that the value of inward FDI in particular fluctuates strongly from year to year.

96. Over the past 20 years, **Germany** has experienced **comparatively high FDI outflows** relative to other advanced economies, averaging 3.1 % of GDP. While other advanced economies have resumed increased investment in foreign projects as of 2021 following a pandemic-related slump, there is no evidence of the same trend in Germany according to the latest figures (Aiyar et al., 2023; Fletcher et al., 2023). ↘ CHART 39 LEFT FDI inflows to Germany have been on a downward trend since 2020, a more pronounced decline than in many other advanced economies. This could indicate restrained investment in the short-term given recent geopolitical developments. ↘ CHART 39 RIGHT

97. Increased geopolitical uncertainty (IMF, 2023; GCEE Annual Report 2021 items 500 ff.) and rising geopolitical tensions could trigger a change in the objectives and scope of FDI. Increased political risk, but also the political goal to de-risk, have an impact on investment decisions (IMF, 2023). The past few years, for example, have been characterised by a **global fragmentation of FDI**. Companies tend to reduce their FDI in regions that belong to a different geopolitical bloc (IMF, 2023). For Germany, **FDI** to China and Russia have decreased since 2021 (Fletcher et al., 2023). ↘ CHART 40 RIGHT

↘ ABBILDUNG 39
Foreign direct investment

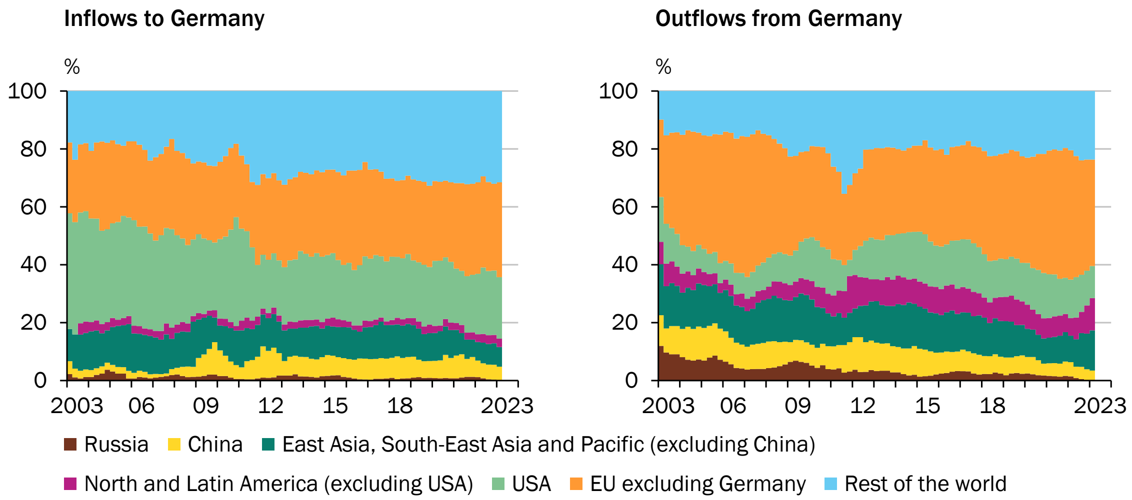


1 – Moving average over the past four quarters, normalised to 2019.

Source: Fletcher et al. (2023)

↘ ABBILDUNG 40

Germany's foreign direct investment flows by region



Source: Fletcher et al. (2023)

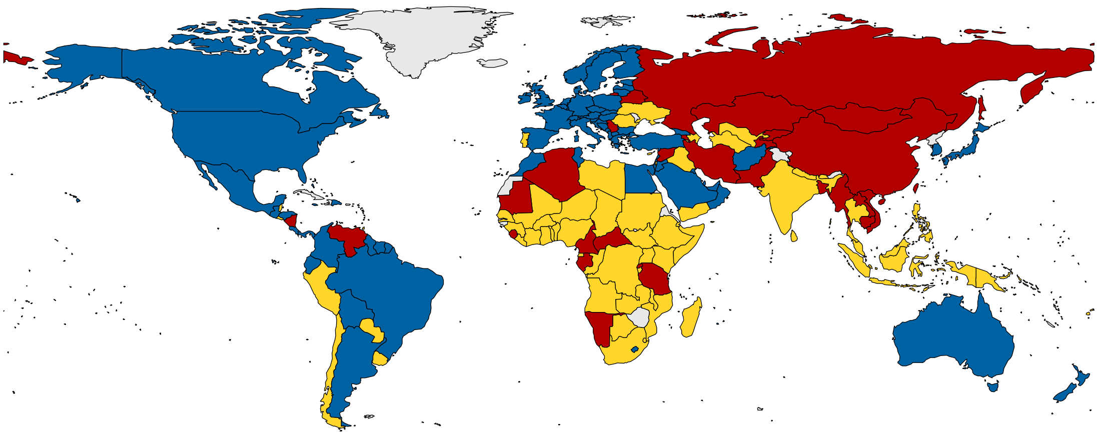
98. German foreign direct investment abroad has become increasingly sensitive to the geopolitical orientation of the destination country due to rising geopolitical tensions over the past decade (Fletcher et al., 2023). A panel regression across destination countries reveals that when **geopolitical tensions increase** globally, there is a **fall in German investment flows to geopolitically distant countries** in favour of flows to countries that share similar geopolitical views. This finding is consistent across several specifications, including the measure chosen to assess geopolitical alignment: a fall in investment flows is evident both towards countries that vote very differently from Germany at the United Nations general assembly (Bailey et al., 2017) and also towards countries that frequently receive arms supplies from China or Russia but rarely from Western countries. ↘ CHART 41 This latter measure is more representative of both the geopolitical situation in the Middle East and the presence of an independent group of countries, such as India or South Africa, than previous measures.

Furthermore, Fletcher et al. (2023) show that **German foreign direct investment of energy-intensive industries is strongly influenced by the energy price** of the destination country and that investment flows of these industries is also particularly sensitive to the geopolitical orientation of the destination country. This suggests that geopolitical tensions will increasingly change the FDI landscape and that this poses both risks and opportunities for Germany. High energy costs in Germany could lead to more investment flows abroad. However, Germany could also attract investments from countries with similar geopolitical views that, like German companies, are relocating their production from geopolitically distant countries.

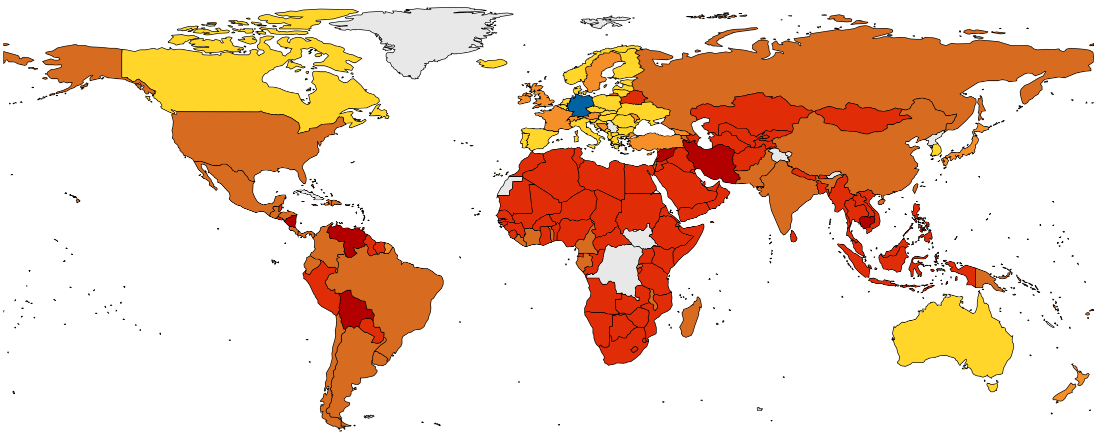
↘ ABBILDUNG 41

Measures of geopolitical orientation in comparison

Bloc allocations according to SIPRI arms imports[1] (2013 – 2022)



IPD in United Nations votes[2] (2021)



1 – Countries are assigned to the US-led bloc if they received two-thirds of their arms deliveries between 2013 and 2022 (Stockholm Peace Research Institute (SIPRI), 2023) from the US, France, Germany, the UK, Italy, the Netherlands, Israel and Spain. Countries are assigned to the China-Russia bloc if they received two-thirds of their arms deliveries from China and Russia between 2013 and 2022. If neither is the case, the country is "non-aligned" (Fletcher et al., 2023). 2 – Ideal Point Distance (IPD) represents the distance according to Bailey et al. (2017) between the voting behaviour of two states at the United Nations. The values here represent the log distance relative to Germany.

Sources: Bailey et al. (2017), EuroGeographics for the administrative boundaries, Fletcher et al. (2023), Stockholm International Peace Research Institute (SIPRI)

III. OUTLOOK: POTENTIAL OUTPUT IN THE LONG TERM

99. The model used by the GCEE ↘ CHART 71 ↘ BOX 11 not only allows the estimation of potential output since 1970, but can also be used for **projections up to 2070**, the end date of the current population forecast of the Federal Statistical Office. It is important to note that these projections are **not predictions** or traditional economic forecasts; instead they function as **scenario calculations**. They provide insights into the possible effects on potential output of macroeconomic and demographic developments that are either already inherent in the data or hypothetical in the future. The possible effects of social and economic policy decisions are also considered. Many **developments can** still be **influenced by** new **economic policy decisions** at the present time. ↘ BOX 11 ↘ ITEM 88

100. In a **reference scenario,** the GCEE examines how potential output will develop **if the present trends in 2023 continue** (Ochsner et al., 2023b). ↘ CHART 42 For this purpose, the trend growth rates of the model components estimated from available data and the GCEE's short-term forecast are extrapolated from the current state.

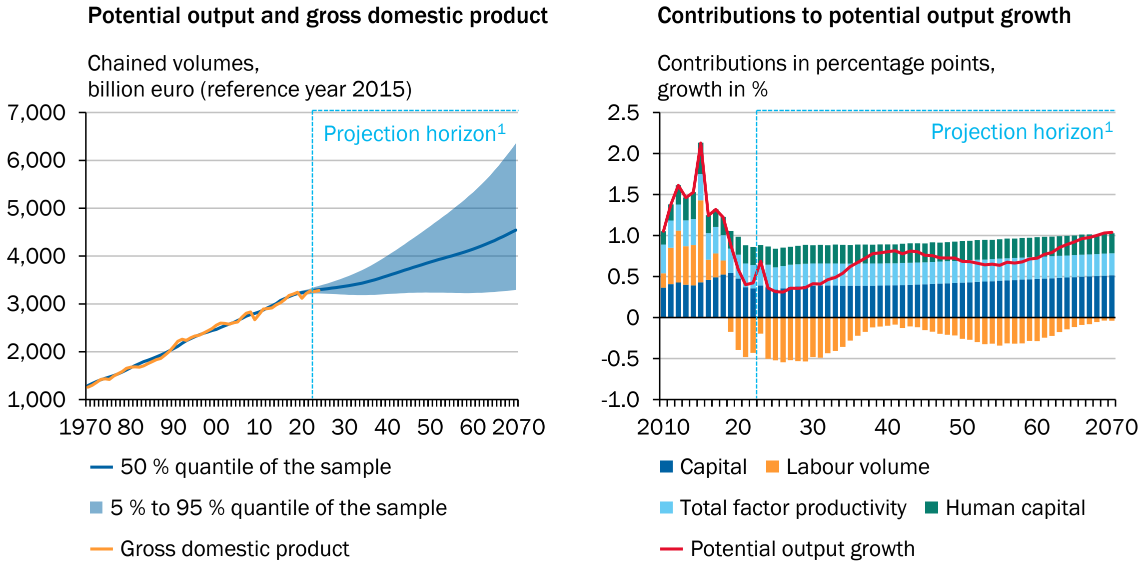
This does not include the population forecast, taken by the GCEE from the Federal Statistical Office. The relevant scenario is G2L2W2, with an average birth rate of 1.55 children per woman, a moderate increase in life expectancy until 2070 and net inward migration of 513,000 in 2023, which drops to 250,000 per year until 2033 and then remains at this level (Federal Statistical Office, 2023). In order to model the lower rate of integration of migrants into the German labour market, it is assumed that this group has a structural unemployment rate of 12 % and a labour force participation rate of 70 % in 2022, and that 75 % of them are of working age (15-74 years). These assumptions yield similar results for the contribution of immigrants to labour input as similar assumptions made in the GCEE Annual Report 2022 (items 84 ff.). By 2062, the labour market characteristics of immigrants in the model converge with those of the native population. ↘ ITEM 106

Taking **assumptions differing from the reference scenario** about the development of production factors allows the effects of alternative developments on potential growth and production factors to be examined. This is particularly relevant in the context of the digital and green transformations, ↘ ITEMS 109 AND 123 FF. which are likely to lead to significant deviations from the trends currently reflected in the data.

1. Low potential growth in reference scenario

101. The GCEE's long-term projection yields **an average annual growth rate of about 0.7 %** for potential output in **the reference scenario** in the years **2023**

↘ CHART 42
Potential output in the reference scenario



1 – Values for 2023 and 2024 are based on the short-term forecast by the GCEE. From 2025 projection, results of the reference scenario.

Sources: Federal Statistical Office, IAB, OECD, own calculations

to 2070. ↘ CHART 42 LEFT AND RIGHT ↘ TABLE 19 APPENDIX In the reference scenario, total factor productivity grows at 0.3 percentage points per year.

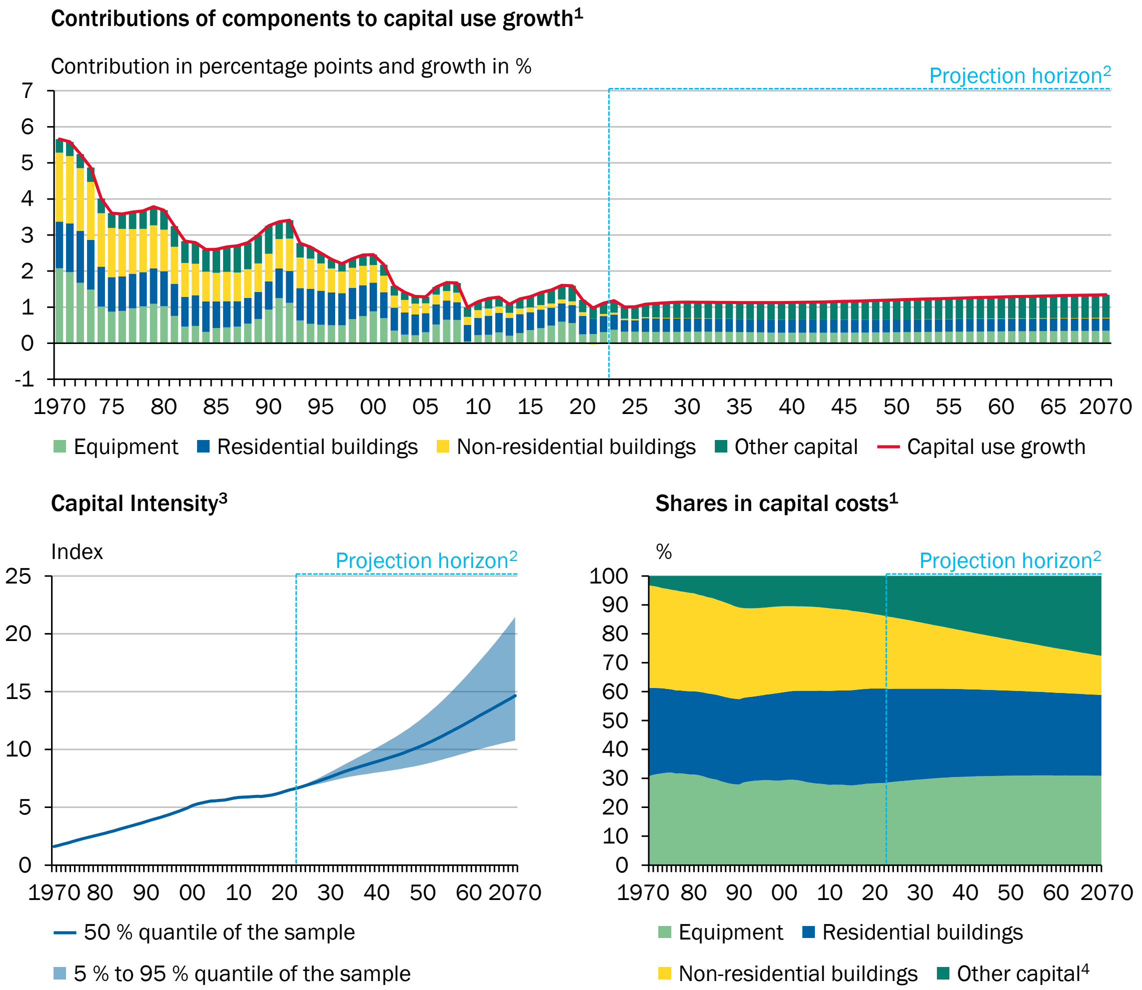
Real **potential output** in 2015 prices **increases by 38 %** in **the reference scenario** between 2023 and 2070. Per capita, this results in an increase from €38,912 in 2023 to €55,018 in 2070, i.e. an increase of about 41 %. In comparison, the potential output per capita grew by 135 % between 1970 and 2023.

102. In view of the long forecast period and the large number of factors that can influence potential output, it makes sense to take into account the many possible trends of the potential output path. **Methodological advances enable** the GCEE to **quantify the estimation and projection uncertainty** of potential output for the first time in this report. In the long run, this uncertainty is considerable. By 2070, potential output per capita in the reference scenario would grow cumulatively by between 5 % (5 % quantile of the simulated trajectories) and 94 % (95 % quantile of the simulated trajectories) compared to 2023. ↘ ITEMS 89 F. It is therefore rather unlikely from today's perspective that potential output will fall below the current level in the long run. However, it seems just as improbable that there will be a sizeable increase similar to that experienced between 1970 and 2023. ↘ ITEMS 89 F.

Capital services more relevant for potential growth

103. The contribution of **capital services** to the growth of potential output in the reference scenario is about 0.4 percentage points per year on average. For the forward projection of real capital formation, the reference scenario assumes that the trend growth rates of capital formation in the respective capital goods remain

↘ CHART 43
Capital in the reference scenario



1 – 50 % quantil of posterior distribution is shown. 2 – Values for 2023 and 2024 are based on the short-term forecast by the GCEE. From 2025 projection, results of the reference scenario. 3 – Capital use divided by billions of hours worked. 4 – Predominantly intellectual property.

Sources: Federal Statistical Office, own calculations

constant at the current level. The depreciation and disposals are derived from the model on the basis of the estimation method and the assumptions of the Federal Statistical Office on the service lives of the capital goods (Schmalwasser and Schidlowski, 2006). ↘ BOX 11 The trend growth rates of capital formation in equipment, other capital, residential and non-residential buildings amount to about 1.6 %, 2.2 %, 1.4 % and 0.4 % annually.

104. The **overall economy's capital intensity**, the ratio of capital services to hours worked, **increases** by 120 % in **the reference scenario** between the years 2023 and 2070. This is the result of both the declining volume of labour and the rising capital services, which increases by about 80 % in the reference scenario. ↘ ITEM 128 Capital services are therefore the most important driver of potential growth in the reference scenario. ↘ CHART 43 ↘ TABLE 19 APPENDIX

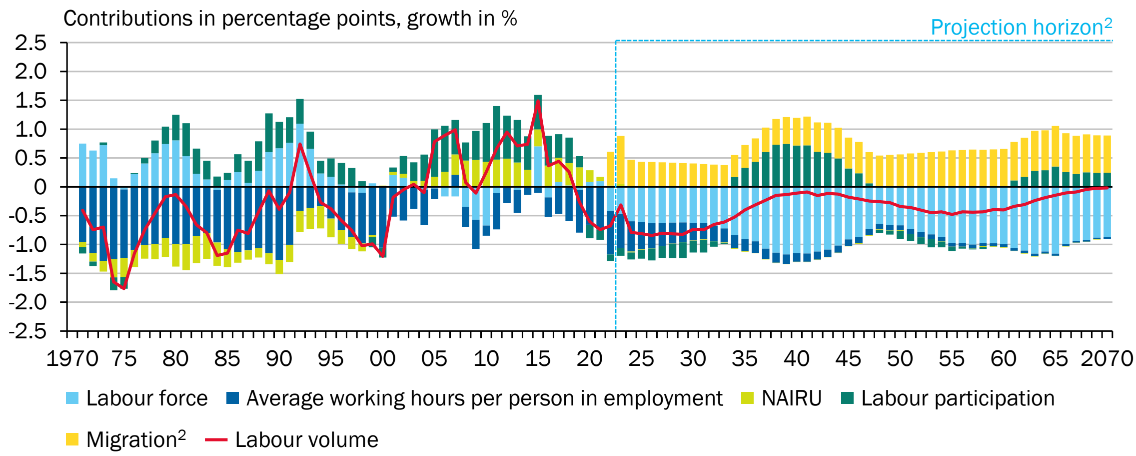
105. **Other capital** has already accounted for an **increasing share of capital services** over the past 40 years. ↘ ITEMS 86, 93 AND 94 In the reference scenario, this trend continues over the forecast period. ↘ CHART 43 Assuming that existing trends continue, ↘ CHART 93 the share of other capital in capital services would increase significantly, amounting to about 28 % at the end of the forecast period. In contrast, the share of non-residential buildings, such as immovable production facilities, factory buildings or infrastructure indicated in the reference scenario drops from a share of about 35 % in 1970 to only 13 % in 2070.

Declining labour volume hindering potential growth

106. For the **projection of labour volume components** (labour force, average hours worked, structural unemployment rate, labour force participation rate) in the reference scenario, it is assumed that the trend growth rates converge to their long-term mean values. This convergence is modelled endogenously. The aggregate trend growth rates of hours worked, the structural unemployment rate and the labour force participation rate are –0.15 % (long-term mean: 0 %, not reached in the reference scenario), 0 % and 0.14 %, respectively, on average per year.

107. In the reference scenario, **the volume of labour significantly reduces potential growth** until around 2050 due to the decline in the labour force. ↘ CHART 44 In contrast, neither negative nor positive contributions to growth are to be expected from the structural unemployment rate in the reference scenario after a significant decline in the years 2005 to 2018 (GCEE Annual Report 2022 items 356 ff.). Due to the continuing decline in full-time hours, i.e. annual working hours in full-time employment, negative contributions to growth of hours worked are also to be expected. In the period from 2050 to 2070, full-time hours in the reference scenario level out at about 6.5 hours per day with 230 working days per year. In addition, the part-time and self-employment rates in the reference

↘ CHART 44
Contributions to labour volume growth in the reference scenario



1 – Values for 2023 and 2024 are based on the short-term forecast by the GCEE. From 2025 projection, results of the reference scenario. 2 – From 2022 explicitly modeled; 1970 – 2021 included in population.

Sources: Federal Statistical Office, own calculations scenario stabilise close to their current levels of about 40 % and 8 %, respectively, by 2030.

Furthermore, the reference scenario projects an **increase in the labour force participation rate** from the current 69 % to about 75 % in 2070. Such an increase would be realisable mainly through labour force participation rate increases in almost all age groups and **longer working lives.** Particularly in the 2040s, this **will** partially compensate for the sharp **decline in the labour force.** The share of 20–59-year-olds, a cohort with a high participation rate, will rise again in the labour force during this period. The same share will decrease in the 2020s and 2030s, periods which will be marked initially by a rise in the numbers of baby boomers ↘ GLOSSAR reaching retirement age and leaving the workforce. ↘ CHART 44 ↘ TABLE 19 APPENDIX

2. Capital services in the transformation

108. In the wake of Russia's war of aggression against Ukraine and the resulting energy crisis, the prices of fossil fuels have risen significantly. This has increased the urgent need and incentives to **substitute fossil fuels with green energy sources and to increase energy efficiency** (GCEE Annual Report 2022 items 325 ff.). ↘ CHART 45 Such a shift would likely already have taken place on the path to greenhouse gas neutrality, but has probably been accelerated by the energy crisis. The associated developments are likely to have an impact on potential output. For example, if fossil-fuel assets are decommissioned before the end of their service life due to high prices of carbon emissions, this will initially reduce potential output. If frictions such as financing restrictions ↘ ITEM 153 limit the investment activity of companies, the lack of replacement investments could further dampen potential growth.

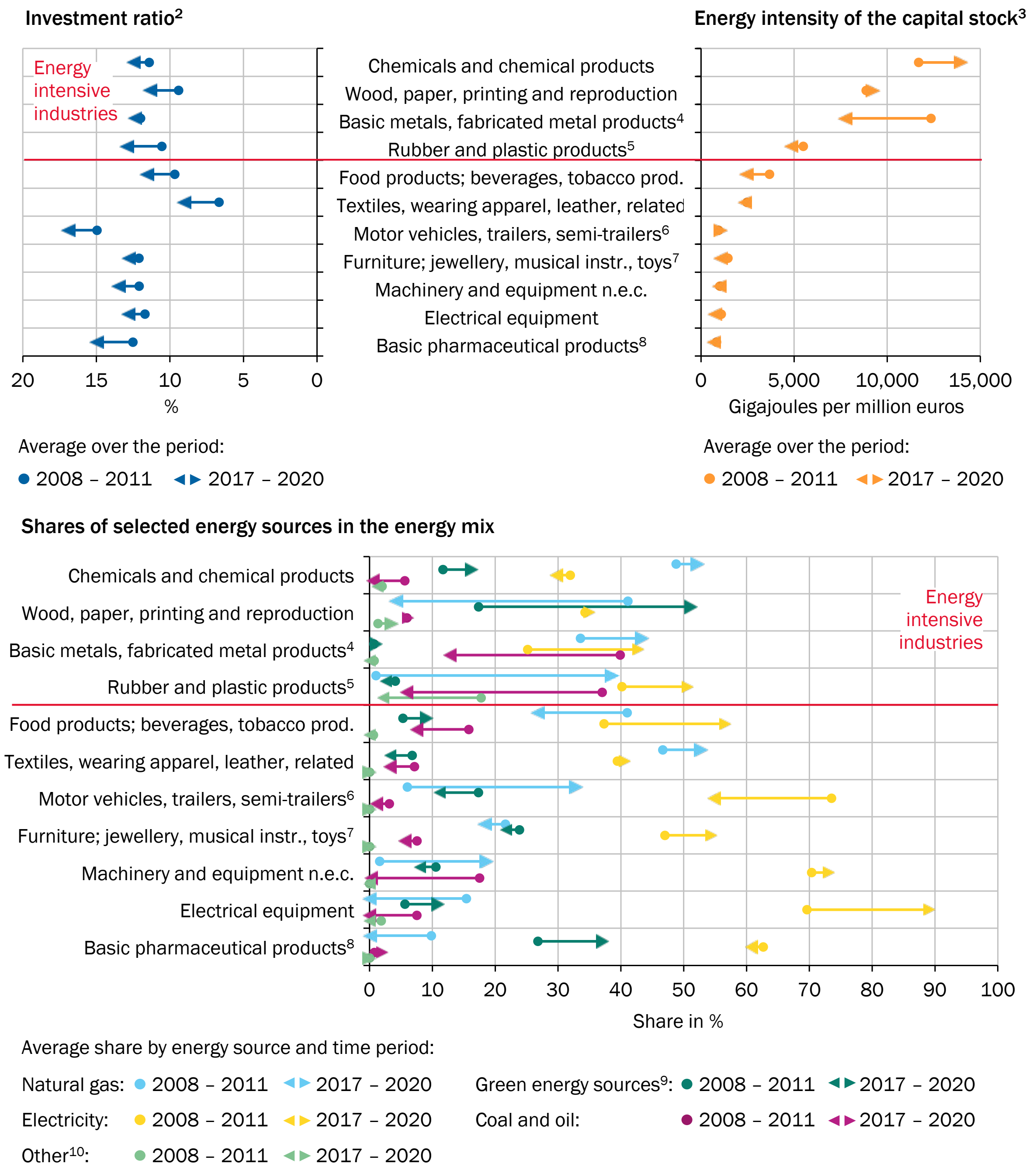
Decarbonisation of energy-intensive industry

109. Managing the green transformation poses particular challenges for the **energy-intensive sectors** in manufacturing – chemicals, metals, coking and mineral oil, plastics and glass, ceramics and processing of stone and earth, and the paper industry – as well as the energy supply industry. ↘ CHART 45 Taking into account historical investment data, future investment trends and using assumptions about the service life of capital ↘ CHART 54 and the capital structure of energy-intensive industries, the GCEE uses stochastic methods to examine how high the green transformation investments would have to be in these industries in the period from 2025 to 2045 if, **as of 2045, production facilities powered by fossil fuels in energy-intensive industries were no longer used** in Germany (Ochsner et al., 2023a). ↘ CHART 46

110. Three scenarios are used to distinguish how high the annual **green transformation investments in energy-intensive industries and energy supply** would have to be if climate neutrality of the German economy is to be achieved by 2045, the current target of the Federal Government (scenarios 1a and 1b), or by comparison in 2035 (scenario 2). ↘ TABLE 15 The year 2035 repre-

↘ ABBILDUNG 45

Energy inputs and capital formation of selected manufacturing industries[1]



1 – According to the Statistical Classification of Economic Activities in the European Community (NACE Rev. 2). Economic sectors sorted in descending order of energy intensity in the period 2017 – 2020. 2 – Capital formation relative to capital stock of equipment and non-residential buildings. 3 – Energy consumption relative to net capital stock in million euros (current replacement stock; deflated by the price index of gross fixed capital formation, 2015 = 100). 4 – Except machinery and equipment. 5 – And other non-metallic mineral products. 6 – And other transport equipment. 7 – And repair and installation of machinery and equipment. 8 – And pharmaceutical preparations. 9 – Green energy sources include biogas, biomethane (bio natural gas), solid and liquid biogenic materials, geothermal energy, solar thermal energy, hydrogen, heat, heat pumps (geothermal and environmental heat), and other renewable energies. 10 – Waste, landfill gas, sewage sludge, petroleum coke and other energy sources.

Sources: Bontadini et al. (2023), EUKLEMS, Federal Statistical Office, own calculations

↘ TABELLE 15
Scenarios for the decarbonisation of energy-intensive industries

Scenario	End of fossil capital formations by capital good			Climate neutrality in
	Equipment	Buildings	Other capital	
1a	2032	2024	2040	2045
1b	2024	2024	2024	2045
2	2024	2024	2030	2035

Source: own depiction

sents a hypothetical alternative to estimate the extent to which fixed assets would need to be replaced prematurely if not only investment in but also the use of fossil-fuel assets were to end well before 2045.

In the transition to climate neutrality, fossil-fuel capital formation is expected to be reduced or cease completely even before the year in which climate neutrality is to be achieved. By providing appropriate incentives, climate policy can drive an earlier phase-out of fossil-fuel capital formation. Climate-damaging subsidies, on the other hand, could delay the phase-out. In order to estimate the effects of different climate policies on the necessary replacement investments and the potential, two variants of scenario 1 are modelled. In variant 1a, which can be interpreted as a tentative climate policy in the transition, investments are made in energy-intensive industries in equipment until 2032 and in other capital goods based on fossil technology until 2040. In variant 1b, which can be interpreted as an ambitious climate policy in the transition, investments are made exclusively in green capital goods from 2025 onwards. ↘ TABLE 15 This could be achieved, for example, through high prices of carbon emissions, appropriate investment incentives for assets powered by renewable energy or an immediate investment ban on assets that consume fossil fuels.

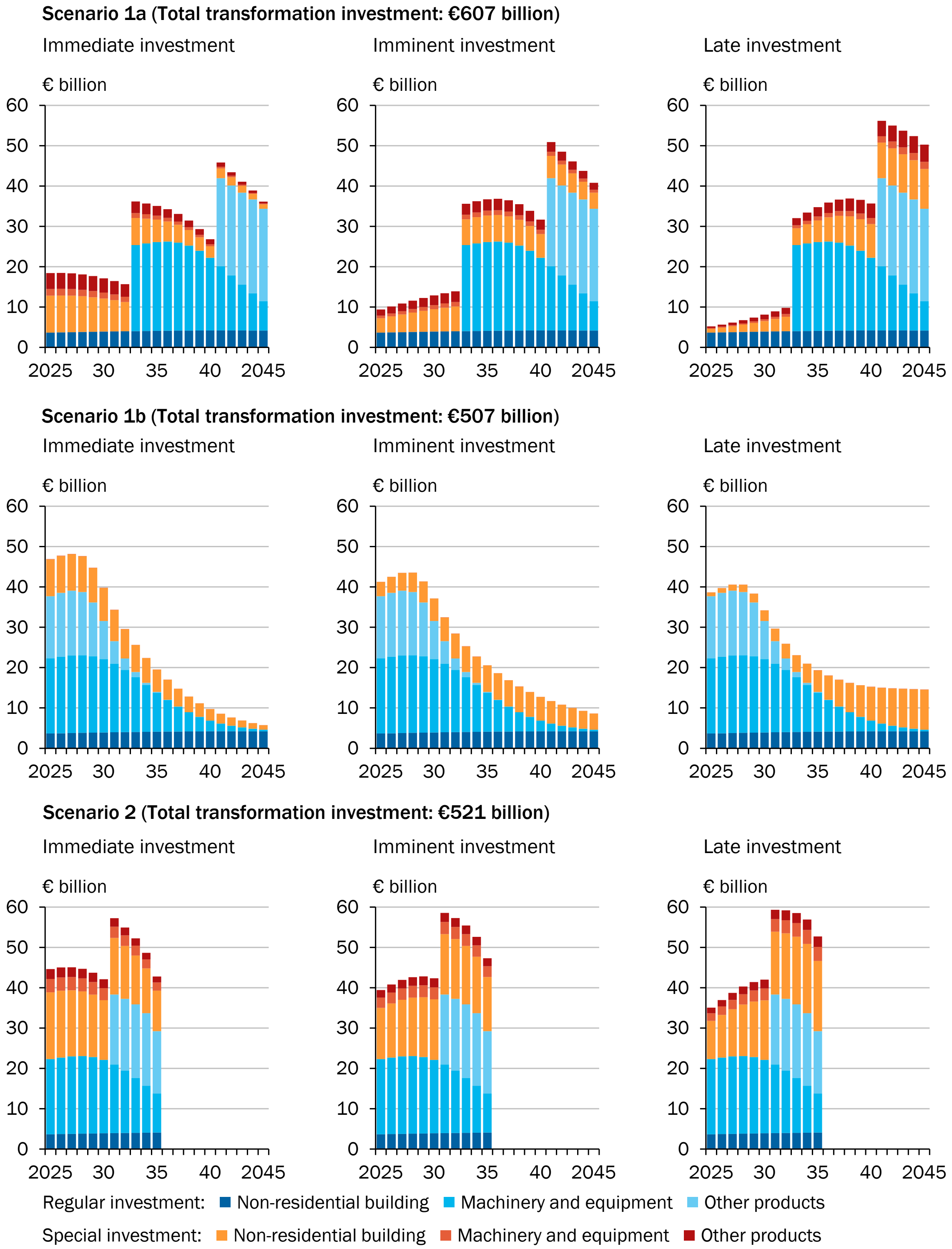
111. In scenario 2, as in scenario 1a, no immediate switch is assumed. However, due to the short time window until climate neutrality is achieved, which in this case is equivalent to a **ban on the use of fossil-fuel capital goods** as of 2035, fossil-fuel capital formation in long-lived capital goods is discontinued earlier. For the calculations of scenarios 1a and 2, it is assumed that capital formation in short-lived capital goods, i.e. equipment and other capital, is fossil-based up to a service life before the specified target year for climate neutrality (2045 and 2035, respectively). ↘ TABLE 15 In scenario 1b, investments are made exclusively in carbon neutral assets for all capital goods from 2025 onwards. ↘ ITEM 176

112. The disposals from the capital stock of the energy-intensive industries correspond to the **regular disposals** until the year of climate neutrality (2035 or 2045). ↘ CHART 46 ROWS Following deduction of the regular disposals, scenario 1 (scenario 2) would leave a fossil capital stock in 2045 (2035) that, without the goal of climate neutrality, would only be taken out of service in the following years.

Instead of an abrupt early disposal of the capital stock, three variants are modelled for the distribution of **early disposals** and the corresponding early green transformation investments for fossil capital goods over the transition period. ↘ CHART 46 COLUMNS In the 'immediate early green transformation investment' vari-

↘ ABBILDUNG 46

Green transformation investment for capital goods in energy-intensive industries and energy supply[1]



1 – Projections by the GCEE.

Sources: Federal Statistical Office, own calculations ant these investments mainly take place in the 2020s, in the 'imminent early green transformation investment' variant in the 2030s and in the 'late-stage early green transformation investment' variant in the early 2040s. ↘ CHART 46 Which of these variants materialises will probably also be significantly influenced by the ambitiousness of climate policy. The more ambitious the climate policy, the earlier the green transformation investments are likely to take place, as fossil capital goods would be relatively more cost-intensive.

113. Under the assumptions made, in scenario 1a with a **less ambitious climate policy** ↘ TABLE 15 real green transformation investment volume of up to €607 billion is likely to be required by 2045 to replace the energy-intensive capital stock that has so far been fuelled by fossil fuels (Ochsner et al., 2023a). ↘ CHART 46 SECOND COLUMN This corresponds to about 5 % of the total real gross fixed capital formation of the last two decades. It is made up of €423 billion of green transformation investments that would be needed anyway due to the age of the assets (since many assets will be regularly disposed of by 2045), and another **€184 billion that will be** incurred as **early green transformation investments** (for assets that would not otherwise be disposed of until after 2045).

If instead, in a scenario **with ambitious climate policy** (scenario 1b ↘ TABLE 15), no more investments were made in energy-intensive capital goods from 2025 onwards, the investment requirement until decarbonisation of the energy-intensive capital stock in 2045 would only be €507 billion, of which €115 billion would be early green transformation investments. In the transition to 2045, less fossil capital would be accumulated and the capital stock remaining in 2045 that would need early replacement would be lower. In contrast, in scenario 1a, there is continued investment in fossil capital assets in the transition to 2040 and these are still present in the capital stock in 2045. Part of the early replacement investments would therefore be for fossil capital goods accumulated between 2025 and 2040.

In an alternative scenario, ↘ TABLE 15 in which the **decarbonisation of the** energy-intensive industries is already completed in **2035,** €521 billion replacement investments would be required, of which €**211** billion would be early green transformation investments). ↘ CHART 46 FIRST ROW

114. For simplicity, the calculations assume that climate-neutral production capacities can be created at the same costs as energy-intensive capacities. It is also conceivable that due to **capital-embodied technological change** (CETC) the level of replacement investment required to achieve the same production capacity may be lower. ↘ ITEM 139 FF. That said, if **learning effects** are necessary, the potential productivity of the new (climate-neutral) assets might not be fully achieved at first and thus higher capital formation could be necessary. ↘ ITEM 142

Furthermore, the **migration** of energy-intensive industries from Germany is also possible. This would reduce the replacement investment of these industries, which could initially reduce potential output in Germany. However, if other industries invest additionally, for example because labour is freed up, the negative effect on potential output could be limited. ↘ CHART 96 Some of the assets that would otherwise only be replaced after 2045 could possibly also be operated with energy from renewable sources and do not have to be completely replaced. As energy costs are expected to remain higher than in other countries, energy-intensive economic activities could slacken off (Bauer et al., 2023; Landais et al., 2023).

115. While the green transformation investments associated with the regular disposals are not expected to have a negative impact on potential output (since they will take place as replacement investments in any case), **replacement of early disposals** could lead to **inefficiencies** in capital services. Capital goods are decommissioned before the end of their service life, which entails additional costs. In all scenarios and variants, however, these costs are low and spread over almost two decades, so that the early green transformation investments are likely to have only a very minor effect on potential growth.

116. The GCEE's calculations show that **by 2045,** regardless of decarbonisation, **a very large share of fixed assets in energy-intensive industries will need to be replaced** because the capital can no longer be put to productive use due to its age. A significantly smaller share will need to be replaced in advance in all scenarios due to decarbonisation.

117. An **ambitious climate policy** (scenario 1b) which ensures that fossil-fuel assets are replaced by climate-friendly assets at the end of their service lives can **result in lower overall decarbonisation costs** for energy-intensive industries than a tentative climate policy. This is especially true **if the productivity differences** – and thus the cost differences in the long run – **between renewable and fossil-fuel capital goods are small.** ↘ CHART 46 FIRST AND SECOND COLUMN This effect works through regular disposals: if less fossil-fuel capital is accumulated, less will have to be replaced (regularly) by the year of climate neutrality.

A **ban on the use of fossil-fuel capital goods** from 2035 (scenario 2) **could** significantly **increase the costs of the transformation**. Even if the productivity of renewable and fossil-fuel capital goods were identical, the early disposals would be almost twice as high as in the scenario based on an ambitious climate policy and climate neutrality from 2045 (scenario 1b). This is because investments in fossil-fuel capital goods are made in this case until 2024, and would then need to be disposed of early. ↘ CHART 46 SECOND AND THIRD COLUMN

118. The **timing of replacement investments has an impact** not only on the **level of** green transformation investments, but also on German **CO2 emissions**. If assets powered by fossil fuels are not replaced early (scenario 1a), it may not be possible to achieve German emission reduction targets. If special disposals (early replacement investments in climate-neutral assets) do not take place until the 2030s or 2040s, very long periods of high carbon emissions will be need to be taken into account. ↘ CHART 46 RIGHT

Effects of tax incentives on investment

119. The ratio of net to gross fixed assets, which indicates the **degree of modernity** of the capital stock, has fallen by about 12 % in Germany since 2000. ↘ CHART 62

APPENDIX Earlier capital vintages are often less productive than recent vintages. ↘ ITEM 139 **Tax incentives** can help stimulate capital formation to increase the capital stock and modernise the stock of equipment and non-residential buildings. **Immediate depreciation of an increased percentage of the value of the investment** – such as that provided for in the investment premium in the Federal Government's draft of the Growth Opportunities Act ↘ ITEM 172 – is likely to lead to an increase in gross fixed capital formation (Ochsner et al., 2023a).

120. A simple estimation of the depreciation elasticity of capital formation in German manufacturing from JANIS microdata ↘ BACKGROUND INFO 3 suggests that, in the case of equipment, one euro of additional depreciation translates into 40 cents of additional capital formation. The same assumption is made for non-residential buildings. If, for example, companies were able to **directly depreciate** the value of their real **capital formation in equipment and non-residential buildings** from 2025 onwards for a period of ten years, each starting with 15 % in the first year, this would result in a total additional capital formation volume of €230 billion by 2035 in the model calculations. Of this, about €155 billion are allocated to equipment and about €75 billion to non-residential buildings.

3. Opportunities and risks in the development of labour volume

121. There are **opportunities and risks associated with the development of the labour volume.** ↘ TABLE 16 If the **labour force participation rate** does not increase to 75 %, as projected in the reference scenario ↘ ITEM 107, but remains at its current level of 69 %, this would reduce potential output per capita by 3 % in 2070 compared to the reference scenario. ↘ CHART 47 A higher **net inward migration** of about 400,000 per year on average instead of the 250,000

↘ TABLE 16

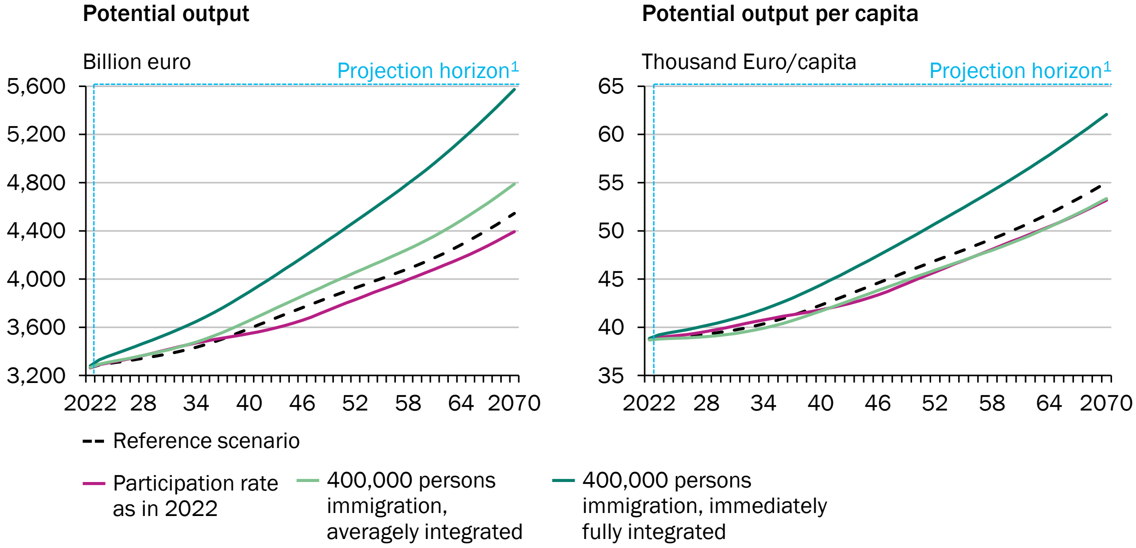
Scenarios for labour volume development

Scenario	Immigration per year	Employment rate excluding immigration	Immigrants[1]					
			Working age[2]		Participation rate		Unemployment rate	
		2070	2022	2070	2022	2070	2022	2070
	People	%						
Reference scenario	250,000	75	75	75	70	75	12	2.4
Increased immigration								
Averagely integrated	400,000	75	75	75	70	75	12	2.4
Fully immediately integrated	400,000	75	100	100	100	100	0	0
Participation rate not rising	250,000	69	75	75	70	75	12	2.4

1 – Labour market characteristics converge with those of the native population by 2062. 2 – Proportion of working-age immigrants (15 to 74 years).

Source: own calculations

↘ CHART 47
Median potential output and possible labour volume development



1 – Values for the years 2023 and 2024 are based on the short-term forecast by the GCEE. From 2025 projection.

Sources: Federal Statistical Office, IAB, OECD, own calculations

assumed in the reference scenario would increase potential output by about 5 % in 2070. However, due to the assumed lower level of integration of immigrants into the German labour market, potential output per capita could fall by 3 percentage points compared to the reference scenario.

122. If **net inward migration** consisted of 400,000 **people who were immediately and fully integrated into the labour market**, potential output would be 22 % higher and potential output per capita 13 % higher in 2070 than in the reference scenario. ↘ CHART 47 This would only be the direct effect on potential output. Since the share of highly skilled people may also increase TFP due to an increase in innovation activity, the rise in potential output could be much higher.

4. Possible productivity gains through use of artificial intelligence

123. **Artificial intelligence** (AI) could **increase overall economy productivity** as a new cross-cutting technology in the future (Brynjolfsson et al., 2019; Felten et al., 2023). There are already indications that generative AI in particular can lead to high productivity gains in the double-digit percentage range for individual professions in the area of customer services, software development and consulting (Brynjolfsson et al., 2023; Dell'Acqua et al., 2023; Peng et al., 2023).

124. In the past, automation has mainly substituted for the activities of low-income workers while increasing the demand for high-skilled labour (Autor et al., 2003). **Advances in AI** have **also** been empirically shown to have a **positive impact**

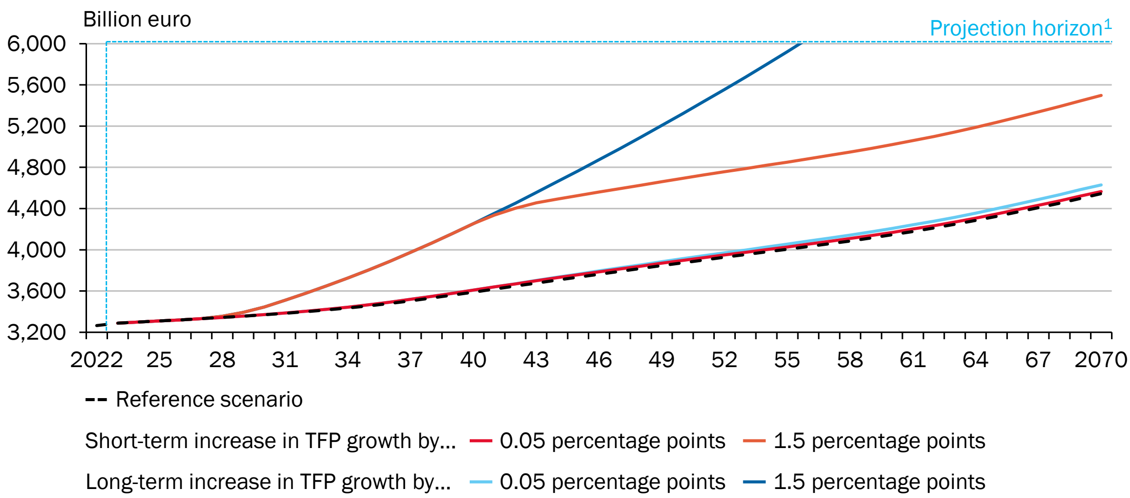
on the demand for and productivity of highly skilled workers over the past decade (Alekseeva et al., 2021; Albanesi et al., 2023).

However, at least within some occupational groups, **less efficient workers** could **also benefit from access to generative AI**. Various studies on the use of generative AI show that the productivity of less efficient workers increases significantly more than that of their more productive colleagues (Dell'Acqua et al, 2023, Brynjolfsson et al 2023): generative AI enables the less productive workers to imitate the behaviours of their productive colleagues. Regardless of whether AI has a complementary or substitution effect on to the activities of highly skilled workers, **potential TFP increases from AI** will be **particularly concentrated in advanced economies** (Chui et al, 2023).

125. The **macroeconomic effects of the widespread use of AI** and thus the accumulation of corresponding other capital ↘ ITEMS 93 AND 105 are still **highly uncertain** at present. ↘ CHART 48 An increase in annual TFP growth of 1.5 percentage points in the euro area over 10 years is under discussion (Hatzius et al., 2023). In Germany, the last time the joint contributions to growth of TFP and human capital to potential output growth were comparably high was between the years 1970 and 1989. If the current TFP growth rate of about 0.3 % (0.5 % in the 95 % quantile in 2023) were increased by 1.5 percentage points, this rise would be unprecedented in Germany since the beginning of TFP estimation, even taking human capital growth into account (Ochsner et al., 2023b). ↘ CHART 34

In addition, it may take some time before such productivity gains materialise. In the past, the development of TFP as a result of technological progress followed a **"J-curve"**. The intangible capital that makes productive use of technology possible ↘ ITEMS 93 AND 105 must first be accumulated. This results in **initially slow** productivity growth **followed by a rapid growth phase** (Brynjolfsson et al., 2021). In the United States, for example, it took over 15 years for the use of

↘ CHART 48
Median potential output and TFP growth



1 – Values for the years 2023 and 2024 are based on the short-term forecast by the GCEE. From 2025 projection.

Sources: Federal Statistical Office, IAB, OECD, own calculations computer technology to bring about increases in TFP growth of over one percentage point (Byrne et al., 2016).

126. Due to the fundamental uncertainty attached to the macroeconomic **effects of AI, scenario calculations** are suitable for estimating the range of possible consequences for potential output (Ochsner et al., 2023a). In an extremely optimistic scenario, TFP trend growth increases of 1.5 percentage points per year are modelled (Hatzius et al., 2023). ↘ ITEM 125 In an alternative scenario, the TFP growth rate is increased by only one standard deviation, or 0.05 percentage points. ↘ CHART 48

If the adoption of AI in Germany were to increase the TFP growth rate by 0.05 (or 1.5) percentage points by 2030 from 2027 onwards, remain at this level until 2040 and return to the current level of about 0.3 % annually by 2043, potential output in 2043 would be about 0.5 % (or 17 %) higher than in the reference scenario. If **AI were to permanently increase TFP growth** until 2070, for example because AI favours the development of technologies that keep TFP growth at elevated levels, ↘ ITEMS 93 AND 105, potential output would **increase by 2 % (or 85 %) in** 2070 under the above assumptions. However, there is currently no empirical evidence of a possible permanent increase in productivity growth through AI. ↘ ITEM 161

↘ BOX 12

Focus: Declining productivity growth

Total factor productivity (TFP) is the most important determinant of economic growth in the long run. In many advanced economies, TFP growth has been declining for more than 30 years. Some countries, such as Italy, have even experienced prolonged periods of negative TFP growth. In the literature, there are two central explanations for this "productivity growth slowdown", namely **diminishing marginal returns in the innovation process** and **increasing misallocation** of production factors (Jones, 2017; GCEE Annual Report 2019 items 132 ff.).

Innovation is considered a key driver of productivity growth (Romer, 1990; Aghion and Howitt, 1992; GCEE Annual Report 2020 items 481 ff.). An influential hypothesis is that **new ideas** in research and development are **increasingly hard to find**, which should weaken innovation over time (Gordon, 2012, 2017; Bloom et al., 2020). For example, empirical evidence suggests that **research productivity** has **plummeted** in many industries (Bloom et al., 2020). In the United States, only a massive increase in resources devoted to research and development has so far prevented innovation from falling as sharply as research productivity. An example of this is "Moore's Law", according to which the density and thus the performance of computer chips doubles approximately every two years (Moore, 1998). However, the number of researchers required to this end is now 18 times higher than in the 1970s.

Distorted allocation of capital and labour can significantly reduce the level of TFP (Restuccia and Rogerson, 2008, 2017). This misallocation is evident in persistent differences in the marginal products of capital and labour between companies within an industry. ↘ ITEMS 148 FF. AND 183 Hsieh and Klenow (2009) estimate that TFP in manufacturing would be 30-43 % higher in the United States, 86-115 % higher in China and 100-128 % higher in India if capital and labour were efficiently allocated. Empirical studies show that **allocative efficiency** has **also** been **declining in advanced economies** for some time, in Europe especially in Southern Europe (Reis, 2013; Gopinath et al., 2017; Calligaris et al., 2018). In Italy, for example, TFP would have been 18 % higher in 2013 had allocative efficiency not deteriorated significantly since 1995

(Calligaris et al., 2018). Contributing factors to **misallocation** include **weak business dynamism**, characterised by low numbers of business start-ups and closures (GCEE Annual Report 2019 items 183 ff.), **inefficient management practices** that significantly reduce business productivity (Bloom and Van Reenen, 2007; Bender et al., 2018), **financial frictions** and sometimes inefficient bank lending (Zombie Lending; Midrigan and Xu, 2014) ↘ BOX 14, and **lobbying** by low-productivity industries (Huneeus and Kim, 2021).

Other explanations for low productivity growth in the overall economy include **structural change**, as the service sector grows relative to manufacturing despite its low productivity (Baumol, 1967; Duernecker and Sanchez-Martinez, 2023), and **measurement problems**, especially related to capital goods quality improvements and creative destruction. According to Aghion et al. (2018, 2019), annual TFP growth in France and the United States is underestimated by about 0.5 percentage points. However, since this error has barely changed since the early 1980s, it can hardly be blamed for the downward trend in productivity growth.

IV. CAPITAL SERVICES AND LABOUR INPUT IN THE ECONOMIC SECTORS

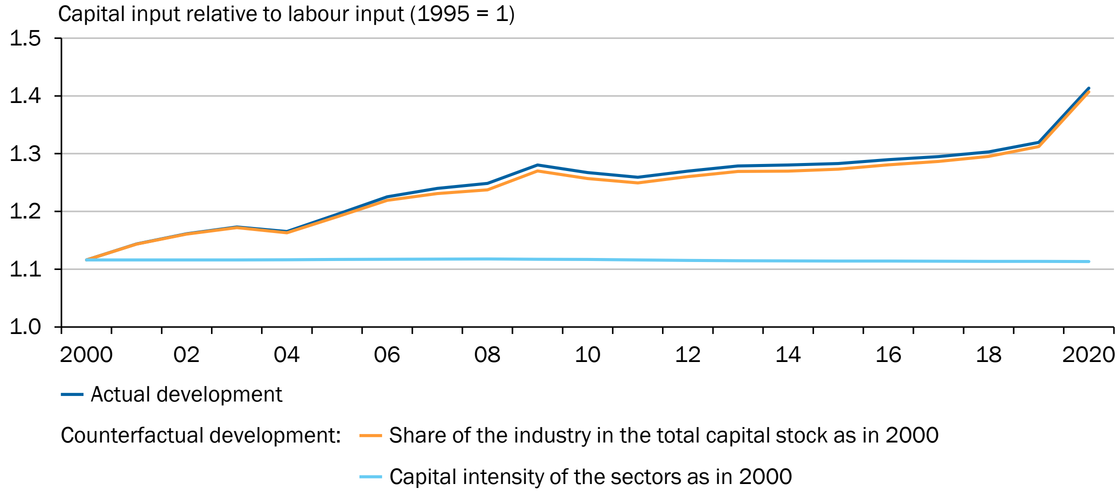
127. The **declining volume of labour** due, among other things, to demographic ageing, which will increasingly lead to shortages of skilled workers in certain occupations in the future, is expected to have **different** effects on the various **sectors of the economy.** ↘ ITEM 106 Industry-specific bottlenecks and the options for replacing labour input with capital services play a central role here. Both factors differ, sometimes significantly, between the economic sectors. ↘ ITEMS 129, 132 AND 136 Higher capital formation in capital goods can counteract a fall in potential output caused by the decline in labour as a factor of production through increased capital accumulation and capital-embodied technological change. ↘ ITEMS 103 FF. AND 139

Due to different production processes, this is unlikely to be possible to the same extent in all economic sectors. First, the **capital intensity** of production **varies** and the different **capital goods** are used at different intensities. ↘ ITEMS 129 AND 130 Second, the **substitution of capital for labour** is possible to varying degrees. ↘ ITEM 133 Therefore, different sectors of the economy will likely be able to adapt more or less readily to unfavourable demographic developments, but also to the use of AI, digitalisation, decarbonisation and possible other developments.

1. Heterogeneity in capital services at sector level

128. In the period between 2000 and 2020, the overall economy's capital intensity increased by about 23 %. There are two possible causes for the overall increase in capital intensity in the economy as a whole. ↘ ITEM 104 First, economic sectors with high capital intensity could grow more strongly than the other economic sectors. Second, capital intensity could rise equally across all economic sectors. A

↘ CHART 49
Decomposition of capital intensity



Sources: Bontadini et al. (2023), EUKLEMS, own calculations

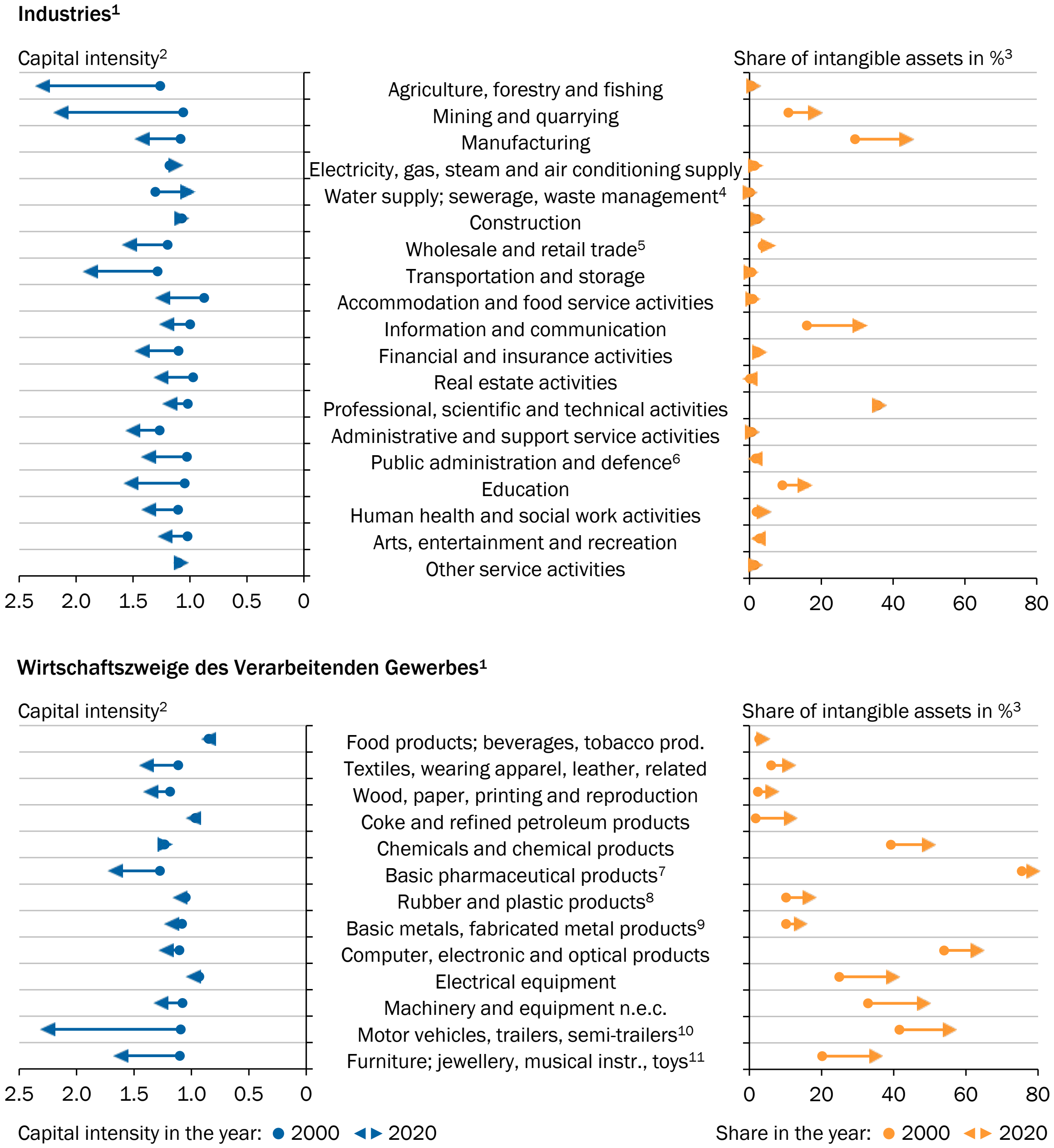
breakdown of the development of capital intensity in the private sector into two components – the impact of structural change and the general increase in capital intensity – shows that **structural change** has had **hardly any effect** on the development of the **overall economy's capital intensity** since 2000. **Capital intensity has increased across economic sectors**. The hypothetical development of capital intensity with the same economic sector structure as in 2000 is almost identical to the actual development. ↘ CHART 49

129. The capital-labour input ratio or **capital intensity has risen in most economic sectors** over the period of 2000 to 2020. This increase is particularly notable in the manufacture of motor vehicles, where it roughly doubled between 2000 and 2020, as well as in the manufacture of furniture and in the transport sector, where it rose by about 46 % in each case. By contrast, the increase is less pronounced in the information and communication sector and in technical services. ↘ CHART 50 LEFT

130. Not only the input ratio of labour and capital, but also the **composition of fixed assets** varies greatly across the economic sectors, due to the different production processes. For example, intangible capital goods, such as patents and software, are most important in manufacturing (on average about 36 % of fixed assets from 2000 to 2020), in information and communication (24 %) and in technical services and scientific activities (36 %). In the remaining service sectors, non-residential buildings mostly account for the largest share of the capital stock (often over 60 %). ↘ CHART 50 RIGHT ↘ CHARTS 60 AND 61 APPENDIX

Over time, the share of intangible capital in fixed assets has **increased** in many sectors of the economy as well as in all industries of the manufacturing sector. ↘ CHART 50 RIGHT ↘ CHARTS 60 AND 61 APPENDIX ↘ ITEM 103 This suggests that there is a **trend towards increased use of intangible capital goods** throughout the economy. ↘ ITEMS 93 AND 94

↘ CHART 50
Capital intensity and intangible assets



1 – According to the Statistical Classification of Economic Activities in the European Community (NACE Rev. 2). 2 – Capital input (1995 = 100) relative to labour volume (1995 = 100). 3 – Share of capital stock (excluding residential and cultivated assets). 4 – And remediation activities. 5 – And repair of motor vehicles and motorcycles. 6 – And compulsory social security. 7 – And pharmaceutical preparations. 8 – And other non-metallic mineral products. 9 – Except machinery and equipment. 10 – And other transport equipment. 11 – And repair and installation of machinery and equipment.

Sources: Bontadini et al. (2023), EUKLEMS, own calculations

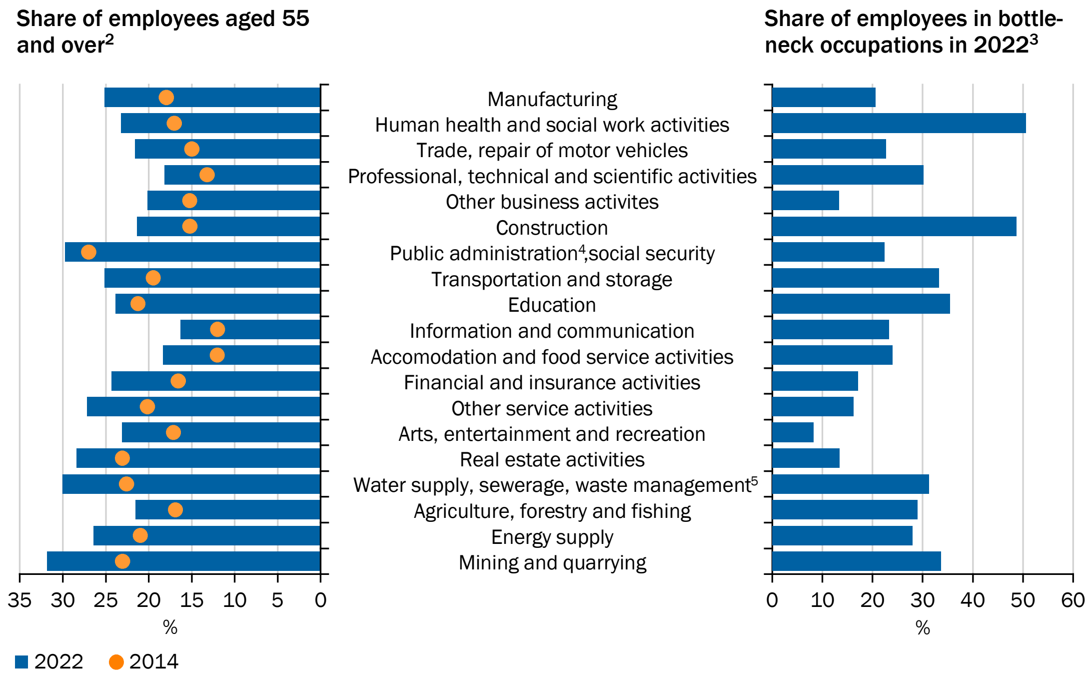
2. Substituting capital for labour can compensate for declining labour volume

131. At present, many sectors of the economy are already unable to meet their labour demand due to shortages of skilled workers in certain occupations. This applies in particular to the construction industry, the health sector and the manufacture of electronic and electrical equipment in the manufacturing sector. ↘ CHART 51 RIGHT In addition, the workforce is evidently ageing – the **proportion of employees aged over 55 is rising in almost all sectors of the economy**. Partly due to longer working lives, this is also caused by low levels of vacancies being filled by young workers due to a declining labour volume. ↘ CHART 51 LEFT

132. The substitution of capital for labour, for example as part of automation or the use of artificial intelligence, can be a way to counteract the adverse demographic trends. For example, higher proportions of older workers lead to increased automation of production (Acemoglu and Restrepo, 2022). However, the scope for **replacing human labour** with equipment such as **computers or computer-controlled machines** differs significantly between economic sectors. For instance, manufacturing occupations in particular, but also occupations in transport and logistics as well as in trade can be substituted, while the options for replacing human labour in health and social occupations are rather limited (Dengler and Matthes, 2021).

↘ CHART 51

Employees aged 55 and over and employees in bottleneck occupations by industry[1]



1 – As of June each year. According to the Classification of Economic Activities, 2008 edition (WZ 2008). The economic sectors are sorted according to the number of employees in 2022. 2 – Share of employees aged 55 and over subject to social security contribution in all employees subject to social security contribution per economic sector. 3 – Share of employees subject to social security contribution in bottleneck occupations in all employees subject to social security contribution. 4 – Including defence. 5 – Including remediation activities.

Sources: Federal Employment Agency, own calculations

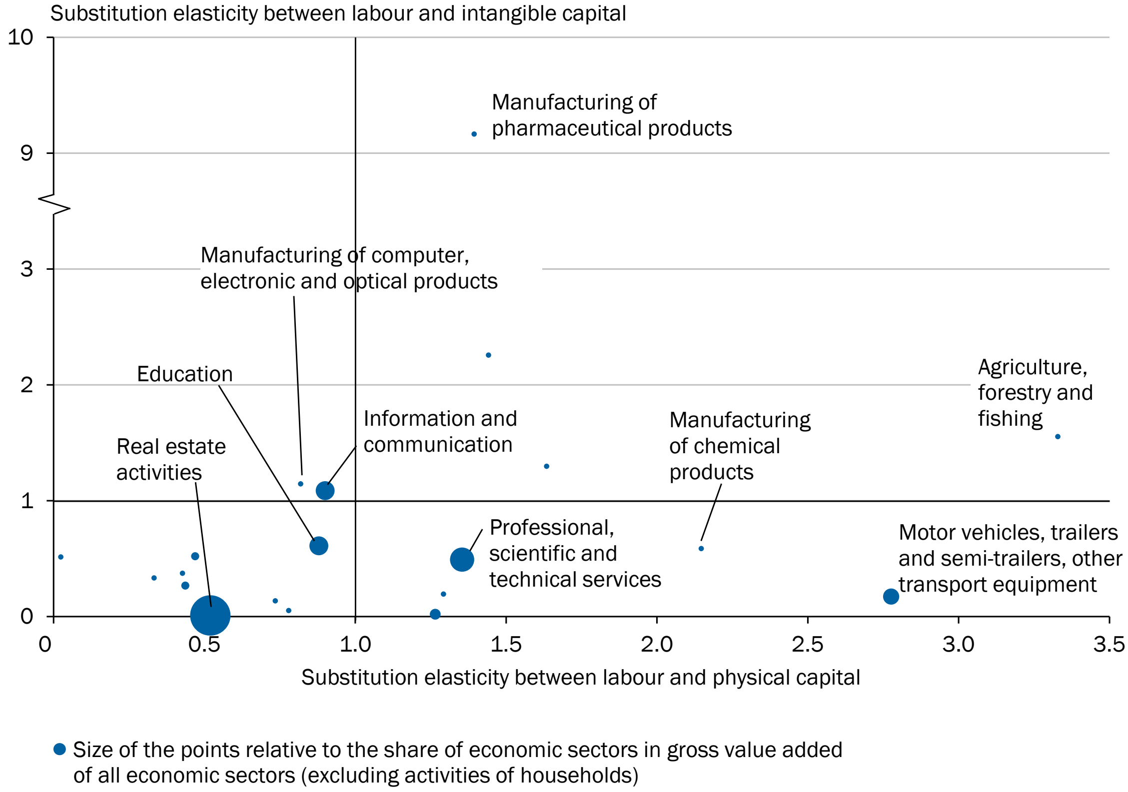
Substitution of capital for labour

133. A structural estimation of **elasticities of substitution** may be carried out to systematically investigate the options for substitution between labour and capital. ↘ ITEM 178 APPENDIX Economic sectors in which it is relatively easy to substitute labour with tangible capital, i.e. a combination of equipment and non-residential buildings, are the manufacture of motor vehicles, the manufacture of chemical products, and also furniture (elasticities of substitution of 2.8, 2.2 and 1.6).

For the motor vehicle industry, for example, this means that if the factor cost of labour increases by 1 % relative to that of tangible capital, the capital intensity increases by 2.8 %. Labour and tangible capital thus behave like (imperfect) substitutes. **In other sectors of the economy,** such as metal production and processing (elasticity of substitution of 0.4), **it is much more difficult to carry out this substitution**. In these cases, labour and physical capital are (imperfect) complements. ↘ CHART 52

↘ ABBILDUNG 52

Elasticities of substitutions between labour and physical and intangible capital[1]



1 – Data of 1995 –2020, pooled for the countries Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom, USA. Data in current prices, capital corresponds to capital input, labour corresponds to labour input (in each case indexed 2015 = 100). Economic activities according to the Statistical Classification of Economic Activities in the European Community (NACE Rev. 2). Elasticities of substitution of labour by capital estimated per economic activity using a nested CES production function; for details sie Table 17 Annex. If the elacticity of substitution is greater than 1, we speak of (imperfect) substitutes, if the elasticity of substitution is less than 1, we speak of (imperfect) complements.

Sources: Bontadini et al. (2023), EUKLEMS, Federal Statistical Office, own calculations

134. A different picture emerges if we look at the **elasticity of substitution between labour and intangible capital**. In particular, in the production of pharmaceuticals and the manufacture of data processing equipment and optical equipment, labour can be increasingly substituted by intangible capital (elasticities of substitution of 9.2 and 1.1). In most other sectors, intangible capital is complementary to labour. ↘ CHART 52

135. There are various **explanations for different** or changing elasticities of substitution. In particular, when capital services are high, there may be little scope to substitute capital for the activities of the few remaining workers (Xue and Yip, 2013). Differences in the in the ability to mechanise production processes in manufacturing also play a role (Nakamura, 2009). For example, industrial robots can be particularly versatile in vehicle manufacturing (Dauth et al., 2021; Adachi et al., 2022).

In service industries, the **use of intangible capital,** such as software and AI, can **substitute for labour**. ↘ ITEM 133 In these industries, in contrast to the substitution of labour through automation in the manufacturing sector, workers with **higher skill levels** are **more affected** (Acemoglu and Restrepo, 2018; Chui et al., 2023). With the application of AI, the scope for substituting capital for labour is therefore likely to increase in line with the relative importance of high-skilled, nonphysical services in total value added. ↘ ITEMS 125 AND 126 At the same time, companies using AI will increasingly need highly skilled workers who can handle the technology, while other workers may be less in demand. AI has only been in use for a short time and to a very small extent. Reliably determining the effects of increased use of AI on the economy as a whole is difficult (Acemoglu et al., 2022). Whether AI is a substitute or complement for highly paid labour is therefore empirically unclear. The question of whether or not the use of AI leads to lower labour demand also remains open. ↘ ITEMS 125 AND 126

Reallocating labour between economic sectors can facilitate substitution

136. The **reallocation of labour** between companies and industries **facilitates the substitution of capital for labour at macroeconomic level.** Workers can therefore move from industries where labour can be relatively easily substituted by capital to other industries where this substitution is more difficult (Alvarez-Cuadrado et al., 2017). However, higher labour demand in labour-intensive sectors of the economy, such as the service sector, which mainly employ occupational groups that are difficult to substitute with capital, ↘ ITEM 132 can lead to higher labour shortages across sectors in the short term. Demand for labour in these sectors is high, with low wage elasticity, because the options for substitution by computers, robots, machines or equipment are limited (Sinn et al., 2006; Brinca et al., 2021; Díez et al., 2022).

Studies on the manufacturing sector in Germany indicate that **workers** can **switch between** different **economic sectors.** If they are able to transfer occupation- and industry-specific knowledge to the new job, the switch is not necessarily associated with significant drawbacks in terms of employment security. In cases where this knowledge transfer is not possible, short- to medium-term wage losses may be around 10 % compared to the original job (Boddin and Kroeger, 2021; Yi et al., 2023).

137. The **international division of labour** plays a major role especially for internationally integrated economies like Germany. Not only consumer and intermediate goods are tradable, but also a large range of **services** (Melvin, 1989). Trade in services is set to rise in the coming years. Countries with labour shortages such as Germany will benefit from this trade by increasingly importing services from countries with an abundant labour force such as the Philippines or India (Baldwin, 2022; Hoekman, 2022; Stöllinger and Guarascio, 2023). In this context, services can be provided not only by visiting the customer on-site, but also delivered digitally. Expanding the imports of digital services can thus help to dampen the declining volume of labour, even in economic sectors with necessary activities that are difficult to substitute with capital.

V. BOOSTING PRODUCTIVITY THROUGH CAPITAL FORMATION IN MANUFACTURING

138. An economy's **TFP grows** largely **as a result of innovations** and general technical progress, but also through technical improvements in the quality and thus efficiency of individual capital goods, so called **capital-embodied technological change**. ↘ ITEMS 139 FF. TFP can also increase if **input factors** are **used more efficiently** and productive companies consequently experience stronger growth than less productive companies. ↘ ITEM 147 Manufacturing is crucial in this regard for potential output growth, as it produces capital goods such as machines, computers or motor vehicles that are used in other sectors of the economy. The quality of capital influences not only the quality of the capital stock, but also the TFP of other economic sectors (Basu et al., 2013; Chen and Wemy, 2015). Quality improvements and product innovation not only increase TFP in manufacturing, but also reduce the cost of capital goods, facilitating the substitution of capital for labour in other sectors. The goods produced in this sector are also key factors in the green transformation.

1. Capital-embodied technological change increases TFP growth

139. **Capital formation** is **essential to take advantage of new, more productive technologies,** as newer capital vintages tend to be more productive than older vintages (Jensen et al., 2001; Gittleman et al., 2006). Some technological changes can only be exploited if new capital goods are used in production. The use of these goods increases aggregate productivity through capital-embodied technological change (CETC) (Jorgenson, 1966; Comin and

Hobijn, 2010). Estimates of the impact of CETC on TFP growth differ depending on the methods used and the time period studied. For example, estimates of **CETC rates,** i.e. capital-embodied productivity growth per new capital vintage, vary for advanced economies. In the US manufacturing sector, the CETC rate was 3.14 % according to Hulten (1992). Wolff (1996) determines a CETC rate of 7.18 % for the combined economies of France, Germany, Japan, the Netherlands, the United Kingdom and the United States. In the case of the German economy, Wolff (1996) shows that at such a CETC rate, about 40 % of the decline in TFP growth over the period 1973 to 1989 can be explained by an increase in the service life of capital. However, ageing capital stocks may also be due to investment cycles. This suggests that **increased disposals and replacement investment** could make a **significant contribution to capital stock modernisation and TFP growth** in future.

140. The **rate of CETC** can be determined for both the manufacturing sector as a whole and also for its individual industries over the period **2000 to 2020** based on the methodology of Caunedo et al. (2023) using data on corporate balance sheets of corporates of the manufacturing sector. ↘ BACKGROUND INFO 3 ↘ ITEM 179 In the manufacturing sector as a whole, the rate of CETC is around **2.4 % to 5.4 % per year.** This means that, on average, capital goods such as assets and machinery create 2.4 % to 5.4 % more production value per year (i.e. become more productive), with acquisition costs remaining constant.

↘ BACKGROUND INFO 3

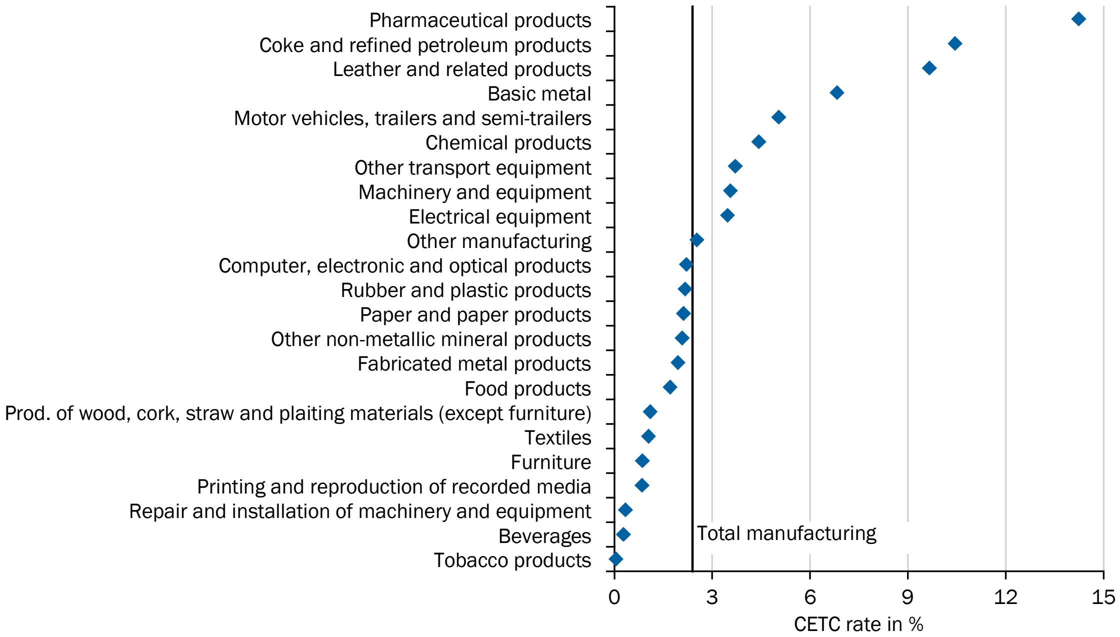
The JANIS dataset

JANIS is a **panel dataset containing annual financial statements of German non-financial companies** (1997-2022), which are sent to the Bundesbank for credit assessment purposes (Becker et al., 2023, doi 10.12757/Bbk.JANIS.9722.11.11). In addition to the usual items in the balance sheet and in the profit and loss statement, it also contains information on the capital goods used as well as on capital formation and disposals of fixed assets. JANIS covers about 7 % of the companies in the manufacturing sector. However, these account for more than two-thirds of total revenue in manufacturing. Since the dataset therefore mainly includes large companies, the results are not necessarily representative.

141. The **rate of CETC differs between industries, sometimes significantly**. ↘ CHART 53 ↘ TABLE 18 APPENDIX It ranges from 0.05 % in the tobacco industry to 14.2 % in the manufacture of pharmaceuticals. In general, it can be observed that in sectors that have a high share of gross value added and are technologically more demanding, the rate of capital-embodied technological change is higher than in other sectors of the economy.

142. A **technological changeover** to new production processes can also bring about changes in TFP (Sakellaris and Wilson, 2004). Since such changeovers usually only make economic sense if the existing assets are already older and at least partially depreciated, new assets will be more modern after the conversion. However, **learning processes** are necessary when switching to new

↘ CHART 53
Rate of capital-linked technical progress in manufacturing[1]



1 – According to the Classification of Economic Activities, 2008 edition (WZ 2008).

Sources: RDSCZ of the Deutsche Bundesbank, microdata set JANIS 1997-2022-1, own calculations

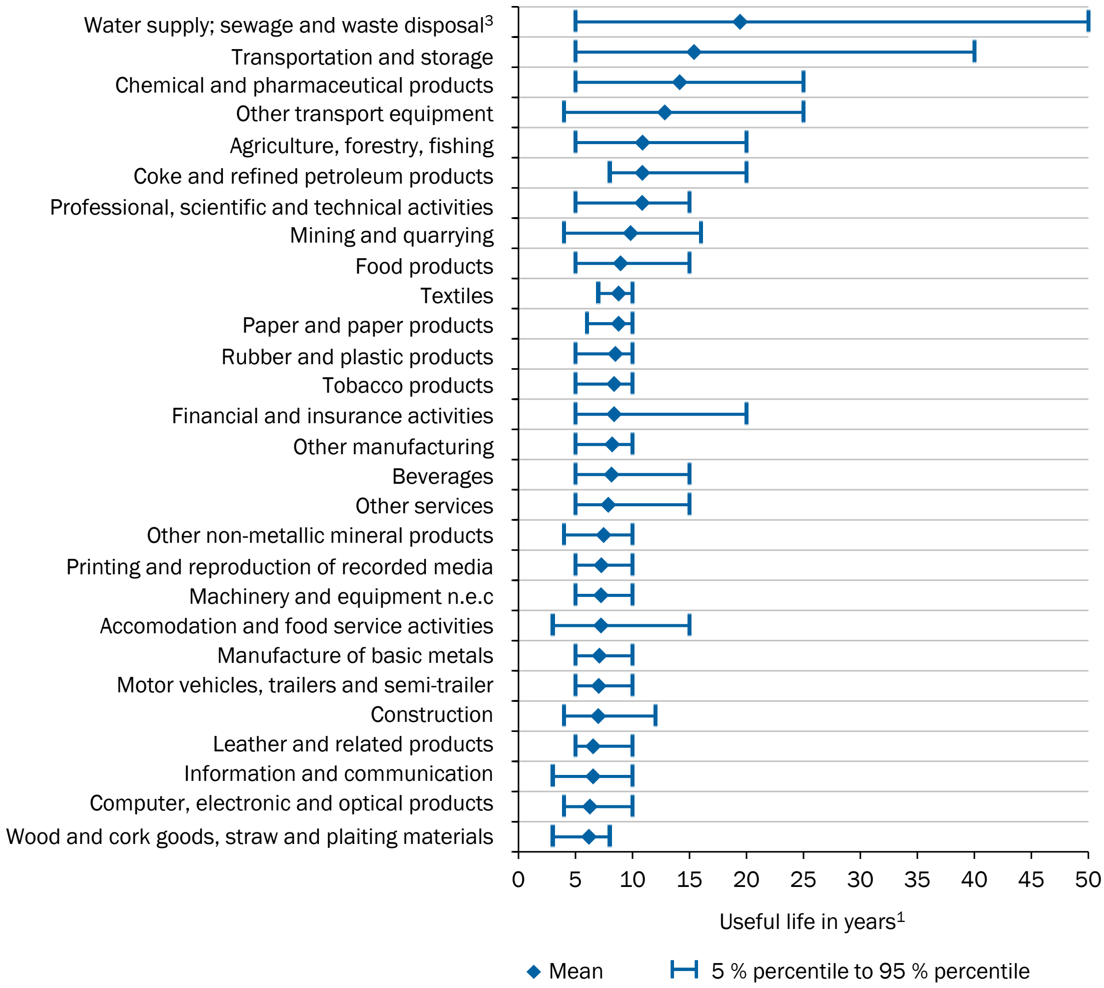
technologies – for example in the transition to climate neutrality – and therefore the new capital goods do not initially achieve full productivity in use (Brynjolfsson et al., 2021).

143. **TFP growth can increase in line with structural change** if **economic sectors** with **relatively high CETC rates grow** faster than others. This is the case in Germany, for example, for the motor vehicle manufacturing sector, whose share of total value added increased between the years 2000 and 2020. An increase in TFP growth can also occur if the rate of CETC rises over time. If recent capital vintages become increasingly more productive than earlier vintages, TFP growth will increase proportionally to the CETC rate with the same investment rate (Sakellaris and Wilson, 2004; Jones and Liu, 2022). However, the useful lives of fixed assets differ. Correspondingly, in industries with long useful lives, the realisation of CETC is likely to be low. ↘ CHART 54

144. **Investment in assets, intangibles or processes can significantly increase labour productivity** and thus also stabilise potential output growth. Labour productivity growth, which has been declining since the 1990s from 3 % p.a. to recently below 1 % p.a. (GCEE Annual Report 2019 items 143 ff.), could resurge more strongly through the increased use of technologies such as artificial intelligence, cloud computing and robotics. However, this effect has so far largely failed to materialise in the aggregate because the application of many of these technologies has been limited so far (Brynjolfsson et al., 2019; GCEE Annual Report 2019 paras 175 ff.). ↘ ITEM 125

145. One possible explanation for the low measurable effects of new information technologies (AI and cloud computing) on labour productivity is that their

↘ ABBILDUNG 54
Useful life of fixed assets[1,2]



1 – The chart shows unweighted statistics on fixed assets per economic sector. The useful life indicated in the depreciation tables serves as a reference point for assessing the appropriateness of the tax deductions for depreciation (AfA), as of 2023. It takes into account the technical wear and tear of assets in a business operating under normal conditions (including shift work customary in the industry). 2 – According to the statistical classification of economic activities in the European Community (NACE Rev. 2). 3 – And removal of environmental pollution.

Sources: AfA tables of the BMF, own calculations

effective utilisation demands not only the acquisition of the technology, but also substantial additional investments. Necessary complementary investments include, for example, database systems, new equipment with necessary connectivity, and research and development (R&D) in intangible capital in order to adapt information technology to the companies' production (Lee et al., 2022). In addition, a skilled workforce is essential for application of the new technologies (Alekseeva et al., 2021). This delays their diffusion (Arntz et al., 2019). Nevertheless, these technologies are expected to continue having a positive impact on labour productivity in the medium term if their use becomes more widespread. Case studies on specific applications indicate substantial increases in labour productivity of 14 % to 30 % (Brynjolfsson et al., 2023). However, the magnitude of the impact on aggregate TFP is unclear. ↘ ITEMS 125 AND 126

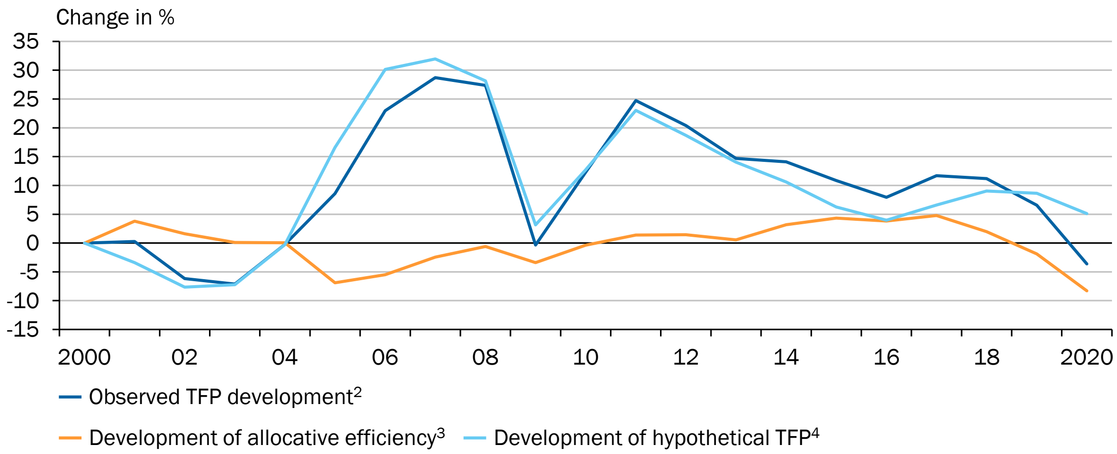
2. Improving allocative efficiency can increase productivity

146. **Aggregate TFP** can be represented as a **weighted average of companies' TFP**. Companies with a higher gross value added are included with a higher weight. Companies increase their gross value added either through an increase in company-specific TFP or by using more capital and labour. The factors of production can either be newly created or re-allocated from other, less productive companies. TFP can therefore grow, for example, due to **capital reallocation** between companies, if productive companies invest more than unproductive ones, thus increasing their weight in the aggregate (Melitz and Polanec, 2015). **Allocative efficiency** describes the **efficient use of limited available input factors between companies.**

147. **A lack of allocative efficiency** within industries can lead to **TFP in the aggregate** being **lower** than potentially possible (Restuccia and Rogerson, 2008, 2017). The efficient allocation of inputs can be hindered by disincentives, such as distortions in taxation or barriers to financing (Midrigan and Xu, 2014). Disincentives in capital formation have a larger effect on aggregate TFP when the CETC rate is high. In this case, the negative effect of too low investment on TFP is particularly high (Jovanovic and Robb, 1997).

148. Using the methodology of Hsieh and Klenow (2009), the GCEE highlights a significant degree of misallocation between companies within industries in the manufacturing sector in Germany. ↘ ITEM 183 F. **Allocative efficiency** is calculated as the **share of observed TFP in the counterfactual TFP** that would result from the efficient allocation of production factors. The

↘ CHART 55
Development of aggregate total factor productivity in manufacturing[1]
Relative TFP development



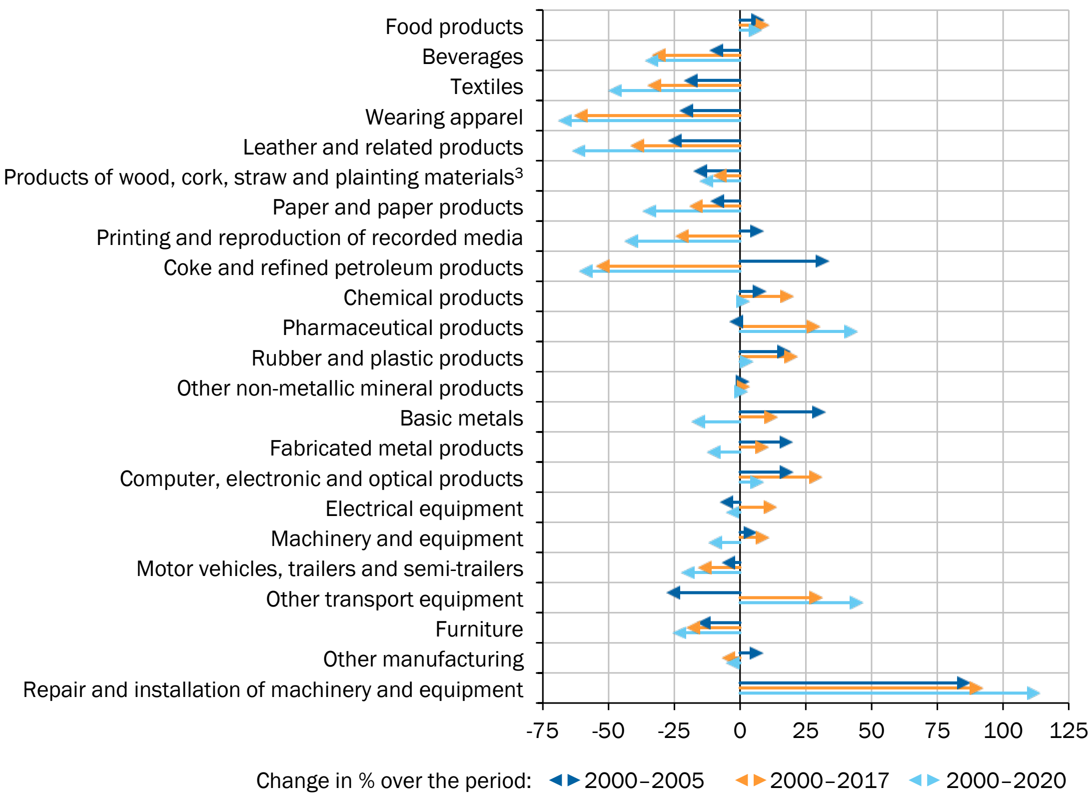
1 – According to the classification of economic sectors, 2008 edition (WZ 2008). Aggregate according to Hsieh and Klenow (2009). 2 – Percentage change in TFP compared to 2000. 3 – Percentage change in allocative efficiency (TFP/TFP^{eff}) compared to 2000. 4 – Percentage change in hypothetical TFP^{eff} with efficient allocation of production factors compared to 2000.

Sources: RDSC of the Deutsche Bundesbank, Microdata set JANIS 1997-2022-1, own calculations

development of allocative efficiency can be divided into **three phases in** the period from 2000 to 2020. Between 2000 and 2005, allocative efficiency initially remained unchanged, but was then subject to a sharp fall in 2005. Between 2005 and 2017, allocative efficiency **rose again** and in 2017 was slightly above the level of 2001. However, from 2017 onwards and especially during the coronavirus pandemic, allocative efficiency fell sharply and in 2020 was significantly below the level of 2000. ↘ ITEM 55 During this period, distortions appear to have had a stronger effect on more productive companies, causing them to grow at a slower pace compared to less productive companies.

149. For the industries within the manufacturing sector, the development of TFP and allocative efficiency from 2000 to 2020 can be split three ways, similar to the aggregate. In many **low-tech economic sectors** (according to the classification of the European Commission, 2023b), **TFP contracts constantly** over the period from 2000 to 2020, for example in the manufacture of leather goods and shoes, wood products or paper production. The phase of strong **productivity growth** between 2005 and 2017 can be seen **mainly in high-tech** industries, such as the manufacture of data processing equipment, electrical equipment or other transport equipment, i.e. the manufacture of aircraft and ships. ↘ CHART 56

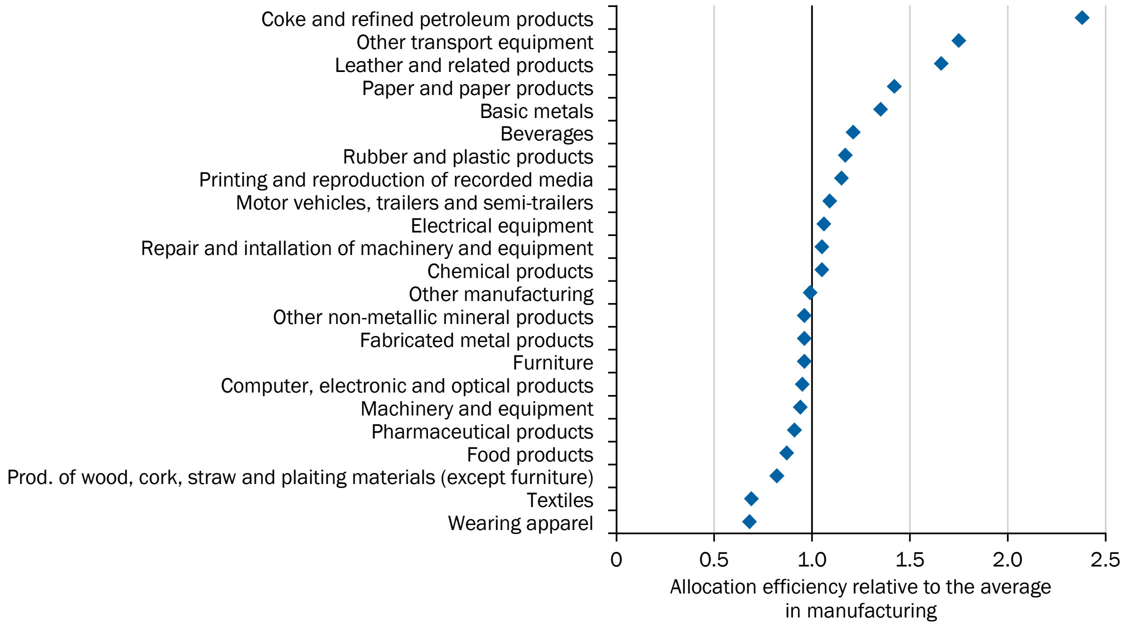
↘ CHART 56
Development of total factor productivity[1] within economic sectors in manufacturing[2]



1 – Percentage change in TFP compared to 2000. 2 – According to the classification of economic activities, 2008 edition (WZ 2008). 3 – Except furniture.

Sources: RDSC of the Deutschen Bundesbank, microdata set JANIS 1997-2022-1, own calculations

↘ CHART 57
Relative allocation efficiency within economic sectors in manufacturing[1]



1 – According to the Classification of Economic Activities, 2008 edition (WZ 2008).

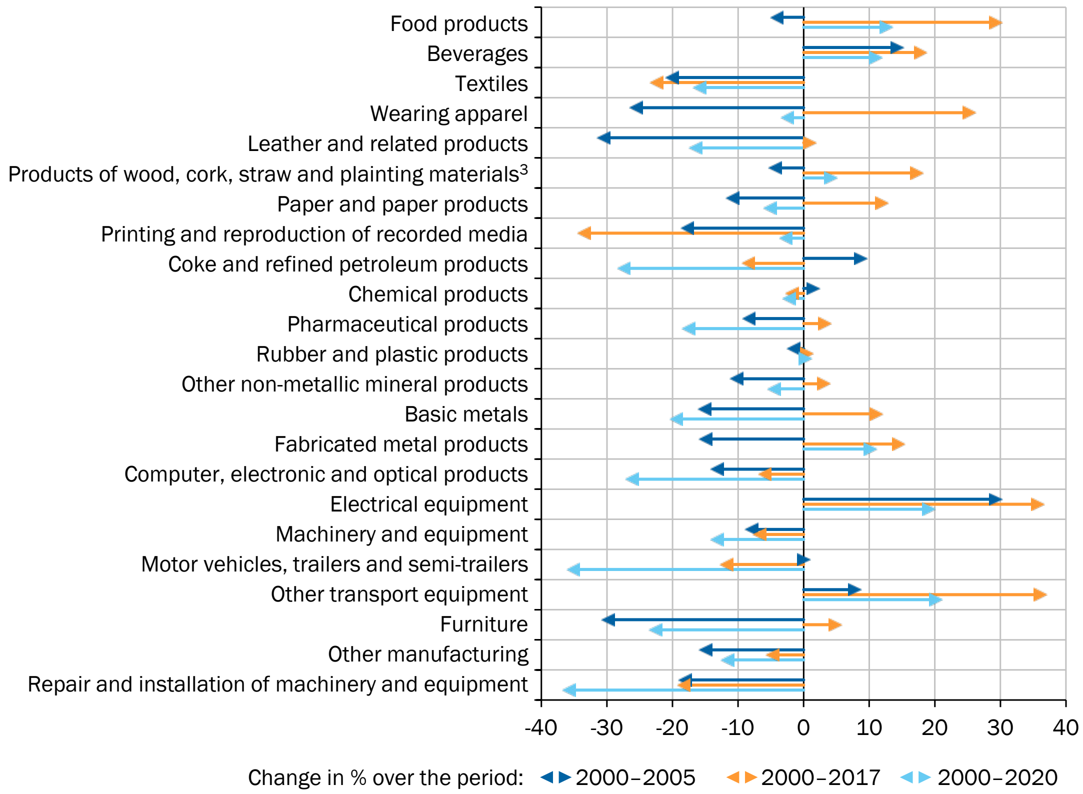
Sources: RDSC of the Deutsche Bundesbank, microdata set JANIS 1997-2022-1, own calculations

150. Improvements in the allocation of input factors within manufacturing industries have contributed positively to the development of aggregate TFP, especially between 2005 and 2017. Allocative efficiency increased by 4.8 % between 2000 and 2017, while TFP was 11 % higher in 2017 than in 2000. The **increase in allocative efficiency** thus accounted for **about 43 % of the increase in TFP** between **2000 and 2017**. ↘ CHART 55 From 2017 to 2020, TFP fell by 13.7 %. Of this, 12.5 percentage points were due to a drop in allocative efficiency. Therefore about 91 % of the decline in TFP in the manufacturing sector between 2017 and 2020 can be attributed to decreasing allocative efficiency. If allocative efficiency had not deteriorated, the decline in TFP would have been significantly less over this period, as shown by the change in the counterfactual, efficient TFP. ↘ CHART 55

151. There are considerable **differences in allocative efficiency between the individual industries in manufacturing**. In particular, a high allocative efficiency of inputs across companies is evident in coking and petroleum refining, other vehicle construction, paper processing and leather goods manufacturing. Input misallocation is low in these industries and sectoral TFP is close to the hypothetical optimum. Industries that have a comparatively high increase in TFP over time tend to be similarly efficient in input allocation as the manufacturing aggregate (for example, manufacturing of electrical equipment, fabricated metal products or computer equipment, but they also have high value-added weights). ↘ CHART 57 Apart from few exceptions, allocative efficiency improved between 2005 and 2017, especially in the high-tech industries. ↘ CHART 58

↘ ABBILDUNG 58

Change in allocative efficiency[1] within economic sectors in manufacturing[2]



1 – Percentage change in allocative efficiency (TFP/TFP^{eff}) compared to the year 2000. TFP^{eff}: TFP that would result from efficient use of production factors. 2 – According to the classification of economic activities, 2008 edition (WZ 2008). 3 – Except furniture.

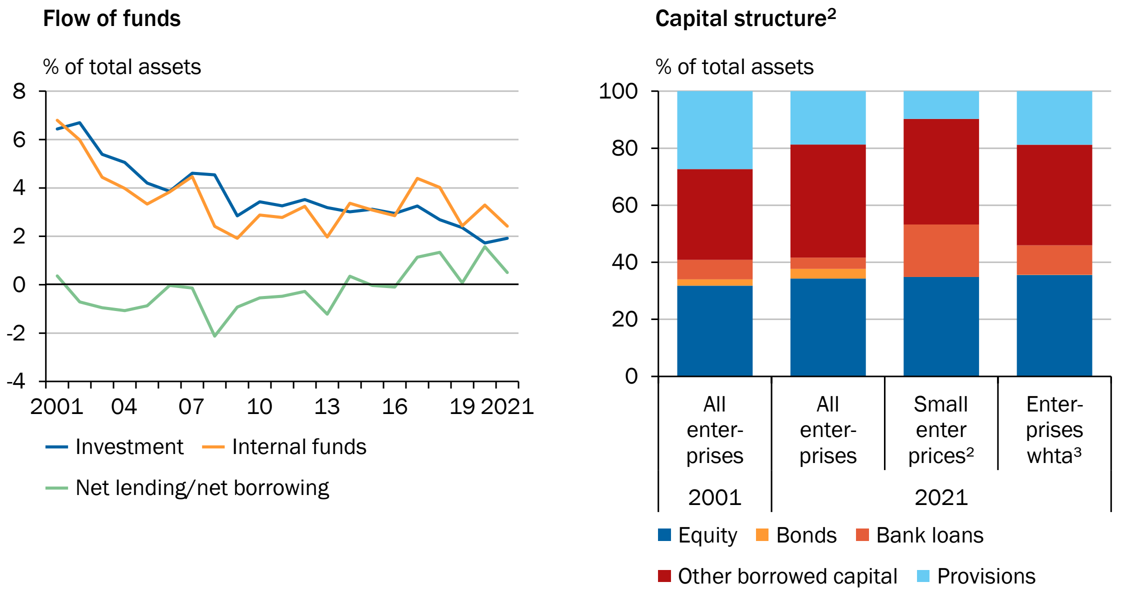
Sources: RDSC of the Deutschen Bundesbank, microdata set JANIS 1997-2022-1, own calculations

3. Financing needed for capital formation

152. To facilitate capital formation, companies must have access to appropriate financing. For this purpose, they can either use **internal funds**, which essentially correspond to retained cash flow, or **external equity and debt capital**, in particular newly issued shares, bonds or bank loans.

153. An analysis of investment financing ↘ ITEM 184 of companies in the manufacturing sector using micro data from the Bundesbank ↘ BACKROUND INFO 3 reveals a particularly **close connection between investment** in tangible fixed assets as well as intangible capital goods **and internal funds.** ↘ CHART 59 LEFT The share of investment in total assets declined in the period between 2001 and 2021, falling from an average of 6.4 % to 1.9 %. Internal funds showed a largely parallel trend, but partly picked up again since 2016. The financing balance, or difference between internal funds and investment, was to the most part only slightly negative in view of high internal financing. Companies financed this deficit primarily with debt capital. Since 2017, however, the financing balance has been positive, which means a net saving for the companies. The persistent net saving, which is also visible in the financial accounts of the national accounts (Deutsche Bundesbank,

↘ CHART 59
Flow of funds and capital structure of firms[1] in German manufacturing



1 – Companies older than one year, averages weighted by total assets. 2 – Only small companies: balance sheet below 25th percentile, data for 2020. 3 – Only companies with high share of tangible assets: tangible fixed assets/total assets above 75th percentile.

Sources: RDSC of the Deutsche Bundesbank, microdata set JANIS 1997-2022-1, own calculations

2023b), can be explained by lower profit distributions due to tax considerations (Joint Economic Forecast, 2017) and the general increase in intangible capital assets. The latter are not generally suitable as collateral for bank loans because they are often highly company-specific and lack liquid secondary markets (Dell'Ariccia et al., 2021), which is why companies increasingly finance these assets internally (Bates et al., 2009; Falato et al., 2022). Lower profitability of capital formation, for example due to increased regulatory uncertainty, could also explain the hesitancy in this regard (EIB, 2021, p. 257).

154. The capital structure of the companies examined here exhibits an **increasing equity ratio.** ↘ CHART 59 RIGHT Between 2001 and 2021, it rose by an average of 2.5 percentage points to 34.3 %. At the median the increase was much more pronounced, at around 17 percentage points, and was most pronounced among small and medium-sized companies (GCEE Annual Report 2021 item 406). The higher equity should help reduce financing constraints. Nevertheless, the capital ratio remains low by international standards. ↘ CHART 69 At the same time, the **share of bank loans** in total assets decreased on average **from around 6.8 % to 4 %.** For small companies and companies with a high share of tangible assets, that are highly suitable as loan collateral, loans remain a particularly important form of financing.

155. Given the high level of internal funds, which often exceeded capital formation in recent years, and the significant rise in capital ratios, **financing** probably does **not** currently constitute **a significant barrier to investment** for established German industrial companies. For example, in surveys by the European Central Bank (ECB) on companies' access to financing, the share of German companies

that report obstacles to accessing bank loans has fluctuated around 5 % for some time. This figure is low compared to other European countries (ECB, 2023). Previous empirical studies (Bond et al., 2003, 2005; Chatelain et al., 2003) also found that financing constraints on capital formation in Germany were less pronounced than in other industrialised countries. However, financing constraints are likely to arise for young growth companies (start-ups) that still have minimal internal funds and equity. ↘ ITEMS 224 F.

VI. TARGETED INCREASE IN POTENTIAL GROWTH

156. In the coming decades, **potential output growth** may be **significantly lower than in the past decade** due to the foreseeable decline in the volume of labour. If the contributions of capital services and total factor productivity to potential output growth remain at the current low level, potential output is unlikely to grow at the same consistent rates as between 2010 and 2019 for the foreseeable future. Without an economic policy correction and changes in the investment behaviour of companies, there may be significantly less leeway in the distribution of value added between consumption and capital formation and in the distribution of income within the population.

157. The GCEE's analyses clearly show that **this situation is not inevitable** if timely and decisive economic policy action is taken. Reforms that strengthen incentives to work ↘ ITEM 319 FF. and thus increase labour supply are an important component of a possible **growth strategy.** In addition, there is a need for long-term measures which not only enable productivity gains through technological progress and factor reallocation, but also mitigate the decline in labour supply due to labour migration and promote modernisation of the capital stock through capital formation. ↘ ITEMS 125, 139, 145 AND 147

1. Realising productivity gains

158. **Innovations** by private companies, often building on publicly funded basic research, are the driving force behind the translation of technological innovations into **TFP growth** (GCEE Annual Report 2020 items 487 ff.). Apart from improving TFP, innovation activity also increases the intangible capital stock. ↘ ITEMS 86, 104 AND 130

In 2020, the **research allowance** was introduced, providing tax incentives for research and development (R&D) in Germany for the first time. **Tax incentives for R&D** in Germany are now above the European average (Bührle et al., 2023). Since the R&D intensity of small and medium-sized companies in Germany is comparatively low (GCEE Annual Report 2020 items 502 ff.), the GCEE already proposed in 2020 to increase the subsidy rates for small companies and medium-sized companies (by 20 and 10 percentage points respectively) (GCEE Annual Report 2020 item 588). The Growth Opportunities Act follows this proposal in part and increases the research allowance by 10 percentage points in each case.

159. In the medium to long term, **improving the quality of school education** and strengthening **universities** can act as drivers for increasing TFP (Jaffe, 1989; Schlegel et al., 2022; GCEE Annual Report 2019 items 355 ff.; GCEE Annual Report 2021 items 494 ff.). Making universities more attractive to students and researchers from third countries can attract more highly qualified professionals. In addition to having a direct effect on working hours, high-skilled immigration can above all stimulate the innovation process ↘ ITEM 122 (Kerr and Kerr, 2018).

160. Start-ups can promote further diffusion of innovations and thus increase TFP (GCEE Annual Report 2019 items 181 ff.). ↘ ITEM 203 In order to make Germany more attractive as a location for business and for scale-up of companies, improving the venture capital market in Germany is especially relevant. ↘ ITEM 256 The **Future Fund**, through which the German state participates directly in start-ups together with private investors, is a step in the right direction, especially to improve financing for the scaling phase. ↘ ITEM 25

161. **Artificial intelligence** has the potential to be the next **general purpose technology** to increase productivity growth across the wider economy. ↘ ITEMS 123, 133 AND 145 In 2022, there was **low investment in AI start-ups in Germany** compared to other countries (OECD, 2023). To date, both the development and application of AI in Germany has lagged behind (Lane et al., 2023). The main reasons for this low use of AI are the high costs of AI investments, a shortage of skilled AI workers and regulatory barriers (Lane et al., 2023).

In order for the application of AI to develop its full potential ↘ ITEM 126, **research** (for example in the field of algorithms or microelectronics) must be **intensified.** Applications must also be developed and their usability ensured. Strong positive externalities in general purpose technologies (Brynjolfsson et al., 2021) justify a special focus on the promotion of – also application-oriented – R&D from an industrial policy perspective (GCEE Annual Report 2019 items 260 ff.; GCEE Annual Report 2020 items 524 ff.). Spillover effects can shorten learning phases in the introduction of AI and realise TFP gains at an early stage. ↘ ITEMS 142 AND 145 Finally, the limited **availability of data and digital capabilities** are further obstacles to the implementation of AI in Germany.

162. Given the potential of AI to significantly increase productivity across industries (Brynjolfsson et al., 2023; Dell'Acqua et al., 2023; Peng et al., 2023), ensuring that European companies have **access to this technology** is vital in the long term. It is also crucial that the **potential risks associated with AI**, for example through behavioural manipulation or incomprehensible processes in the development of products that fall under EU product safety regulations (European Parliament, 2023), are **limited through regulation**.

2. Slowing the decline in labour volume

163. Due to a shrinking labour force and diminishing average number of hours worked per person in employment, a **decrease** in the **volume of labour** is **foreseeable.** ↘ ITEMS 87 AND 107 This trend can be mitigated by improving **incentives and opportunities to take up work or to increase average working hours.** Human capital formation can also help to compensate for the declining volume of labour. For example, **further training, retraining and lifelong learning can** maintain and expand labour market potential (GCEE Annual Report 2019 items 220, 356 and 626; GCEE Annual Report 2022 items 360 et ff.). Such measures can also facilitate the **reallocation of labour between companies** (GCEE Annual Report 2021 items 393 ff.). ↘ ITEM 132 FF.

164. A **reversal of the trend in average annual hours worked per person in employment** could help to mitigate the tightening of labour supply. Similarly, **adjusting working lives to take account of longer life expectancy** could dampen the expected decline in the number of available workers towards the end of this decade and into the middle of the next, while keeping experienced skilled workers in the workforce. Steps in this direction, which would already have an effect in the short term, could be taken by **withdrawing or redesigning the pension system for those with particularly long insurance records.** ↘ ITEMS 403 AND 417 FF.

165. Moreover, **incentives to work can be improved** in many contexts. For example, the current **basic income support** system provides only weak incentives to take up employment on a significant scale or to expand part-time employment. ↘ ITEM 320 For **second earners**, especially women, the incentive to work is lessened by, for example, joint tax assessment of spouses, family insurance in statutory health insurance, and the deduction of personal pension entitlements from widows' pensions. ↘ ITEM 337 However, further increasing the labour force participation of women and the average hours worked by them is likely to be a challenge without **better childcare** and **well-developed infrastructure** in areas such as transport and digital. ↘ ITEM 345

166. Beyond the increase in the domestic labour volume, an increase in **immigration** into the labour market is necessary to effectively dampen the foreseeable decline in the labour volume (GCEE Annual Report 2022 items 452 ff.). ↘ ITEMS 121, 122 AND 159 Facilitating the **integration of immigrants** into the German labour market is crucial. ↘ ITEM 122 In the case of refugees, this is currently possible after three months at the earliest (GCEE Annual Report 2022 items 457 ff.). Accelerating labour market access for those refugees who are likely to stay would be desirable. An even more important matter is simplifying labour migration from non-EU states. This could, for example, be linked to job offers instead of multiple criteria, such as minimum income limits and equivalent qualifications (GCEE Annual Report 2022 items 418 f. and 454).

The adoption of the Skilled Workers Immigration Act in July 2023 will expand possible immigration routes and will also, for example, make it easier for immigrants to switch employers (GCEE, 2023a; GCEE Annual Report 2022 items

450 ff.). Furthermore, administrative improvements are needed, both in the consulates and in the foreigners' registration offices. A **welcome culture** and **more certainty** about which workers are needed, for which jobs, for which period of time and under which conditions they can come to Germany would also help to attract potential immigrants (GCEE Annual Report 2022 items 447 ff. and 456).

3. Improving investment incentives and supporting diversification

167. **Capital formation** plays a **central role** in **boosting potential output growth** through increased capital accumulation and capital-embodied technological change. In particular, the twin transition of digitalisation and decarbonisation requires timely modernisation and restructuring of the capital stock. ↘ ITEMS 109 FF, 132 FF. AND 139

Improving the **regulatory framework for capital formation**, e.g. through efficient administration, tax policy measures and provision of infrastructure, can support capital accumulation in productive sectors and companies and accelerate technological progress. ↘ ITEMS 139 FF. Factor reallocation to productive companies as part of capital formation can increase TFP. ↘ ITEMS 148 FF.

Facilitating investment activity through efficient administration

168. **Administrative reforms** and **reducing bureaucracy** can lead to an increase in capital formation activities by companies (Lapuente and Van de Walle, 2020). For example, the introduction of digital processes and application procedures can shorten the time between application and approval (Handke, 2021). Clear legislation also supports companies' investment decisions.

There is still a great need for action to speed up administrative tasks through **increased digitalisation of internal processes** (Handke, 2021). Bureaucratic processes require considerable compliance effort on the part of companies and individuals (NRCC, 2022). Another important approach is the **once-only principle** (GCEE Annual Report 2018 item 154). According to this principle, citizens should only have to submit documents once. These are then stored and can be retrieved for future processes. This principle should also be applied to corporate planning and approval procedures.

169. Speedy implementation of the procedures laid out in the **Online Access Act** (OZG) can establish shorter administrative processes. To date, however, the OZG has not been fully implemented (NRCC, 2022). A rapid **amendment** of the OZG, as set out in the government draft from May 2023, would provide a roadmap for the future, with the goals of **standardising the interfaces of the digital infrastructure** while ensuring **technological neutrality**. With this approach, providers of digital solutions would remain competitive and there would be no dependencies in the event of later changes or extensions to the software or digital processes (NRCC, 2022).

170. **Newly founded businesses are likely** to increase aggregate TFP and **facilitate reallocations** (GCEE Annual Report 2019 items 334 ff.). ↘ ITEM 148 According to the coalition agreement, it should be possible to complete the process for setting up a new business within 24 hours by means of digital applications. This requires considerable further digitalisation and standardisation of processes, including those used by the authorities. The registration processes in particular should be digitally designed to reduce the effort for entrepreneurs.

Tax policy

171. Given the backdrop of declining potential output growth, the goal set out in the Growth Opportunities Act to stimulate capital formation in the green transformation through **tax incentives** is to be welcomed. Subsidies of this kind can stimulate early green transformation investments. ↘ ITEMS 86, 93, 120 AND 172 However, it is feared that the **reporting obligations** for increasing energy efficiency and for energy-saving concepts will create even more bureaucratic processes, rather than reducing them as agreed in the coalition agreement. Tax incentives should be linked to specific requirements in such a way that the creation of bureaucratic processes is minimised. Due to staff shortages in public administration, there are already considerable delays between application and approval. Standardised **documentation** and automated **verification** can help resolve this problem.

172. The Growth Opportunities Act is also designed to encourage capital formation by smaller and younger companies by **extending bonus depreciation of investment costs.** ↘ ITEM 120 At present, businesses with profits of €200,000 or less can write off 20 % of their investment costs. The depreciation rate is to be increased to 50 %. This regulation should be advantageous for start-ups, for example, which only become profitable after a scaling phase. As a result, their growth will be boosted. In addition to increasing growth of the capital stock, this also has the potential to improve allocative efficiency and lead to TFP increases (GCEE Annual Report 2020 item 284). ↘ ITEM 148

Energy policy can facilitate investments for decarbonisation

173. The prices for energy sources and electricity, which are high by international standards, impair Germany's attractiveness as a location for business investment. This is especially true for energy-intensive industries (GCEE, 2023b; GCEE Annual Report 2022 items 316 ff.). ↘ CHART 45 Given that average electricity prices in the first half of 2023 are still 60 % higher than prices in the period 2015 to 2019, **expansion of the electricity supply** is **urgently needed.**

It is crucially important to **expand electricity generation capacities** to strengthen the electricity supply and to **expand the grid infrastructure** (GCEE, 2023b). In particular, the north-south power lines should be expanded as quickly as possible. Although citizens' interests must be taken into account when expanding the electricity grids, there are considerable advantages to overland lines in terms of costs and speed of expansion compared to underground routing.

In view of the changed situation caused by the energy crisis, in particular the fact that grid expansion has once again become a matter of urgency, fresh consideration should urgently be given to decisions on underground routing of cables. These measures offer a sustainable means of **making Germany a more attractive location for investment** by reducing electricity costs. To **support sector coupling**, a permanent **reduction of the electricity tax** for companies to the statutory EU minimum of 0.05 cents per kilowatt hour could be implemented (GCEE Annual Report 2020 item 391; GCEE Annual Report 2022 item 196). In addition, the structure of grid charges could be critically reviewed (Consentec, 2021).

174. Access to CO2-neutral energy sources based on **climate-friendly hydrogen is a crucial prerequisite** for the **decarbonisation of large parts of energy-intensive industry** (Egerer et al., 2023a). Expectations regarding the wide availability of climate-friendly energy sources and the prices to be paid for them are of central importance to investment decisions on the assets and buildings that are necessary within this framework. Greater availability and lower expected prices increase the incentives for corresponding capital formation. The **H2Global mechanism** provides a suitable means of **increasing the availability of hydrogen and hydrogen-based energy sources** in a timely manner (Bauer et al., 2023). Based on the price signals the mechanism generates on the buy and sell side, hydrogen indices can be constructed and traded, e.g. on the European Energy Exchange (EEX). In order for hydrogen to be used, the necessary transport routes, especially the grid capacities in Germany and Europe, have yet to be expanded. Various concepts have been developed for this purpose (e.g. dena, 2023), which should be evaluated and implemented promptly (Federal Ministry for Economic Affairs and Climate Action, 2023).

Geopolitics: import substitution helped by international cooperation

175. Both the European Union and the United States are trying to encourage **de-risking** by companies in order to mitigate the external effects of global shocks on supply chains and the domestic economy (Sullivan, 2023; von der Leyen, 2023). Both political will and corporate planning currently envisage the diversification of supply and production chains (Flach et al., 2021). International cooperation with third countries can help cushion economic risks and **increase** the attractiveness of **capital formation in geopolitically allied regions.** For example, a trade agreement was recently concluded between the European Union and New Zealand, which also includes an investment agreement (European Commission, 2023c). ↘ ITEMS 96 AND 97 The conclusion of further **trade agreements**, e.g. with Mercosur, is also a key building block. **Reciprocal investment (protection) agreements** likewise reduce investment costs in third countries and can also help achieve climate protection goals (GCEE Annual Report 2021 items 602 ff.; Annual Report 2022 items 511 f. and 517).

Companies may also have a vested interest in **substituting intermediate products** with **imports** for which liquid markets can be expected to emerge and where imports can be diversified, as in the case of methanol, SAF (sustainable aviation fuels) or ammonia (Egerer et al., 2023a, 2023b). In particular where **new markets are emerging**, e.g. markets for green hydrogen or critical raw materials that will be needed in much larger quantities in future, efforts should be made from the outset to **diversify supply channels**.

APPENDIX

1. Explanation of analyses

Decarbonisation calculations

176. With the help of assumptions about service life, disposals from the capital stock of the manufacturing sector can be calculated per capital good. ↘ CHART 54 An **average life** of about 13 years is assumed for equipment, 5 years for other capital and about 49 years for buildings (Ochsner et al., 2023b, 2023a). ↘ CHART 54 Since the **average service life** of buildings is well over 40 years, it is assumed that no further capital formation will be directed towards energy-intensive buildings with fossil technology from 2025 onwards. For equipment and other capital, on the other hand, which remain economically viable with respective service lives of about 13 and about 5 years to a much later date, it is assumed that capital formation in fossil energy-intensive equipment and other assets will not cease until 2031 and 2040. This means that equipment and other assets may have to be replaced several times by then due to their short service lives.

177. The capital formation volumes are derived from the total gross fixed capital formation in the reference scenario. Furthermore, it is assumed that the **share of energy-intensive industry** in total gross fixed capital formation will remain constant until 2045. Energy-intensive industries and energy supply accounted for about 9 % of equipment, 3.25 % of non-residential buildings and 13 % of other capital in gross fixed assets on a weighted average basis between 1991 and 2021. ↘ CHART 61 For the purpose of determining historical investment paths, it is assumed that 65 % of fixed assets in energy supply are currently based on fossil technology (Ochsner et al., 2023a), while the total fixed assets of energy-intensive manufacturing industries are considered to be based on fossil technology.

Estimation of elasticities of substitution

178. The **elasticity of substitution describes the change in the capital-labour ratio** within industries or companies in the case of a one percent change in the price ratio of the input factors: If a factor, e.g. labour relative to capital, becomes 1 % more expensive, the elasticity of substitution indicates by how many percent the capital-labour ratio changes. Higher values of the elasticity of substitution indicate easier substitution of inputs. If the elasticity of substitution is greater than 1, we refer to (imperfect) substitutes; if the elasticity of substitution is less than 1, we refer to (imperfect) complements, because the exchange of the factors of production under consideration takes place disproportionately to the relative price change. The determination of elasticities of substitution is based on the EUKLEMS database, which in turn is based on statistics from the national accounts of the EU member states, the United Kingdom, the United States and Japan. In the economic literature, a CES production function is mostly assumed, which is a good approximation at least in the vicinity of the prevailing capital intensity. **The GCEE estimates substitution elasticities using non-linear**

ML estimation of the CES production function at the level of individual manufacturing sectors (Lagomarsino, 2020). A nested CES structure is assumed, with the inner "nest" containing the factors labour and intangible capital and the outer nest containing physical capital, i.e. equipment + non-residential buildings:

$Y_{ict} = (\delta_{ic} K^{Equip.+NRB}{}_{ict}{}^{-\rho_i} + (1-\delta_{ic})(K^{intang}{}_{ict}{}^{-\gamma_i} + L_{ict}{}^{-\gamma_i})^{\rho_i/\gamma_i})^{-1/\rho_i}$. The elasticities of substitution are determined as $\sigma^{intang}{}_{i,L,K} = 1/(\gamma_i - 1)$ and $\sigma^{Equip.+NRB}{}_{i,L,K} = 1/(\rho_i - 1)$. ↘ TABLE 17

Capital-embodied technological change

179. The GCEE analyses capital-embodied technological change (CETC) in German manufacturing based on micro data provided by the Bundesbank (Becker et al., 2023). ↘ BACKGROUND INFO 3 As described, ↘ ITEM 139 **the impact of CETC on an economy's potential growth can be significant.** For example, Eaton and

↘ TABLE 17

Elasticities of substitution between labour and capital[1]

Economic sectors[2]	Physical capital	Tangible capital
Agriculture, forestry and fishing	3.33	1.55
Mining and quarrying	1.44	2.26
Food products, beverages, tobacco products	0.02	0.51
Wood, paper, printing[3]	0.33	0.33
Coke and refined petroleum products	0.78	0.05
Chemical products	2.15	0.59
Pharmaceutical products	1.39	9.16
Rubber and plastic products, non-metallic products[4]	0.73	0.13
Basic metals and fabricated metal products	0.44	0.27
Computer, electronic and optical products	0.82	1.14
Electrical equipment	1.29	0.19
Machinery and equipment	1.26	0.02
Motor vehicles, trailers and semi-trailers, other transport equipment	2.78	0.17
Furniture, other manufact., repair and installation of machinery and equipm.	1.63	1.30
Energy supply	0.47	0.52
Information and communication	0.88	0.61
Real estate activities	0.52	0.01
Professional, scientific and technical activities	1.35	0.49
Education	0.90	1.09
Arts, entertainment and recreation	0.43	0.37

1 – Elasticities of substitution of labour by capital estimated per economic sector using a CES prodction function in the form $Y_{ict} = (\delta_{ic} K_{ict}{}^{-\rho_i} + (1-\delta_{ic}) L_{ict}{}^{-\rho_i})^{-1/\rho_i}$. Data for 1999 – 2020, pooled for the countries Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Latvia, Lithuania, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom, USA. Data in current prices, capital corresponds to capital input, labour corresponds to labour input (both indexed 2015 = 100). If the elasticity of substitution is greater than 1, we speak of (imperfect) substitution, if the elaticity of substitution is less than 1, we speak of (imperfect) complements. 2 – According to the Statistical Classification of the European Community (NACE Rev. 2). 3 – Wood and products of wood and cork, articles of straw and plaiting materials paper and paper products, printing and reproduction of recorded media.

Sources: Bontadini et al. (2023), EUKLEMS, own calculations

Kortum (2001) have shown that productivity differences, i.e. differences in TFP, can be attributed to quality differences and thus different capital-embodied technologies in equipment to an extent of about 12.5 %.

180. **CETC is determined using a structural estimation according to Caunedo et al. (2023).** CETC is defined as the change in the utilisation costs of capital relative to labour costs as the capital stock renews. The GCEE determines the rate of CETC both for manufacturing as a whole and for all manufacturing industries individually over the period 2000-2020. For manufacturing, the rate ranges from 2.4 % to 5.2 %. Sakellaris and Wilson (2004), using a different methodology, estimate the rate to be between 7.7 % and 17.0 % for the United States over the period 1979 to 1996. However, the economic conditions of the United States in this period differ considerably from the current conditions in Germany. ↘ ITEM 88

↘ TABLE 18

Rate of capital-linked technical progress (CETC rate in %)

Economic sectors of manufacturing[1]	CETC rate in %
Food products	1.71
Beverages	0.28
Tobacco products	0.05
Textiles	1.05
Leather and related products	9.66
Products of wood, cork, straw and plainting materials (except furniture)	1.10
Paper and paper products	2.12
Printing and reproduction of recorded media	0.85
Coke and refined petroleum products	10.45
Chemical products	4.43
Pharmaceutical products	14.24
Rubber and plastic products	2.17
Other non-metallic mineral products	2.08
Basic metals	6.83
Fabricated metal products	1.95
Computer, electronic and optical products	2.21
Electrical equipment	3.47
Machinery and equipment	3.56
Motor vehicles, trailers and semi-trailers	5.04
Other transport equipment	3.71
Furniture	0.86
Other manufacturing	2.53
Repair and installation of machinery and equipment	0.34

1 – According to the Classification of Economc Activities, 2008 edition (WZ 2008), excluding wearing appareal.

Sources: RDSC of the Deutsche Bundesbank, microdata set JANIS 1997-2022-1, own calculations

181. Assuming constant returns to scale and perfect competition, the elasticity of substitution between labour and capital can be expressed as the percentage change in the input ratio of capital and labour given a one percent change in relative factor prices, i.e. labour compensation, or the effective wage, and the utilisation costs of capital. Taking into account capital-embodied technological change, the elasticity of substitution can be expressed as $\sigma_i = \frac{dln(k_{it}/n_{it})}{dln(\lambda^n{}_{it}/\lambda^k{}_{it})} = \frac{dln(k_{it}/n_{it})}{dln(\lambda^n{}_{it}exp(\gamma_{it})/\lambda^k{}_{it})}$ where γ_{it} is the CETC progress in industry i per year t. Under the further assumption that the latter follows an exponential evolution, the **elasticity of substitution and the CETC** can be estimated **jointly using** $\boldsymbol{ln\,(\frac{k_{ijt}}{n_{ijt}}) = \beta_{1ij} + \beta_{2i}t + \beta_{3i}\,ln\,(\frac{\lambda^n{}_{ijt}}{\lambda^k{}_{ijt}}) + \epsilon_{ijt}}$ where $\frac{k_{itj}}{n_{ijt}}$ is the input ratio of capital to labour, in this case of the real capital stock to the number of workers per company j, and $\frac{\lambda^n{}_{ijt}}{\lambda^k{}_{ijt}}$ is the ratio of factor costs. The rate of CETC is then determined as $\gamma = \beta_2/\sigma$ with $\sigma = \beta_3$ (for more details see Caunedo et al. (2023)). The factor price ratio is determined as the ratio of average wages and average interest expense on external capital. ↘ TABLE 18

Factor misallocation, TFP and investments

182. Various factors lead to an **inefficient allocation of production factors** in national economies **between companies** in the same economic sector and between economic sectors. This can be **caused by differing investment rates** between companies (Hsieh and Klenow, 2009; Chen and Irarrazabal, 2015). For example, companies grow at different rates due to their intrinsic productivity and usually also because of different investment intensities. However, if companies are unable to invest optimally due to exogenous factors such as limited access to external financing↘ ITEM 153 or supply constraints, the resulting lack of capital formation can contribute to lower (TFP) growth (Luttmer, 2011).

183. The GCEE follows the **methodology of Hsieh and Klenow** (2009; see also Chen and Irarrazabal, 2015 and Ruzic and Ho, 2023) and **determines the misallocations in the German** manufacturing sector **using the JANIS data of the Bundesbank in a structural model.** ↘ BACKGROUND INFO 3 Company-specific distortions are modelled as wedges, which have a multiplicative effect on the output price of the company and the cost of capital input. In the absence of misallocation, i.e. if the distortion wedges were zero, the marginal revenue products of all companies within an industry would converge, assuming that companies within an industry face the same factor costs. Misallocation in an industry is present whenever a dispersion is observed in the marginal revenue products of the inputs. The JANIS data allow the method outlined here to be applied directly. Like Hsieh and Klenow (2009), the GCEE sets the elasticity of substitution of the companies' outputs within an industry to a value of 3 and chooses the labour or capital shares in the production function according to the average of the relevant industry. All monetary variables are normalized in 2015 prices according to the German producer price index.

Investment financing and capital structure

184. The GCEE analyses the **financing situation of corporations in the manufacturing sector** using the Bundesbank's JANIS dataset (Becker et al., 2023). ↘ BACKGROUND INFO 3 The dataset used for the balance sheet analysis contains information on 35,612 companies in the period 2000 to 2021. The analysis of financing flows ↘ ITEM 153 based on Frank and Goyal (2008) takes into account the corporations in the manufacturing sector included in the JANIS dataset. The weighted averages by total assets of all companies under review are calculated and expressed in each case as a percentage of annual average total assets. Investment corresponds to the sum of additions to tangible assets and the change in intangible capital stock adjusted for depreciation. Internal funds consist of retained profits (profit after tax less dividends) and depreciation less the change in net current assets (current assets minus current liabilities). Net lending/borrowing is the difference between internal funds and investment.

2. Additional tables and charts

↘ TABLE 19

Summary of the results of the long-term projection[1]

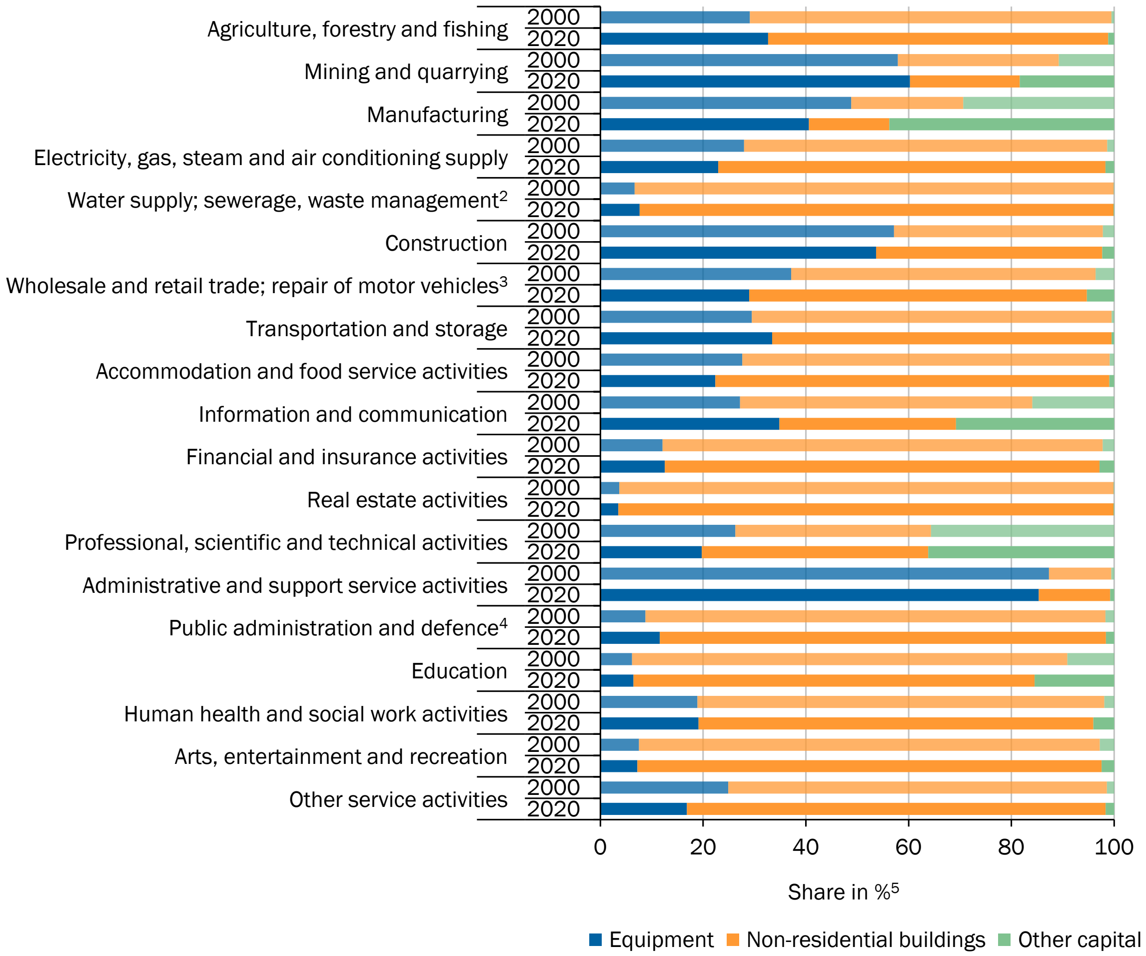
		Unit	Years[2]										
			1970 –79	1980 –89	1990 –99	2000 –09	2010 –19	2020 –29	2030 –39	2040 –49	2050 –59	2060 –69	2070
Potential output		Billion euro in prices of 2015	1,457.6	1,842.9	2,277.7	2,638.6	3,033.7	3,299.8	3,453.0	3,718.9	3,992.7	4,311.6	4,544.4
Potential output growth		%	2.5	2.2	1.9	1.4	1.4	0.4	0.6	0.8	0.7	0.9	1.0
Potential output per capita		1,000 euro per capita in prices of 2015	18.6	23.6	28.1	32.5	37.1	39.1	40.6	44.0	47.8	52.1	55.0
Labour volume		Billion hours	61.7	57.5	55.5	53.9	56.8	55.9	52.3	51.1	49.3	47.6	47.3
Labour volume growth		%	-0.8	-0.6	-0.3	0.1	0.6	-0.7	-0.5	-0.2	-0.5	-0.2	-0.1
NAIRU		%	1.7	4.9	7.5	7.8	4.3	2.4	2.4	2.4	2.4	2.4	2.4
Self-employment rate		%			9.9	10.7	10.2	8.5	8.3	8.3	8.3	8.3	8.3
Part-time rate		%			23.4	32.5	37.7	38.8	39.3	39.6	39.8	39.8	39.9
Hours	Full-time	1,000 hours			1,655.3	1,664.0	1,652.0	1,570.9	1,524.6	1,510.1	1,505.3	1,502.9	1,502.0
	Part-time				742.0	720.6	805.3	830.6	832.2	832.6	832.7	833.1	833.7
	Self-employed				2,286.1	2,132.3	1,967.6	1,787.9	1,659.0	1,582.2	1,534.3	1,503.2	1,491.3
Potential participation rate	Aggregate	%	58.9	60.4	62.7	64.3	68.4	69.2	68.9	72.5	72.8	73.7	74.9
	Age 15 – 19	%	53.4	42.9	34.2	30.8	29.5	31.0	31.0	28.4	23.8	17.5	13.4
	Age 20 – 59	%	72.6	74.6	78.7	83.1	84.7	86.2	88.6	91.1	93.8	96.4	97.8
	Age 60 – 64	%	33.4	20.7	19.9	30.5	55.0	66.5	70.2	72.0	72.3	71.5	70.7
	Age 65 – 69	%	5.1	5.1	5.1	6.3	13.9	20.8	25.1	28.3	30.7	32.6	33.5
	Age 70 – 74	%	2.5	2.5	2.5	3.0	6.1	8.7	9.6	10.4	11.2	11.9	12.4
Human capital growth		%	0.8	0.6	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Total factor productivity		%	1.1	1.2	1.2	0.6	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Capital use		Index	128.0	180.3	240.2	296.9	339.8	385.2	430.9	484.2	549.2	631.2	684.6
Gross fixed assets	Aggregate	Chained volumes, billion euros (reference year 2015)	6,818	9,436	12,414	15,292	17,393	19,394	21,257	23,342	25,803	28,770	30,625
	Equipment		1,103	1,425	1,807	2,188	2,472	2,813	3,128	3,449	3,815	4,252	4,523
	Other investments		142	337	589	756	954	1,239	1,609	2,080	2,667	3,399	3,869
	Non-residential		2,635	3,640	4,683	5,521	5,952	6,133	6,167	6,154	6,152	6,188	6,224
	Residential		2,938	4,033	5,335	6,826	8,015	9,210	10,354	11,659	13,169	14,930	16,009
Net fixed assets	Aggregate	Chained volumes, billion euros (reference year 2015)	4,731	6,228	7,818	9,124	9,761	10,442	11,113	11,915	12,919	14,157	14,938
	Equipment		611	747	947	1,118	1,286	1,468	1,646	1,820	2,025	2,271	2,424
	Other investments		611	747	947	1,118	1,286	1,468	1,646	1,820	2,025	2,271	2,424
	Non-residential		1,866	2,426	2,943	3,201	3,151	3,055	2,951	2,858	2,793	2,749	2,731
	Residential		2,165	2,853	3,610	4,398	4,803	5,252	5,719	6,280	6,945	7,728	8,211
Capital use costs	Equipment	% of the price of a unit of capital good	16.9	17.4	21.2	23.3	21.2	20.4	20.8	21.4	22.1	22.8	23.1
	Other investments		19.1	20.2	24.5	24.8	23.6	23.2	23.6	23.9	24.2	24.4	24.5
	Non-residential		7.8	7.6	8.6	9.4	8.7	8.0	7.6	7.5	7.4	7.5	7.6
	Residential		5.9	6.1	7.3	8.1	7.7	7.0	6.5	6.2	6.1	6.0	6.0
Minimum return on capital		%	9.0	7.9	7.5	7.5	7.2	6.4	5.8	5.4	5.1	4.9	4.8
Capital intensity[3]		Capital use / Labour volume	2.1	3.1	4.3	5.5	6.0	6.9	8.3	9.5	11.2	13.4	14.6

1 – The medians of the sample are shown in each case. 2 – Mean values over the periods. Projection from 2023 onwards. 3 – Capital use divided by billion hours worked.

Sources: Federal Statistical Office, IAB, OECD, own calculations

↘ CHART 60

Structure of the capital stock in the economic sections[1]

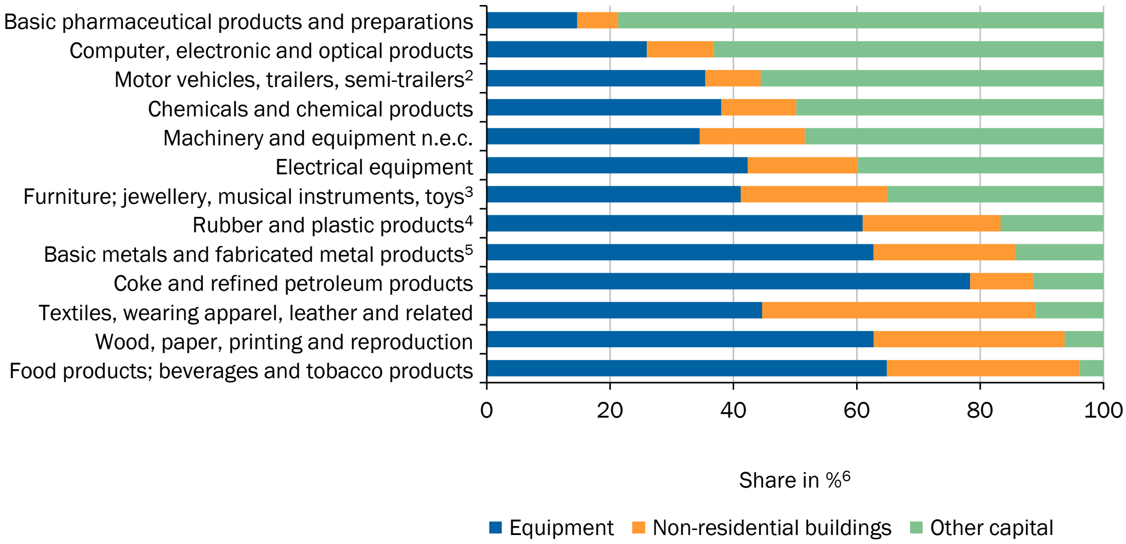


1 – According to the statistical classification of economic activities in the European Community (NACE Rev. 2). 2 – And remediation activities. 3 – And motorcycles. 4 – And compulsory social security. 5 – Share of capital stock (excluding housing and livestock and plantations). Net fixed assets at replacement cost.

Sources: Bontadini et al. (2023), EUKLEMS, own calculations

↘ CHART 61

Structure of the capital stock in the manufacturing sector[1] in 2020

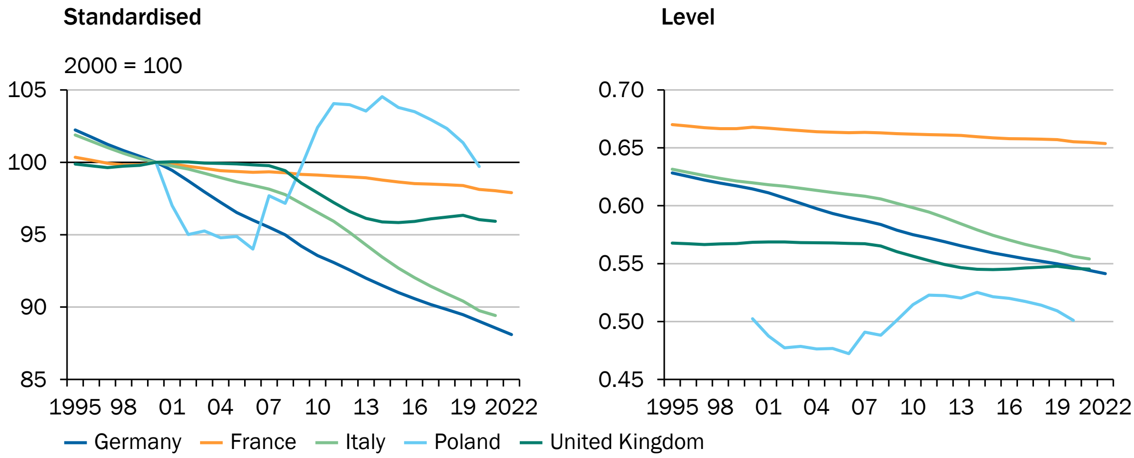


1 – According to the statistical classification of economic activities in the European Community (NACE Rev. 2). 2 – And of other transport equipment. 3 – And repair and installation of machinery and equipment. 4 – And other non-metallic mineral products. 5 – Except machinery and equipment. 6 – Share of capital stock (excluding housing and livestock and plantations). Net fixed assets at replacement prices.

Sources: Bontadini et al. (2023), EUKLEMS, own calculations

↘ CHART 62

Degree of modernity[1] of the capital stock in international comparison



1 – Net capital stock in relation to gross capital stock. Price-adjusted.

Sources: Federal Statistical Office, OECD, own calculations

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