

Zarges, Lara; Lehmann, Robert

**Conference Paper**

## What Drives Trend German GDP Growth? A Disaggregated Sectoral View

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# What Drives Trend German GDP Growth? A Disaggregated Sectoral View\*

Robert Lehmann

Lara Zarges

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## Abstract

In this paper, we outline the material and capital linkages across sectors and quantify the role of the German production network in amplifying sectoral dynamics on aggregate trend GDP growth. This allows us to study the impact of sectoral labor and TFP trend-growth variation on the persistent decline of German trend GDP growth. Our estimation reveals that sector-specific developments have historically accounted for half of the long-run changes in German GDP growth. Zooming into the reunification period, we find a pronounced decline of TFP growth in Public and Business Services together with a fall in labor input growth in the Construction sector to drive the sharp decline of German trend GDP growth over the 1990s. We further document significant changes regarding the sectors' importance as input suppliers to the economy in the past decades. Our analysis identifies the labor-intensive construction sector as a major input hub in the production network, its long-run amplification effect exceeding its share in value added. Given the looming demographic change, the low automation potential of this sector may significantly further reduce German trend growth in the near future.

**Keywords:** trend GDP growth; sectoral multiplier; amplification effects

**JEL-Classification:** C32; E23; O41

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\***Lehmann:** ifo Institute Munich and CESifo ([lehmann@ifo.de](mailto:lehmann@ifo.de), +49 89/9224-1652); corresponding author.  
**Zarges:** ifo Institute Munich ([zarges@ifo.de](mailto:zarges@ifo.de)).

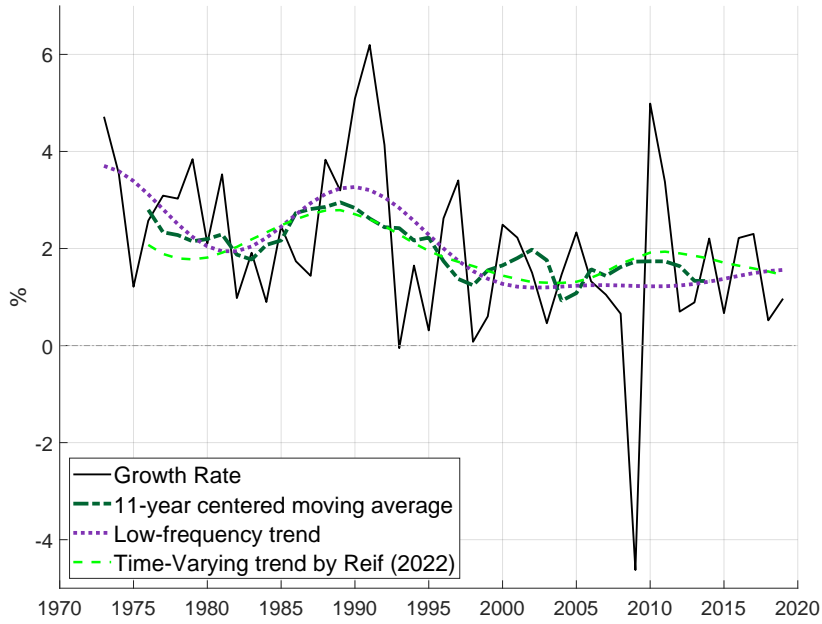
# 1 Introduction

The sluggish recovery of the US economy of the Great Recession and the following low average US GDP growth rate over the 2010s prompted rose concerns about slowing trend growth. Presenting evidence of slowing TFP growth and stalling labor input being responsible for the secular decline, Fernald *et al.* (2017) further underlined that those two developments had been present already before 2008. Similarly, Antolin-Diaz *et al.* (2017) find the deceleration of US output growth to have preceded the Great Recession. While Germany recuperated astonishingly fast from the Great recession, its labor market only hit mildly (Rinne and Zimmermann (2012), Burda and Hunt (2011)). Its economy is however no exception regarding decelerating long-term GDP growth rates: Reif (2022) documents a slowdown of German trend growth. This paper embarks on an empirical investigation into the sources of the decline, situating its analysis within a historical context and drawing comparisons with the decline observed in the United States.

Being Europe's largest economy, the German case presents a unique lens through which to explore the intricacies of decelerating economic growth. During the last five decades, the German economy has undergone enormous structural changes. Next to integrating into the global and particularly into the European economy, its recent economic history includes a unique structural break given by the country's reunification in 1989. A variety of economic consequences following the economic integration of two neighbouring countries at different levels of economic development, such as labor market effects and migration patterns have been studied intensively (e.g. Burda and Hunt (2001), Uhlig (2006)). Apart from the German "labor market miracle" (Jacobi and Kluve (2006), Krebs and Scheffel (2013)) and the current account imbalances arising around the turn of the century (Sabbatini and Zollino (2010)), trends underlying unified Germany's aggregate economic developments, (not focusing on either former West- or East Germany) have on the contrary not been subject to much empirical investigation. Even less attention has been given to developments on the disaggregated level, Coricelli and Wörgötter (2012) focusing on the gap in productivity growth between manufacturing and services underlying the pronounced German current account surplus being an exception. Intending to change this, this paper focuses on the role of sectoral trends in the evolution of German aggregate economic trend growth dynamics.

Following Foerster *et al.* (2022), we estimate a low-frequency trend for Germany capturing developments over 15 years smoothing out the associated 11-year moving average of GDP growth, see Figure 1. The method, a "low-pass filter", is explained in Section 2. Our estimation confirms the finding of Reif (2022): German trend GDP growth has been on a downward path since more than 4 decades, declining from more than 3% in the 1970s to around 1% in the mid 2000s. Besides the overall trend growth decline, Figure 1 also points towards periods of substantial increases in growth, e.g. during the late 1980s. We further note that in recent years, German long term trend growth has been picking up.

**Figure 1:** Trend Rate of Growth of German GDP



*Notes:* The low frequency trends capture variability for periodicities longer than 15 years.

The declining German business cycle volatility, also the focus of Reif (2022), has been subject of several publications. One relevant finding from this literature for our purpose is that structural shifts — accelerated by the German reunification — and changing relationships between various GDP components have contributed significantly to the lower volatility (Assmann *et al.* (2009)). We suspect those shifts in sectoral importance to also influence long-run trend growth dynamics. Loosely related to our work is Wolf (2018), who examines German economic growth between the beginning of the 20th century and 2010. He however focuses on regional divergence such as the effects of e.g. early industrial production in the North-West or small-scaled crafts production in the South. In contrast, we contribute to the literature by expanding the level of analysis to the sectoral level: Disentangling low-frequency trends in labor and TFP for 15 sectors constituting the German private economy, we are able to identify the key sectors contributing to the declining trend growth rate of GDP during the past decades (between 1973 and 2019). We further examine the amplifying effects of sectoral changes on aggregate growth in labor, TFP and GDP relying on a model summarizing the amplification effects as multipliers stemming from sectoral interactions in the German material provider- and capital network. The analysis follows the methodology of Foerster *et al.* (2022), who investigate aggregate implications of changing sectoral trends for the United States. Amongst other results, they find sector-specific factors having accounted historically for around 75% of long-run changes in US GDP growth. As the German economy differs in fundamental characteristics considerably from the US, comparing results emerging from the German application to the corresponding observations for the United States is of major

interest: For Germany, we find sector-specific forces accounting historically for only about 50% of long-run variation in GDP. This higher importance of common sources for output growth in Germany might root in the major shock represented by reunification as well as the compared to the US delayed and still ongoing shift from manufacturing towards services. German GDP trend growth declined by 2.3 percentage points over our sample (between 1973 and 2019). We find the Durables sector alone to have contributed 0.5 percentage points to that decline, mainly driven by a decline in the sector’s TFP trend growth. Zooming into the reunification period, we find that a 1.4 percentage point decline of TFP growth in Public and Business Services together with a fall of 0.63 percentage points in labor input growth in the Construction sector to have driven the sharp decline of German trend GDP growth (1.7 percentage points) over the 1990s. Interestingly, we find no major positive contributions of the service sectors to TFP growth. We further contribute to the literature by providing the to our knowledge first capital tables for the 15 sectors comprising the German private economy, spanning the period between 1990 and 2018. They allow an annual approximation of the German investment network in Germany. Starting in 1995, the capital tables further account for investments in intangibles. The construction of those capital tables allows us to analyze the evolution of the sectoral multipliers denoting the importance of a specific sector as input supplier to the economy and hence containing its amplification effects over the production network on the entire economy. Not surprisingly, we document a rise for the majority of the labor multipliers of service sectors with the PBS sector quadrupling over the sample period. While we register a significant decline of the labor multiplier of the Durables sector (most likely due to automation processes), the labor multiplier of the Construction sector remains rather high. Due to the sector’s high labor intensity, it’s overall high importance as input supplier in the production network and the looming demographic change on the German labor market, we find the the Construction sector to have the potential to significantly depress German trend GDP growth in the future.

After describing our dataset and presenting stylized facts regarding the long-run growth dynamics in Germany in Section 2, the paper proceeds by zooming in detail into sectoral trend growth in labor and TFP in Section 3. Next to presenting the low-frequency trends estimated for each industry it further illustrates the factor model used to entangle idiosyncratic and common forces shaping the trends. The model used to extract sectoral multipliers quantifying the extent of the production linkages is described in Section 4 next to the resulting German production network and the implied sectors’ contributions to trend GDP growth. Before concluding in Section 6, our results and their robustness are discussed in detail in Section 5.

## 2 Long-run Growth Dynamics in Germany

We start by presenting selected descriptive facts about Germany’s long-term economic development. Along those lines we discuss its economic structure and point out why the German economy is quite different from that of the US. We introduce our applied database constructed from official sources and data transformations that go in hand with our empirical questions. We further debate the long-term growth dynamics of gross domestic product (GDP), labour input and total factor productivity (TFP) at both the aggregate and the sectoral level.

### 2.1 Database

**Construction of historical series.** Studying the evolution of economic trends in Germany is due to historical reasons challenging: reunification only took place around 30 years ago and included the integration of the centrally planned economy of the German Democratic Republic (GDR) into the market-traded economy of the former Federal Republic of Germany (FRG). Time series for macroeconomic aggregates of unified Germany are available since 1991. As we are interested in long-term growth trends over a period of at least 15 years, this leaves us with an insufficient number of observations to formulate meaningful results. In order to extend our sample, we rely on data from the former FRG for the period from 1970 to 1990. As a result, our sample describes the evolution of key German macroeconomic variables as a combination of their respective evolution in the FRG until 1990 and their further development in unified Germany from 1991 to 2019. We exclude the year 2020 to avoid the distorting effects of the COVID-19 pandemic.

For the two sub-periods surrounding German reunification, the Federal Statistical Office of Germany has published detailed national accounts figures on a two-digit level, comprising 63 sectors. These figures include gross value added (GVA), the total number of employees representing labor input, capital, and labor compensation. The two sub-periods both include the year 1991, theoretically allowing for the combination of both data sources. Unfortunately, the raw datasets do, however, not adhere to the same classification standards. Although the systematization is comparable, there is one notable difference given by the information and communication sector. Data on this sector was specifically sampled only after the change in classification standards and is hence only included for the post-reunification period. For the former FGR, it has to be calculated from the raw data. To do so, we start by dividing the “old” sectors (according to the classification of the sub-period covering the FGR data) based on employment shares. Second, we either add up the values to the newly created sector (e.g., nominal value added) or apply share-weighted Divisia indices. To ensure conformity with classification standards in both data sources, we combine the 1991 post-reunification levels with the pre-reunification growth rates. This preserves the historical dynamics while updating the levels. However, the focus is on the exact growth rates rather than the exact

levels. The provided data presents macroeconomic information for Germany and its sectors from 1970 to 2019.

One of our main objectives is to compare the results for Germany with those of Foerster *et al.* (2022) for the US. This comparison is ensured by collapsing the German raw data to their sectoral definitions. We end up with 15 sectors that make up the German private economy, excluding all government and non-market activities.<sup>1</sup> Unlike Foerster *et al.* (2022), we do not possess data to construct a housing sector, hence the German FIRE aggregate (financial, insurance and real estate) includes it. This difference is important to keep in mind when comparing our quantitative results with the US case.

**Calculation of Total Factor Productivity.** Sectoral TFP growth is defined as the Solow residual of a Cobb-Douglas-type production function, where all firms operate under constant returns to scale and perfect competition. According to Hulten (1978), the aggregate private-economy TFP is then simply the sum of sectoral TFP weighted by the means of their value added shares. The availability of a long time series for Germany comes at the price that TFP can only be extracted from a much smaller pool of data. Compared to the EU KLEMS data we cannot distinguish between labor services (e.g., different qualification levels) and capital services (e.g., different types of assets) but have to use the sheer number of employees and a standard measure for capital instead.<sup>2</sup> However, both aggregate TFP series are highly correlated for the period from 1996 to 2019 (correlation coefficient: 0.97); some remarks on this issue can be found in the Supplementary Material.

A more recent strand of the literature is concerned with the (mis-)measurement of TFP, for example, due to business cycle effects. Existing studies mostly argue that standard TFP measures not only capture technological improvements but are also influenced by the degree of factor utilization. More recent measures—either called factor-utilized or purified TFP—extend standard TFP estimates to include a variable that captures the degree of factor utilization. In the case of Basu *et al.* (2006) and Fernald (2014) this variable is growth in hours per worker. Other studies use survey-based capacity utilization measures instead (see Christofzik *et al.*, 2021; Comin *et al.*, 2023). The common feature of the German measures is that the series only begin in the mid-1990s, thus, making them too short for our purposes. However, we believe that TFP (mis-)measurement is not a major issue in our case for two reasons. First, we adjust our TFP estimates for short-run fluctuations, which is described in the next section. Second, since we are interested in the long-run movements of the series, these should not be strongly influenced by business cycle movements as long as we capture enough phases of upswings and downswings in economic activity. For this reason, we apply

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<sup>1</sup>The Supplementary Material provides further information on the data, together with some computational issues and sectoral aggregation.

<sup>2</sup>Unfortunately, the calculation or estimation of total hours worked is only available for Germany since 1991. Before 1991, only the number of persons employed is available from the national accounts. Thus, our approach captures only the extensive margin of labor supply and ignores the intensive margin.

an 11-year centered moving average to both our TFP growth estimates and those of Comin *et al.* (2023). If we interpret this moving average as the slow moving component or trend of the series, then both series show a downward sloping behavior from the early 2000s to the mid-2010s. This observation gives us confidence that our approach grasps the underlying long-run dynamics of the German economy quite well.

**Cyclical adjustment.** The raw annual growth rates of GDP, labor input and TFP are quite volatile over time. A significant part of this variation can be attributed to rather short-lived business cycle fluctuations. To focus on the long-run variability of our time series, we eliminate these short-run fluctuations by using an Okun’s law-type regression following Fernald *et al.* (2017) and Foerster *et al.* (2022). The cyclically adjusted series are defined as the residuals after regressing the series’ annual growth rates on contemporary changes in the unemployment rate as well as both one lag and one lead. It could be argued that the unemployment rate is not a sufficient indicator for capturing the variability associated with the overall German business cycle, given that Germany has undertaken some fundamental labor market reforms in the mid-2000s and its job market is much more regulated compared to that of the US. To address concerns regarding the cyclical adjustment using the unemployment rate, we conducted a full additional analysis using one of the most important survey-based leading indicators for the German economy, the Ifo Business Climate Index, as instrument.<sup>3</sup> The emerging results are discussed in the robustness section.

## 2.2 Facts on German Long-run Economic Development since 1970

The dynamics of cyclically adjusted German GDP growth from 1971 to 2019 are shown in Figure 2. GDP is measured as the share-weighted (chain-weighting) value added growth from 15 sectors comprising the German private-sector economy. To visually analyze the potential impact of structural changes in the German economy on GDP growth, we calculate hypothetical growth rates using three sets of fixed sectoral shares: the average from 1970 to 1979, the average from 2010 to 2019, and the average over the full sample period. We apply a similar procedure to labor and TFP growth, using the same time periods. Based on the raw but cyclically adjusted data (left column in Figure 2), it appears that structural shifts have primarily impacted labor growth, as the differences for GDP and TFP are not that pronounced. Structural changes tend to occur gradually, and their effects become more apparent in long-term fluctuations.

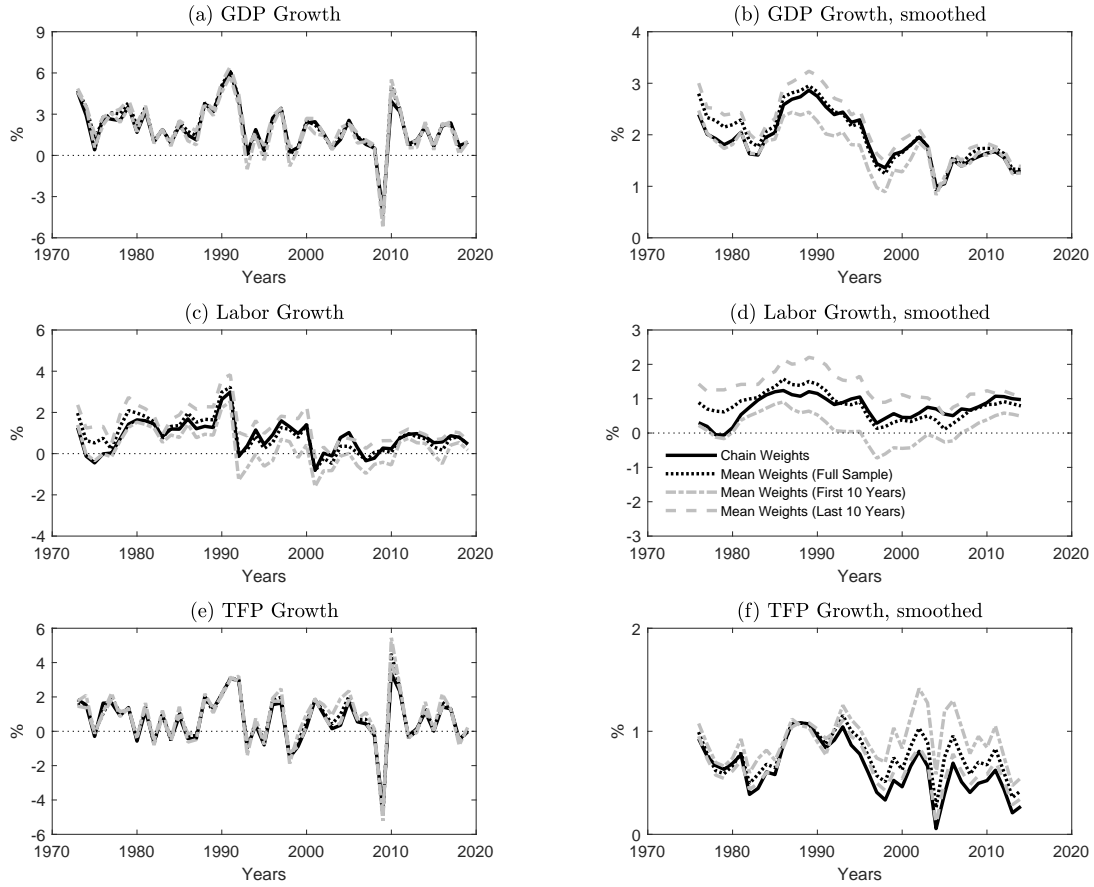
The right column of figure 2 therefore shows smoothed annual growth rates using an 11-year centered moving average. It is clear that the long-term growth patterns of all three aggregates may be due not only to inter-sectoral changes but also, to a large extent, to shifts

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<sup>3</sup>The Ifo Business Climate is regarded as one of the most important leading indicators for German GDP growth, is listed on Bloomberg’s “12 Global Economic Indicators to Watch”, and has proven to be useful in business cycle dating as well as in nowcasting economic aggregates (Lehmann, 2023).



**Figure 2:** Annual Growth Rates of GDP and Input Factors 1971 to 2019



*Notes:* The figure shows cyclical adjusted annual growth rates which are share-weighted averages from 15 sectors making up private-sector economic activity in Germany. Smoothed values represent 11-year centered moving averages. The weighting scheme is either based on official national accounting standards (chain-weighting) or on constant share-averages of three different (sub-)periods.

between sectors reflecting structural change. This is a remarkable difference to the US case as argued by Foerster *et al.* (2022). They claim that it is mainly changes within sectors that affect aggregate growth trajectories. For now, we apply mean weights over the full sample. However, we discuss the influences of different weights in the robustness section.

Panel (b) clearly indicates the slowdown of GDP growth in the long run as it was also reported by Reif (2022). This picture is reflected in the growth rates of cyclically adjusted GDP averaged over different sub-periods (see Section. Smoothed GDP growth fell to two percent in the late 1970s and early 1980s before rising to approximately three percent around German reunification. After the brief reunification boom, long-term GDP growth fell rapidly over the 1990s, reaching a trough shortly before the new century. After recovering in the early 2000s, smoothed GDP growth declined sharply in the mid-2000s, most likely as a result of the financial crisis. Over the past decade, long-term growth rates have stabilized at around one and a half percent.

Unraveling long-term GDP development into both labor input and TFP growth reveals interesting patterns in the German economy. Panels (d) and (f) spotlight the 11-year centered

moving averages for these two input factors. After the low levels of labor growth rates in the late 1990s and the early 2000s, the mid-2000s marked the reversal of declining labor input growth. In Panel (d), the long-term growth trend can be observed to increase after the turn of the twenty-first century. As Burda and Seele (2020) elucidate, labor input in the 15 years between 2003 and 2018 grew sustainably by 19.3% (or 7.3 million employees), resulting in employment levels last seen before reunification.<sup>4</sup> This development, often referred to as the “German labor market miracle”, was however accompanied by unspectacular GDP growth. Further, TFP growth over the same period unfolded only disappointingly and volatile. This slowdown in TFP growth is not a German-specific issue, but rather a global phenomena since the mid-2000s. In contrast to the labor market miracle, Hutter and Weber (2021) refer to it as the “productivity debacle”. The German TFP slowdown is a particularly interesting case, which, as Christofzik *et al.* (2021) state, does not only reflect the US slowdown in productivity. They identify two domestic factors explaining the decline. First, they find the structural shift from the highly productive manufacturing to the service sector to have a restraining effect on productivity. Second, they underline that technology advancements in information and communications technologies have lead to higher output and employment. Elstner *et al.* (2022), however, find persistent technology spillovers from producers of information and communication technology to intensive users of these inputs in the mid-2000s, thus, enhancing TFP.

To comprehend these advancements, we follow the methodology of Foerster *et al.* (2022) and trace the aggregate declines back to sectoral factors, thereby expanding on the existing research for Germany (for example, Reif, 2022). Additionally, we aim to compare our findings to the results of Foerster *et al.* (2022) for the US while attempting to link significant sectoral developments to key events in Germany’s recent economic history. Due to significant structural differences between the two economies, we suspect that sectoral drivers have a prominent influence, outstanding particularly in terms of their intensity. The German economy is characterized by its above-average share in manufacturing compared to many other industrialized countries. In 2021, service activities accounted for almost 70% of market-traded nominal gross value added in Germany, while manufacturing accounted for more than 22%. Constituting 80% of the US private economy, services dominate the sectoral mix in the US even more, manufacturing only contributes 12%. German manufacturing is characterized by medium- and high-level sectors such as automotive production, chemicals and machinery and equipment. It has a high degree of trade specialization (“export champion”).<sup>5</sup> Most of the firms are owner-managed small- and medium-sized enterprises (SME), defining the group of the German “Mittelstand”. This group is widely regarded as primary

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<sup>4</sup>This growth in employment is unique compared to any other OECD country over that period, which, on average, grew by about 5% (Burda and Seele, 2020).

<sup>5</sup>The degree of trade openness is quite different between the German and the US economy. Whereas the sum of exports and imports expressed in terms of GDP was approximately 89% in Germany in 2021, the US, instead, had a foreign trade quota of 25% in the same year.

driver of innovation and is considered to be quite crisis resistant (Berleemann *et al.*, 2022). A significant number of those firms are “Hidden Champions”, world leaders in small product niches. The US economy on the other hand specializes in knowledge-intensive services and high-tech manufacturing, such as biotechnology. Although the share of total manufacturing is smaller than in Germany, high-tech manufacturing is considerably bigger in the US. An important contributor to US growth and competitiveness is the significant start-up and spin-off scene, mainly operating in the information and software business. These firms are primarily responsible for innovations in the US. The Global Innovation Index of the World Intellectual Property Organization ranks the United States on the second place among 48 high-income economies in 2022, while Germany is ranked on the eighth place. Compared to the US, Germany has, however, almost twice as many global market-relevant patents per million inhabitants according to the German Ministry for Education and Research. Investments in future technologies are conducted by different actors in the two countries, mirroring the respective economic structure. In Germany, most spending on research and development (R&D) activities is conducted in the medium high-technology sectors (automobiles, machine building, chemicals), while R&D expenditures for cutting-edge technologies such as in the ICT sector, where most of the US R&D spending takes place, are rather small. Further, the R&D share of the service sector is considerably higher in the US than in Germany (see Hommes *et al.*, 2011; Gehrke and Schasse, 2011). Finally, as European economies in general are considerably less digitized compared to their US counterpart: US firms show a superior use of IT in many industries according to Bloom *et al.* (2012).

The future development of labor input and innovation capacities, and therefore TFP growth, is heavily influenced by demographic trends. Currently, the German population is significantly older than the US population. In 2021, 22.2% of Germans were older than 65 years, compared to 16.8% in the US. The effects of an aging labor force will therefore manifest themselves earlier in the German economy. Further, the German labor market is still in the process of structural change, shifting from manufacturing to services. For instance, the sectoral choice of new labor market participants differs compared to previous generations and reentering employment often coincides with a change in sectors (Dauth *et al.*, 2017).

The shift from manufacturing to services is not only reflected in labor input, but also in GVA dynamics. Comparing the average historical growth rates, we observe large variations across the 15 sectors, which are ultimately suppressed when looking at aggregates (see Table 1). Labor input growth varied greatly, ranging from -4.7% in mining to 3.9% in public and business services (PBS). In line with the structural shift, the service sector experienced growth in labor input above the average rate, while negative average labor input growth can be observed for Non-Durable Goods, Construction, and Durable Goods. Overall, TFP and labor input growth do not seem to be highly connected. Variation in TFP growth across sectors is considerably lower, ranging from -1.2% in Arts, Entertainment, and Accommodation to 3.6% in Information and Communication. Similar to the US, we notice negative TFP

growth rates in the disaggregated data for Germany. As Foerster *et al.* (2022) explain, this well-known issue is likely due to measurement errors in output. Average real GVA growth ranges from a strong average decline in Mining (-2.7%) to a strong increase in Information and Communication (5.5%). Total GDP growth was primarily driven by service sectors growing above average rates.

**Table 1:** Average Annual Growth and Industry Shares in Germany from 1973 to 2019

Sector	Average Growth (in %)			Average Share (in %)	
	GVA	L	TFP	L	TFP
Agriculture	0.7	-2.6	2.9	3.5	1.6
Mining	-2.7	-4.7	1.7	0.7	0.8
Utilities	2.0	0.4	0.5	1.5	3.1
Construction	-0.4	-0.3	-0.1	8.1	6.4
Durable Goods	1.9	-0.3	1.7	17.0	19.0
Non-Durable Goods	1.2	-1.0	1.7	8.4	8.7
Wholesale Trade	2.5	0.2	1.9	5.4	4.8
Retail Trade	2.1	0.9	0.8	10.0	6.0
Transp. & Wareh.	2.1	0.8	0.7	5.6	4.9
Inform. & Commun.	5.5	1.5	3.6	2.8	4.1
FIRE	2.3	1.0	0.2	4.1	14.9
PBS	3.6	3.9	0.1	8.5	9.2
Educ. & Health	2.0	2.6	-0.6	14.9	10.8
Arts, Entert. & Accom.	1.1	2.4	-1.2	4.6	2.8
Misc.	1.3	1.8	-0.8	5.0	2.8
Aggregate	2.0	0.9	0.8	100	100

*Notes:* The table shows average annual growth rates for each of the 15 sectors considered and three macroeconomic indicators: gross value added (GVA), labor input (L) and total factor productivity (TFP). The row labeled 'Aggregate' is the chain-weighted average of the 15 sectors representing market-traded economic activity in Germany.

In contrast to the US, where according to Foerster *et al.* (2022) labor as an input factor for production has over the years on average declined only in Agriculture, in Germany it has over the years also lost importance as input factor in, for example, Construction and Durable Goods. Further, it is interesting to observe that the average labor shares of the service sectors are mostly higher in Germany than in the US.

### 3 Sectoral Trend Growth in TFP and Labor

We start by presenting the methodology to extract a series' low-frequency movements and apply it to both sectoral labor and TFP growth in Germany. Together with the description of sectoral trends since the 1970s, we classify remarkable developments into German economic history and compare them to the US. The trends for Germany are then plugged into a

factor model to decompose trend growth rates into common forces influencing all sectors and idiosyncratic forces that can be interpreted as sector-specific developments.

### 3.1 Low-Frequency Movements by Sector

**Trend extraction.** For the extraction of low-frequency movements in GDP, labor input and TFP, we follow the empirical framework of Foerster *et al.* (2022), who apply a method formerly introduced by Müller and Watson (2008). Their method produces smooth trend estimates that are fitted values from OLS-based regressions for each aggregate separately.<sup>6</sup> In these OLS regressions, the slow moving components in the time series are approximated by a constant term and  $q$  low-frequency cosine functions,  $\Psi_j(s) = \sqrt{2}\cos(js\pi)$ , with a period equalling  $2/j$ . With  $s = (t - 1/2)/T$ ,  $j = 1, \dots, q$  and  $t = 1, \dots, T$ , the fitted values from the regression represent slow moving components of the time series longer than  $2T/q$ . Our sample for Germany runs—after the cyclical adjustment—from 1973 to 2019, thus, the total number of observations is  $T = 47$ . With  $q = 6$  we capture long-run movements with periodicities longer than 15.7 ( $= 2 \times 47/6$ ) years. As the filtering of trends is also influenced by the preceding adjustment of short- and medium-run fluctuations, the cyclical adjustment becomes even more valuable. We work with these smooth trends in the following and answer the question how industrial developments influence the aggregate GDP trend.

**Trend growth in Germany.** Germany has undergone several economic policy and structural changes in the last five decades. Our sample start coincides with a new episode in German economic history: in March 1973, Germany left the Bretton Woods system and allowed the German Mark to float freely. Furthermore, the prospering years of the German economic miracle after World War II ended with the first oil crisis in October 1973. This crisis revealed the lack of Keynesian demand management as economic policy. Fiscal policy, instead, had then been the central instrument of the government in shaping the future German economic development. With the economic downturn following the oil crisis, unemployment rose sharply and immigrant working schemes were stopped abruptly. To evaluate the impact of such major events, Figure 3 highlights both the sector-specific labor (purple line) and TFP (green line) trend growth rates over the last five decades. The two trend growth rates appear to be negatively correlated within sectors.<sup>7</sup>

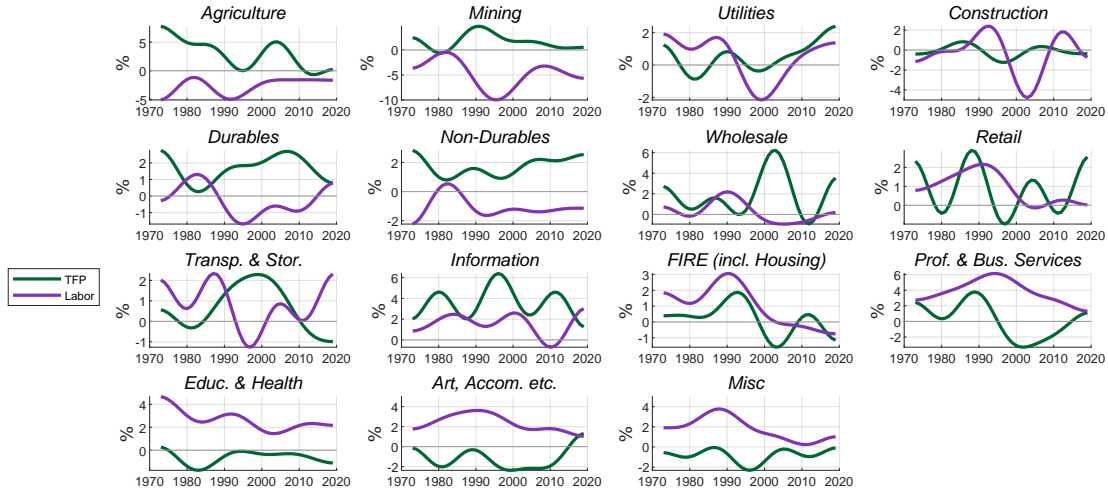
We note that labor input in Agriculture and Mining has constantly been decreasing, while the majority of the service sectors, such as PBS and Education and Health, recorded only increases. This development coincides with Germany’s late start of the shift from an industrial towards a service economy, also underlined by the steady declines observed

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<sup>6</sup>Müller and Watson (2020) provide a very detailed discussion on the low-frequency extraction method applied here. We hence refer the reader to this important contribution. Some methodological details are, however, presented in the Supplementary Material.

<sup>7</sup>The Supplementary Material holds two figures for labor and TFP growth each, showing the cyclical adjusted series together with the trend rates.

**Figure 3:** Sectoral Labor and TFP Trend Growth in Germany



Notes: Each panel shows the low-frequency movements in labor (purple) and TFP (green) growth by sector.

in both the Durables and Non-Durables sector. With a majority of employees working in services rather than in manufacturing only in 1975, structural change evolved only slowly.<sup>8</sup> Interpreted as a timeline, we can infer episodes of German economic history from the sectoral trends plotted in Figure 3: The rise in labor input trends from the 1970s to the early 1980s can be interpreted as a structural recovery after the oil crises. Interestingly, we also note that the rise in the long-term trend growth of labor as an input factor peaked in many service sectors in the beginning of the 1990s. This might be attributable to reunification acting like a supply shock to the German labor market, as the German workforce increased by several million people overnight: Due to run-down production facilities, firms in the former GDR were operating under non-competitive productivity levels. This resulted in a substantial wave of firm and plant closures after reunification, leading to the migration of many workers from East to West. Around the turn of the millennium, a labor market malaise due to high unit labor costs lead to Germany being identified as the “sick man of Europe”. In response, the Social-Democrat lead government reformed the labor market with the so called Agenda 2010. The following “German labor market miracle” can be deduced by noting the recoveries of labor trend growth rates following the early 2000s in several sectors, for example, in Transportation. Notably, the labor trend growth rates do not appear to be heavily impacted by the Great Recession.

Comparing the sectors’ labor growth trends, we note their uniqueness. While, for example, Arts and Accommodation shows a rather stable development of labor trend growth, Construction exhibits a very lively trend development instead. This heterogeneous evolution of the sectors’ labor trends observed in Figure 3 suggest that next to common factors

<sup>8</sup>In the US, the share of employees in the service industry was already higher than the share of employees in manufacturing in 1950, in 1970 only around 30% of employees worked in the industrial sector—in Germany this share concurrently still amounted to 45% according to the Federal Agency for Civic Education.

affecting all sectors without exception, sector-specific developments dominate labor trend growth. Characterizing the two forces governing the evolution of a sectors' labor trend growth, common factors are represented by historic events such as the oil crisis mentioned above. Sector-specific factors driving labor trend growth are, for example, represented by the introduction of labor productivity augmenting a sectors' technology.

We also observe large sectoral differences for the evolution of TFP trend growth rates. Over the last decades, both the Durables and Non-Durables sector registered steady positive TFP increases. In Construction and Retail trade on the other hand, TFP trend growth fluctuated around zero. Interestingly, trend TFP growth decreased in the second half of our sample in both FIRE and PBS, whereas we observe a steady and large increase in Information and Communication as well as in Durables. This might reflect the adoption of new technologies such as the internet, the change to business models relying on E-Commerce, and the advancing digitization of the German economy. Overall, we observe more variation in the cyclical adjusted TFP growth rates across sectors than for the labor growth rates.

**Comparison to US developments.** We again put the spotlight on the comparison between Germany and the US. Therefore, Table 2 introduces the coefficients of variation in labor and TFP trend growth, which is defined as the ratio between the standard deviation and the mean of a series.<sup>9</sup> Some remarkable differences stand out. The trends in Construction look quite different across the two states, with a significant higher volatility in Germany. This might be attributable to the huge construction crises between 1995 and 2005: The short construction boom due to housing construction and huge infrastructure renovation projects after reunification led to large over-capacities in the construction sector, which, as governmental support stopped in 1995, resulted in numerous bankruptcies among construction firms. The consequences were severe structural problems until the beginning of the 2000s. The year 2005 generally applied as the year in which German construction returned back on a rather stable growth path.

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<sup>9</sup>The Supplementary Material also shows the coefficients of variation for the US when using the same period as for the German analysis.

**Table 2:** Coefficient of Variation for Sectoral Trends in Labor and TFP

Sector	Labor		TFP	
	Germany	US	Germany	US
Agriculture	-0.5	-1.4	0.8	0.6
Mining	-0.6	9.3	0.9	13.7
Utilities	3.2	1.1	1.8	-3.6
Construction	-5.6	0.9	-4.3	-8.7
Durable Goods	-3.4	3.8	0.5	1.0
Non-Durable Goods	-0.6	15.6	0.4	2.2
Wholesale Trade	4.0	0.5	1.0	0.6
Retail Trade	0.9	0.7	1.4	1.3
Transp. & Wareh.	1.3	1.3	1.6	0.9
Inform. & Commun.	0.6	1.1	0.4	1.2
FIRE <sup>†</sup>	1.3	0.5	5.3	-26.7
PBS	0.4	0.4	20.7	3.7
Educ. & Health	0.3	0.2	-0.8	-3.5
Arts, Entert. & Accom.	0.3	0.5	-0.8	2.2
Misc.	0.6	2.6	-0.7	1.8

*Notes:* The table compares the coefficients of variation for sectoral trends in labor and TFP across Germany and the US. FIRE includes housing in the German case, but not for the US (†). Furthermore, the time period under investigation for Germany runs from 1973 to 2019 and for the US from 1950 to 2018. A comparison of equal time periods across both states can be found in the Supplementary Material. The coefficients of variation for the US are calculated from Foerster *et al.* (2022).

Another major difference is observed for Mining, which can be explained by structural changes in the Ruhr and Lausitz areas due to several closures of mines (for example, hard coal) over the past decades. Further, the declining long-term labor growth trends in Durables and Non-Durables compared to the increases in the sectors constituting the tertiary sector again emphasize the ongoing “late” structural shift from an industrial towards a service economy. For Non-Durables and Durables, the volatility of TFP trend growth is found to be considerably lower in Germany than in the US. Further, TFP trend growth in PBS is shown to have performed highly volatile in Germany over our sample period. In the following, we aim to study the effects of sectoral differences on aggregate trend GDP growth.

### 3.2 Common and Sector-Specific Trend Components

**Factor model.** Although the trend variation across sectors highlights several sector-specific developments over the past decades, studying the trend variations closely also reveals time periods when sectoral trend movements did not significantly diverge. In addition, labor and TFP trend growth appear to be (mostly negatively) correlated in sectors as, for example, PBS or Non-Durable Goods. To adequately capture these features, we apply the factor



model from Foerster *et al.* (2022),

$$\begin{bmatrix} \Delta \ln l_{j,t} \\ \Delta \ln z_{j,t} \end{bmatrix} = \begin{bmatrix} \lambda_j^l & 0 \\ 0 & \lambda_j^z \end{bmatrix} \begin{bmatrix} f_t^l \\ f_t^z \end{bmatrix} + \begin{bmatrix} u_{j,t}^l \\ u_{j,t}^z \end{bmatrix}, \quad (1)$$

with which we aspire to separate the sector-specific disturbances ( $u_{j,t}^l, u_{j,t}^z$ ) as well as the unobserved factors ( $f_t^l, f_t^z$ ) together with the factor loadings ( $\lambda_j^l, \lambda_j^z$ ) from observed labor and TFP growth ( $\Delta \ln l_{j,t}, \Delta \ln z_{j,t}$ ). Following Foerster *et al.* (2022), we can find a factor model representation in terms of the estimated low-frequency trends from the previous section. This representation can be estimated to uncover the common components ( $g_{f,t}^l, g_{f,t}^z$ ) and the sector-specific components ( $g_{u,j,t}^l, g_{u,j,t}^z$ ) from the labor input and TFP trend growth rates.

The term “common component” hereby denotes a broad development affecting all sectors, although possibly to varying degrees. To illustrate the characteristics of both components, consider again the case of labor input: Common factors here might—next to historic events—include changes in labor force participation among women and older generations or changes in the education level of the workforce. Sector-specific factors instead only affect the given industry, possibly including the shifting needs of worker characteristics. For the TFP trends, common factors could materialize due to the introduction of general purpose technologies (GPT) such as computers or other information and communication technologies (ICT). A main advantage of the factor model is its representation to include lags of one or more decades, thus, it captures the time delay needed for GPTs to affect productivity growth (see Basu *et al.*, 2003). For the German case, Elstner *et al.* (2022) find pronounced TFP spillovers arising from the ICT producing industry that also need time to materialize. The factor model—and here especially the common factors—is suitable to detect such a form of technology diffusion. As argued previously, the trend extraction is based on  $q = 6$  observations, thus, the estimation is a ‘small sample’ problem. We apply Bayesian methods for estimation. Details on the factor model together with the chosen priors can be found in the Supplementary Material.

**Component decomposition.** Table 3 summarizes the factor decomposition for labor input and TFP in Germany, together with a comparison to their US equivalents.<sup>10</sup> The fraction in trend variability that is described by common factors is marked by  $R_l^2$  for labor input and  $R_z^2$  for TFP, respectively. The correlation between sector-specific trends in labor and TFP is labeled by  $\rho(l, z)$ ; for the aggregate, this correlation represents the connection between the common trends of both inputs. What stands out is the similarity in aggregate trend growth

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<sup>10</sup>The German trends apply to the period between 1973 and 2019 while the US trends are estimated for the time period between 1950 and 2018. Further, the German trends describe low-frequency movements for more than 15 years compared to more than 17 years in the US case. Comparisons with US trends estimated for a more comparable time period (1973 to 2018) and hence an almost identical frequency as the German ones are presented in the Supplementary Material. Overall, we note only small differences across the different estimations for the US case.

explained by common factors across Germany and the US. Two-third of aggregate labor trend growth (0.68) and one-third of aggregate TFP trend growth (0.30) can be explained by common trend movements.

Looking more closely at the sectoral level, we yet observe several significant differences across industries and countries which are suppressed when only looking at aggregates: We find that in Germany, particularly the service sectors' labor trend growth rates are to a large extent explained by common factors (for example,  $R_l^2 = 0.84$  for Arts, Entertainment etc.). Again, this presents an illustration of the ongoing shift towards a service-oriented economy. While this pattern is also present in the US, it is considerably less pronounced compared to the German case (see, for example, the differences in trade or the remaining service sectors). On the opposite, labor trend growth in the German secondary sector is driven by sector-specific rather than common movements. For the German Durable Goods industry, the common trend explains 9% of historical labor trend growth. Another pronounced difference between the two countries is remarked by the extent of the common trend explaining labor trend growth in the Construction sector. Turning to TFP, the industrial influence of common trends is rather low. However, we observe some exceptions, for example, Construction (40%) or the Non-Durable Goods industry (27%). For exactly those two sectors we also find remarkable differences to the US, where common trends do not seem to play any role at all (2% and 4%).

Moving on to the correlations between sector-specific labor and TFP trend growth, we can partially confirm the pattern of negative connections as observed across the Atlantic. Overall, we find a slightly negative correlation between aggregate input factors for Germany (-0.08), however it is found to be more pronounced in the US (-0.29). Again, the heterogeneity across sectors and countries is remarkable. We find the largest negative correlations for PBS (-0.88) and Retail trade (-0.84). While this pattern is also true for PBS in the US, sector-specific labor and TFP trend growth do not seem to be connected in US Retail trade (0.06). The opposite holds true for Construction, with a slightly positive correlation for Germany (0.09) and a negative one for the US (-0.25).

The previous figures are averages over the whole sample. Given the degree in low-frequency variability over time, we proceed to analyze how strong the influence of common trends varied over the last five decades. For aggregate labor input and TFP, Figure 4 shows the low-frequency trends and their historical decomposition into common and industry-specific components. We observe—comparable to the US—that the aggregate labour trend is well explained by common factors, peculiarly since the mid-2000s. Sector-specific movements continuously played a supporting role. The picture for TFP is not that unambiguous: Until the 1990s, its trend is well explained by sector-specific movements and supported by common factors. Between the mid-1990s and the new century, we observe a clear divergence of the sector-specific and the common trend. Since the beginning of the twenty-first century, the aggregate TFP trend appears to be dominated by the movement of common forces—

**Table 3:** Factor Decomposition of Labor and TFP Trend Growth

Sector	Germany			US		
	$R_l^2$	$R_z^2$	$\rho(l, z)$	$R_l^2$	$R_z^2$	$\rho(l, z)$
Agriculture	0.05	0.02	0.04	0.21	0.02	-0.32
Mining	0.03	0.05	-0.65	0.01	0.01	-0.35
Utilities	0.10	0.07	0.24	0.24	0.05	0.22
Construction	0.18	0.40	0.09	0.33	0.02	-0.25
Durable Goods	0.09	0.15	-0.73	0.03	0.03	-0.35
Non-Durable Goods	0.04	0.27	-0.66	0.06	0.04	-0.36
Wholesale Trade	0.88	0.02	-0.09	0.53	0.04	0.20
Retail Trade	0.94	0.21	-0.84	0.26	0.05	0.06
Transp. & Wareh.	0.13	0.06	-0.36	0.05	0.06	0.06
Inform. & Commun.	0.14	0.02	-0.18	0.22	0.03	-0.25
FIRE <sup>†</sup>	0.75	0.02	0.23	0.76	0.08	0.01
PBS	0.56	0.01	-0.88	0.64	0.06	-0.92
Educ. & Health	0.25	0.04	0.31	0.16	0.10	-0.63
Arts, Entert. & Accom.	0.84	0.03	-0.77	0.37	0.05	-0.18
Misc.	0.80	0.80	0.32	0.06	0.02	-0.07
Housing	—	—	—	0.01	0.10	0.07
Aggregate	0.68	0.30	-0.08	0.67	0.30	-0.29

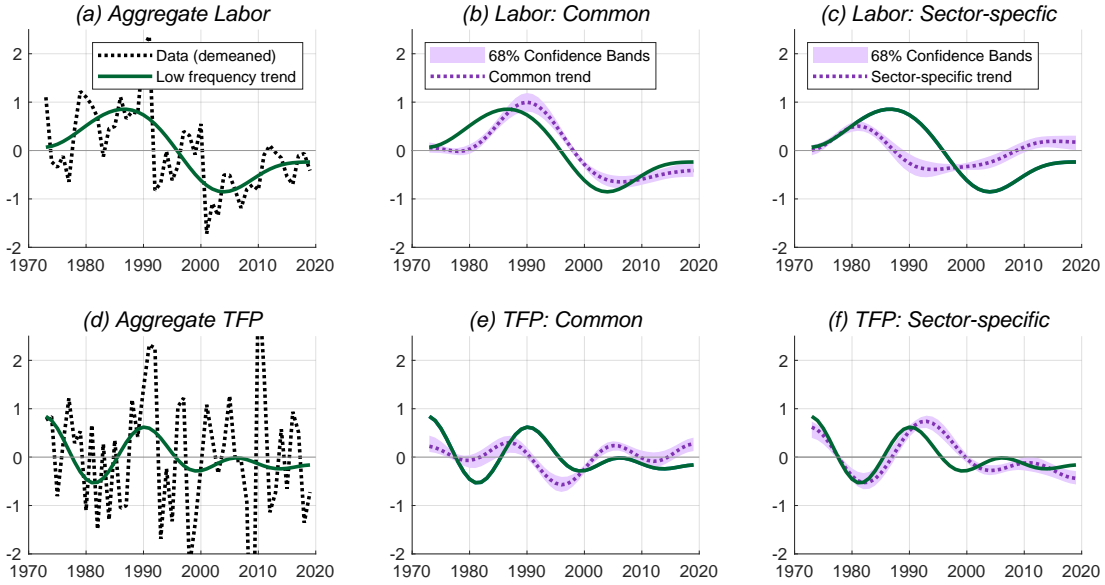
*Notes:* The table presents the fraction in trend variation explained by common factors for both labor input ( $R_l^2$ ) and TFP ( $R_z^2$ ) as well as the correlation between sector-specific trends in labor and TFP,  $\rho(l, z)$ . For the aggregate,  $\rho(l, z)$  corresponds to the correlation between common trends. FIRE includes housing in the German case, but not for the US (†). Furthermore, the time period under investigation for Germany runs from 1973 to 2019 and for the US from 1950 to 2018. A comparison of equal time periods across both states can be found in the Supplementary Material. The values for the US are extracted from Foerster *et al.* (2022).

increasingly so in the recent years.

Seen in comparison to the US, the low-frequency aggregate labor trend has been catching up in Germany again since the mid-2000s. While the German labor trend growth rates are still weak, they slightly exceed the current low-frequency labour trend growth rates in the US, which had also been catching up until the financial crisis but then worsened. Focussing on TFP trend growth, we note that the US has experienced a steep decline of the respective aggregate low-frequency trend during the 2000s followed by a slow recovery after 2010. In Germany, the decrease of TFP trend growth evolved more gradually: German TFP trend growth rates expanded already in the 1990s with rates only below average. In the two subsequent decades, German TFP trend growth has been moving sideways. In both countries, the aggregate trend growth rate of TFP is currently upsurging. Again, in the Supplementary Material, the reader can find the low-frequency trends of the input factors for the US with exactly the same model specification over a similar period as in the German case. From there, we observe that while labour—as in the longer sample—is mostly determined by common movements, the picture for TFP is slightly different: common factors seem to play a more important role in total.

Going deeper, we proceed by analyzing the trend growth rates jointly with the sector-

**Figure 4:** Historical Decomposition of Aggregate Labor and TFP Trend Growth for Germany



*Notes:* Panels (a) and (d) show the raw labor and TFP growth rates as deviations from their sample means (demeaned, dotted black lines), together with the estimated low-frequency trends (green lines). The other panels show the trends' decomposition into common and sector-specific components, separately shown as purple dotted lines. While the dotted lines denote the posterior median, the shaded areas are equally-tailed 68% credible intervals.

specific part of the trend for each of the sectors; the corresponding figures can be found in the Supplementary Material. In line with our results for the industrial  $R^2$  values from Table 3, we observe that sector-specific variation in TFP trends is, on average, less aligned with the total trend in Germany than this is the case in the US. Further, labor trends are also in Germany more determined by common forces: Especially for service-orientated sectors, the sector-specific trend behaves very different from the aggregate trend. A good example underlining the latter is Retail trade. While the sector's overall trend is even almost equal to the US one, its sector-specific component diverges considerably from the overall trend. Notably, in Germany the long-term labor trends in the secondary sector of the economy, especially in Durables and Non-Durables, are even more explained by the respective sector-specific trends than in the US. In both countries, we observe a strict divergence of the sector-specific and the overall labor trend after 2000 for FIRE and PBS. We further highlight that particularly in the sectors in which the labor long-run trends are well explained by sector-specific forces—which is the case for the industrial sector (Durables and Non-Durables)—TFP trend growth is mainly driven by common forces. In this context we again also point to the high negative correlation between the input factors in several sectors, such as in Durables and Non-Durables as well as in Wholesale trade.

As explained by Foerster *et al.* (2022), we cannot trace a sectors' influence on the overall trend growth rate of GDP by simply comparing shares in value added or labor. Instead, aggregate importance depends on the type of goods or services supplied by the specific sector and its position in the inter-sectoral production network. Sectors acting as crucial suppliers

for other sectors (for example, investment goods) can have a large influences on aggregate trends, even if their share in value added or labor is rather small. In the following, we discuss the production network of the German economy and quantify sectoral multipliers depending on the production linkages between sectors.

## 4 Production Linkages and Sectoral Multipliers

The differences in sectoral growth rates have implications for long-term GDP growth. Sectors are highly interconnected due to production linkages and capital investments, which amplifies sector-specific growth for the aggregate. This implies that a change in, for example, the growth rate of TFP in Durable Goods does not only affect the sector’s own value-added growth but also the value-added growth of other sectors having invested capital in the latter. Such amplification effects for aggregate growth can be quantified by sectoral multipliers composed of the direct effect (the sector’s share in value added) as well as the indirect effect, the multiplier arising from the production network. The magnitude of the multiplier is governed by the importance of a given sector as a supplier of capital and/or material for other sectors. An extensive description of the derivation of the sectoral multipliers central to the following analysis of our quantitative findings can be found in Foerster *et al.* (2022). Referring the reader to the latter and its very useful appendix for details, we limit the characterization of the multi-sectoral growth model to the essential mechanisms. We, however, closely describe the construction of a capital flow table for Germany, which was not available before.

### 4.1 Theoretical Considerations

**Multi-sector growth model.** To adequately account for production linkages and their meaning for long-run growth dynamics, we adopt the multi-sector growth model from Foerster *et al.* (2022). The model is characterized by two sources of inter-sectoral connections: linkages via (i) material inputs and (ii) capital goods. Gross output,  $y_{j,t}$ , of sector  $j$  at time  $t$  is—according to standard national accounts identities—composed by gross value added,  $v_{j,t}$ , and aggregated materials used for production,  $m_{j,t}$ . Both inputs are used according to the following technology:

$$y_{j,t} = \left( \frac{v_{j,t}}{\gamma_j} \right)^{\gamma_j} \left( \frac{m_{j,t}}{1 - \gamma_j} \right)^{(1-\gamma_j)}, \text{ with } \gamma_j \in [0, 1]. \quad (2)$$

The aggregate material input of each sector,  $m_{j,t}$ , captures material purchased by sector  $j$  from all sectors  $n$  representing the economy (including its own intra-sectoral linkages). The technology behind the material aggregate is given by:

$$m_{j,t} = \prod_{i=1}^n \left( \frac{m_{ij,t}}{\phi_{ij}} \right)^{\phi_{ij}}, \text{ with } \sum_{i=1}^n \phi_{ij} = 1 \text{ and } \phi_{ij} \geq 0. \quad (3)$$

Material linkages across sectors are captured by a standard  $n \times n$  Input-Output (IO) matrix,  $\Phi$ , with  $\phi_{ij}$  being the typical output coefficient. In Section 4.2, the German IO data is introduced in detail.

Sectoral gross value added,  $v_{j,t}$ , is produced with labor input,  $l_{j,t}$ , and capital,  $k_{j,t}$ , following a Cobb-Douglas-type production function of the form:

$$v_{j,t} = z_{j,t} \left( \frac{k_{j,t}}{\alpha_j} \right)^{\alpha_j} \left( \frac{l_{j,t}}{1 - \alpha_j} \right)^{(1 - \alpha_j)}, \text{ with } \alpha_j \in [0, 1]. \quad (4)$$

Capital accumulation is captured by the standard Perpetual Inventory Method: Tomorrow's capital stock,  $k_{j,t+1}$ , equals the sum of today's capital stock after depreciation,  $(1 - \delta_j)k_{j,t}$ , and today's investment in new capital,  $x_{j,t}$ . With  $x_{ij,t}$  denoting the quantity of investment or capital goods from sector  $i$ , the investment aggregate mirrors the technology of the material aggregate:

$$x_{j,t} = \prod_{i=1}^n \left( \frac{x_{ij,t}}{\omega_{ij}} \right)^{\omega_{ij}}, \text{ with } \sum_{i=1}^n \omega_{ij} = 1 \text{ and } \omega_{ij} \geq 0. \quad (5)$$

Capital goods originating in external sectors can be of central importance for a sector's production. Hence, in addition to materials, capital embodies a second source of inter-sectoral linkages. As it has been demonstrated by vom Lehn and Winberry (2022), capital linkages across sectors constitute a main mechanism of business cycle movement propagation in the US. This idea is adopted and transferred to long-run dynamics in Foerster *et al.* (2022). The capital linkages are captured in the  $n \times n$  capital flow matrix,  $\Omega$ , with  $\omega_{ij}$  referring to the coefficient capturing each sector's importance as capital good supplier. We again refer to Section 4.2, where we present a new data source to approximate this capital flow matrix for Germany.

Market clearing takes place under the resource constraint  $y_{j,t} = c_{j,t} + \sum_{i=1}^n m_{ji,t} + \sum_{i=1}^n x_{ji,t}$  with  $c_{j,t}$  denoting the quantity of a representative household's consumption expenditure for a good produced in sector  $j$ . The household's aggregate consumption bundle is defined as  $C_t = \prod_{j=1}^n \left( \frac{c_{j,t}}{\theta_j} \right)^{\theta_j}$ . Sectoral labor input and TFP are assumed to be exogenous, thus, we can reformulate gross value added as  $v_{j,t} = A_{j,t} (k_{j,t}/\alpha_j)^{\alpha_j}$ , where  $A_{j,t} = z_{j,t} (l_{j,t}/(1 - \alpha_j))^{(1 - \alpha_j)}$  represents a composite variable capturing both inputs. Sectoral change is approximated by the development of this composite variable over time:

$$\Delta \ln A_{j,t} = \Delta \ln z_{j,t} + (1 - \alpha_j) \Delta \ln l_{j,t}. \quad (6)$$

Using the theoretical foundations laid out above to account for sectoral linkages, we proceed by examining how the sectoral changes in labor input and TFP observed in Section

3 have impacted German aggregate trend GDP growth. In this context, it is important to remember that a change in one sector does not only affect that sector's contribution to aggregate growth but via its position in the production network also the output of all remaining sectors.

**Balanced growth path and sectoral multipliers.** We now derive the steady-state behavior of the economy's variables. Along a balanced growth path (BGP), labor input and TFP grow with constant and exogenous rates,  $g_j^l$  and  $g_j^z$ , respectively. According to Equation (6), the composite variable,  $A_{j,t}$ , therefore evolves according to

$$\Delta \ln A_{j,t} = g_j^a = g_j^z + (1 - \alpha_j)g_j^l. \quad (7)$$

As suggested before, changes in a sectoral input growth rate of labor or TFP result not only in output changes in the respective sector: Due to the production network a change in one sector indirectly also influences value added in other sectors. Depending on its importance as material or capital goods supplier to others, a sector's multiplier can further exceed its share in value added.

To pin down the sectoral multipliers, we need to focus on the development of the economic variables along the BGP. Given the exogenous growth rates for labor and TFP, sectoral gross output,  $y_{j,t}$ , and its usages ( $c_{j,t}$ ,  $m_{ji,t}$ , and  $x_{ji,t}$ ) will grow by the same sector-specific rate defined as  $g_j^y$ . According to Equation (3), sectoral material input growth then reads as  $g_j^m = \sum_i \phi_{ij} g_i^y$ , such that  $g^m = \Phi' g^y$  holds. For sectoral capital accumulation and investment a similar outcome emerges:  $g_j^k = g_j^x = \sum_i \omega_{ij} g_i^y$  and  $g^k = \Omega' g^y$ . The gross output rate—according to Equation (2) with  $\Gamma_d = \text{diag}\{\gamma_j\}$ —has the following form:  $g^y = \Gamma_d g^v + (I - \Gamma_d)g^m$ , with gross value added evolving as  $g^v = g^a + \alpha_d g^k$  and  $\alpha_d = \text{diag}\{\alpha_j\}$ . Reducing all terms to gross output yields  $g^y = \Gamma_d g^a + \Gamma_d \alpha_d \Omega' g^y + (I - \Gamma_d)\Phi' g^y$ , hence gross output can be expressed in the compact form

$$g^y = \Xi' g^a. \quad (8)$$

In this equation,  $\Xi' = [I - \Gamma_d \alpha_d \Omega' - (I - \Gamma_d)\Phi']^{-1} \Gamma_d$  represents what Foerster *et al.* (2022) call the “generalized Leontieff inverse” capturing both material and capital linkages. Finally, gross value added growth,  $g^v$ , can be expressed as:

$$g^v = g^a + \alpha_d g^k = g^a + \alpha_d \Omega' g^y = g^a + \alpha_d \Omega' \Xi' g^a = [I + \alpha_d \Omega' \Xi'] g^a. \quad (9)$$

The value added expression is divided into a direct and an indirect effect. The first term,  $I g^a$ , denotes the direct effect, it entails how sectoral gross value added is affected by own changes in labor input and TFP. The indirect effect is given by the second term,  $\alpha_d \Omega' \Xi' g^a$ , which captures all network effects within the economy, stemming either from material or capital linkages.

As a last step, we want to quantify the influence of the sectoral linkages on total GDP growth. To do so, we rely on the Divisa index for GDP, which is according to accounting standards simply given by the product of sectoral gross value added,  $g^v$ , and constant sectoral shares in GDP,  $s^v$ :

$$g^V = s^{v'} g^v = s^{v'} [I + \alpha_d \Omega' \Xi'] g^a. \quad (10)$$

As in Foerster *et al.* (2022), the vector of *sectoral multiplier* is the first derivation of  $g^V$  with respect to the composite variable  $g^a$ :  $\partial g^V / \partial g^a = s^v + \Xi \Omega \alpha_d s^v$ . Thus, a sectoral change in the composite variable *directly* effects GDP growth by a sector's value added share and *indirectly* via production linkages across the economy.

## 4.2 German Production Network

**Data source.** The data underlying our estimated sectoral multipliers stem from both official (material linkages) and non-official (capital flow matrix) sources. Material linkages are extracted from the IO tables provided by the Federal Statistical Office of Germany. Tables for unified Germany are currently available for the years 1991 to 2020. For the baseline estimation, the results of which are compared to those of Foerster *et al.* (2022), we apply the IO-coefficients of 2018,  $\{\phi_{ij}^{2018}\}$ . They entail the share of materials flowing from sector  $j$  to sector  $i$  for production and can easily be extracted from the IO table published by official sources. The German IO tables also capture data on gross output and labor compensation. For consistency reasons, we hence use this information to calculate both the sectoral value added share in total sectoral expenditures ( $\gamma_j$ ) and the sectoral labor share ( $1 - \alpha_j$ ). The value added shares to calculate the sectoral multiplier for GDP growth,  $s^v$ , are taken from national accounts.

Quantifying the German investment network and the corresponding coefficients,  $\{\omega_{ij}\}$ , is more difficult, as, to the best of our knowledge, no capital flow table is published by the Federal Statistical Office of Germany. We therefore combine two non-official sources to estimate the first German capital flow matrix: the ifo Investment Database and the INTAN-Invest Database. The ifo Investment Database (IIDB) provides annual investment data for 12 investment assets in 50 German sectors from 1991 to 2018; the data can be accessed via the LMU-ifo Economics & Business Data Center (IIDB, 2018). A detailed description of the IIDB can be found in Strobel *et al.* (2013). It is consistent with national accounts' investment figures published by the Federal Statistical Office of Germany and provides estimates of the volume that companies in a certain sector invest in the respective investment assets. To comply with the 15 sectors defined earlier to constitute the German private economy, we aggregate the IIDB sectors to match them accordingly. Further, except for intangible assets, we assign the investment assets to their corresponding sectors, namely Durables, Construction, and the Information sector.



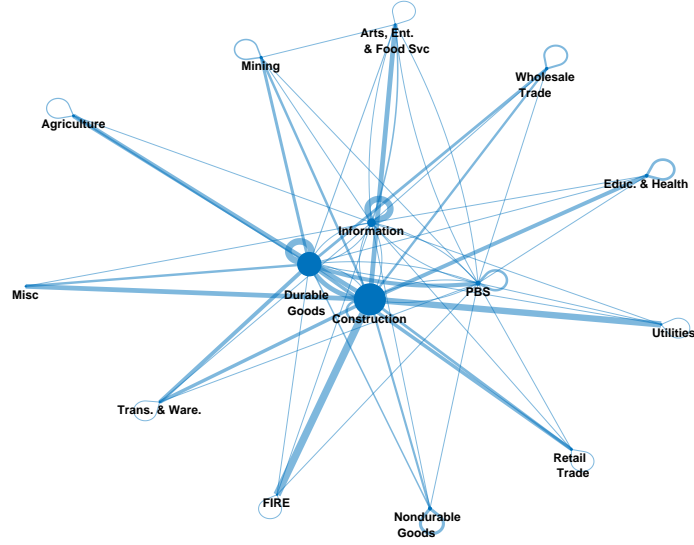
An issue arising from the category of intangible assets is that we are not able to deduct from the IIDB in which sector the investment good has been produced. We solve this issue by relying on the INTAN-Invest Database, a research collaboration dedicated to improve the measurement and analysis of intangible assets. It provides data on intangible investment by sector beginning in 1995 and allows us to distribute a sector’s intangible capital expenditures onto sectors producing intangible assets. We use data from the latest release covering the year 2018. Again, also with the INTAN-Invest data, we start by aggregating sectors to have data on intangible asset investment and production of our 15 previously defined sectors. With the database, we can differentiate the broad category of intangible assets into 10 subcategories, which we assign back to sectors producing that type of intangible capital (see the Supplementary Material for more details). A first exploration of the data shows that intangible investment doubled in, for example, the Information as well as Durables sector in the last almost thirty years, and even tripled in case of PBS.

We end up with time-varying IO-coefficients for the years 1991 to 2020 and capital flow matrices between 1995 and 2018. Particularly the latter is an additional source of information compared to Foerster *et al.* (2022), who can only rely on a capital flow table for 1997. It allows us to deepen the analysis of German sectoral multipliers by observing dynamic developments following significant changes within the German production network. Before discussing those dynamics in Section 5, we first compare our baseline results to Foerster *et al.* (2022) by fixing the coefficients to the year 2018 in the baseline case. We first present the latest German investment network based on the resulting capital flow matrix, followed by the corresponding sectoral multipliers.

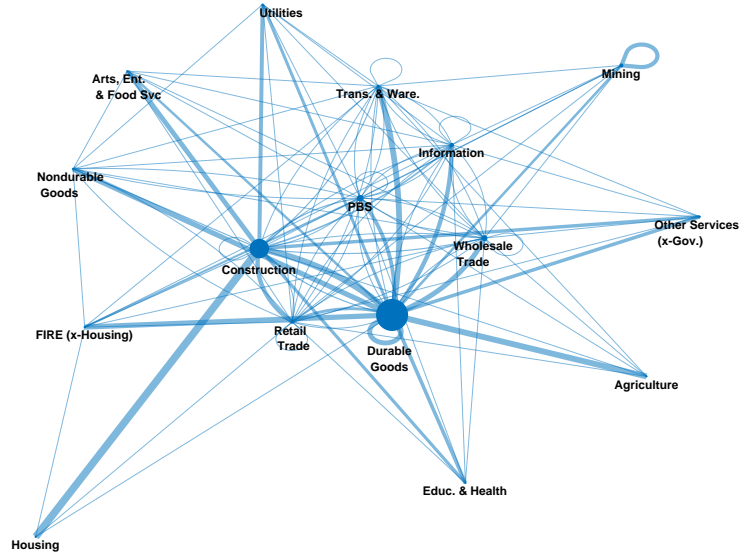
**Investment network.** Panel (a) of Figure 5 shows the German investment network for the year 2018. It highlights the importance of the German construction sector as an investment good supplier to the German economy: on average, all sectors receive the largest share of their capital goods from construction, which is indicated by the size of its node. Compared to the 1997 investment network of the US in panel (b), the Durable Goods sector is only the second largest capital hub in the German economy. Overall, as in the US, the production of investment goods in Germany is concentrated in relatively few sectors. Furthermore, a significant fraction of intangible capital is developed in firms directly and hence used by the producing sector itself. This is indicated by the circles surrounding the nodes. The circle for the German Durable Goods sector is much thicker than its US counterpart, which we explain by the high specialization of German manufacturing in automotive production. Vehicles are used by most other (manufacturing) sectors as investment goods. Interesting is the significant role of the Information and Communications sector, which also produces a lot of intangible capital that it then uses itself. Further, the edge between construction and FIRE stands out, which can be traced back to the housing sector. We also observe a similar linkage between construction and housing in the US.

**Figure 5:** Investment Networks for Germany and the United States

(a) German Investment Network 2018



(b) US Investment Network 1997



*Notes:* The figures show the investment networks for both the German and the US economy based on its corresponding capital flow matrix. Nodes represent sectors and edges express the strength of capital flows between sectors. The larger a node is, the more important is a sector as capital producer for other sectors. The thickness of an edge marks the strength of bi-directional capital flows between or within sectors compared to all other sectors.

### 4.3 Sectoral Multipliers

As mentioned before, for our baseline setup we fix the year 2018 as a representative for both the IO and the capital matrix. This allows us to compare the sectoral multipliers for Germany with those of the US as found by Foerster *et al.* (2022). To be more precise: we apply constant matrices for the year 2018 and constant mean value added shares over the entire sample period. In case of the US, the IO table is from 2015 and the capital flow matrix from 1997; the value added shares are, as in our case, average shares over the

entire sample period. Table 4 compares resulting sectoral multipliers for TFP.<sup>11</sup> Overall, we observe three main sectoral differences between both economies. First, and probably the most pronounced difference, is that the German construction sector reveals to have a much larger multiplier (0.26) than the US construction sector (0.17). This is mainly driven by the indirect effects (0.20 vs. 0.12), that is, the sector’s importance as capital goods supplier within the economy. The multiplier for construction is four (three) times higher than its value added share in Germany (the US) and therefore heavily influences overall trend GDP growth, given the negative trend rates in labor input and TFP growth from Figure 3.

**Table 4:** Sectoral Multipliers in TFP for Germany and the United States

Sector	Germany			United States		
	direct	indirect	total	direct	indirect	total
Agriculture	0.02	0.01	0.02	0.03	0.01	0.03
Mining	0.01	0.01	0.02	0.02	0.03	0.05
Utilities	0.03	0.01	0.04	0.02	0.01	0.03
Construction	0.06	0.20	0.26	0.05	0.12	0.17
Durable Goods	0.19	0.21	0.40	0.13	0.28	0.41
Non-Durable Goods	0.09	0.03	0.12	0.09	0.03	0.13
Wholesale Trade	0.05	0.05	0.09	0.07	0.08	0.15
Retail Trade	0.06	0.01	0.07	0.08	0.02	0.10
Transp. & Wareh.	0.05	0.02	0.07	0.04	0.03	0.07
Inform & Commun.	0.04	0.04	0.08	0.05	0.03	0.08
FIRE <sup>†</sup>	0.15	0.06	0.20	0.10	0.04	0.14
PBS	0.09	0.09	0.19	0.09	0.15	0.24
Educ. & Health	0.11	0.01	0.11	0.06	0.00	0.06
Arts, Entert. & Accom.	0.03	0.01	0.03	0.04	0.01	0.04
Misc.	0.03	0.00	0.03	0.03	0.01	0.04
Housing	—	—	—	0.09	0.00	0.09

*Notes:* The table presents the sectoral multipliers for Germany and the United States. The direct effect equals the sectors’ value added shares ( $s^v$ ). The indirect effect captures both the sector’s importance as material supplier in the IO environment and as capital goods supplier in the investment network ( $\Xi\Omega\alpha_d s^v$ ). For Germany, both the IO table and the capital flow matrix from the year 2018 are applied. In case of the US, the IO table is from 2015 and the capital flow matrix from 1997. FIRE includes housing in the German case, but not for the US (†). Furthermore, the time period under investigation for Germany runs from 1973 to 2019 and for the US from 1950 to 2018. The values for the US are extracted from Foerster *et al.* (2022).

Second, the Durable Goods sector exhibits a sectoral multiplier that is almost equal for both economies. However, the composition varies heavily. Whereas the sector’s value added share is—with almost one fifth—higher in Germany than in the US, the opposite holds true for the indirect effect. This might be an expression for the heterogeneity in the economies’ specialization. The Durable Goods’ multiplier exceed two (Germany) to three (US) times their value added share in total GDP. Overall, the Durable Goods sector has positive effects on German trend GDP growth as we have observed positive but diminishing rates in TFP.

Third, the influence of PBS is much more pronounced in the US. Especially the indirect

<sup>11</sup>The Supplementary Material holds additionally the comparison of the sectoral multipliers for labor input.

effect of the sectoral multiplier is higher. This might again indicate that the structural change of the German economy towards a service-oriented one is still ongoing whereas it has already further progressed and is almost completed in the US economy. Still, the multiplier for German PBS is two times higher than its overall value added share. According to Figure 3, PBS should hence also have contributed positively to trend GDP growth.

We find further minor differences. The multipliers for Mining and Wholesale Trade are higher in the US. Underlying the former might be the diminishing importance of mining activities especially in the German Ruhr and Lausitz area where numerous mines have been closed during the last decades. Today, Germany imports the majority of its required raw materials (for example, natural gas and rare-earth metals). The US, instead, is the second largest producer of rare-earth metals after China and also an exporter of many other raw materials. Furthermore, the multiplier for the German Education & Health sector is twice as high as in the US, which is mainly driven by the raw value added share. Internationally compared, the German health sector is rather large in size. This is attributable to a high density of both doctors and hospital beds as well as the demographics of the German population. Given the negative employment trend growth in Education & Health since the turn of the millennium, this sector has most likely contributed negatively to trend GDP growth over the last decades.

#### 4.4 Contributions to Trend GDP Growth

Having estimated the common and sector-specific trend components and derived the sectoral multipliers, we continue by combining the two. Bringing together trend components and multipliers allows us to calculate a decomposition of trend GDP growth by means of sectoral trend labor input and TFP growth. Recall that along the balanced growth path value added growth evolves as:  $g^v = [I + \alpha_d \Omega' \Xi'] g^a$ . As we are exclusively interested in long-run movements, we approximate them by our sectoral trend estimates for labor input ( $g_{j,t}^l$ ) and TFP growth ( $g_{j,t}^z$ ). Value added can hence be expressed as:  $g_t^v = [I + \alpha_d \Omega' \Xi'] (g_t^z + (I - \alpha_d) g_t^l)$ . Our aim is to quantify the contribution of both common factors and sector-specific developments to the long-run movements. To be able to do so, we restate sectoral value added using the factor model introduced in Section 3.2 as:

$$g_t^v = [I + \alpha_d \Omega' \Xi'] \left( \lambda^z g_{f,t}^z + g_{u,t}^z + (I - \alpha_d) \left( \lambda^l g_{f,t}^l + g_{u,t}^l \right) \right). \quad (11)$$

The BGP of value added is characterized by the common components in labor input and TFP growth ( $g_{f,t}^l, g_{f,t}^z$ ), the vectors of factor loadings ( $\lambda^l, \lambda^z$ ), and the sector-specific components ( $g_{u,t}^l, g_{u,t}^z$ ). Model-implied GDP growth can then be written as:  $g_t^V = s^{v'} g_t^v$ . We first show the sector-specific components, followed by a discussion on average sector contributions for two sample sub-periods. Third, we present model-implied trend GDP growth. Finally, we discuss the decomposition of trend GDP growth by means of common factors and sector-

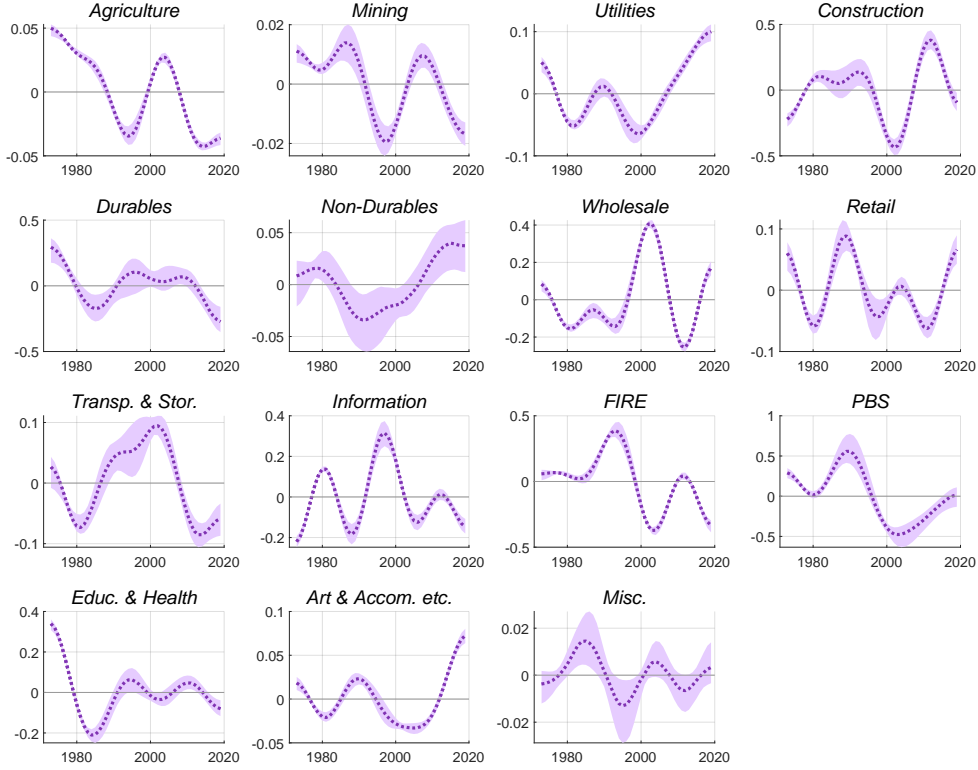
specific developments. All following results are based on constant multipliers from the year 2018. As we are able to apply time-varying multipliers, we discuss their impact in Section 5.

Figure 6 shows the year-by-year sector-specific trend contributions to aggregate GDP growth. In short, it shows the combination of labor input and TFP trend growth according to the respective sectoral multipliers. Obviously, no sector steadily contributed with a positive or negative sign to trend GDP growth. However, there is a tendency towards negative contributions of Durables, FIRE, PBS, and Education & Health. Rather positive contributions can be observed for Non-Durables, Information, Utilities, Wholesale, and Construction. The Supplementary Material contains a table with the average contributions for several sub-periods and the total period under investigation. Given the sectoral value added shares, the heterogeneity in the contributions' magnitude is very interesting. Small sectors such as Construction, Wholesale and Information contributed in a similar way to trend GDP growth—expressed by the y-axes' magnitudes—as large sectors. Further, although we have referred to the ongoing structural shift in the German economy, we do not observe major positive contributions of the service sectors to trend GDP growth.

In the next step, we evaluate how much the sectors contribute to the change in trend GDP growth between 1973 and 2019. German trend GDP growth decreased by approximately **2.3** percentage points in the last five decades. The largest negative contribution of 0.72 percentage points comes entirely from the trend TFP growth decline in the Durables sector (see Table 5). Another -0.30 percentage points stem from the negative TFP development in FIRE and PBS. Also the TFP decline in Education & Health contributes negatively (-0.19 percentage points) to the decline in total trend GDP growth between 1973 and 2019; a negative contribution of trend labor input (-0.27 percentage points) further increases the overall negative impact of Education & Health. Remarkable positive contributions only stem from increases in labor input. The negative TFP effect observed for Durables is, on average, reduced by a positive contribution of labor input growth (0.25 percentage points). The same holds true for the sector Information & Communication with a positive contribution in trend labor input growth of 0.13 percentage points.

The decade following reunification mark a special period for Germany. Trend GDP growth faced a strong decline in the 1990s (-1.7 percentage points), which is especially characterized by a far-reaching transformation of the construction sector. In the following, we zoom into this period. Table 5 lists both the labor input and TFP contributions of all sectors to that decline. What stands out is the large impact from PBS: With a contribution of -1.40 percentage points from its decline in TFP growth, it accounts for more than half of the decline in German trend GDP growth over that decade. FIRE added another half percentage point to the 1990s decline. Notably is further the impact of the decline in labor input in the Construction sector (-0.63 percentage points). Between 1991 and 2000, only the Durables and the Wholesale trade sector acted as stabilizers: Their individual TFP trend growth as well as their importance in the production network resulted in the two sectors

**Figure 6:** Sector-Specific Contributions to the Trend Growth Rate of GDP (percentage points at an annual rate)



*Notes:* Each panel shows the implications of sector specific trends for the trend growth rate of GDP using the model-based multipliers. The solid lines denote the posterior median and the shaded areas are (pointwise) equal-tail 68% credible intervals

contributing positively to aggregate GDP trend growth. While the differences resulting from the multipliers used in the model—baseline year 2018 or the average multiplier over the decade—are small overall, they are pronounced for the impact of the labor trend growth of the construction sector. Its negative contribution to the overall decline is significantly higher using the average multipliers, which indicates the decline of the sector’s importance as capital and materials provider over the decades. The opposite is true for PBS: Using the average multiplier results in a smaller contribution than applying the baseline multiplier. This might hence indicate that the importance of PBS as an investment good supplier has grown over the years. Using specific annual multipliers therefore seems to be of overall importance, particularly when focusing on a specific time period. We discuss this issue in the next section.

Figure 7 compares the low-frequency movement in German GDP growth (green line), calculated in Section 3, with the trend implied from the balanced growth multipliers (dotted purple line) and the direct effect’s contribution to the trend (dashed blue line), which is based

**Table 5:** Sectoral Contributions to the Decline in German Trend GDP Growth

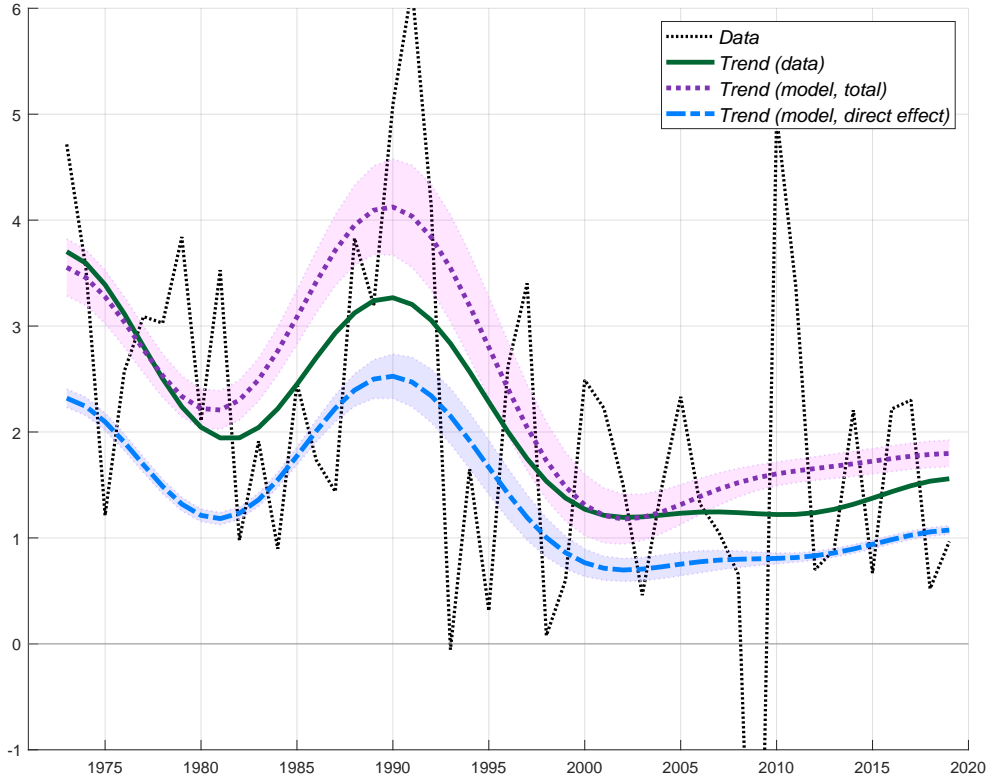
Sector	1973–2019		1991–2000	
	Labor	TFP	Labor	TFP
Agriculture	0.01	-0.10	0.01	0.02
Mining	-0.01	-0.02	0.00	0.03
Utilities	-0.01	0.05	-0.05	-0.05
Construction	0.05	0.01	-0.63	-0.14
Durable Goods	0.25	-0.72	0.01	0.15
Non-Durable Goods	0.06	-0.02	0.02	-0.02
Wholesale Trade	-0.03	0.08	-0.16	0.44
Retail Trade	-0.04	0.01	-0.08	-0.13
Transp. & Wareh.	0.01	-0.11	-0.07	0.05
Inform. & Commun.	0.13	-0.08	0.07	0.11
FIRE <sup>†</sup>	-0.10	-0.31	-0.10	-0.51
PBS	-0.20	-0.29	-0.11	-1.40
Educ. & Health	-0.27	-0.19	-0.15	0.00
Arts, Entert. & Accom.	-0.02	0.06	-0.04	-0.07
Misc.	-0.01	0.01	-0.02	-0.01

*Notes:* The table shows the sector-specific contributions (in percentage points) of trend labor input and TFP growth to trend GDP growth for two separate time periods. The calculation of contributions are based on constant sectoral multipliers for the year 2018.

on the sectoral value added shares. The bands around both model-implied trend components mark the estimations' standard deviations resulting from time-varying IO as well as capital matrices and value added shares. As the total multipliers' bands are significantly more pronounced, we suspect the additional indirect effects stemming from sectoral inter-linkages to be the major contributor to the variation in the total multipliers over the years. Overall, long-term GDP trend growth declined by about 2% over the entire period. The pronounced gap between the trend estimated using the direct multiplier only and the trend arising using the balanced growth path multiplier underlines that accounting for intersectoral linkages is crucial to not underestimate the long-term trend growth rate. Our model including indirect effects tends to estimate higher trend growth rates than the ones retrieved directly from the data in the period around reunification. We suggest that a periodicity of 15 years might not perfectly grab the special dynamics in capital accumulation and the renewal of the Eastern German capital stock in the 1990s. Similarly, accounting for network effects results in slightly higher long term GDP growth rates from 2005 onwards. If we apply time-varying weights and thus account for structural change over the years, the model-implied trend growth rate comes even closer to the estimated low-frequency movement (see the Supplementary Material for more information).

Finally, we discuss the decomposition of the model-implied trend GDP growth rate into its components derived from common factors and sector-specific developments (see Figure 8). The model indicates that sector-specific or unique factors in trend labor input and TFP

**Figure 7:** Estimated and Multiplier-implied Trend Growth in GDP



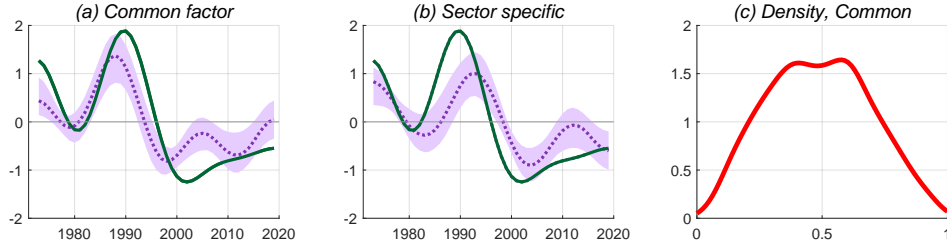
*Notes:* The figure shows the cyclically adjusted GDP growth rate (thin dashed black line) and its estimated low-frequency trend (thick green line). The dashed purple line marks the multiplier-implied trend growth rate along the balanced growth path. The dashed blue line, instead, presents the trend growth rate based on the value added shares, or direct effects, only. These lines represent the baseline case and are calculated from the 2018 IO as well as capital flow matrices and constant value added shares, respectively. The shaded areas mark the one standard deviation bands from estimates based on either time-varying IO and capital flow matrices or non-constant value added shares.

growth (panel (b)) have historically accounted for roughly 1/2 of the long-run changes in German GDP growth. Hence, the remaining half of the variation of trend GDP growth since 1973 has been arising from common factors of input growth (panel (a)). Panel (c) shows the posterior for the fraction of the variance explained by common factors. This stands in contrast to the finding in Section 3, where common factors explaining roughly 2/3 of the variation in the trend growth rate of aggregate labor. The main reason is that sectors with high multipliers like Construction or PBS experience large trend growth variation over the period. These trends are almost entirely driven by idiosyncratic factors.

Our results for Germany are quite different to those found by Foerster *et al.* (2022) for the US. There, 3/4 of US trend variation is explained by sector-specific developments. We suggest that the main drivers are the delayed structural change in Germany and the significant impact of reunification. We, however, note that the common factor can almost entirely explain the rise of German trend GDP growth over 1980s. Further, the slowdown of German trend GDP growth since the mid 1990s is driven by two opposite forces: While sector-specific developments contributed positively to aggregate trend GDP growth until the turn of the century, common factors drove the decline. For the following decades, we further observe



**Figure 8:** Decomposition of the Trend Growth Rate in GDP



*Notes:* Panels (a) and (b) show the (demeaned) model-implied trend GDP growth (green line) together with the changes stemming from common factors and sector-specific developments (red lines), respectively.

that the contributions by common factors and sector-specific developments are moving in opposite directions. In the next section, we elaborate more on the robustness of these results.

## 5 Discussion

In this section, we present the outcome of a bunch of robustness checks that underpin our baseline results. Furthermore, we discuss the impact of structural change on the sectoral multiplier as our new data sources allow for time-varying analyses. The section closes with some implications of our results for future German trend GDP growth, which is heavily influenced by changing demographic conditions.

### 5.1 Robustness Checks

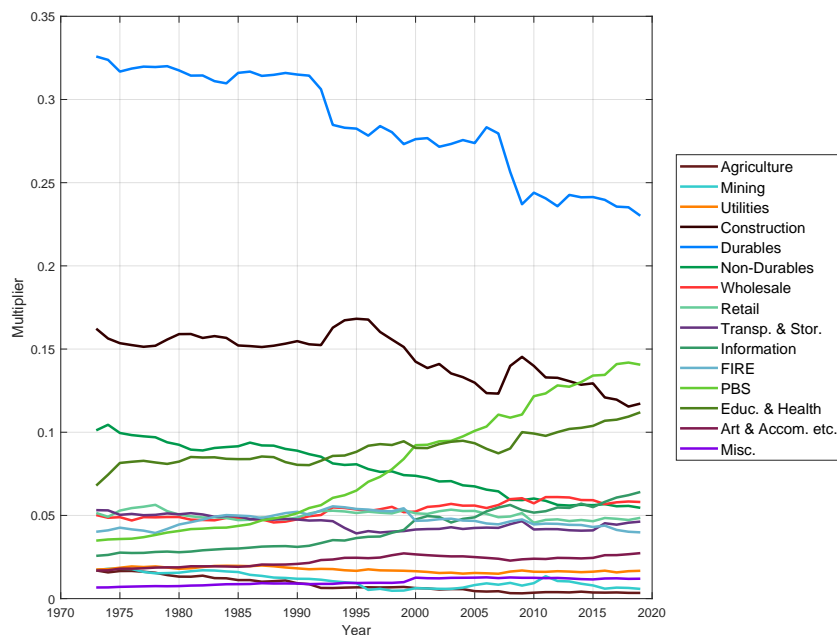
The results of this robustness check confirm the findings obtained from the data adjusted with the unemployment rate, albeit with some differences in magnitude. Therefore, we interpret the results obtained from the unemployment rate-adjusted data as the upper bound and the results obtained from the ifo Business Climate-adjusted data as the lower bound for the low frequency trends. The results utilizing the ifo Business Climate for cyclical adjustment can be found in the Supplementary Material. The rationale for presenting the results using the unemployment rate to adjust for business cycle fluctuations in the main paper is also explained in detail there.

### 5.2 Discussion: Structural Changes in the German Economy

While Foerster *et al.* (2022) claim their multipliers to be robust to varying the IO table and share in value added, we note differences in the German multipliers depending on the tables and shares used. The volatile nature of the multipliers is illustrated by the evolution of the sectoral multipliers in TFP and labor over our estimation period, depicted in Figure

10 and Figure 9. They show the value of the respective sectoral multiplier for each year the corresponding capital flow table, input-output table and share in value added. All variation in the multipliers before 1991 results uniquely from the different sectoral shares in value added. For both input factors we observe ambivalent trends in the evolution of the multipliers. Examining Figure 9, we note that while changes to the labor supply in the Durables sector continue to have the biggest multiplier effect, it has a negative trend: it declined from around 0.33 at the start of our sample to 0.24 in 2019. Further, we can identify two significant drops, the first happening in the early 1990s - most likely related to reunification. The second drop between 2007 and 2009 might be heavily influenced by the change in the WZ categories in 2008. We further observe the significant influence the aftermath of reunification had for the importance of the construction sector in the German economy. Showing a constant multiplier of around 0.15 until 1992, the construction boom following reunification rose its importance as labor input supplier in the German production network, but only for a limited time. Peaking in 1996, the labor construction multiplier follows a declining trend over the following years, reaching about 0.12 in 2019. Another sector registering a decline in its labor multiplier is the Non-Durables sector. On the other hand, we can observe a constant rise of the labor multipliers in several service sectors: the PBS multiplier quadrupled between 1973 and 2019, surpassing the construction multiplier in 2017. Further, the labor input of the Education and Health sector has become considerably more important for long-run aggregate GDP variation over the past years. Another labor multiplier showing an increasing trend over our sample is found for the Information center. The remaining sectors display rather constant labor multipliers.

**Figure 9:** Evolution of Labor Multiplier

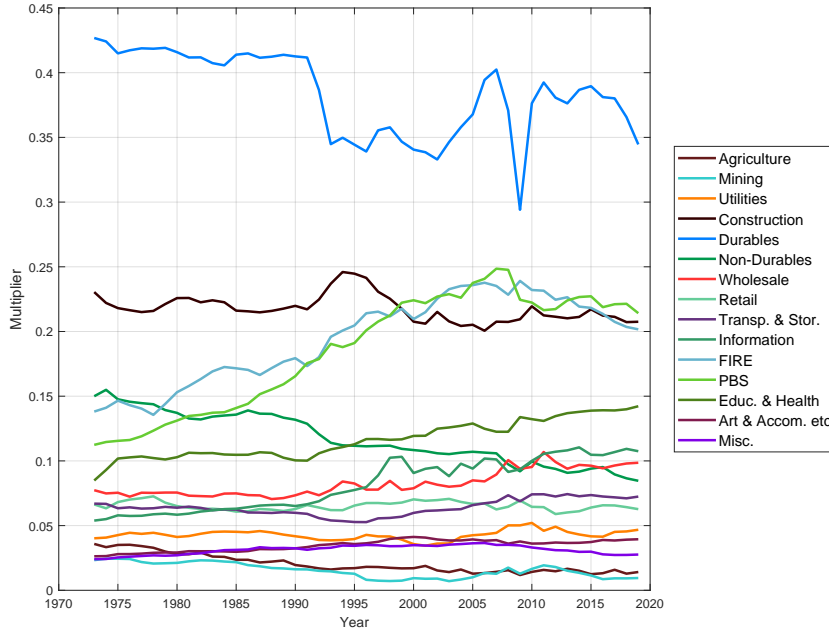


Focusing on the TFP multipliers next, we note an overall increasing trend in the multipliers of many service-related sectors. While the multipliers for FIRE and PBS however already have started reverting following the Great Recession, the TFP multiplier of the Education and Health sector has been increasing until 2019. On the contrary, as for labor, also the TFP multipliers for the industrial sectors (Durables and Non-Durables) have experienced substantial decreases over the past decades. However, with a TFP multiplier of almost 0.35, a change to TFP input in 2019 still sparked the highest potential for altering the long-run aggregate GDP movement. Notable for the Durables sector is the drop in 2009: Although the change in the WZ categories in 2008 might already account for some of the drop in the multiplier between 2007 and 2010, however the large outlier in 2009 might be driven by the financial crisis, which hit the export based German manufacturing industry considerably and hence shows to have also influenced the sector's role as a materials/capital goods producer to other sector. What is however also remarkable is the fast recovery of the multiplier: Already in 2010 it reached almost its pre-crisis level again. The fast rehabilitation of the Durables sector — a key material and capital provider for the remaining sectors — might have been central for the astonishingly fast recovery of the German economy after the Great Recession. Overall, the changes in the multipliers for TFP are more pronounced than for labor, indicating that changes in the sectoral long-run TFP trends might have influenced aggregate trend variation more than changes in the industrial labor supply. Similar to its labor multiplier, also the construction sector's TFP multipliers shows a slight increase shortly after reunification followed by a decade-lasting decline. In total, the sector's TFP multiplier does not vary much over our estimation period.

The evolution of the multipliers draws attention to the changing nature of the German production network over the years. The decline of the industry-related sectors' multipliers underline the ongoing structural transformation of the German economy towards a service based economy. We note that the sectoral TFP multipliers are on average higher — particularly for the key supply sectors of the German production network — than their labor counterparts. This indicates that small changes in TFP on average yield stronger aggregate effects than changes in labor input.

An interesting observation can be made for the PBS sector: Its TFP multiplier shows a steep increase from the start of our sample until shortly before the financial crisis and is moving sideways afterwards. Its labor multiplier instead continues increasing, aiming at closing the gap between the two input multipliers in the future.

**Figure 10: Evolution of TFP Multiplier**



Notes: The picture above

### 5.3 Implications for Future German Trend GDP Growth

In the following, we aim to lay out potential effects of demographic change on long-run German aggregate trend GDP accounting for the labor multipliers calculated. As it has been shown, a shock to the long term labor supply in one sector can due to amplification effects have huge effects on the long term evolution of German GDP. Germany is aging, and compared to other industrialized countries, demographic change is progressing fast. The comparison of its old age dependency ratio with the US reveals no surprise: In 2019, Germany's ratio of people older than 64 to its working-age population (aged between 15 and 64 years)<sup>12</sup> was considerably higher (33.6%) than it was in the US (24.2%). Further, it is estimated that by 2035, one out of four Germans will have reached retirement age (67 years).

The German working-age population is anticipated to undergo a discernible contraction in the foreseeable future, a consequence of the impending retirement of the baby boomer generation until 2035. Commencing in 2030, a demographic imbalance is projected, wherein the influx of new entrants into the labor market will be outnumbered by a twofold surge in retirements.<sup>13</sup> Table 6 shows the sectoral labor intensity in the 15 sectors of our analysis. The construction sector is by far the most labor intensive, followed by Misc. and the Retail Trade sector. A recent study by Gründler and Potrafke (2023) further shows that an boost of the pensioner-worker ratio has a negative effect on TFP. In detail, they find that a 10 percentage point increase in the pensioner-worker ratio results in an up to 6% decline in

<sup>12</sup>Old age dependency ratio as defined by the World Bank

<sup>13</sup>Berlin Institute for Population and Development

TFP. The effect is found to be stronger when production is labor intensive and has a low potential for automation — an accurate description of the construction sector. Hence, a drop in the construction sectors labor input might not only weight on aggregate GDP due to its labor multiplier on the German production network, but have an additional damping effect on aggregate growth via its TFP multiplier. Note that PBS as well as the Education and Health sector are also more labor intensive than the industrial sectors and that particularly jobs in Education and Health have low potential for automation. Due to its extensive labor multiplier, a drop in labor input to the Durables sector might no matter the sector’s potential for automation weight on aggregate TFP.

**Table 6:** Sectoral Labor Intensity 2019

Sector	Labor Intensity
Agriculture	1.65
Mining	1.49
Utilities	0.54
Construction	20.92
Durable Goods	4.64
Non-Durable Goods	4.94
Wholesale Trade	8.05
Retail Trade	14.96
Trans. & Ware.	2.63
Information	3.94
FIRE	0.15
PBS	6.56
Educ. & Health	5.03
Arts, Ent. & Acc.	5.39
Misc.	19.96

*Notes:*

An advantage of our approach computing a specific multiplier for the majority of the years contained in our sample is that we do not have to rely on a constant multiplier for every year but can instead take into account the non-stationarity of the production network: we expect that the production network has evolved alongside the German economy’s structural shift towards services. Therefore, next to our baseline results, we also provide the sectoral contributions computed using the average sectoral multipliers over the full sample<sup>14</sup>. Note that the contributions of labor trend growth of important key material/capital good suppliers of the economy, such as Durables and PBS, differ significantly depending on the multiplier used. Overall, the differences between the contributions for the entire sample period however prove to be small.

<sup>14</sup>The corresponding average sectoral multipliers, also for several time periods, can be found in the Supplementary material.

## 6 Conclusion

Our analysis offers a comprehensive perspective on the structural changes and sectoral dynamics that have shaped Germany's economic trajectory. Several findings emerge from our investigation: The Durable Goods sector exhibits a sectoral multiplier that is nearly equal for both the German and US economies, yet the composition of this sector varies significantly between the two nations. While Germany boasts a higher value-added share in Durable Goods, the US surpasses in the indirect effect. This underscores the heterogeneity in the economies' specialization. Despite positive effects on German trend GDP growth from the Durable Goods sector, challenges arise, particularly in the diminishing rates of Total Factor Productivity (TFP). The influence of Professional and Business Services (PBS) is more pronounced in the US than in Germany, reflecting the still ongoing structural change in the German economy towards a service-oriented model. However, the multiplier for German PBS remains notably higher than its overall value-added share, contributing positively to trend GDP growth. Notably however is that despite the ongoing structural shift, service sectors do not demonstrate major positive contributions to trend GDP growth. Constructing the to our knowledge uniquely available capital tables for Germany allows us to construct year-specific production networks and therefore annually differing multipliers. Employing a specific multiplier for every year allows for a more nuanced understanding of the non-stationary nature of the production network. Further, it enables us to calculate total average contributions over different time periods taking into account the specific shape of the production network at the time. Demographic changes, particularly an aging workforce, pose potential challenges, especially in labor-intensive sectors like Construction and PBS. The declining labor input in these sectors not only exerts pressure on aggregate GDP due to their labor multipliers but may also dampen aggregate growth via their TFP multipliers. Recognizing the intricate interplay between sector-specific and common factors is crucial for policymakers seeking to navigate the challenges and opportunities in the evolving economic landscape.

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