Diagnosing the UK Productivity Slowdown: Which Sectors Matter and Why?

Authors:
Diane Coyle[x]
The University of Cambridge
Jen-Chung Mei[x]
The University of Cambridge

Date:
April 2022

The Productivity Institute
Working Paper No.018 Version 1 (updated from original March 2022 version)

[x]**Bennett Institute for Public Policy**

Key words
Productivity, manufacturing, ICT, Decomposition, information and communication

Authors' contacts:
dc700@cam.ac.uk

JEL codes:
O47, L16, L60, L86

Acknowledgements
We thank Peter Goodridge, Shane Greenstein, Jonathan Haskel, Richard Heys and ONS colleagues, Bart Van Ark and Tony Venables for their helpful comments, and Adam Muhtar for excellent research assistance. Coyle is grateful for funding from the Productivity Institute, ESRC grant number ES/V002740/1, and Mei for funding from the Gatsby Foundation.

Suggested citation

D. Coyle, J. Mei (2022) *Diagnosing the UK Productivity Slowdown: Which Sectors Matter and Why?*. Working Paper No. 018 version 1, The Productivity Institute.

The Productivity Institute is an organisation that works across academia, business and policy to better understand, measure and enable productivity across the UK. It is funded by the Economic and Social Research Council (grant number ES/V002740/1). The Productivity Institute, headquartered at Alliance Manchester Business School, The University of Manchester, Booth Street West, Manchester, M15 6PB. More information can be found on The Productivity Institute's website. Contact us at theproductivityinstitute@manchester.ac.uk

Abstract

This paper explores the slowdown in labour productivity growth in the UK and other advanced economies by decomposing its growth into contributions from different sectors of the economy, looking both at within-industry productivity growth and labour reallocation between sectors. We find that the within-industry contribution is the main source of the slowdown. Comparing trends pre- and post-2008, the aggregate productivity slowdown can largely be attributed to the manufacturing and the information and communication sectors. Disaggregating further, the UK productivity growth slowdown can be mainly attributed to transport equipment and pharmaceuticals within manufacturing, and computer software and telecommunications within information and communication.

Strikingly, these are advanced, high value-added sectors considered to be strengths of the UK economy. Looking across other advanced economies, our results confirm that manufacturing and information sectors are the main drivers of the labour productivity growth slowdown. Part of the explanation for the slowdown in in these sectors may relate to the underlying question of how to construct deflators for a modern economy when technological and structural changes are leading to large relative price shifts. The structure and supply chains of the key slowdown sectors also merit further investigation.

1. Introduction

The 'puzzle' of the productivity slowdown has been extensively explored. This paper extends this body of work by decomposing the aggregate productivity statistics into the different sectors and sub-sectors in order to see how either dispersed or concentrated the slowdown has been. One of the questions often raised in discussions of the slowdown is to what extent it reflects specific sectoral slowdowns or, instead, shifts in activity from high to low productivity sectors. We find that the main contribution to the slowdown is within the manufacturing and information and communication sectors, and within these in certain sub-sectors such as pharmaceuticals and software generally considered to be among the leading industries in the economy.

The term `productivity' itself has a meaning in everyday use that differs from its specific meaning in economics. For example, in business the variable of interest will often be engineering efficiency, or perhaps revenue or value added per hour worked in current price terms, whereas economists are interested in real terms output or value added per hour (i.e. revenue or value added deflated by a price index). This is because deflating by a price index removes general inflationary effects to give a measure (in constant prices) closer to an economic welfare measure: deflators are constant utility constructs (e.g., Diewert 1995). The intuitive way to think about the deflation exercise is as separating the quantity of something sold from its price; how many haircuts or apples are bought and sold is more relevant to economic progress than how many dollars or pounds are involved in the transaction. Yet for aggregate economic measurement, the 'real' quantities need to be added together; and as apples, haircuts, cars and all the myriad other products are counted in different volume units (and indeed the volume units are not obvious in many services such as accountancy or software), they are all converted into monetary terms for the purposes of aggregation. Real GDP is thus a money metric of economic welfare or utility (Hillinger, 2002), not a straightforward measure of quantity. Thomas Schelling (1958) was referring to this when he stated: "[W]hat we call `real' magnitudes are not completely real; only the money magnitudes are real. The `real' ones are hypothetical".

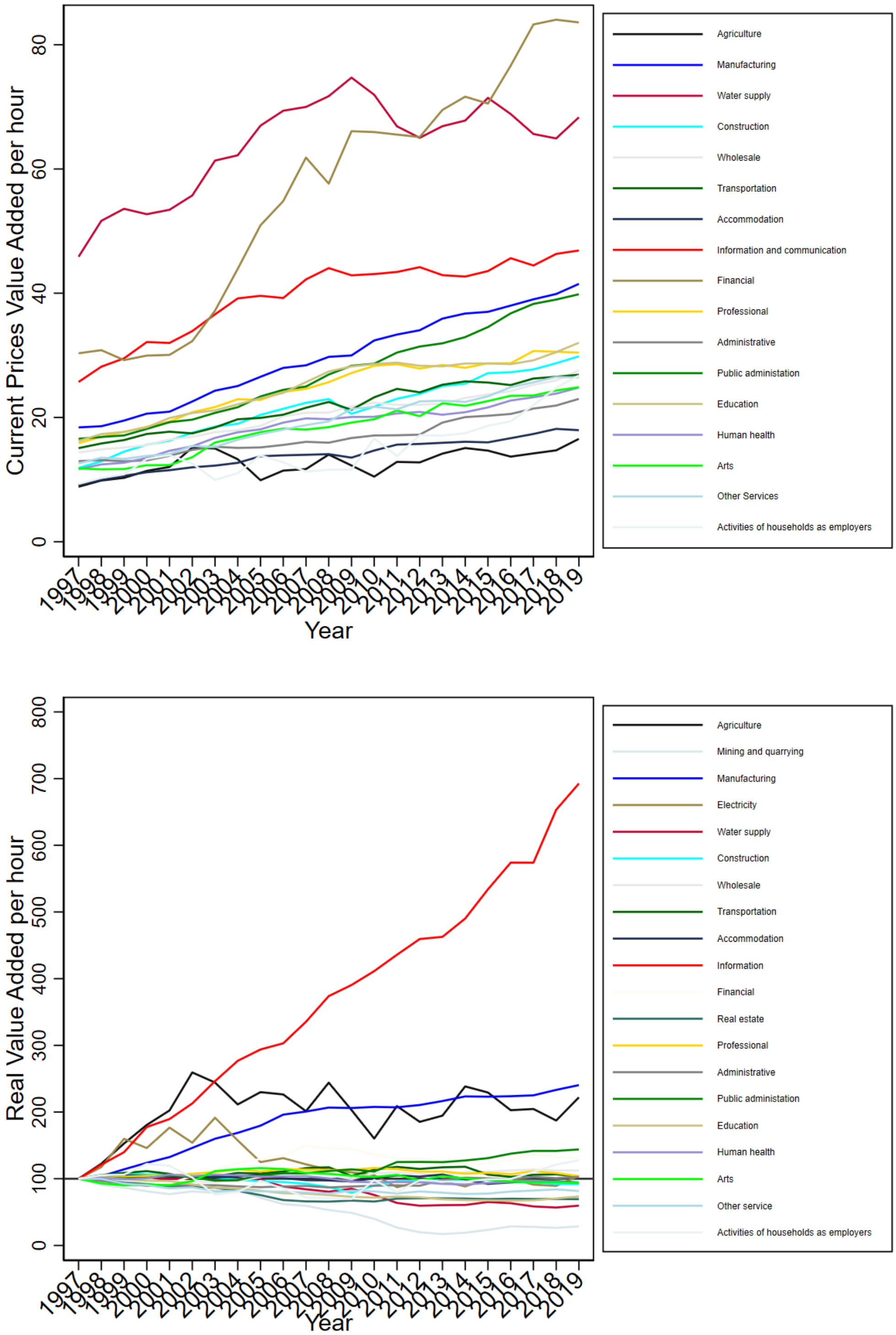
As economic statistics are often generated from collecting data in terms of monetary revenues, the price-quantity split is then constructed by deflating revenues by a price index (industry-level deflators are constructed from product prices). In moving from current price revenue or value added per hour to the real terms labour productivity figures economists are interested in therefore requires using an appropriate price index to deflate current price value added. Similarly, in moving from aggregate labour productivity to individual sectoral level measures, there are choices to be made in calculating labour productivity; is current price output to be deflated using a separate output price index for each sector, or should nominal value added simply be adopted when estimating? In moving from gross output to value added, similarly, the most appropriate input price deflators will differ between sectors. A further choice concerns how to weight the sectors of the economy to add them up to the aggregate level - should the weights use their share in total revenues, or volume or employment shares instead? When sectoral relative prices are changing these will differ substantially (e.g. Abdirahman et al., 2022). The weights, therefore, have an important meaning in the analysis of the sectoral contributions to aggregate labour productivity growth.

For an initial look, we show in Figure 1 current price value added per hour worked in the UK. The figure omits real estate, mining and utilities, which all have substantially higher current price value added per hour due to their distinctive features. After these, finance (brown) and manufacturing (blue) have highest current price value added per hour, and for both the decrease in gradient post-2007 is visually evident; indeed there has been an absolute decline for finance. Slowdowns are also readily visible for Professional, scientific and technical activities (industry M) and wholesale and retail trade (industry G). We test for a break in trend (log change) between 1998-2007 and 2008-2019 in Appendix I Table AI 1, confirming that Water supply (industry E), Construction (industry F), Information communication (industry J), Professional and scientific (industry M), Education (industry P), and Human health (industry Q) experienced a statistically significant slowdown (at the 5% level) in current price terms during the post-crisis period.

Yet the picture is different when we turn to the deflated or 'real terms' value added per hour, where the revenue series for each sector is deflated by a sector-specific output price deflator. These do not have natural units so are rebased to 1997=100. The labour productivity of the information and communication sector has grown substantially in real terms over the entire period, and both manufacturing and agriculture have grown too. Other sectors experienced either modest productivity growth or some decline – particularly mining and quarrying. As our focus is explaining the slowdown after the mid-2000s, we test for a break in growth rates for 1998-2007 compared to 2008-2019; the results in Appendix I Table AI 2 reveal that both manufacturing and information communication nevertheless experienced the most significant slowdowns in real value added per hour growth (at the 1% statistical significance level) over the post-crisis period. Other industries including wholesale and retail trade, financial services, administrative services, and public administration have also grown significantly more slowly in the period 2008-2019 compared to 1998-2007.

These charts nevertheless do not answer the question about the role played by reallocation of activity from high to low productivity sectors and the pure within-sector productivity contribution. To disentangle this question, previous studies have estimated the trend differences (before and after 2008) using different decomposition approaches (see, for

Figure 1.Current Price Value Added per hour (Top, £) and Real Value Added per hour (Bottom, 1997=100), 1998-2019



Notes: Nominal value added per hour is measured by using the all-industry current price value added divided by total hours worked. There are 20 industries making up the whole economy sector (A-T, see data section for more details). We exclude mining and quarrying, electricity, gas, steam and air conditioning supply, and real estate activities. Real gross value added per hour is measured by using total gross value added in chain volume measure divided by the total hours worked based on the new double deflated data updated since 30th Sep 2021 by ONS. See ONS Bluebook 2021 for more details.
Source: Authors' calculations by using bb2102industrialanalysis and gdpolowlevelaggregates2021q3 data series from ONS.

instance, Fabricant, 1942; Maddison, 1952; Tang and Wang, 2004; De Vries, McMillan and Rodrik, 2011; Erumban, Timmer, Voskoboynikov, and Wu, 2012; Diao, McMillan, and Rodrik, 2019; Moussir and Chatri, 2020; Voskoboynikov, 2020; De Vries, Erumban, and van Ark, 2021).

Although the recent empirical literature (such as Harris and Moffat (2014)[1] and Craft and Mills (2020), Goodridge, Haskel, and Wallis, 2018)[2] confirms the UK productivity slowdown, this paper updates prior research on UK labour productivity by using recent ONS statistics that have incorporated double deflation for the first time. In Section 2, we clarify how the aggregate data and the sectoral data relate to each other in a diagnostic exploration of the UK productivity slowdown through the lens of sectoral decomposition, discussing the role played by different weights used in deflating nominal value added. We consider issues raised by the existing sectoral decomposition approaches such as Generalized Exactly Additive Decomposition (GEAD) employed in Tang and Wang (2004).[3] In this paper we adopt the Tornqvist method, which has also been used in Goodridge at el., (2018), as it allows output prices and production functions to differ across sectors and we are interested in sectoral differences. We then decompose labour productivity growth into within and reallocation components through each sector.

For the period since 2008 compared with the prior 10 years, we find that shifts between sectors play little role in accounting for the aggregate labour productivity slowdown in the UK, although they do have a small negative effect on productivity when the real estate sector (whose output is mainly imputed rent) is excluded from the calculation. Our data and results (Sections 3 and 4) show that manufacturing and information and communication are those that have experienced the biggest labour productivity slowdowns. Furthermore, we find that the within-sector slowdowns are mainly attributable to transport equipment and pharmaceuticals in manufacturing, and to computer software and telecommunications in information and communication. Strikingly, these are among the sectors generally considered to be strengths of the UK economy.

For comparison, we set out two alternative decomposition methods, the shift share method and GEAD, in Appendix II. The reallocation effects seem to be relatively more important to the aggregate slowdown using the GEAD approach, whereas the shift-share method suggests

[1] Harris and Moffat (2014) found that labour productivity for the whole UK economy by the end of 2014 was 13% lower compared to a potential output per worker level had the pre-2007 trend had continued.
[2] Craft and Mills (2020) found that the current productivity slowdown has resulted in productivity being 19.7% less than the pre-2008 trend path by 2018.
[3] Tang and Wang (2004) adopt the GEAD formula to take into account changes in relative prices. By incorporating price effects into contributions, this approach captures the overall economic significance of different sectors to aggregate labour productivity growth, but not the impact of sectoral real contribution on aggregate labour productivity growth. It has been argued that the generalized exactly additive decomposition approach often produces results being perceived as counterintuitive (Avillez, 2012; Reinsdorf, 2015; De Vries et al., 2021)

that it is relatively unimportant, which is similar to what we find under the Tornqvist approach. The alternative methods therefore highlight the importance the different weights in the decomposition exercise. We suggest that the choice of weights and output price deflators, as well as omitted quality change, therefore plays a part in the story.

In order to see how UK compares with other countries, we also look in Section 5 at 12 other countries including Japan, the US, and several European economies for 1998-2015, using the EU KLEMS database. The reallocation term contributes little to explaining the slowdown in all cases, and the within-industry contribution is also the driver in the other 12 advanced economies. In these countries too, the manufacturing and information and communication sectors are the main driving force that cause the slowdown in labour productivity growth. The decomposition exercise does not allow us to control for other observed and unobserved drivers of the slowdown so it should be interpreted with caution. However, in Section 6 we test the robustness of the analysis by using a difference-in-difference approach, which confirms that the manufacturing and information and communication sectors experienced productivity growth statistically and significantly lower post-2008, by 5.699 percentage points in 2008-2019 for the UK, and by 2.268 percentage points in 2008-2015 for all 13 countries.

Our work is related to the recent papers by Tang and Wang (2004), McMillan and Rodrik (2011), De Vries et al. (2012), de Vries, Timmer, and de Vries (2015), Diao et al. (2019), Moussir and Chatri (2020), Voskoboynikov (2020), and De Vries et al. (2021).[4] Tang and Wang (2004) adopt the GEAD method and find that the aggregate labour productivity growth gap between Canada and the United States during 1987-98 was driven by the within-industry contribution in manufacturing and service sectors. Using data including UK, France and US during the COVID period (2020 and 21-Q1), De Vries et al. (2021) find that the reallocation effects until 2019 were slightly negative for the US, UK and France, and all countries saw a decline in within-industry productivity growth since 2011. Relative to these earlier results, our paper adopts a different decomposition approach that relaxes the assumption of an identical production function

[4] Other papers using the shift share method are applied in the developing economy context. McMillan and Rodrik (2011) document large gaps in labour productivity between the traditional and modern parts of the economy such that that labour flows from low-productivity to high-productivity activities are a key driver of productivity growth from 1990-2005. Focusing on structural transformation, De Vries et al. (2012) similarly find that reallocation of labour across sectors contributes to aggregate productivity growth for China, India and Russia but not for Brazil 1993-2004. De Vries et al. (2015) find that resources were reallocated to manufacturing activities, enhancing overall productivity during the early post-independence period in 11 Sub-Saharan African countries. Diao et al. (2019) document that the growth acceleration in Latin America more recently is explained by rapid within-sector labour productivity growth, whereas the growth acceleration in Africa is attributed to the reallocation due to structural change. Examining Morocco's structural transformation process 1999-2017, Moussir and Chatri (2020) report that the within industry contribution rather than reallocation accounts for much of the labour productivity growth.

and relative prices across industries, whereas in McMillan and Rodrik (2011), De Vries et al. (2012), De Vries et al. (2015), Diao, McMillan, and Rodrik (2019), and Moussir and Chatri (2020) the absolute differences in productivity weighted by industry employment shares in the previous period is used. While De Vries et al. (2021) provide useful comparisons with different decomposition methods, their main focus is on the shift-share method and they use data for the UK that predate the implementation of double deflation. We also consider the whole economy, not just the market sector.[5] Section 7 concludes with a discussion of the implications of our findings.

2. Decomposition methods

2.1 Aggregate and sectoral labour productivity growth

In this paper we use the Tornqvist decomposition as it allows output prices to differ across sectors/industries, separating productivity growth into within and reallocation components.[6] The sum of real-terms sectoral labour productivity growth weighted by value added in this approach will not be equal to growth in aggregate value added per hour calculated using an aggregate deflator. But as we are interested in the performance of the different sectors, it is the most appropriate choice. We use estimates of industry real gross value added (V_i) to construct aggregate real gross value added (V) through weighted sum of log changes in industry gross value added:

$$\Delta lnV \equiv \sum_i \bar{\omega}_j \, \Delta lnV_i \tag{1}$$

where

$$\omega_i = {}^{v_i}/_{\sum_i v_i} \tag{2}$$

and

$$\bar{\omega}_i = 0.5(\omega_{it} + \omega_{it-1}) \tag{3}$$

Eq. (1) says the log change in real aggregate gross value added V is the weighted aggregate of the log changes in industry real gross value added V_i, and the weight ω_i is the share of industry i in

[5] While Voskoboynikov (2020) also includes whole economy sector into the aggregate labour productivity analysis and finds that the overall contribution of structural change is growth enhancing but decreasing over time, the Tornqvist approach is absent and the author only focuses on the Russia economy.

[6] We provide findings based on two alternative methods – the shift-share and Generalized Exactly Additive Decomposition in Appendix II. Out results confirm that the shift-share method provides similar results for the aggregate productivity growth pattern compared to our current approach. By contrast, the Generalized Exactly Additive Decomposition approach provides divergent results. See Appendix II for more details.

nominal gross value added v. We using two-period average weights as a Divisia index $\bar{\omega}_i$. Since aggregate total worked hours H can be estimated as a simple sum of industry hours

$$H = \sum_i H_i \tag{4}$$

we can then obtain aggregate labour productivity per hour through taking the change in log of H as

$$\Delta \ln (V/H) = \Delta lnV - \Delta lnH \tag{5}$$

and so the industry labour productivity growth can be defined as:

$$\Delta \ln (V_i/H_i) = \Delta lnV_i - \Delta lnH_i \tag{6}$$

To define aggregate labour productivity growth from the industry data, we can then implement a share-weighted sum over industries i as:

$$\Delta \ln (V/H) \equiv \sum_i \bar{\omega}_i \Delta \ln ({}^{V_i}/_{H_i}) \tag{7}$$

2.2 Sectoral Decomposition

To distinguish within industry productivity growth from reallocation or structural change, following Fabricant (1942) and extending De Vries et al. (2012) and Goodridge et al. (2018), we start by noting that since the weighted sum of within productivity growth in each sector in Eq. (7) produces a different estimate of aggregate labour productivity growth to the estimate from Eq.(5), we can obtain the whole economy sector level reallocation term (R) as the difference between the two:

$$\Delta \ln(V/H) = \sum_i \bar{\omega}_i \Delta \ln(V_i/H_i) + R \tag{8}$$

The second term in Eq. (8) is the term that measures the contribution of labour reallocation across industries, being positive (negative) when activity moves from less (more) to more (less) productive industries. However, Eq. (8) does not allow us to examine the contribution of each component from sub-sector to industry labour productivity growth. As in De Vries et al. (2012),[7] we therefore breakdown industry i into sub-sectors j, and calculate the following:

$$\Delta \ln(V_i/H_i) = \sum_{j\in i} \bar{\omega}_j \Delta \ln\left(V_j/H_j\right) + R_i \tag{9}$$

where

[7] As in De Vries et al. (2015), this term can be further decomposed into a static and dynamic component of structural change. Diao et al. (2019) argue that the structural change term is often negative and may be difficult to interpret. However, it enables distinctions to be drawn between labour moving to sectors with different levels of productivity and sectors with different productivity growth rates (De Vries et al., 2021).

$$\omega_j = {v_j}/{\sum_j v_j} \tag{10}$$

and

$$\bar{\omega}_j = 0.5(\omega_{jt} + \omega_{jt-1}) \tag{11}$$

where the subscript j refers to any of sub-sector, for example, food products, beverages, and tobacco in Manufacturing (in which $j = 1, 2, \dots, n$). R_i is derived from the change in value added weighted labour productivity growth of sub-sectors j, with the share of current price value added v_{ij} in sub-sector j in industry j as weights ω_j, and a residual term measuring the reallocation within industries across subsectors j. The ω_i in Eq. (2) is the average share of an industry i in overall nominal value added, whereas the ω_j in Eq.(10) is the average share of a sub-sector j in an industry i. Substituting Eq. (11) into Eq.(9) obtains a new reallocation effect, as well as a new within industry contribution effect, of labour moving within an industry i across sub-sectors. We apply this decomposition to the high-level sectors of the whole economy, and subsequently to sub-sectors of some of these.

3. Data

We use sector and sub-sector level data on nominal value added, real value added, and labour input (total hours worked). We use the double deflated Office National Statistics (ONS) data for the UK, first published in October 2021, and EU KLEMS date for other European economies, US, and Japan. ONS provides two-digit Standard Industrial Classification 2007 (SIC07) level data, dividing the whole UK economy into 20 (A-T) sectors, aggregated from 97 industries.[8]

The second data source is the EU KLEMS dataset (Jerbashian and Vilalta-Bufi, 2020), January 2022 release. We used data for the US, Japan, France, Belgium, Netherland, Denmark, Germany, Greece, Italy, Portugal, Austria, Sweden, and removed the sectors public administration, defence, education, human health and social work activities, arts, entertainment, recreation; other services and service activities, etc., and activities of extraterritorial organizations and bodies.

[8] The 20 A-T sectors include A Agriculture, B Mining and quarrying, C Manufacturing, D Electricity, gas, steam and air conditioning supply, E Water supply; sewerage, waste management and remediation activities, F Construction, G Wholesale and retail trade and repair of motor vehicles and motorcycles, H Transportation and storage, I Accommodation and food service activities, J Information and communication, K Financial and insurance activities, L Real estate activities, M Professional, scientific and technical activities, N Administrative and support service activities, O Public administration and defence; compulsory social security, P Education, Q Human health and social work activities, R Arts, entrainment and recreation, S Other service activities, T Activities of households as employers.

Finally, our analysis looks at the periods 1998-2019 for the UK, and 1998-2015 for international comparison. Data for the 2020-2021 period for the UK is removed due to the disruption caused by the global pandemic.

4. UK results

Figure 3 and Table 1 show first of the aggregate labour productivity growth for the whole economy sector $\Delta \ln{(V/H)}$ (grey bars), and the separated two terms as the weighted sum of industry labour productivity $\sum_i \bar{\omega}_i \Delta \ln(V_i/H_i)$ (i.e., the pure within-sector contribution) and the aggregate reallocation effect R estimated from Eq. (8). For the whole period 1998-2019, on average, Table 1 shows that the aggregate labour productivity growth $\Delta \ln{(V/H)}$ was 1.04% per year, the weighted sum of labour productivity growth $\sum_i \bar{\omega}_i \Delta \ln(V_i/H_i)$ was 0.792% per year, and the reallocation term R 0.248% per year. The slowdown since 2008 for the whole economy is apparent from the chart in Figure 3, with the within-sector productivity growth component being negative in 2008 and 2009, and relatively small afterwards. Also evident is the relatively small part played by reallocation (red bars) post-2008.

To explore the slowdown, Table 2 delineates two time periods, namely 1998-2008 and 2008-2019. Focusing on column (1) of Table 2, overall average productivity growth rates for the periods 1998-2008 and 2008-2019 were 1.632% and 0.350% respectively. Columns (2) and (3) then decompose these into the contributions from within productivity growth and labour reallocation during the two periods. It shows that about a quarter ((0.086-0.409)/-1.282) of the slowdown is explained by reallocation, and about three quarters ((0.263-1.222)/-1.282) of the slowdown has occurred within the industries.

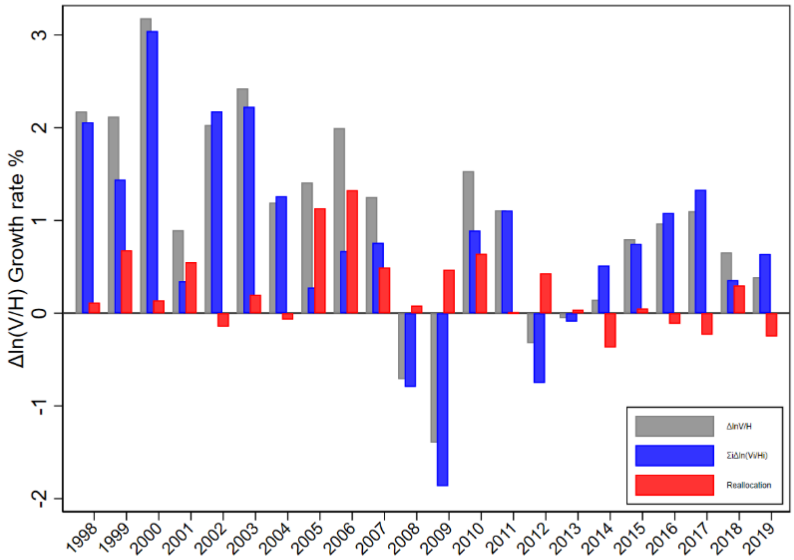
It is worth noting the difference in aggregate labour productivity growth, as well as the within and reallocation effects, when the real estate sector (L) is excluded. As highlighted in the ONS 2019 Labour Productivity Report, the output of industry real estate is mainly imputed rents for owner-occupiers of housing, while labour input (mainly estate agents) is small. We also show the effect when industry real estate is removed in Tables 1 and 2. As can be seen from Table 1, excluding imputed rental from GVA reduces the aggregate by 0.22 percentage points (from 1.040% to 0.818%), increases the within component and reduces the average reallocation effect by 0.45 percentage points so that it becomes negative rather than positive (i.e., 0.248% to -0.202%). The exclusion thus changes not only to the labour reallocation term, but also whole economy sector productivity performance (see also Riley, Rincon-Aznar, and Samek, 2018). This

Table 1. Labour Productivity Growth Whole Economy 1998-2019

	$\Delta\ln(V/H)$ (1)	$\sum_i \bar{\omega}_i \Delta\ln(V_i/H_i)$ (2)	R (3)
# Whole Economy (20 Industries)	1.040%	0.792%	0.248%
# Whole Economy (Industry L excluded)	0.818%	1.020%	-0.202%
# Whole Economy (Industries O,P,Q excluded)	0.978%	0.810%	0.168%

Notes: Data are average growth rates per year for 1998-2019 based on Eq. (8). Industry L represents real estate activities, O represents public administration, P represents Education, and Q represents human health.

Figure 3. Growth in Real Terms Whole Economy Labour Productivity 1998-2019



Notes: This graph plots the aggregate sector level $\Delta\ln(V/H)$, $\sum_i \bar{\omega}_i \Delta\ln(V_i/H_i)$, and R based on all 20 industries. Blue is 'within' and red is 'reallocation'.
Source: Data sources as above and authors' calculations.

Table 2. Labour Productivity Growth Whole Economy $\Delta\ln(V/H)$, $\sum_i \bar{\omega}_i \Delta\ln(V_i/H_i)$, R; 1998-2008 vs. 2008-2019

	$\Delta\ln(V/H)$ (1)	$\sum_i \bar{\omega}_i \Delta\ln(V_i/H_i)$ (2)	R (3)
# Whole Economy (20 Industries)			
1998-2008	1.632%	1.222%	0.409%
2008-2019	0.350%	0.263%	0.086%
# Whole Economy (Industry L excluded)			
1998-2008	1.502%	1.738%	-0.236%
2008-2019	0.048%	0.216%	-0.168%
# Whole Economy (Industry O,P,Q excluded)			
1998-2008	1.719%	1.316%	0.403%
2008-2019	0.179%	0.233%	-0.053%

Notes: Data are average growth rates per year for 1998-2019 based on Eq.(8). Industry L represents real estate activities, O represents public administration, P represents Education, and Q represents human health.

Table 3. Labour Productivity Growth by sector

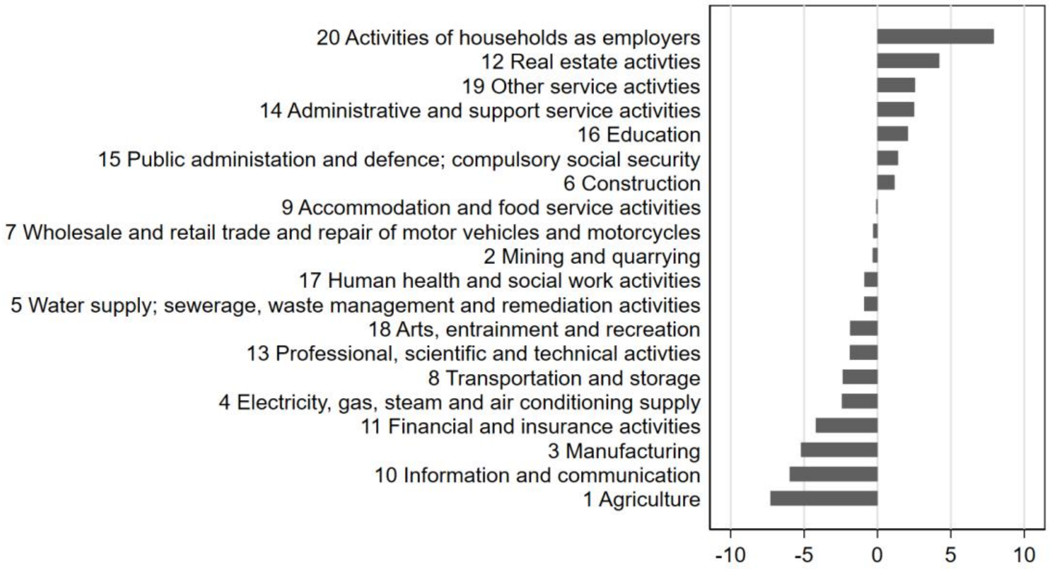
	1998-2019	$\Delta\ln(V_i/H_i)$ 1998-2008	2008-2019
	(1)	(2)	(3)
Industry Breakdown A-T			
A Agriculture	3.625%	8.112%	0.814%
B Mining and quarrying	-5.687%	-5.773%	-6.098%
C Manufacturing	3.845%	6.522%	1.311%
D Electricity, gas, steam and air conditioning supply	0.193%	1.152%	-1.275%
E Water supply; sewerage, waste management and remediation activities	-2.345%	-1.959%	-2.870%
F Construction	-0.394%	-1.233%	-0.070%
G Wholesale and retail trade and repair of motor vehicles and motorcycles	0.498%	0.449%	0.144%
H Transportation and storage	-0.002%	1.271%	-1.100%
I Accommodation and food service activities	-0.282%	-0.245%	-0.330%
J Information and communication	8.260%	11.460%	5.474%
K Financial and insurance activities	0.971%	3.005%	-1.200%
L Real estate activities	-1.663%	-3.808%	0.399%
M Professional, scientific and technical activities	0.158%	1.105%	-0.776%
N Administrative and support service activities	0.062%	-1.358%	1.150%
O Public administration and defence; compulsory social security	1.656%	0.991%	2.388%
P Education	-1.406%	-2.557%	-0.484%
Q Human health and social work activities	-0.292%	0.042%	-0.849%
R Arts, entrainment and recreation	-0.301%	0.635%	-1.232%
S Other service activities	-0.926%	-2.307%	0.253%
T Activities of households as employers	1.116%	-3.121%	4.806%

Notes: Data are average growth rates per year for 1998-2019.
Source: Authors' calculation.

implies a different scenario in terms of labour reallocation from high to low productive industries during the two distinct periods (1998-2008 and 2008-2018). Imputed rent is a return to capital, largely reflecting the appreciation of land values (Nguyen and Johansson 2022) so there are strong conceptual reasons to exclude it from consideration of labour productivity. We also show results with the public sector omitted. These services present well-known distinctive conceptual and measurement challenges; we include them in the decomposition nevertheless.

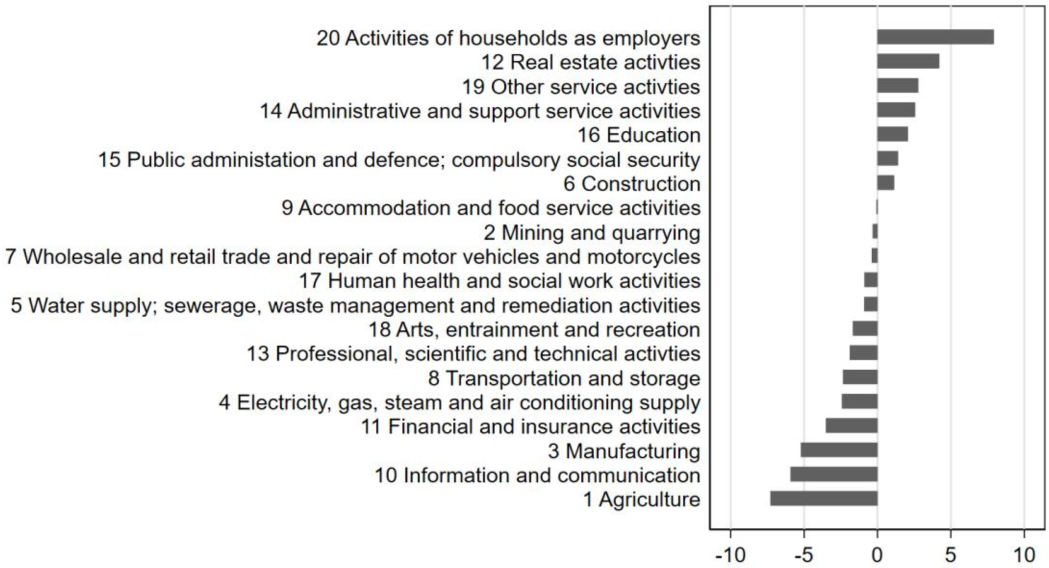
Turning to the sectors, Table 3 and Figure 4 look at the disaggregation for the whole period 1998-2019, pre-crisis (1998-2007), and post-crisis (2008-2019). Comparing columns (2) and (3) in Table 3, agriculture (-7.296%), information and communication (-5.986%), manufacturing (-5.211%), financial and insurance activities (-4.205%), and electricity, gas, steam and air conditioning supply (-2.427%) were the five industries with the largest productivity downturn between the two periods. Figure 4 presents data for contributions of the nominal value added-weighted within-sector labour productivity growth for each industry ranked by the slowdown in growth rates $\Delta(\bar{\omega}_i \Delta\ln(V_i/H_i)$ between the two periods. Focusing on the bottom five industries, it shows again that the slowdown in labour productivity $\Delta\ln(V_i/H_i)$ in these industries

Figure 4. Industry Labour Productivity Slowdown



Notes: Data show slowdowns for each industry, where each bar is $\Delta(\Delta ln\, V_i/H_i)) = \Delta ln\, V_i/H_i^{2008-2019} - \Delta ln\, V_i/H_i^{1998-2008}$ *Source*: Authors' calculations.

Figure 5. Within Industry Labour Productivity Slowdown



Notes: Data show slowdowns for each industry, where each bar is $\Delta(\bar{\omega}_i \Delta \ln(V_i/H_i)) = \bar{\omega}_i \Delta \ln(V_i/H_i)^{2008-2019} - \bar{\omega}_i \Delta \ln(V_i/H_i)^{1998-2008}$
Source: Authors' calculations.

is the slowdown within the industry; e.g., the slowdown in manufacturing $\Delta(\Delta ln\, V_i/H_i)$ is -5.211% (2008-2019 vs. 1998-2008), which consists of a slowdown in within-sector productivity -5.226% and a slowdown in labour reallocation term 0.015%; similarly the slowdown in information and communication is -5.986%, which consists of a slowdown in within-sector productivity growth

Table 4. Within Labour Productivity Growth $\bar{\omega}_j \Delta \ln(V_j/H_j)$ in Manufacturing and IT

	$\bar{\omega}_j \Delta \ln(V_j/H_j)$			$\Delta(\bar{\omega}_j \Delta \ln(V_j/H_j))$
	98-19	98-08	08-19	Slowdown
	(1)	(2)	(3)	(3)-(2)
Manufacturing Sub-sectors				
Food products, beverages and tobacco	0.272%	0.530 %	0.0487%	-0.4813%
Textiles	0.373%	0.528 %	0.193%	-0.335%
Wood and paper products	0.391%	0.595 %	0.267%	-0.328%
Coke and refined petroleum products	0.021%	-0.048 %	0.083%	0.131%
Chemicals and chemical products	0.369%	0.389%	0.384%	-0.005%
Basic pharmaceutical products	0.108%	0.618 %	-0.188%	-0.811%
Rubber and plastics products	0.271%	0.349 %	0.145%	-0.204%
Basic metals and fabricated metal products	0.234%	0.306%	0.204%	-0.102%
Computer, electronic and optical products	0.546%	0.850 %	0.263%	-0.587%
Electrical equipment	0.142%	0.280 %	0.046%	-0.234%
Machinery and equipment n.e.c.	0.286%	0.620 %	-0.117%	-0.737%
Transport equipment	0.3718%	0.879 %	-0.138%	-1.017%
Other manufacturing; repair	0.277%	0.459 %	0.069%	-0.390%
Information and Communication Sub-sectors				
Publishing activities	0.650%	1.271%	0.065%	-1.206%
Motion picture, video and TV programme	0.147%	0.349%	0.004%	-0.345
Programming and broadcasting activities	-0.057%	0.129%	0.065%	-0.064%
Telecommunications	7.174%	8.313%	5.869%	-2.444%
Computer programming	0.707%	1.643%	-0.316%	-1.959%
Information service activities	-0.162%	-0.041%	-0.400%	-0.359%

Source: Authors' calculation.

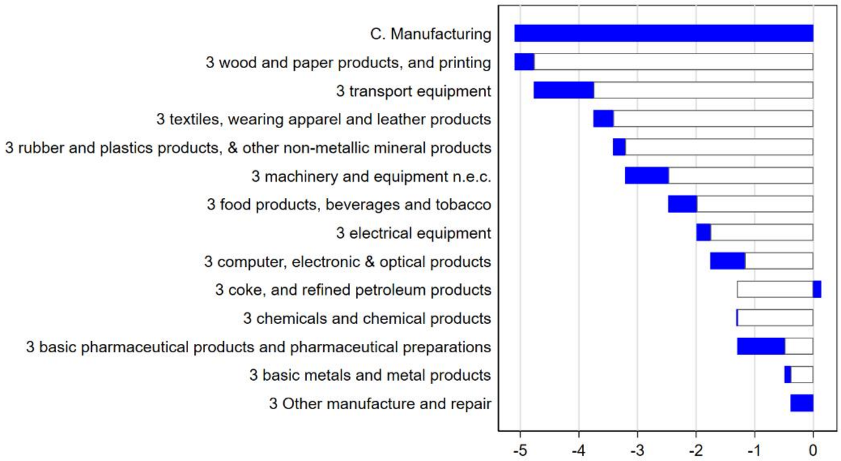
of 5.933% plus a slowdown from labour reallocation term -0.053%.[9] The reallocation components are small.

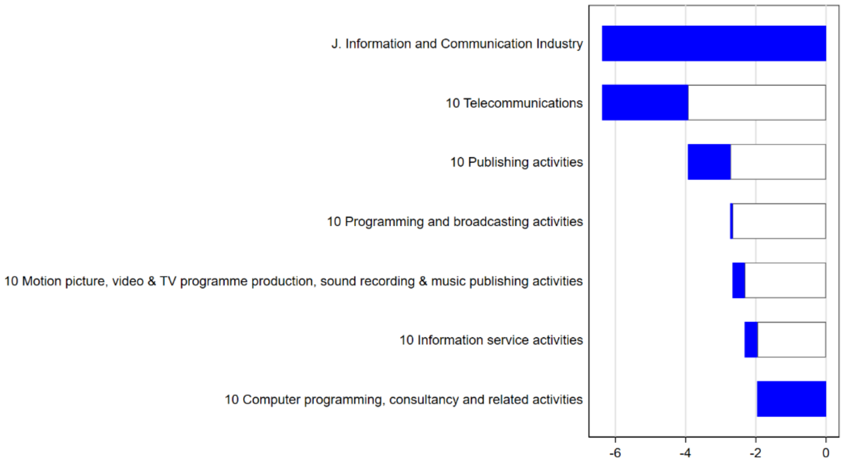
Having looked at the productivity pattern across sectors, we now repeat the exercise as above and move to the next level of disaggregation for two of the sectors displaying the biggest slowdowns, namely manufacturing, and information and communication. The results are shown in Table 4 and Figure 5. There are 13 sub-sectors in manufacturing and six in information and communication industries, respectively.

Table 4 reveals five sub-sectors where labour productivity growth ($\Delta \ln(V_j/H_j)$) turns negative during the post-crisis period 2008-2019; three in manufacturing, namely machinery and equipment n.e.c, (-0.117%), basic pharmaceutical products and pharmaceutical preparations (minus 0.188%), and other manufacturing, repair and installation of machinery and equipment (minus 0.138%); and two in information and communication, computer programming, consultancy and related activities (minus 0.316%), and information service activities (minus 0.400%). There are other sub-sectors with significant slowdowns, albeit not turning negative in

[9] The reallocation is simply calculated as residual, subtracting the slowdown in $\Delta\bar{\omega}_i \Delta \ln(V_i/H_i)$ from the slowdown in $\Delta(\Delta ln\, V_i/H_i)$).

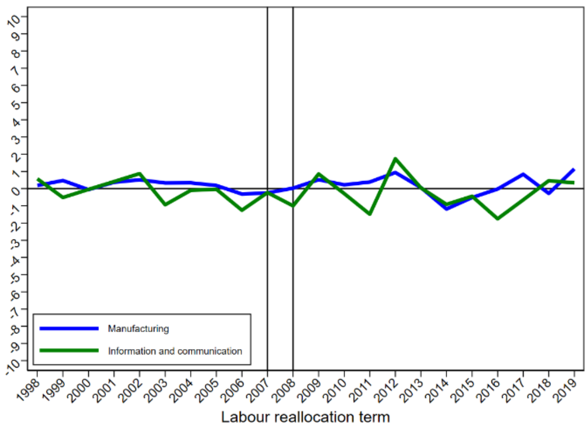
Figure 6. Sub-sectors *within* Labour productivity slowdown: (a) manufacturing and (b) information and communication





Notes: Data show slowdowns for each industry, where each bar is $\Delta(\bar{\omega}_j \Delta \ln(V_j/H_j)\ ) = \bar{\omega}_j \Delta \ln(V_j/H_j)^{2008-2019} - \bar{\omega}_j \Delta \ln(V_j/H_j)^{1998-2008}$.
Source: Authors' calculations

Figure 7. Labour Reallocation R_i Within Manufacturing and ICT Industries



Notes: Labour reallocation term R_i where i refers to manufacturing and information communication industries, respectively. A positive term implies movement of labour from low-productivity sub-sector toward high-productivity sub-sector either within manufacturing or information communication, respectively.
Source: Authors' calculations.

the second period, and no sub-sectors experiencing an increase. The only subsectors not to experience much of a 'within' slowdown are chemicals and coke/refined petroleum products.

In Figure 6, the top panel shows the contribution to the slowdown from each sub-sector's within component in manufacturing (top panel) and in the information and communication industry (bottom panel). About 60%[10] of the slowdown in manufacturing overall is attributable to transport equipment, machinery and equipment, computer and electronics manufacture, and basic pharmaceuticals. For the information and communication industry, telecommunications and computer programming contribute about 69% of the labour productivity slowdown. It is striking that the most pronounced slowdowns occurred in some industries considered to be UK success stories, and with high nominal value added per hour, such as autos (in transport equipment), pharmaceuticals, and telecommunications.

What about the reallocation between the sub-sectors? Figure 7 confirms that the reallocation contribution is small although positive on average in manufacturing and information and communication.

5. Comparison with other advanced economies

We explored how the productivity decomposition for the UK compares to some other economies.[11] use Eqs. (8) and (9) to carry out the decomposition exercise for an additional we economies for 1998-2015.[12]

Table 5 shows the decomposition results, which reveal that the US economy experienced the highest productivity growth and Italy, Greece, Japan, and Portugal the weakest during the entire period 1998-2015. The average reallocation term is negative for the US and France, which implies that labour was moving from more productive to less productive industries during 1998-2015, while Japan and UK have a positive contribution from labour reallocation. Nevertheless, the reallocation term is relatively small in all countries, and is negative for all countries once real estate is excluded. Finding the reallocation term to be small is consistent with McMillan and Rodrik (2011) and Moussir and Chatri (2020) who find that labour reallocation made very little contribution to productivity performance in the high-income countries during the period 1990-2005. In Figure 8 we show the correlation between aggregate labour

[10] 60.39% = (1.017%+0.737%+0.586%+0.807%)/5.211%.

[11] Jorgenson and Timmer (2011) highlight that specialisation may generate differences across European countries when relatively small countries trade widely and suggest that it is important to aggregate across European countries as a region rather than nation. While we are aware of this concern, it is worth looking at, similar to Kaldor (1963) and Kuznets (1971), how each nation's labour productivity perform individually and how differences may exist across industries. We also provide other European countries' statistics, including Ireland, Czechia, Estonia, Poland, Romania, Slovenia, and Slovakia in Appendix IV.

[12] We restrict this exercise within the time frame 1998-2015 due to across countries data availability.

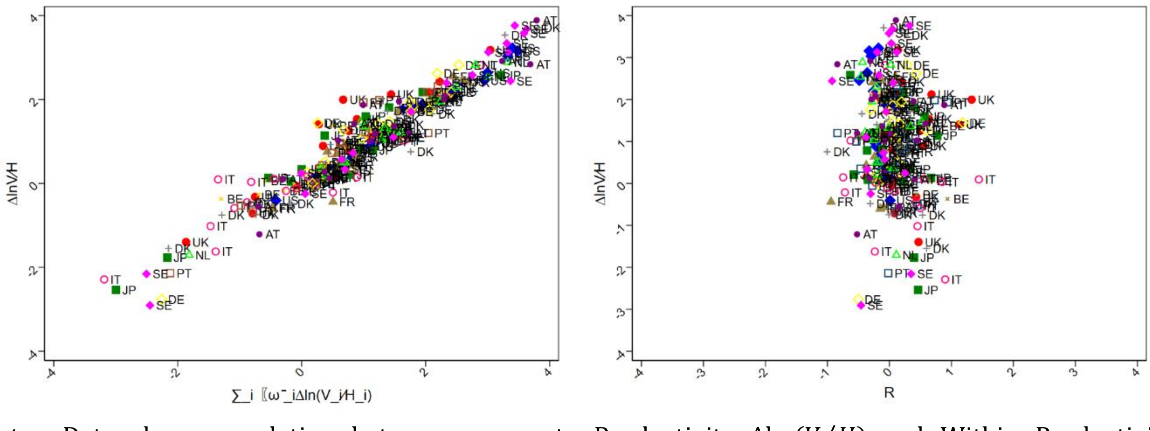
Table 5. Growth in Whole Economy $\Delta\ln(V/H)$, $\sum_i \bar{\omega}_i \Delta\ln(V_i/H_i)$, R, 1998-2015

	$\Delta\ln(V/H)$ (1)	$\sum_i \bar{\omega}_i \Delta\ln(V_i/H_i)$ (2)	R (3)
Whole Economy (20 sectors)			
UK	1.098%	0.778%	0.319%
US	1.549%	1.709%	-0.160%
Japan	0.616%	0.537%	0.079%
France	1.068%	1.150%	-0.081%
Belgium	0.781%	0.619%	0.161%
Netherland	1.242%	1.362%	-0.120%
Denmark	1.113%	1.009%	0.103%
Germany	0.888%	0.892%	-0.003%
Italy	0.060%	-0.065%	0.125%
Portugal	0.696%	0.625%	0.071%
Austria	1.308%	1.328%	-0.019%
Greece	0.127%	-0.576%	0.703%
Sweden	1.522%	1.626%	-0.103%
Whole Economy (Industry L Excluded)			
UK	0.863%	1.057%	-0.193%
US	1.504%	1.746%	-0.242%
Japan	0.556%	0.662%	-0.106%
France	1.067%	1.116%	-0.048%
Belgium	0.819%	0.822%	-0.003%
Netherland	1.262%	1.412%	-0.149%
Denmark	1.079%	1.011%	0.068%
Germany	0.912%	1.038%	-0.125%
Italy	0.005%	-0.062%	0.068%
Portugal	0.697%	0.641%	0.056%
Austria	1.297%	1.325%	-0.028%
Greece	-0.347%	-0.212%	-0.134%
Sweden	1.639%	1.776%	-0.137%

Notes: Data are average growth rates per year for 1998-2015. Data are decomposition of labour productivity in per hour terms based on Eq. (8). We remove industries public administration, defence, education, human health and social work activities, arts, entertainment, recreation; other services and service activities; and activities of extraterritorial organizations and bodies from our aggregation exercise. Industries L represents real estate activities

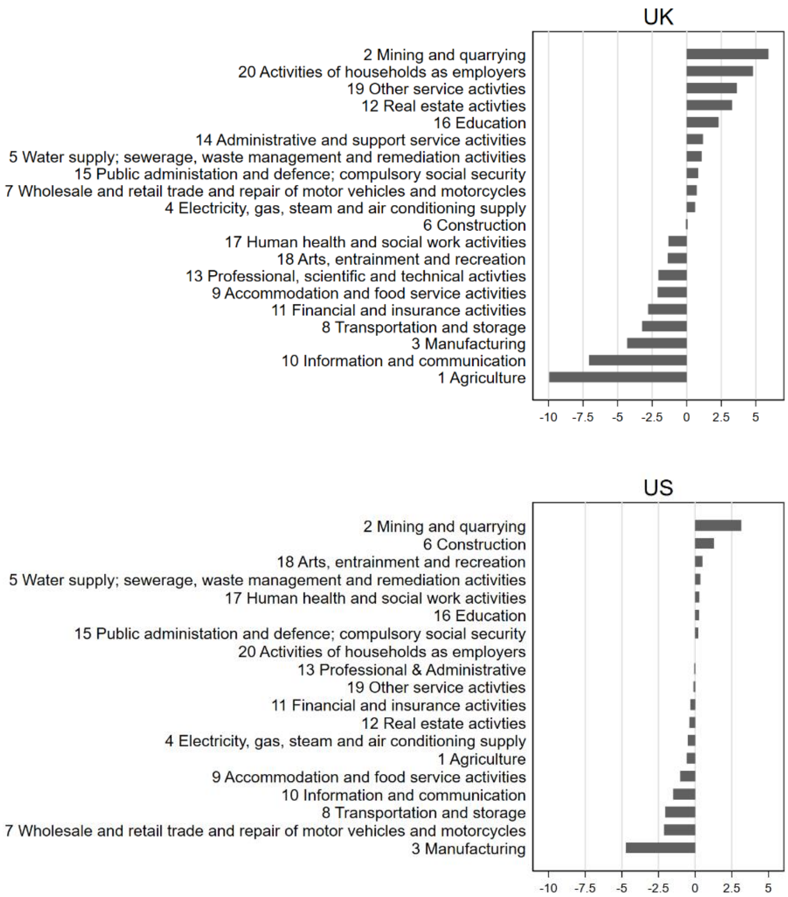
Sources: ONS, EU KLEMS National Account Data files, and authors' calculation.

Figure 8. Industry Labour Productivity $\Delta\ln(V/H)$, Within Productivity $\sum_i \bar{\omega}_i \Delta\ln(V_i/H_i)$, and Reallocation R across Countries 1998-2015



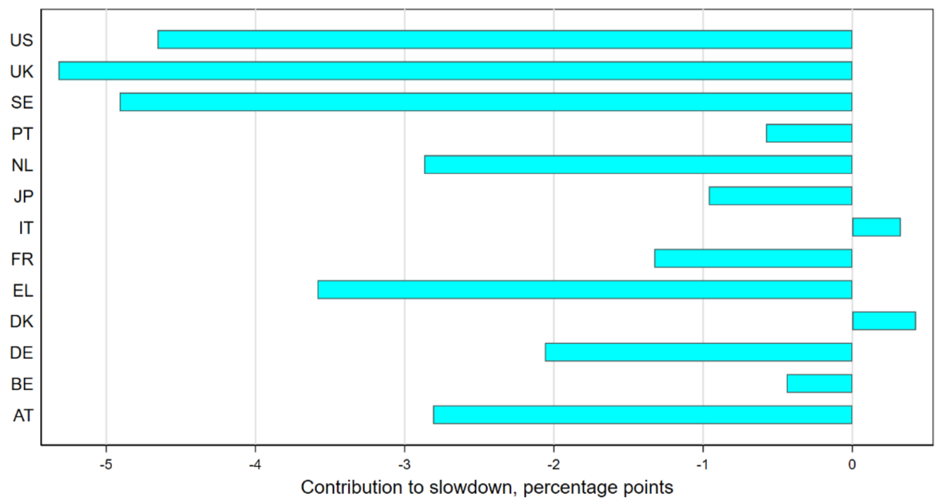
Notes: Data show correlation between aggregate Productivity $\Delta\ln(V/H)$ and Within Productivity $\sum_i \bar{\omega}_i \Delta\ln(V_i/H_i)$, and Within Productivity $\sum_i \bar{\omega}_i \Delta\ln(V_i/H_i)$, and Reallocation R. We remove Greece (as it is an outlier country) for visualisation purpose. Figure AIV 1 in Appendix IV provides results for 21 countries.

Figure 10. Sectoral contributions to Labour Productivity Slowdown UK and US 1998-2015



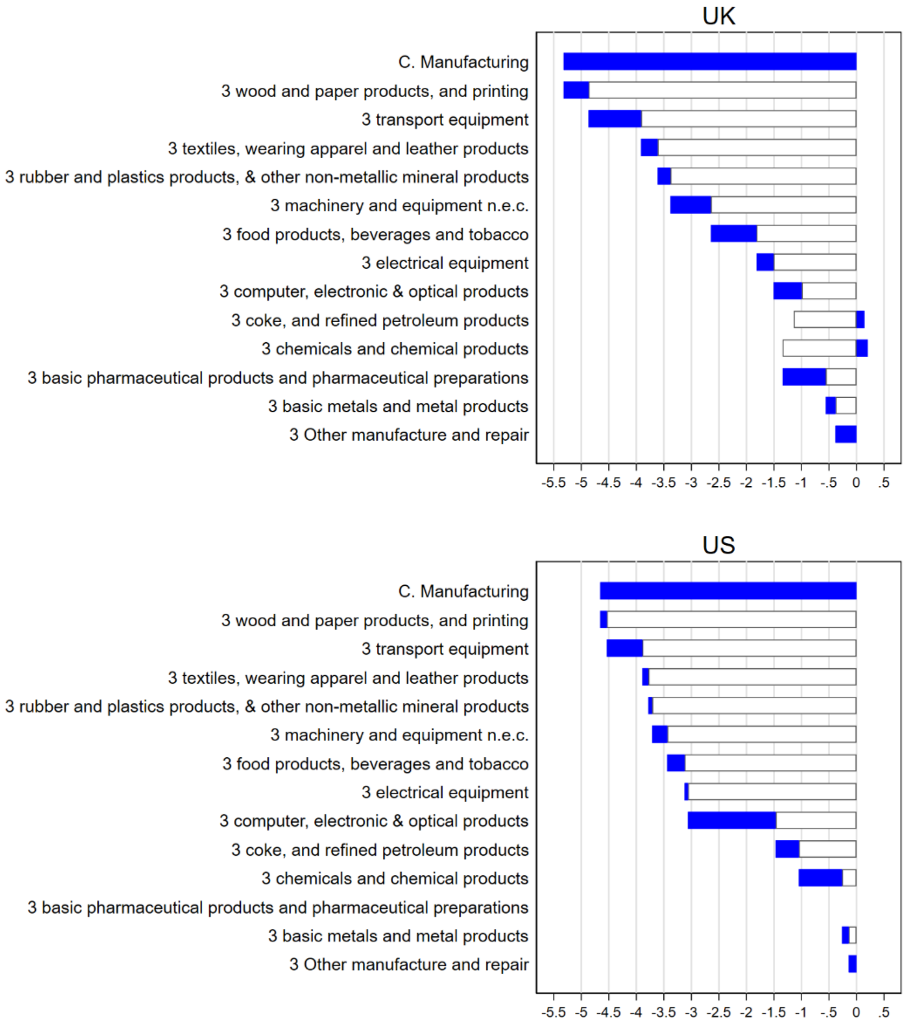
Notes: Data show slowdowns for each industry, where each bar is $\Delta(\Delta ln\, V_i/H_i)) = \Delta ln\, V_i/H_i^{2008-2015} - \Delta ln\, V_i/H_i^{1998-2008}$. To save space, we move other countries into Appendix III Figure AIII 1.
Source: ONS, EU KLEMS database, and authors' calculations.

Figure 11. Contribution of slowdown from Manufacturing Industry across Countries 1998-2015



Notes: Data show slowdown contribution from manufacturing for each country.
Source: ONS, EU KLEMS database, and authors' calculations.

Figure 12. Sub-sectors *within* labour productivity slowdown 1998-2008 vs. 2008-2015; Manufacturing Industry



Notes: Data show slowdowns for each industry, where each bar is $\Delta(\bar{\omega}_j \Delta \ln(V_j/H_j))$ = $\bar{\omega}_j \Delta \ln(V_j/H_j)^{2008-2015} - \bar{\omega}_j \Delta \ln(V_j/H_j)^{1998-2008}$. To save space, we move other countries into Appendix III Figure AIII 2.
Source: ONS, EU KLEMS database, and authors' calculations.

productivity growth and the within and reallocation terms, confirming that there is indeed a positive and linear correlation between aggregate growth $\Delta\ln(V/H)$ and the within contribution $\sum_i \bar{\omega}_i \Delta \ln(V_i/H_i)$, but no pattern between the aggregate growth $\Delta \ln(V/H)$ and reallocation R.

Figure 10 shows the decomposition in average labour productivity growth between 1998-2008 and 2008-2015 across all 20 sectors for each country.[13] There is a slowdown in average productivity growth in manufacturing (except Denmark and Italy, see Figure 11) and information and communication in each. Although somewhat less pronounced in Japan, Belgium,

[13] To save space, we keep the US and UK in the main context, but move other countries into Appendix III. In addition, we provide overall growth patterns between 1998-2008 and 2008-2015 across the 13 economies in Appendix III Tables AIII 1 and AIII 2.

and Portugal than in the other countries, manufacturing industry is the main contributor to the growth slowdown with minus 4.721% (US) and minus 4.310% (UK), minus 1.327% (France), minus 2.868% (Netherlands), minus 2.060% (Germany), minus 2.809% (Austria), minus 3.585% (Greece), and minus 4.910% (Sweden), respectively. The information and communication sector also contributes to the overall productivity slowdown in all economies (except Denmark), although it is relatively smaller in Belgium (-0.906%) and France (-0.810%) than other countries.

What industries in the UK are doing better compared to other countries? Figure 10 shows that the better-performing sectors include mining and quarrying (5.910%), activities of households as employers (4.781%), other service activities (3.617%), education (2.305%), and real estate (3.278%). There are some differences across countries in the ranking of the sectors contributing to the overall productivity slowdown. For instance, the slowdown mainly is attributable to wholesale trade (minus 2.125%) and transport and storage (minus 2.039%) in the US; electricity (minus 15.327%) and mining (minus 14.801%) in Japan; and electricity (minus 6.536%) and other service activities (minus 3.416%) in France (see Figure 10 and Figure AIII 1 in Appendix III).

We next decompose manufacturing into 13 sub-sectors. Figure 12 shows the results. Overall, the sub-sector transport equipment shows a somewhat similar picture contributing notably to the decline across all economies . However, the pattern for other sub-sectors differs across countries. Another notable pattern is that chemicals and computers in the US have post-2008 growth rates of minus 0.785% and minus 1.594%, respectively, which account for almost two-quarters and one-third of the US manufacturing productivity slowdown. While these two sub-sectors perform relatively better in the UK compared to the US, in the UK the computer sub-sector makes a substantial negative contribution. The pharmaceutical subsector also shows different patterns across countries; the UK shows the biggest slowdown in pharmaceuticals, but productivity growth in this sub-sector accelerates in Japan, Germany, Denmark, Italy, Netherlands, and Greece (see Appendix III Figure AIII 2).

Overall, as Figures 10 and 11 show, the slowdown occurs 'within' sectors rather than reflecting reallocations of labour between sectors, although the reallocation that occurs is negative. The productivity slowdown is common across these 13 advanced economies, and in all countries the decompositions show that the high value added sectors of manufacturing and information and communication make a notable contribution to accounting for the slowdown. While there is variation among these countries, there is enough consistency for certain sub-sectors to warrant further investigation: information and communication, and, within manufacturing, transport equipment, computer and electronics manufacture, and pharmaceuticals stand out.

6. Robustness Check: Difference-in-Difference Estimates

As a final robustness check to examine whether the two sectors definitively account for the labour productivity slowdown in the UK and the other countries, we carry out a difference-in-difference estimation. We adopt a general two-way fixed effects (TWFE) with difference-in-difference estimation to test for difference in mean labour productivity growth rates between the two sub-periods as follows:

$$\bar{\omega}_i \Delta \ln(V_i/H_i) = \alpha + \gamma MIT + \beta Post + \delta MIT \cdot Post + \varphi d_t + \varepsilon_{i,t} \quad (14)$$

where $\bar{\omega}_i \Delta \ln(V_i/H_i)$ is the pure within industry labour productivity contribution estimated by Eq. (9), $post$ is a dummy equal to 1 if $t > 2008$ and 0 otherwise, MIT is an indicator equal to 1 if industry i is either manufacturing or information communication industry and 0 otherwise, d_t is a year fixed effect, and $\varepsilon_{i,t}$ is a zero mean error term. As in Stiroh (2002), the estimate α captures the mean within-industry labour productivity contribution for industries excluding manufacturing and information (i.e., industries in the control group) in the period prior to 2008, $\alpha + \gamma$ is the mean within-industry labour productivity contribution for treated industries prior to 2008, β measures acceleration/deceleration for control industries after 2008 (including $t =$ 2008), $\beta + \delta$ is then the acceleration/deceleration for treated industries after 2008. The notation highlights that δ is the differential labour productivity growth contribution of manufacturing and information and communication industries relative to others. We cluster robust standard errors at the industry (for the UK) and country-industry pair level (for worldwide) to allow for arbitrary forms of serial correlation and heteroscedasticity.

Table 6 reports the results; columns (1) and (2) are for the UK 20 industries (A-T) 1998–2019, and columns (3)-(6) for worldwide comparison 1998–2015. The first column reports simple OLS estimates and shows that the manufacturing and information and communication sectors experienced an economically and statistically significant lower labour productivity growth compared to other industries. When industry fixed-effects are accounted for (column 2), the point estimate remains negative and statistically significant at the 1% level. The next four columns report the cross-country comparison. When 21 countries[14] are included in the sample, column (3) shows that both manufacturing and information and communication sectors exhibit a negative within-industry labour productivity contribution 2.227 percentage points lower than other industries post 2008. When focusing only on the 13 countries discussed above, columns (4) and (5) still suggest that the treatment group's labour productivity growth was 1.97 percentage points lower than the control group post-2008. Column (6) re-groups manufacturing

[14] They are the UK, US, Japan, France, Belgium, Netherlands, Ireland, Denmark, Germany, Italy, Portugal, Austria, Czechia, Estonia, Greece, Finland, Sweden, Slovenia, and Slovakia.

Table 6. Labour Productivity Growth Post-2008

	Within industry labour productivity growth $\sum_{j\in i}\bar{\omega}_j\Delta\ln(V_j/H_j)$					
	UK 9807 vs. 0819		Worldwide 9807 vs. 0815			
	(1)	(2)	(3)	(4)	(5)	(6)
MIT	9.420***		4.112***	4.169***		
	(1.997)		(0.364)	(0.479)		
Post	-0.002	-0.002	-0.0676	-0.233	-0.245	-0.233
	(1.421)	(1.419)	(0.598)	(0.503)	(0.504)	(0.503)
MIT*Post	-5.699***	-5.699***	-2.227***	-1.975***	-1.967***	-2.268***
	(0.823)	(0.822)	(0.481)	(0.598)	(0.599)	(0.605)
Constant	1.932	2.874*	0.228	0.364	0.823**	0.823**
	(1.658)	(1.420)	(0.375)	(0.352)	(0.321)	(0.320)
R-squared	0.104	0.052	0.018	0.037	0.017	0.018
Number of countries	1	1	21	13	13	13
Number of industries	20	20	20	20	20	20
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	No	Yes	No	No	No	No
Country-Industry FE	No	No	No	Yes	Yes	Yes
Regroup BD countries	No	No	No	No	No	Yes
Observations	440	440	8,034	3,952	3,952	3,952

Notes: This table reports the estimates based on the model specification in equation 14. The dependent variable is the log change $\Delta(\bar{\omega}_j\Delta\ln(V_j/H_j)$. Columns (1), (3), and (4) are OLS; columns (2), (5), and (6) are the two-way fixed-effect estimates. Column 6 regroups manufacturing and information industries into control for Denmark since the slowdown in Denmark was not mainly caused by the two industries. See Figure 10 for more details. Robust standard errors are clustered at industry and country-industry pair, respectively, reported in parentheses. *, **, and *** represent significance levels at the 10%, 5% and 1% respectively.

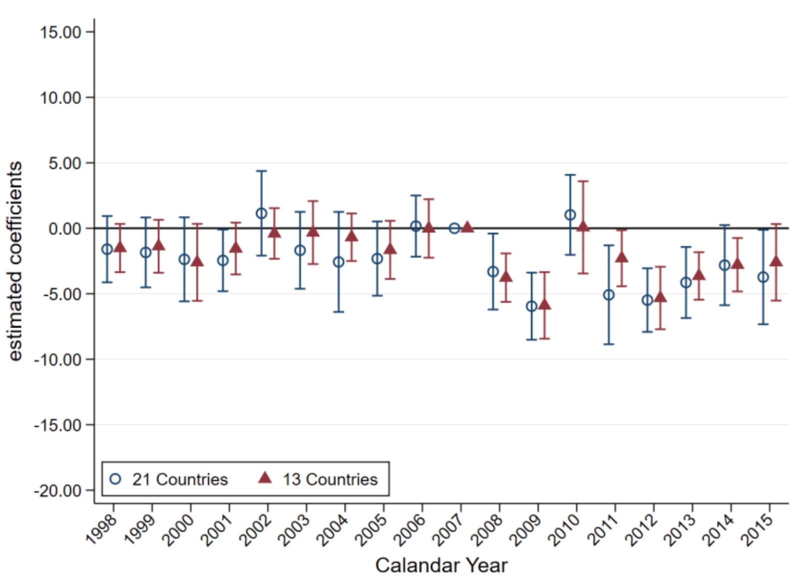
and information and communication sectors into the control group for Denmark as a robustness check, as there they do not contribute much to accounting for the overall productivity slowdown (see, Figure AIII 1 in Appendix III). However, the regrouping does not change the overall pattern; we see that manufacturing and information remain as significant and negatively contribute to the aggregate labour productivity, with estimated coefficient -2.268 at the 1% significance level.

We next extend our DiD estimates from Eq. (14) by breaking down the average treatment effect across each year to capture the accumulated dynamic within-sector productivity contribution as well as the assumption of a common trend in the prior period. The specification is identified as follows:

$$\bar{\omega}_i\Delta\ln(V_i/H_i) = \sum_{k=1998}^{2007}\pi_k PreMIT + \sum_{m=2008}^{2015}\emptyset_m PostMIT + \varphi d_t + \varepsilon_{j,t} \qquad (15)$$

where $PreMIT$ is a dummy taking value 1 if an observation pertains to calendar year k and is in treatment group (manufacturing and information industries) and 0 otherwise, $PostMIT$ is a dummy taking value 1 if an observation pertains to calendar year m and is in treatment group(manufacturing and information industries) and 0 otherwise. We normalise year 2007 to be our reference year. This specification thus allows us to further examine if any if there was any pre-existing difference in trends between the control and the treated industries. Figure 13 provides the results. Reassuringly, the coefficients on the $PreMIT$ dummy variables are not

Figure 13. DiD Estimates of the Labour Productivity Slowdown



Notes: In this exercise, we study the dynamic within-productivity growth difference before and after 2008 financial crisis between MIT (treated group) and other industries (control group) across countries 1998-2015. The figure plots the baseline estimates of the yearly DiD coefficients, together with their 95% confidence intervals. Year and country-industry pair fixed effects are controlled for throughout the specifications. We regroup manufacturing and information industries into control group for Belgium and Denmark based on Table 6 column 6. Robust standard errors are clustered at country-industry pair level, respectively, reported in parentheses.

significantly different from zero for all years prior to 2008, confirming a lack of pre-existing differential trends between treated and control industries. After 2008, manufacturing and information and communication experience a significant slowdown in their within-sector contribution, such that by 2009 and 2012 they have about 6% lower within-sector labour productivity growth compared to other sectors.

7 Discussion

This has been an era of substantial technological change, reflected in large declines in output prices in some sectors 1998-2019. One example is the sub-sector of information and communication in telecommunication industry. Improvements to the UK's telecoms output deflator suggest it declined by between 37% and 96% between 2010 and 2017 (Abdirahman et al., 2020), and a revised deflator adopted by ONS (Martin, 2021) captures a price decline that shows up in the large rise in real value added per hour as illustrated in Figure 1. However, there appears to be a puzzle: why then does telecommunications appear as the biggest contributor to the slowdown in 'within' labour productivity growth in the UK information and communication sector – and indeed why does information and communication overall appear to be one of the bigger contributors to the aggregate slowdown? Figure 1 shows nominal growth in value added per hour slowing post-2007, but it also shows consistently high real value added per hour post-2007.

Part of the resolution lies in the fact that the within figures in the Tornqvist decomposition use *nominal* value added shares as weights, and hence the slowdown reflects slower (albeit still quite rapid) revenue growth in the sector. It might seem that using volume weights instead – for example growth in bytes of data used – would give a 'truer' picture of the contribution of telecommunications to productivity growth but this would be misleading in the sense that user value lies in the content carried by the telecoms network, value generated by downstream sectors. It is not immediately obvious how to think about the changing value of bytes of data over time. Does twice the data lead to twice the money-metric utility? Probably not. There are unresolved questions concerning how to think about price indices for markets whose outputs are complements (such as telecoms and sectors using communications intensively) or those whose products demonstrate significant returns to scale and non-rivalry.

One lesson is that interpreting the results of any decomposition must be done with care. The fundamental issue is that the choice of revenue weights versus volume or employment weights (as in alternative decomposition methods) provide two distinct lenses on the economy. For the case of telecommunications, Abdirahman et al (2022) show that the greater the use of volume (in terms of bytes of data) rather than revenue weights, the larger the decline in the deflator and the faster the growth in real terms output. The difference can be large when there is rapid change in a sector, due in this example to technological shifts such as greater compression, more bandwidth and faster speeds, such that the relationship between volume and revenue shifts. The use of a unit value deflator (which uses pure volume weights) rather than the ONS output price deflator might tell a different productivity story.

In this paper, we adopt the Tornqvist decomposition formula to allow for relative price shifts between different sectors of the economy, while also using two alternative methods to demonstrate the importance of different weights employed in the exercise. We demonstrate that within-sector labour productivity growth is the main source accounting for the slowdown in aggregate labour productivity growth, while labour reallocation between sectors accounts for little. We further show that some other high value added sectors – transport equipment manufacture (mainly motor vehicles), pharmaceuticals, and computer, electronic and optical products within manufacturing, and telecommunications and computer programming, consulting and related activities withing in information and communication – experienced the biggest within labour productivity slowdowns in the UK.

Looking at 13 (including the UK) advanced economies, the pattern at the sector level is consistent across countries. Within manufacturing, there is variation across sub-sectors but some common elements with slowdowns in within-industry labour productivity growth in transport equipment, pharmaceuticals and computer and electronics manufacture. Since many of the sub-sectors in this list are regarded as success stories in the UK and worldwide, it is striking that the productivity slowdown is greatest in some of the most technologically-advanced industries.

There are two possible avenues to pursue in exploring the reasons for this pattern. One concerns price deflators: the shift share method, using employment share weights, ensures that the sum of the sectors' labour productivity growth is equal to the aggregate by assuming relative prices between sectors do not change. The difference with the Tornqvist method can be large when there is rapid change in a sector, due for example to technological shifts (such as greater compression, more bandwidth and faster speeds in telecoms) such that the relationship between volume and revenue shifts. Alongside this, our findings call for more detailed investigation of the slowdown sub-sectors and their supply chains, including across countries. There is more work to be done to understand the rapidly-changing advanced sectors of the economy.

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Appendix I. Tests for breaks in trend

We test whether the difference in the means is zero. Column (3) in Table A1 provides means for current price value added per hour for the period 1998-0007, whereas column (4) shows them for 2008-2019. The test (columns 5 and 6) confirms that almost all industries, except mining and quarrying (industry B) and real estate (industry L), experienced a significant slowdown during the post-crisis period. Table A2 repeats the tests for real terms data.

Table AI 1. T-test on Current price value added per hour, £, 1998-2007 vs 2008-2019

	Mean1 (1)	Mean2 (2)	t value (3)	p-value (4)
A Agriculture	0.028	0.029	0.000	0.984
B Mining and quarrying	0.054	-0.016	0.800	0.431
C Manufacturing	0.044	0.032	1.250	0.230
D Electricity, gas, steam and air conditioning supply	0.061	0.003	1.000	0.318
E Water supply; sewerage, waste management and remediation activities	0.043	-0.002	2.450	0.024
F Construction	0.064	0.024	2.400	0.026
G Wholesale and retail trade and repair of motor vehicles and motorcycles	0.037	0.024	1.500	0.147
H Transportation and storage	0.036	0.018	1.150	0.255
I Accommodation and food service activities	0.043	0.021	1.650	0.117
J Information and communication	0.050	0.009	2.950	0.007
K Financial and insurance activities	0.071	0.025	1.650	0.110
L Real estate activties	-0.020	0.011	-1.650	0.111
M Professional, scientific and technical activties	0.044	0.018	2.300	0.032
N Administrative and support service activities	0.022	0.03	-0.650	0.511
O Public administation and defence; compulsory social security	0.041	0.039	0.250	0.814
P Education	0.046	0.018	2.900	0.009
Q Human health and social work activities	0.053	0.018	3.900	0.001
R Arts, entrainment and recreation	0.043	0.026	0.800	0.424
S Other service activties	0.040	0.029	0.800	0.439
T Activities of households as employers	0.019	0.072	-0.850	0.393

Notes: This table performs T-test for a trend break on Current price value added per hour in log change between 1998-2007 (column 1) and 2008-2019 (column 2).
Source: Authors' calculation.

Table AI 2. T-test on Real terms value added per hour, 1997=100, 1998-2007 vs 2008-2019

	Mean1 (1)	Mean2 (2)	t value (3)	p-value (4)
A Agriculture	0.070	0.008	0.900	0.370
B Mining and quarrying	-0.052	-0.061	0.150	0.888
C Manufacturing	0.070	0.015	6.200	0.000
D Electricity, gas, steam and air conditioning supply	0.019	-0.013	0.500	0.613
E Water supply; sewerage, waste management and remediation activities	-0.017	-0.029	0.450	0.667
F Construction	-0.007	-0.001	-0.350	0.733
G Wholesale and retail trade and repair of motor vehicles and motorcycles	0.009	0.002	0.450	0.647
H Transportation and storage	0.015	-0.010	1.150	0.268
I Accommodation and food service activities	-0.002	-0.003	0.050	0.948
J Information and communication	0.121	0.060	2.850	0.011
K Financial and insurance activities	0.040	-0.011	2.400	0.025
L Real estate activties	-0.042	0.004	-3.950	0.001
M Professional, scientific and technical activties	0.013	-0.007	2.050	0.053
N Administrative and support service activities	-0.011	0.012	-1.950	0.066
O Public administation and defence; compulsory social security	0.008	0.024	-1.050	0.313
P Education	-0.025	-0.005	-1.750	0.096
Q Human health and social work activities	0.004	-0.009	1.250	0.234
R Arts, entrainment and recreation	0.009	0-.012	1.000	0.34
S Other service activties	-0.024	0.003	-1.900	0.072
T Activities of households as employers	-0.033	0.048	-1.350	0.198

Notes: This table performs T-test for a trend break on Real terms value added per hour in log change between 1998-2007 (column 1) and 2008-2019 (column 2).
Source: Authors' calculation.

Appendix II. Comparison of Shift-Share and Generalized Exactly Additive Approaches

The advantage of our Tornqvist decomposition is that is allows for different value-added functions across industries. However, it does so at the cost of additivity and it matters when we more industry detail information are available as reallocation effects by its natural setting in Tornqvist approach become larger. Since our main concern are the of value weights in Tornqvist, the shift-share method that employs labour input weights may provide interesting differences. Furthermore, the Generalized Exactly Additive Decomposition approach adopted by Tang and Wang (2004) and implemented by ONS may also provide different story since different weights are used. Therefore, in this section we further provide two alternative approaches to measuring productivity growth and slowdown.

The first one, which is called shift-share, is to assume that relative prices between sectors do not change and so the sum of the labour productivity growth across industries is equal to the aggregate one. This enables us to obtain aggregate value added (Y) and aggregate hours worked (H) by summing value added and hours across industries (see, Fabricant, 1942; Haltiwanger, 1997; De Vries et al., 2015; Moussir and Chatri, 2020; De Vries et al., 2021):

$$\frac{\Delta v_t}{v_{t-1}} = \frac{\sum_i \Delta v_t^i s_{t-1}^i}{v_{t-1}} + \frac{\sum_i \Delta s_t^i v_{t-1}^i}{v_{t-1}} + \frac{\sum_i \Delta v_t^i \Delta s_t^i}{v_{t-1}} \tag{16}$$

Where $v_t = \sum_i v_t^i / \sum_i H_t^i$ is the aggregate labour productivity, $s_t^i = H_t^i / \sum_i H_t^i$ is the worked hours of industry i to the overall economy. Thus, the first term is the hours worked weighted sum of productivity growth within individual sectors. $\sum_i \Delta s_t^i v_{t-1}^i$ is the the movement of workers to sectors with above-average productivity levels (static reallocation effect, which we will call the cross-sectoral effect) and $\sum_i \Delta v_t^i \Delta s_t^i$ is the transversal term or interaction term. We combine the last two terms as $R_{it} = \sum_i \Delta s_{it} y_{it-1} + \sum_i \Delta s_{it} \Delta s_{it}$ to refer the reallocation term. Finally, dividing all terms by v_{t-1} we then obtain the growth rate of aggregate labour productivity.

The second one, which is called Generalized Exactly Additive Decomposition (GEAD) approaches and adopted in Tang and Wang (2004), considers the formulation outlined as follows:

$$\frac{X_t - X_{t-1}}{X_{t-1}} = \sum_i w_{t-1}^i \frac{X_t^i - X_{t-1}^i}{X_{t-1}^i} + \sum_i x_{t-1}^i \Delta s_t^i + \sum_i x_{t-1}^i \Delta s_t^i \frac{X_t^i - X_{t-1}^i}{X_{t-1}^i} \tag{17}$$

Where $X_t = \sum_i p_t^i l_t^i X_t^i = \sum_i s_t^i X_t^i$ is the aggregate labour productivity weighted by the relative output price $p_t^i = P_t^i / P_t$ and labour input share (worked hours) $l_t^i = H_t^i / H_t$, $s_t^i = p_t^i l_t^i$ is the relative size of industry i, and $w_{t-1}^i = (X_{t-1}^i / X_{t-1}) s_{t-1}^i$ is the output share of industry i at the beginning of the period. Hence, Eq. (14) expresses the growth rate of labour productivity into three components. The first component is the product of labour productivity growth and nominal output share in the base year, capturing the pure productivity growth effect. The second term is the product of relative levels of labour productivity at a given industry in the initial period and the change in employment share, referring to the static effect. The last term is the interaction term of the first and second, representing as the dynamic effect.

Figures AII 1 provides results over the two alternative approaches through the three components 1998-2019 based on the whole economy sector in the UK. At the aggregate level, the two decomposition formulas provide different narratives as to which component drove UK's aggregate productivity growth over the past decade. The reallocation effects seem to be relatively important to aggregate growth pattern by using GEAD approach, whereas the shift-share suggests that it is relatively small and contribute little to the aggregate growth rate, which is similar to what we have shown under Tornqvist approach. Similarly, De Vries et al. (2021) compare the differences in the industry reallocation effects through the shift-share, Tornqvist, and GEAD methods for the UK and find that the GEAD method tends to provide somewhat larger reallocation effects than the other two methods. Table AII 1 provides a general comparison through the three alternative methods. The results again indicate that the reallocation terms are important in aggregate labour productivity under the GEAD approach, but not under the other two frameworks. Furthermore, we note that the shift-share method assumes prices are the same across industries for the aggregate whole economy sector. This assumption seems to be too strong in reality compared to either Tornqvist or GEAD approach.

Figure AII 2 further breakdowns aggregate growth into 20 industries and shows the slowdown pattern between the two approaches. In the shift-share formula Eq. (13), sectoral contributions reflect only the impact of real variables on aggregate labour productivity growth, whereas in the GEAD formula Eq. (14) incorporates the effect of changes in relative prices to capture the overall economic significance of different sectors in the economy, i.e., the weights are different between the two approaches (and of course for our Tornqvist formular too). In the use of GEAD formula, it implies that sector such as mining and oil and gas would have such a strong contribution to aggregate labour productivity growth even without strong sector's productivity performance (Avillez, 2012). This can be easily seen when compared the two charts in Figure A2; shift-share suggests that mining and quarrying leads to aggregate productivity slowdown, whereas GEAD approach indicates accelerating productivity growth post-2008.

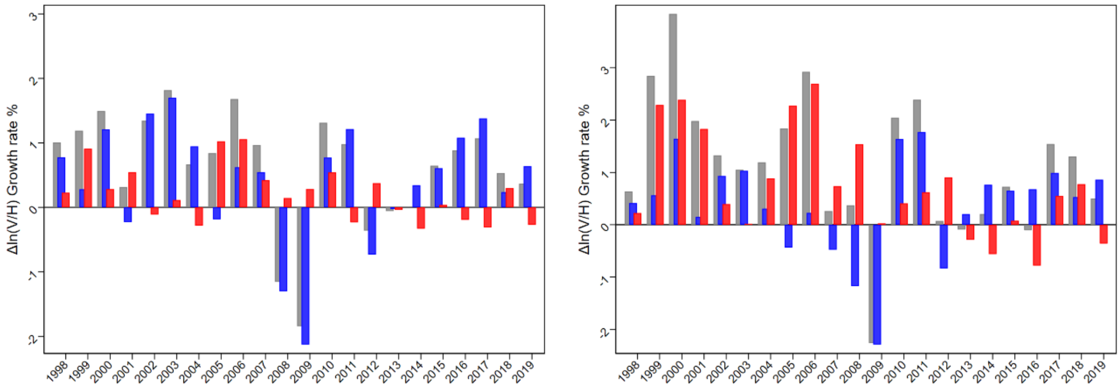
From this perspective, it would be difficult to claim which approach is more accurate in capturing economic reality. From our point of view, although the GEAD approach estimate something quite different and is hard to distinguish effects from either labour or output price changes to productivity compared to Tornqvist or shift-share approach, the GEAD approach still very well takes into account changes in relative prices and generate sectoral contribution estimates that are perfectly additive irrespective of how real output is calculated.

Table AII 1. Labour Productivity Growth Whole Economy UK 1998-2008 vs. 2008-2019

	$\Delta\ln(V/H)$	$\sum_i \bar{\omega}_i \Delta\ln(V_i/H_i)$	R
	(1)	(2)	(3)
Tornqvist Approach			
# Whole Economy (20 Industries)			
1998-2019	1.040%	0.791%	0.248%
1998-2008	1.632%	1.222%	0.409%
2008-2019	0.350%	0.263%	0.086%
# Whole Economy (Industry L excluded)			
1998-2019	0.818%	1.020%	0.202%
1998-2008	1.502%	1.738%	-0.236%
2008-2019	0.048%	0.216%	-0.168%
# Whole Economy (Industry O,P,Q excluded)			
1998-2019	0.978%	0.810%	0.168%
1998-2008	1.719%	1.316%	0.403%
2008-2019	0.179%	0.233%	-0.053%
Shift-Share Method			
# Whole Economy (20 Industries)			
1998-2019	0.622%	0.418%	0.204%
1998-2008	0.923%	0.528%	0.395%
2008-2019	0.199%	0.173%	0.026%
# Whole Economy (Industry L excluded)			
1998-2019	0.584%	0.677%	-0.093%
1998-2008	1.008%	1.063%	-0.055%
2008-2019	0.028%	0.150%	-0.122%
# Whole Economy (Industry O,P,Q excluded)			
1998-2019	0.843%	0.561%	0.282%
1998-2008	1.327%	0.812%	0.515%
2008-2019	0.243%	0.178%	0.065%
Generalized Exactly Additive Decomposition approach			
# Whole Economy (20 Industries)			
1998-2019	1.125%	0.369%	0.756%
1998-2008	1.677%	0.288%	1.389%
2008-2019	0.557%	0.315%	0.242%
# Whole Economy (Industry L excluded)			
1998-2019	1.139%	0.684%	0.455%
1998-2008	1.740%	0.920%	0.820%
2008-2019	0.535%	0.304%	0.231%
# Whole Economy (Industry O,P,Q excluded)			
1998-2019	1.115%	0.496%	0.619%
1998-2008	1.649%	0.491%	1.158%
2008-2019	0.640%	0.369%	0.271%

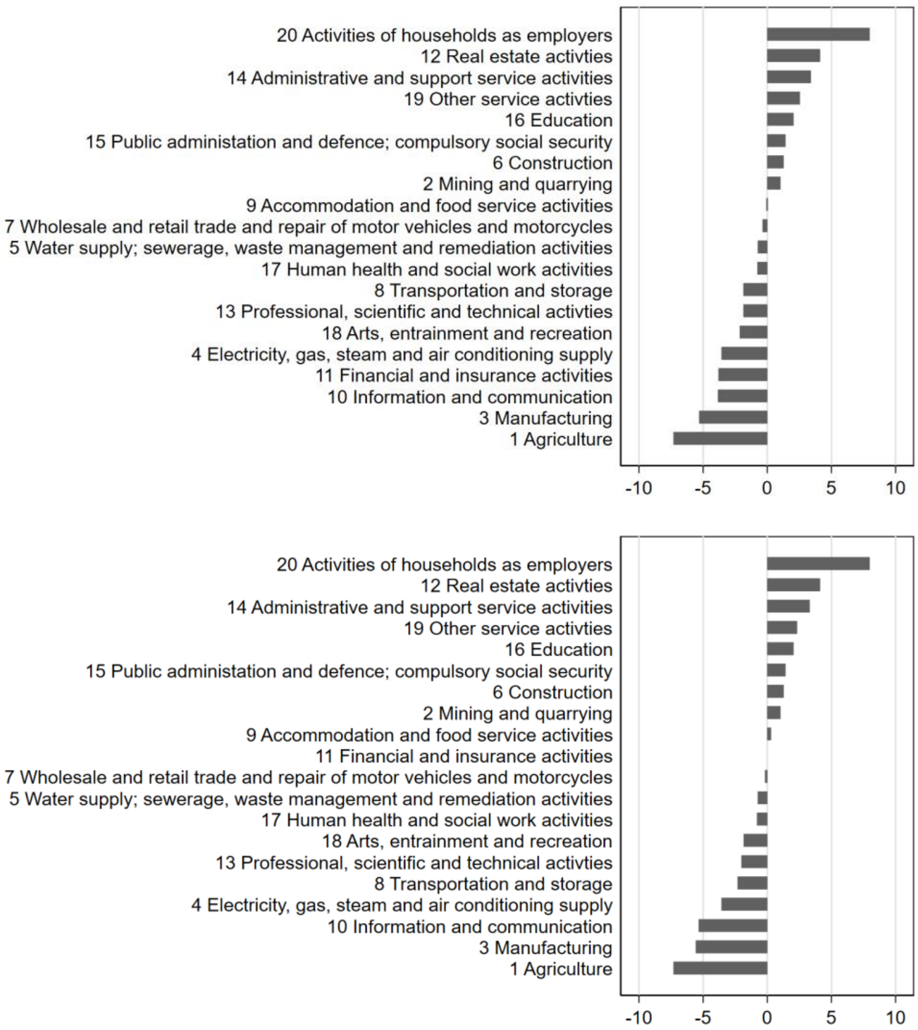
Notes: Decomposition of labour productivity based on Eqs (8), (16) and (17). Industry L represents real estate activities, O represents public administration, P represents Education, and Q represents human health. Column 3 reports reallocation that contains the sum of the last two terms from Eqs. (16) and (17), i.e., $R = \frac{\sum_i \Delta s_t^i v_{t-1}^i}{v_{t-1}} + \frac{\sum_i \Delta v_t^i \Delta s_t^i}{v_{t-1}}$ for Shift-share and $R = \sum_i x_{t-1}^i \Delta s_t^i + \sum_i x_{t-1}^i \Delta s_t^i \frac{x_t^i - x_{t-1}^i}{x_{t-1}^i}$ for GEAD approach.

Figure AII 1. Growth in Real Terms Whole Sector Labour Productivity 1998-2019; Shift Share (left) & Generalized Exactly Additive Decomposition (right).



Notes: This graph plots the aggregate labour productivity (grey), within-contribution (blue), and reallocation term (red). Whole economy sectors.
Source: ONS and authors' calculations.

Figure AII 2. Labour Productivity Gap 1998-2019; Shift Share (Top) & Generalized Exactly Additive Decomposition (Bottom).



Source: ONS and authors' calculations.

Appendix III. International Comparisons for 13 Countries

Table AIII 1. Labour Productivity Growth 1998-2008 vs. 2008-2015, whole economy

	$\Delta\ln(V/H)$	$\sum_i \bar{\omega}_i \Delta\ln(V_i/H_i)$	R
	(1)	(2)	(3)
UK			
1998-2008	1.632%	1.222%	0.409%
2008-2015	0.137%	-0.030%	0.167%
US			
1998-2008	1.927%	2.088%	-0.160%
2008-2015	0.913%	1.077%	-0.164%
Japan			
1998-2008	0.760%	0.572%	0.188%
2008-2015	0.358%	0.354%	0.003%
France			
1998-2008	1.159%	1.178%	-0.018%
2008-2015	0.738%	0.909%	-0.170%
Belgium			
1998-2008	0.860%	0.711%	0.148%
2008-2015	0.542%	0.328%	0.214%
Netherlands			
1998-2008	1.447%	1.589%	-0.141%
2008-2015	0.865%	0.969%	-0.103%
Denmark			
1998-2008	1.616%	1.362%	0.253%
2008-2015	0.301%	0.447%	-0.146%
Germany			
1998-2008	0.614%	0.534%	0.079%
2008-2015	0.961%	1.005%	-0.043%
Italy			
1998-2008	-0.020%	-0.232%	0.212%
2008-2015	-0.039%	-0.001%	-0.038%
Portugal			
1998-2008	0.788%	0.834%	-0.045%
2008-2015	0.538%	0.338%	0.199%
Austria			
1998-2008	1.880%	1.847%	0.032%
2008-2015	0.290%	0.360%	-0.070%
Greece			
1998-2008	0.573%	-0.382%	0.956%
2008-2015	-0.749%	-1.368%	0.619%
Sweden			
1998-2008	2.039%	2.096%	-0.056%
2008-2015	0.352%	0.462%	-0.110%

Notes: Data are average growth rates per year for two periods. Data are decomposition of labour productivity in per hour terms based on Eq. (8). We remove industries public administration, defence, education, human health and social work activities, arts, entertainment, recreation; other services and service activities, etc., and activities of extraterritorial organizations and bodies from our aggregation exercise.
Sources: ONS, EU KLEMS National Account Data files, and authors' calculation.

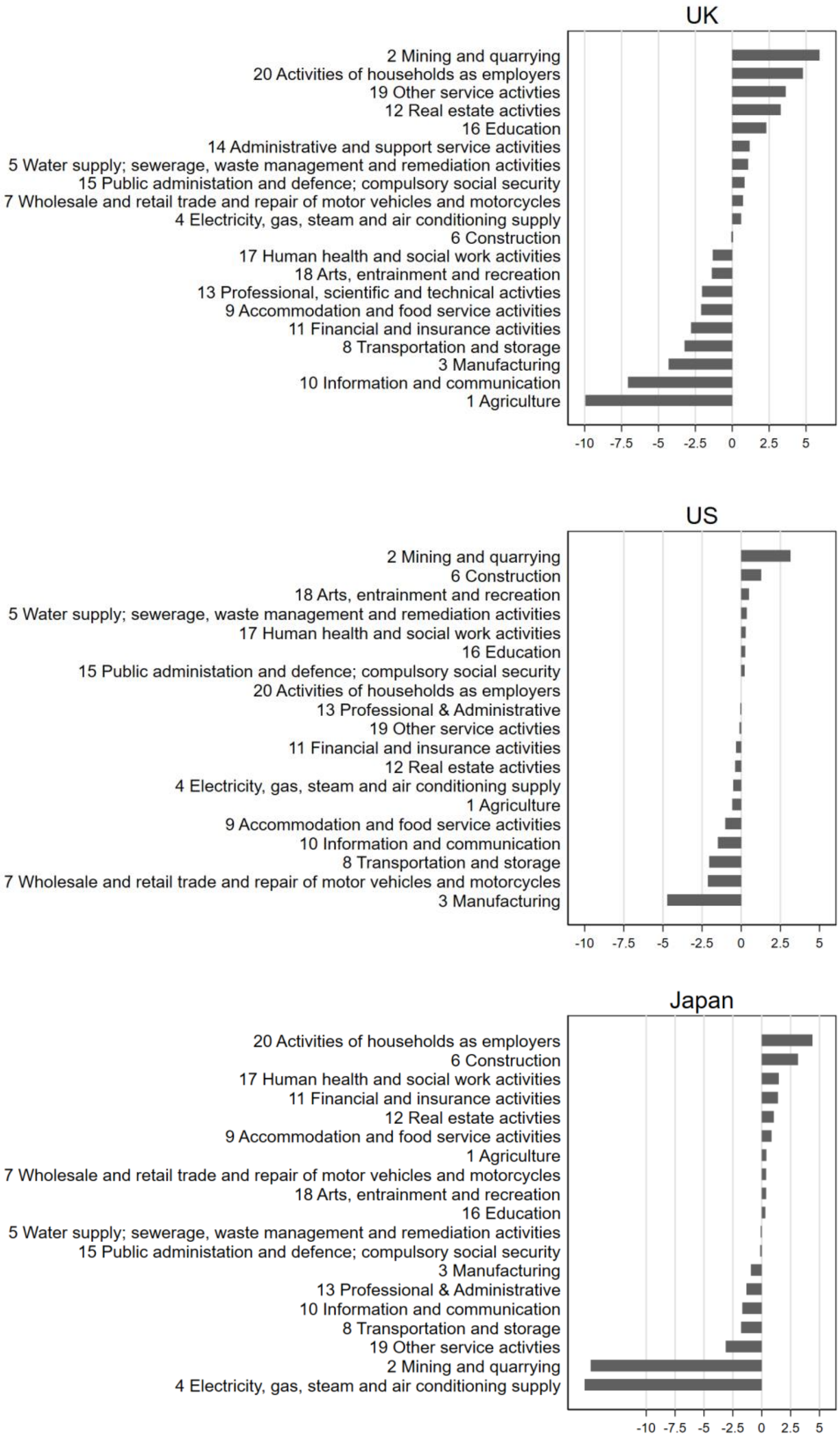
Table AIII 2. Labour Productivity Growth 1998-2008 vs. 2008-2015 (Industry L excluded)

	$\Delta\ln(V/H)$	$\sum_i \bar{\omega}_i \Delta \ln(V_i/H_i)$	R
	(1)	(2)	(3)
UK			
1998-2008	1.502%	1.738%	-0.236%
2008-2015	-0.236%	-0.103%	-0.132%
US			
1998-2008	1.890%	2.135%	-0.245%
2008-2015	0.822%	1.045%	-0.223%
Japan			
1998-2008	0.734%	0.772%	-0.038%
2008-2015	0.236%	0.412%	-0.176%
France			
1998-2008	1.216%	1.290%	-0.073%
2008-2015	0.662%	0.679%	-0.016%
Belgium			
1998-2008	0.967%	0.951%	0.016%
2008-2015	0.475%	0.488%	-0.013%
Netherlands			
1998-2008	1.591%	1.830%	-0.239%
2008-2015	0.728%	0.772%	-0.043%
Denmark			
1998-2008	0.743%	0.851%	-0.108%
2008-2015	0.859%	0.923%	-0.063%
Germany			
1998-2008	1.559%	1.406%	0.153%
2008-2015	0.281%	0.325%	-0.044%
Italy			
1998-2008	-0.002%	-0.150%	0.147%
2008-2015	-0.227%	-0.189%	-0.038%
Portugal			
1998-2008	0.908%	1.020%	-0.111%
2008-2015	0.361%	0.070%	0.290%
Austria			
1998-2008	1.910%	1.931%	-0.021%
2008-2015	0.203%	0.237%	-0.033%
Greece			
1998-2008	0.604%	0.905%	-0.300%
2008-2015	-2.206%	-2.211%	0.050%
Sweden			
1998-2008	2.220%	2.273%	-0.053%
2008-2015	0.292%	0.492%	-0.199%

Notes: Data are average growth rates per year for two periods. Data are decomposition of labour productivity in per hour terms based on Eq. (8). We remove industries public administration, defence, education, human health and social work activities, arts, entertainment, recreation; other services and service activities; and activities of extraterritorial organizations and bodies from our aggregation exercise. Industries L represents real estate activities

Sources: ONS, EU KLEMS National Account Data files, and authors' calculation.

Figure AIII 1. Sectoral contributions to Labour Productivity Slowdown 1998-2015



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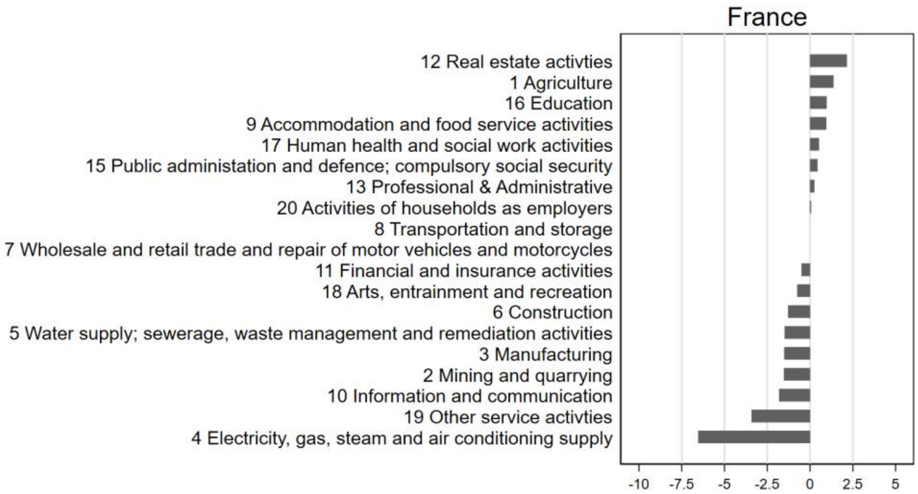
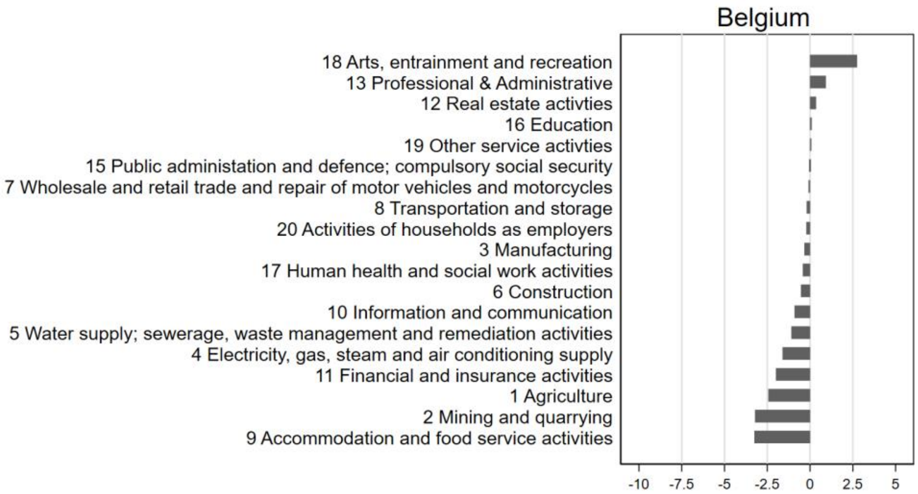
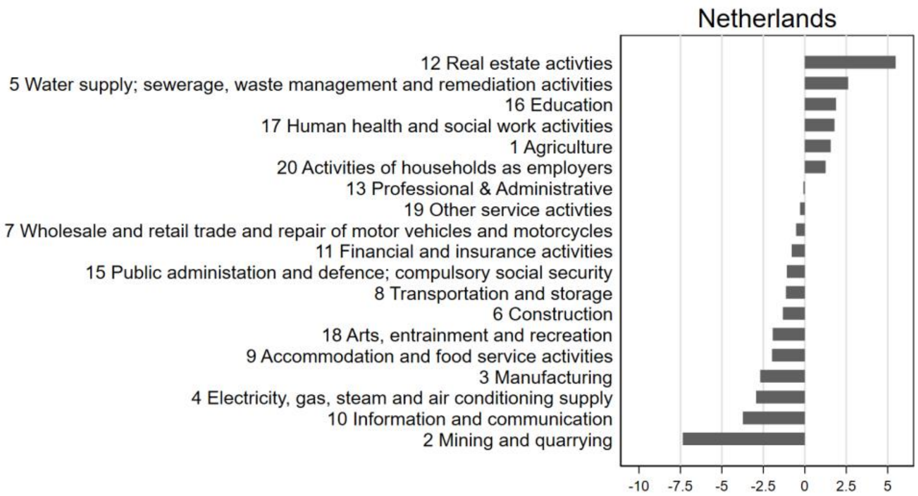

France
12 Real estate activties
1 Agriculture
16 Education
9 Accommodation and food service activities
17 Human health and social work activities
15 Public administation and defence; compulsory social security
13 Professional & Administrative
20 Activities of households as employers
8 Transportation and storage
7 Wholesale and retail trade and repair of motor vehicles and motorcycles
11 Financial and insurance activities
18 Arts, entrainment and recreation
6 Construction
5 Water supply; sewerage, waste management and remediation activities
3 Manufacturing
2 Mining and quarrying
10 Information and communication
19 Other service activties
4 Electricity, gas, steam and air conditioning supply
-10 -7.5 -5 -2.5 0 2.5 5


Belgium
18 Arts, entrainment and recreation
13 Professional & Administrative
12 Real estate activties
16 Education
19 Other service activties
15 Public administation and defence; compulsory social security
7 Wholesale and retail trade and repair of motor vehicles and motorcycles
8 Transportation and storage
20 Activities of households as employers
3 Manufacturing
17 Human health and social work activities
6 Construction
10 Information and communication
5 Water supply; sewerage, waste management and remediation activities
4 Electricity, gas, steam and air conditioning supply
11 Financial and insurance activities
1 Agriculture
2 Mining and quarrying
9 Accommodation and food service activities
-10 -7.5 -5 -2.5 0 2.5 5


Netherlands
12 Real estate activties
5 Water supply; sewerage, waste management and remediation activities
16 Education
17 Human health and social work activities
1 Agriculture
20 Activities of households as employers
13 Professional & Administrative
19 Other service activties
7 Wholesale and retail trade and repair of motor vehicles and motorcycles
11 Financial and insurance activities
15 Public administation and defence; compulsory social security
8 Transportation and storage
6 Construction
18 Arts, entrainment and recreation
9 Accommodation and food service activities
3 Manufacturing
4 Electricity, gas, steam and air conditioning supply
10 Information and communication
2 Mining and quarrying
-10 -7.5 -5 -2.5 0 2.5 5

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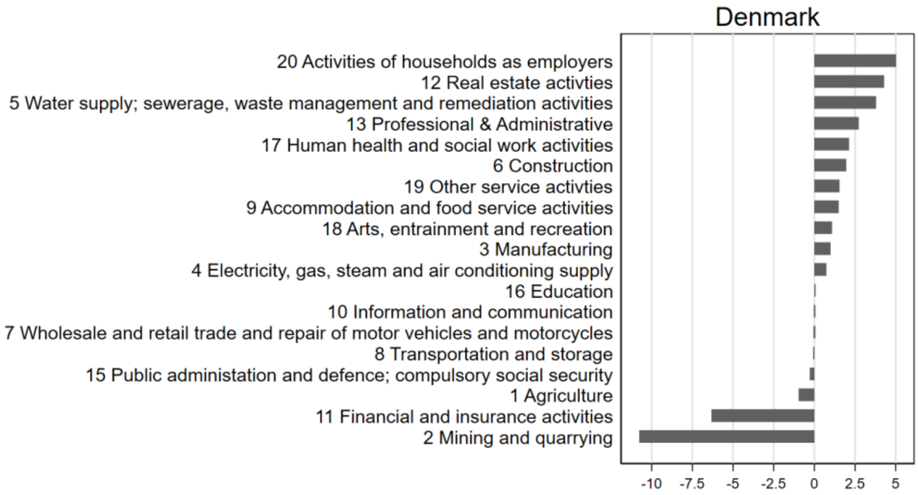
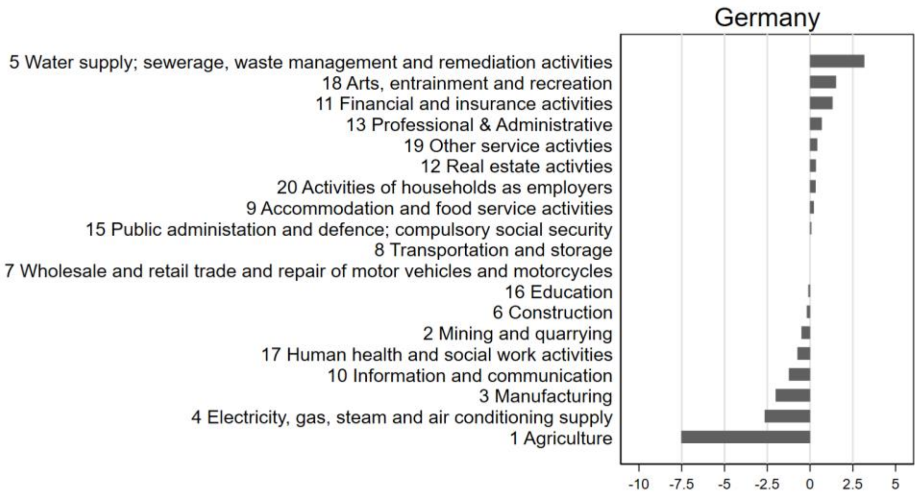
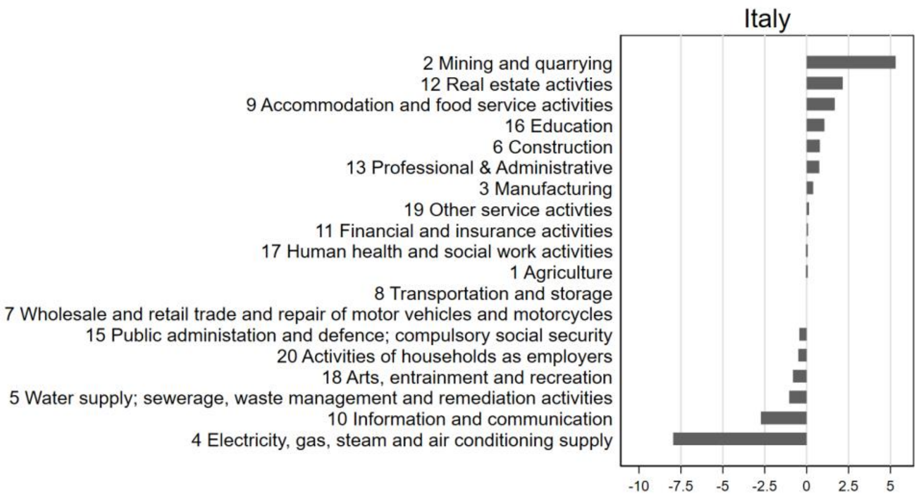

Denmark
20 Activities of households as employers
12 Real estate activties
5 Water supply; sewerage, waste management and remediation activities
13 Professional & Administrative
17 Human health and social work activities
6 Construction
19 Other service activties
9 Accommodation and food service activities
18 Arts, entrainment and recreation
3 Manufacturing
4 Electricity, gas, steam and air conditioning supply
16 Education
10 Information and communication
7 Wholesale and retail trade and repair of motor vehicles and motorcycles
8 Transportation and storage
15 Public administation and defence; compulsory social security
1 Agriculture
11 Financial and insurance activities
2 Mining and quarrying
-10 -7.5 -5 -2.5 0 2.5 5


Germany
5 Water supply; sewerage, waste management and remediation activities
18 Arts, entrainment and recreation
11 Financial and insurance activities
13 Professional & Administrative
19 Other service activties
12 Real estate activties
20 Activities of households as employers
9 Accommodation and food service activities
15 Public administation and defence; compulsory social security
8 Transportation and storage
7 Wholesale and retail trade and repair of motor vehicles and motorcycles
16 Education
6 Construction
2 Mining and quarrying
17 Human health and social work activities
10 Information and communication
3 Manufacturing
4 Electricity, gas, steam and air conditioning supply
1 Agriculture
-10 -7.5 -5 -2.5 0 2.5 5


Italy
2 Mining and quarrying
12 Real estate activties
9 Accommodation and food service activities
16 Education
6 Construction
13 Professional & Administrative
3 Manufacturing
19 Other service activties
11 Financial and insurance activities
17 Human health and social work activities
1 Agriculture
8 Transportation and storage
7 Wholesale and retail trade and repair of motor vehicles and motorcycles
15 Public administation and defence; compulsory social security
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18 Arts, entrainment and recreation
5 Water supply; sewerage, waste management and remediation activities
10 Information and communication
4 Electricity, gas, steam and air conditioning supply
-10 -7.5 -5 -2.5 0 2.5 5

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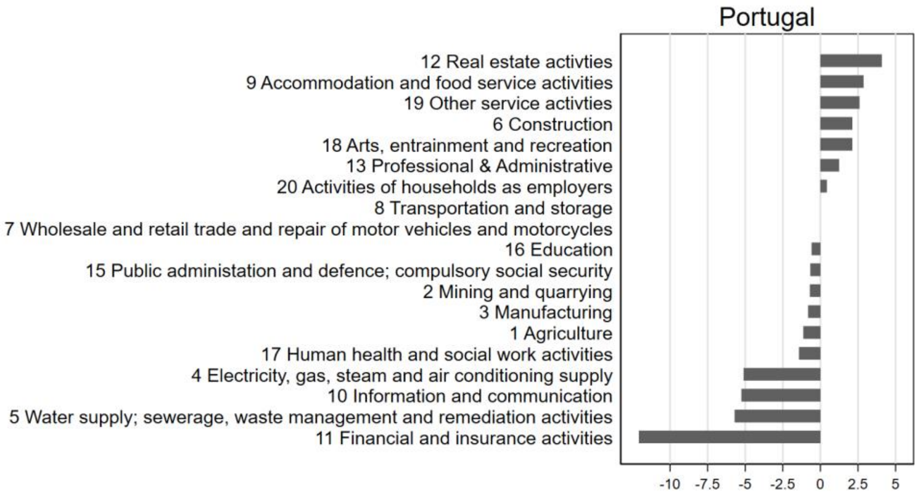
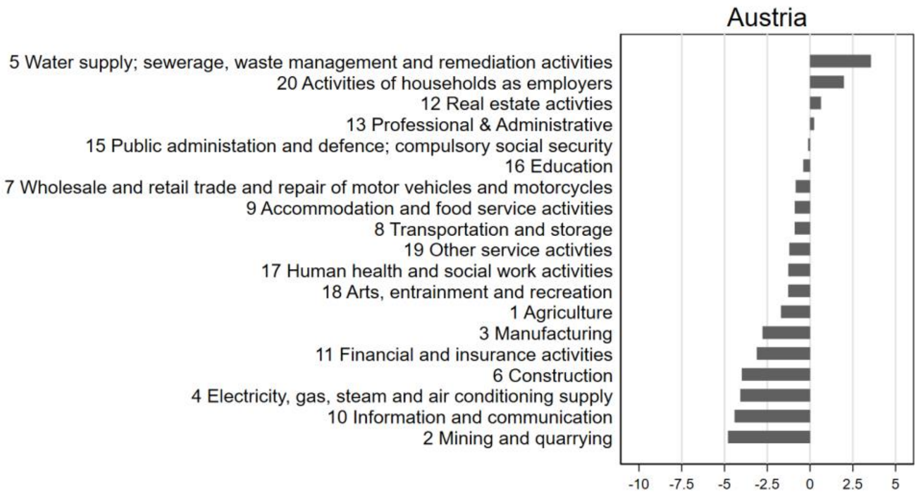
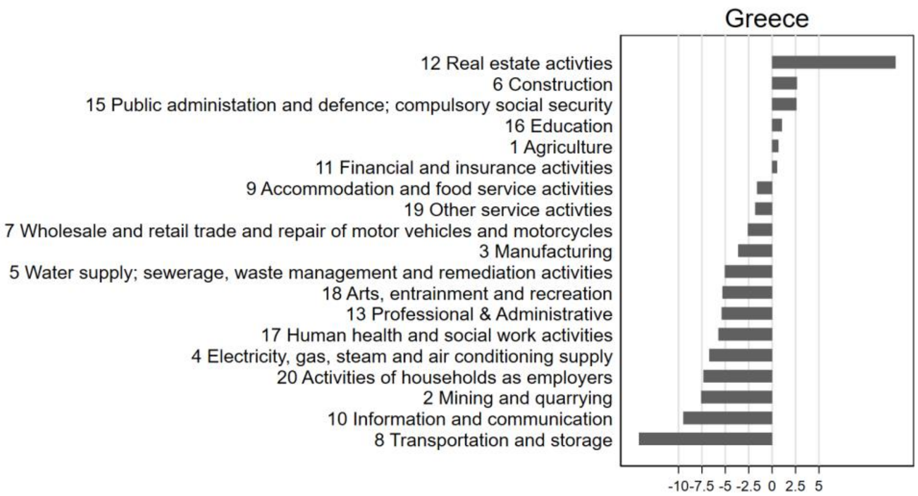

Portugal
12 Real estate activties
9 Accommodation and food service activities
19 Other service activties
6 Construction
18 Arts, entrainment and recreation
13 Professional & Administrative
20 Activities of households as employers
8 Transportation and storage
7 Wholesale and retail trade and repair of motor vehicles and motorcycles
16 Education
15 Public administation and defence; compulsory social security
2 Mining and quarrying
3 Manufacturing
1 Agriculture
17 Human health and social work activities
4 Electricity, gas, steam and air conditioning supply
10 Information and communication
5 Water supply; sewerage, waste management and remediation activities
11 Financial and insurance activities
-10 -7.5 -5 -2.5 0 2.5 5


Austria
5 Water supply; sewerage, waste management and remediation activities
20 Activities of households as employers
12 Real estate activties
13 Professional & Administrative
15 Public administation and defence; compulsory social security
16 Education
7 Wholesale and retail trade and repair of motor vehicles and motorcycles
9 Accommodation and food service activities
8 Transportation and storage
19 Other service activties
17 Human health and social work activities
18 Arts, entrainment and recreation
1 Agriculture
3 Manufacturing
11 Financial and insurance activities
6 Construction
4 Electricity, gas, steam and air conditioning supply
10 Information and communication
2 Mining and quarrying
-10 -7.5 -5 -2.5 0 2.5 5


Greece
12 Real estate activties
6 Construction
15 Public administation and defence; compulsory social security
16 Education
1 Agriculture
11 Financial and insurance activities
9 Accommodation and food service activities
19 Other service activties
7 Wholesale and retail trade and repair of motor vehicles and motorcycles
3 Manufacturing
5 Water supply; sewerage, waste management and remediation activities
18 Arts, entrainment and recreation
13 Professional & Administrative
17 Human health and social work activities
4 Electricity, gas, steam and air conditioning supply
20 Activities of households as employers
2 Mining and quarrying
10 Information and communication
8 Transportation and storage
-10-7.5 -5 -2.5 0 2.5 5

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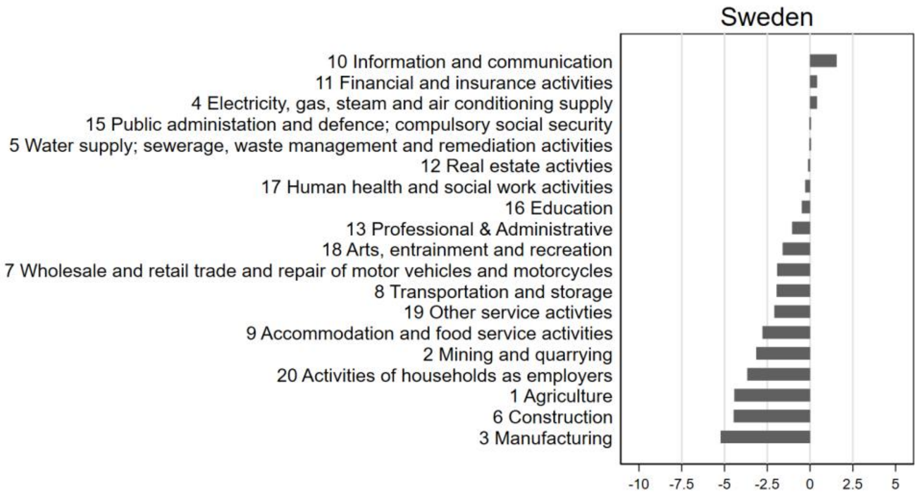
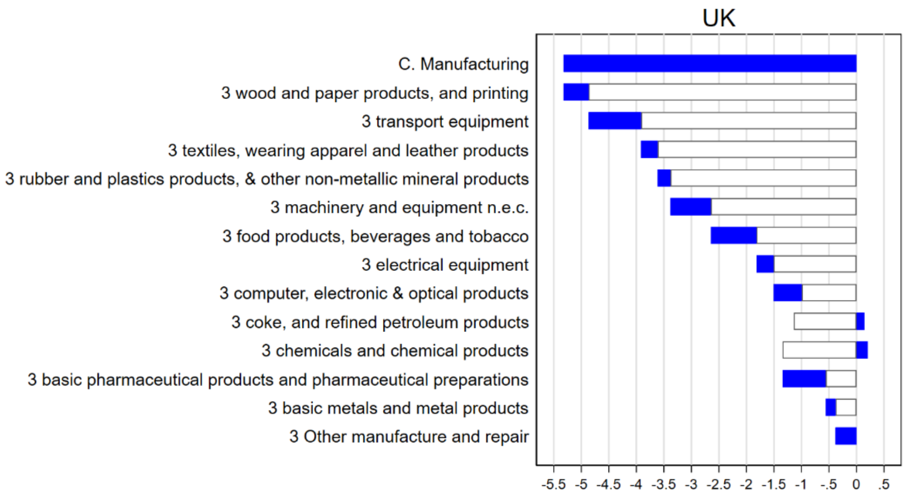
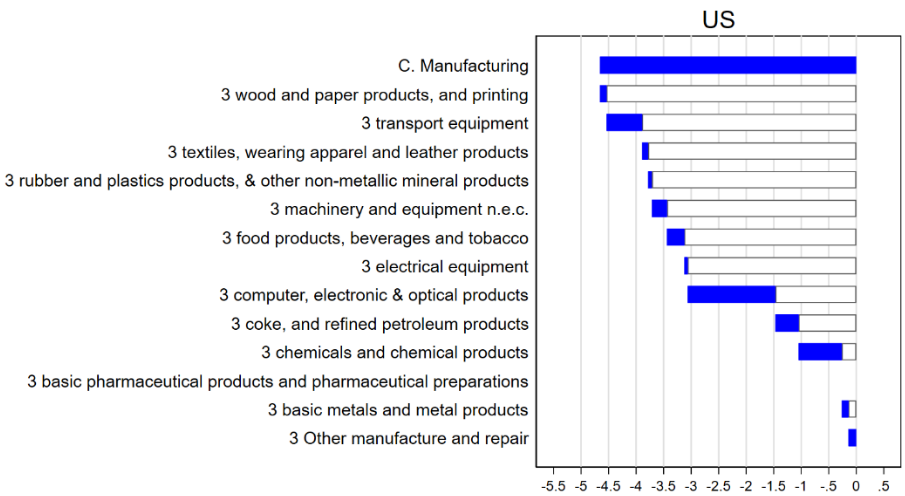


Notes: Data show slowdowns for each industry, where each bar is $\Delta(\Delta ln\, V_i/H_i)) = \Delta ln\, V_i/H_i^{\,2008-2015} - \Delta ln\, V_i/H_i^{\,1998-2008}$
Source: ONS, EU KLEMS database, and authors' calculations.

Figure AIII 2. Sub-sectors *within* labour productivity slowdown 1998-2008 vs. 2008-2015; Manufacturing Industry





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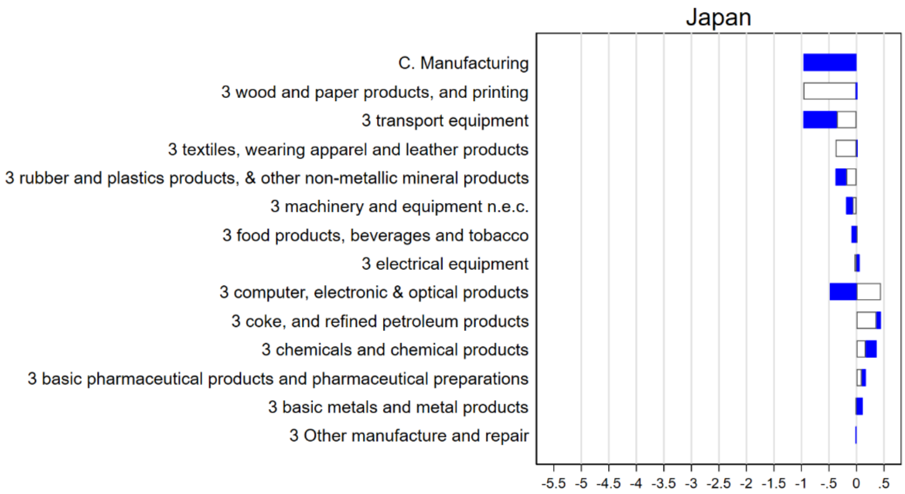
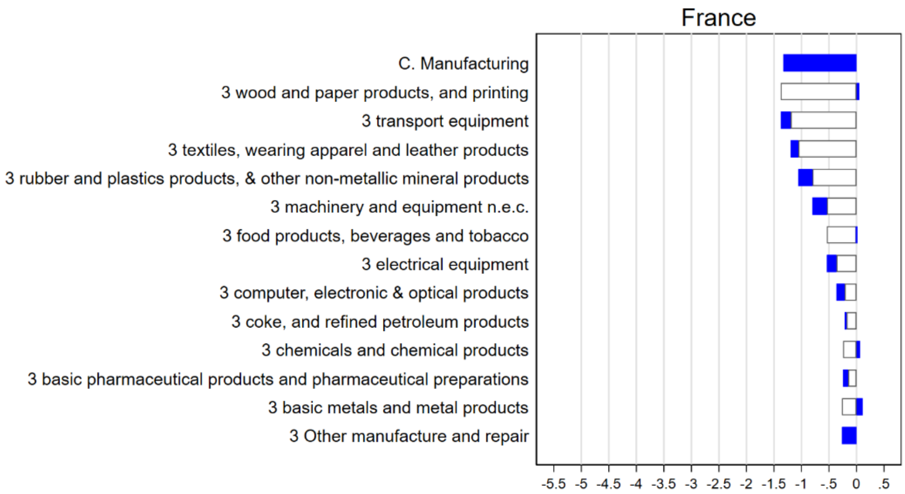
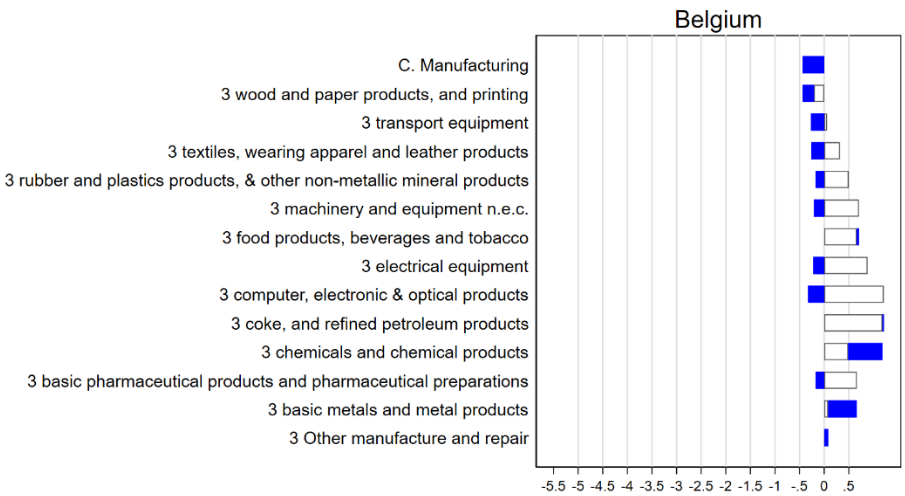
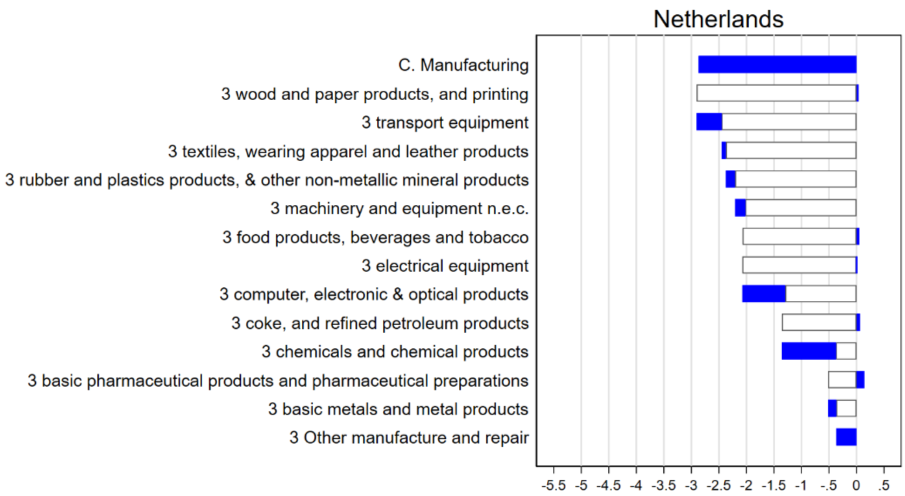
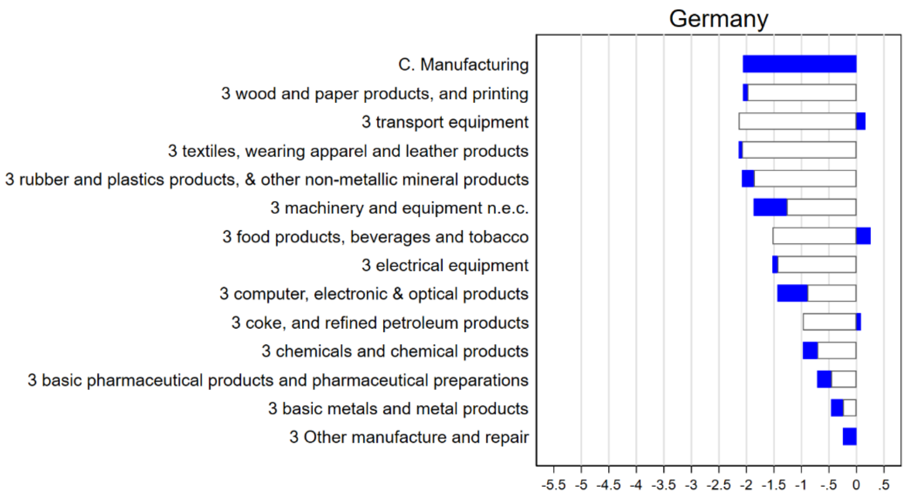

Japan
C. Manufacturing
3 wood and paper products, and printing
3 transport equipment
3 textiles, wearing apparel and leather products
3 rubber and plastics products, & other non-metallic mineral products
3 machinery and equipment n.e.c.
3 food products, beverages and tobacco
3 electrical equipment
3 computer, electronic & optical products
3 coke, and refined petroleum products
3 chemicals and chemical products
3 basic pharmaceutical products and pharmaceutical preparations
3 basic metals and metal products
3 Other manufacture and repair
-5.5 -5 -4.5 -4 -3.5 -3 -2.5 -2 -1.5 -1 -.5 0 .5

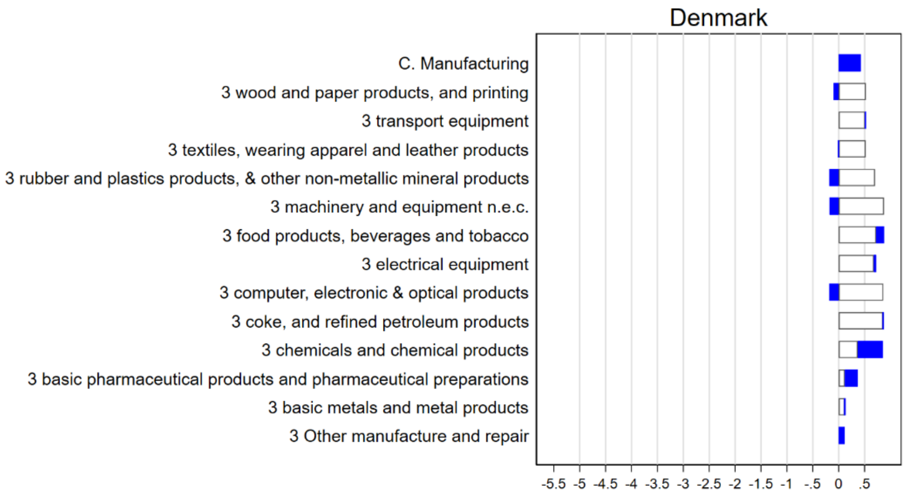

France
C. Manufacturing
3 wood and paper products, and printing
3 transport equipment
3 textiles, wearing apparel and leather products
3 rubber and plastics products, & other non-metallic mineral products
3 machinery and equipment n.e.c.
3 food products, beverages and tobacco
3 electrical equipment
3 computer, electronic & optical products
3 coke, and refined petroleum products
3 chemicals and chemical products
3 basic pharmaceutical products and pharmaceutical preparations
3 basic metals and metal products
3 Other manufacture and repair
-5.5 -5 -4.5 -4 -3.5 -3 -2.5 -2 -1.5 -1 -.5 0 .5


Belgium
C. Manufacturing
3 wood and paper products, and printing
3 transport equipment
3 textiles, wearing apparel and leather products
3 rubber and plastics products, & other non-metallic mineral products
3 machinery and equipment n.e.c.
3 food products, beverages and tobacco
3 electrical equipment
3 computer, electronic & optical products
3 coke, and refined petroleum products
3 chemicals and chemical products
3 basic pharmaceutical products and pharmaceutical preparations
3 basic metals and metal products
3 Other manufacture and repair
-5.5 -5 -4.5 -4 -3.5 -3 -2.5 -2 -1.5 -1 -.5 0 .5

(continued)


Netherlands
C. Manufacturing
3 wood and paper products, and printing
3 transport equipment
3 textiles, wearing apparel and leather products
3 rubber and plastics products, & other non-metallic mineral products
3 machinery and equipment n.e.c.
3 food products, beverages and tobacco
3 electrical equipment
3 computer, electronic & optical products
3 coke, and refined petroleum products
3 chemicals and chemical products
3 basic pharmaceutical products and pharmaceutical preparations
3 basic metals and metal products
3 Other manufacture and repair
-5.5 -5 -4.5 -4 -3.5 -3 -2.5 -2 -1.5 -1 -.5 0 .5


Germany
C. Manufacturing
3 wood and paper products, and printing
3 transport equipment
3 textiles, wearing apparel and leather products
3 rubber and plastics products, & other non-metallic mineral products
3 machinery and equipment n.e.c.
3 food products, beverages and tobacco
3 electrical equipment
3 computer, electronic & optical products
3 coke, and refined petroleum products
3 chemicals and chemical products
3 basic pharmaceutical products and pharmaceutical preparations
3 basic metals and metal products
3 Other manufacture and repair
-5.5 -5 -4.5 -4 -3.5 -3 -2.5 -2 -1.5 -1 -.5 0 .5


Denmark
C. Manufacturing
3 wood and paper products, and printing
3 transport equipment
3 textiles, wearing apparel and leather products
3 rubber and plastics products, & other non-metallic mineral products
3 machinery and equipment n.e.c.
3 food products, beverages and tobacco
3 electrical equipment
3 computer, electronic & optical products
3 coke, and refined petroleum products
3 chemicals and chemical products
3 basic pharmaceutical products and pharmaceutical preparations
3 basic metals and metal products
3 Other manufacture and repair
-5.5 -5 -4.5 -4 -3.5 -3 -2.5 -2 -1.5 -1 -.5 0 .5

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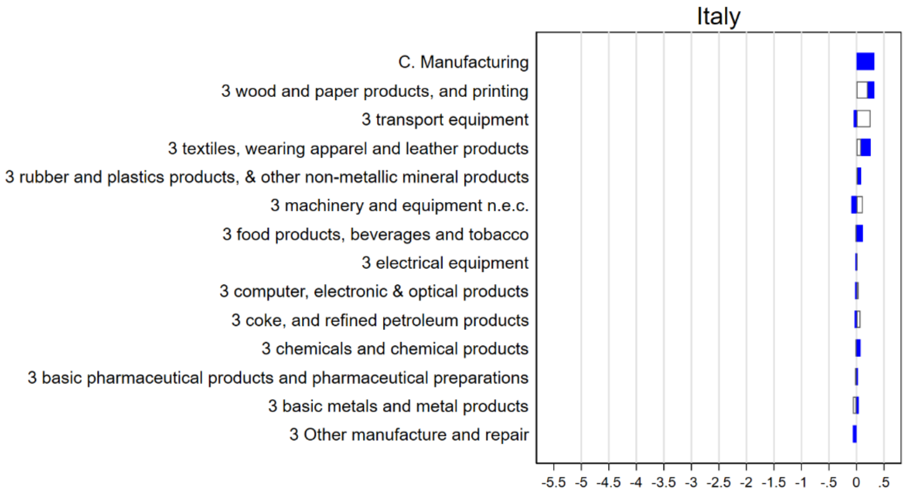
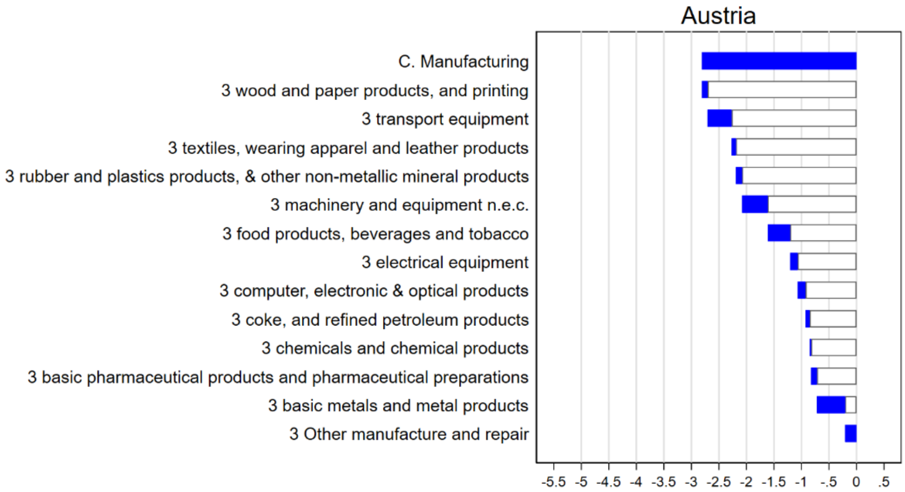
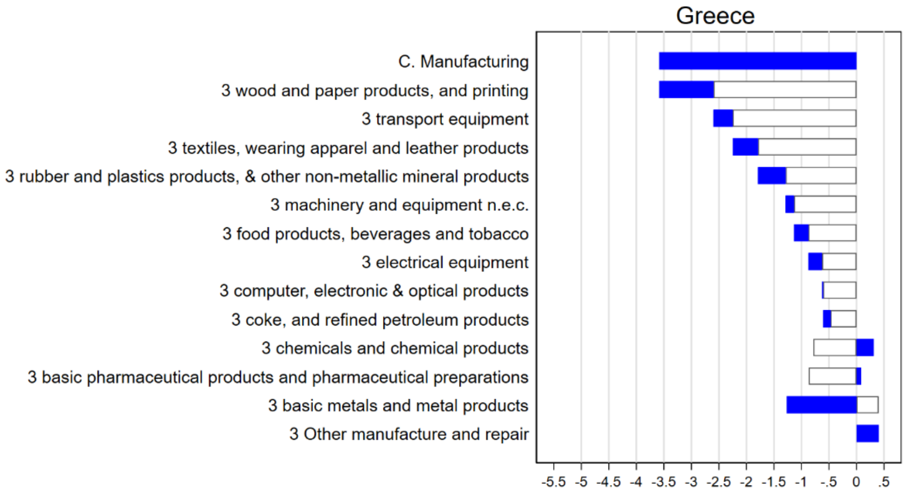
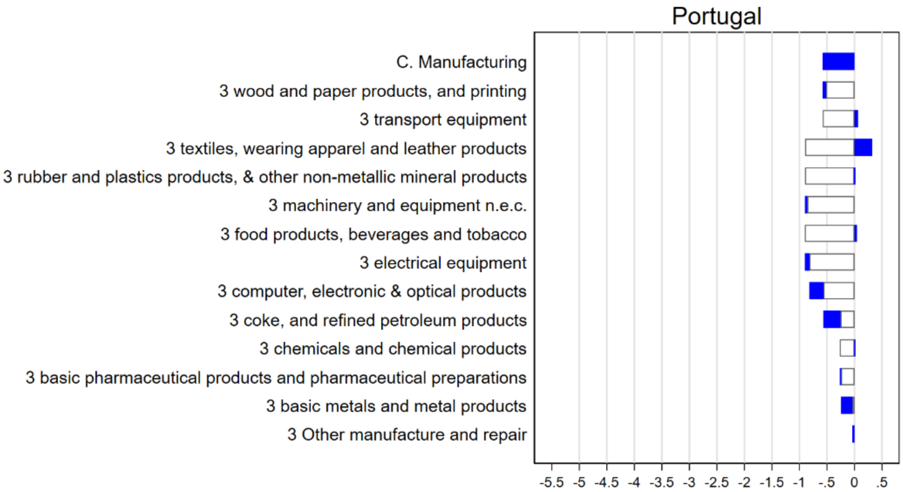
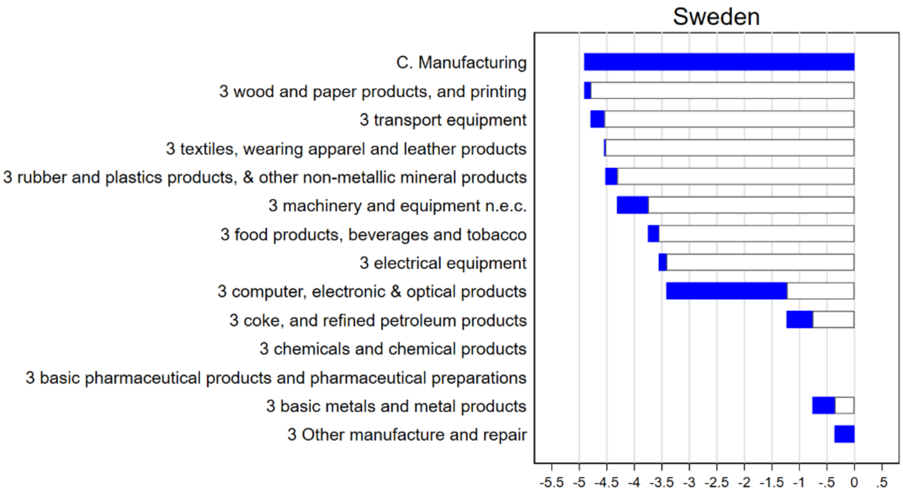

Italy
C. Manufacturing
3 wood and paper products, and printing
3 transport equipment
3 textiles, wearing apparel and leather products
3 rubber and plastics products, & other non-metallic mineral products
3 machinery and equipment n.e.c.
3 food products, beverages and tobacco
3 electrical equipment
3 computer, electronic & optical products
3 coke, and refined petroleum products
3 chemicals and chemical products
3 basic pharmaceutical products and pharmaceutical preparations
3 basic metals and metal products
3 Other manufacture and repair
-5.5 -5 -4.5 -4 -3.5 -3 -2.5 -2 -1.5 -1 -.5 0 .5


Austria
C. Manufacturing
3 wood and paper products, and printing
3 transport equipment
3 textiles, wearing apparel and leather products
3 rubber and plastics products, & other non-metallic mineral products
3 machinery and equipment n.e.c.
3 food products, beverages and tobacco
3 electrical equipment
3 computer, electronic & optical products
3 coke, and refined petroleum products
3 chemicals and chemical products
3 basic pharmaceutical products and pharmaceutical preparations
3 basic metals and metal products
3 Other manufacture and repair
-5.5 -5 -4.5 -4 -3.5 -3 -2.5 -2 -1.5 -1 -.5 0 .5


Greece
C. Manufacturing
3 wood and paper products, and printing
3 transport equipment
3 textiles, wearing apparel and leather products
3 rubber and plastics products, & other non-metallic mineral products
3 machinery and equipment n.e.c.
3 food products, beverages and tobacco
3 electrical equipment
3 computer, electronic & optical products
3 coke, and refined petroleum products
3 chemicals and chemical products
3 basic pharmaceutical products and pharmaceutical preparations
3 basic metals and metal products
3 Other manufacture and repair
-5.5 -5 -4.5 -4 -3.5 -3 -2.5 -2 -1.5 -1 -.5 0 .5

(continued)





Notes: Data show slowdowns for each industry, where each bar is $\Delta(\bar{\omega}_j \Delta \ln(V_j/H_j)\ ) = \bar{\omega}_j \Delta \ln(V_j/H_j)^{2008-2015} - \bar{\omega}_j \Delta \ln(V_j/H_j)^{1998-2008}$.
Source: ONS, EU KLEMS database, and authors' calculations.

Appendix IV. International Comparisons for 21 Countries

Table AIV 1. Growth in Whole Sector 1998-2015; 21 countries

	$\Delta\ln(V/H)$	$\sum_i \bar{\omega}_i \Delta\ln(V_i/H_i)$	R
	(1)	(2)	(3)
Whole Economy Sector (20 Industries)			
UK	1.098%	0.778%	0.319%
US	1.549%	1.709%	-0.160%
Japan	0.616%	0.537%	0.079%
France	1.068%	1.150%	-0.081%
Belgium	0.781%	0.619%	0.161%
Netherland	1.242%	1.362%	-0.120%
Denmark	1.113%	1.009%	0.103%
Germany	0.888%	0.892%	-0.003%
Italy	0.060%	-0.065%	0.125%
Portugal	0.696%	0.625%	0.071%
Austria	1.308%	1.328%	-0.019%
Greece	0.127%	-0.576%	0.703%
Sweden	1.522%	1.626%	-0.103%
Ireland	3.675%	3.652%	0.023%
Czechia	2.737%	2.691%	0.046%
Estonia	4.071%	3.934%	0.137%
Finland	1.010%	1.093%	-0.083%
Poland	2.495%	2.062%	0.019%
Romania	3.650%	4.022%	-0.371%
Slovenia	1.903%	1.555%	0.348%
Slovakia	3.769%	3.740%	0.029%
Whole Economy Sector (Industry L Excluded)			
UK	0.863%	1.057%	-0.193%
US	1.504%	1.746%	-0.242%
Japan	0.556%	0.662%	-0.106%
France	1.067%	1.116%	-0.048%
Belgium	0.819%	0.822%	-0.003%
Netherland	1.262%	1.412%	-0.149%
Denmark	1.079%	1.011%	0.068%
Germany	0.912%	1.038%	-0.125%
Italy	0.005%	-0.062%	0.068%
Portugal	0.697%	0.641%	0.056%
Austria	1.297%	1.325%	-0.028%
Greece	-0.347%	-0.212%	-0.134%
Sweden	1.639%	1.776%	-0.137%
Ireland	3.907%	4.216%	-0.309%
Czechia	2.772%	2.786%	-0.014%
Estonia	4.157%	3.924%	0.232%
Finland	1.015%	1.247%	-0.231%
Poland	2.599%	2.102%	0.075%
Romania	3.690%	3.996%	-0.305%
Slovenia	1.983%	1.997%	-0.013%
Slovakia	4.008%	4.016%	-0.007%

Notes: Data are average growth rates per year for 1998-2015. Data are decomposition of labour productivity in per hour terms based on Eq. (8).
Sources: ONS, EU KLEMS National Account Data files, and authors' calculation. We remove industries public administration, defence, education, human health and social work activities, arts, entertainment, recreation; other services and service activities, etc., and activities of extraterritorial organizations and bodies from our aggregation exercise. Industries L represents real estate activities.

Table AIV 2. Growth in Whole Sector; 1998-2008 vs. 2008-2015; 21 Countries

	$\Delta\ln(V/H)$ (1)	$\sum_i \bar{\omega}_i \Delta\ln(V_i/H_i)$ (2)	R (3)
UK - Whole Economy Sector (20 Industries)			
1998-2008	1.632%	1.223%	0.409%
2008-2015	0.137%	-0.030%	0.167%
19 Industries (Industry L Excluded)			
1998-2008	1.502%	1.738%	-0.236%
2008-2015	-0.236%	-0.103%	-0.132%
US - Whole Economy Sector (20 Industries)			
1998-2008	1.927%	2.088%	-0.160%
2008-2015	0.913%	1.077%	-0.164%
19 Industries (Industry L Excluded)			
1998-2008	1.890%	2.135%	-0.245%
2008-2015	0.822%	1.045%	-0.223%
Japan - Whole Economy Sector (20 Industries)			
1998-2008	0.760%	0.572%	0.188%
2008-2015	0.358%	0.354%	0.003%
19 Industries (Industry L Excluded)			
1998-2008	0.734%	0.772%	-0.038%
2008-2015	0.236%	0.412%	-0.176%
France - Whole Economy Sector (20 Industries)			
1998-2008	1.159%	1.178%	-0.018%
2008-2015	0.738%	0.909%	-0.170%
19 Industries (Industry L Excluded)			
1998-2008	1.216%	1.290%	-0.073%
2008-2015	0.662%	0.679%	-0.016%
Belgium - Whole Economy Sector (20 Industries)			
1998-2008	0.860%	0.711%	0.148%
2008-2015	0.542%	0.328%	0.214%
19 Industries (Industry L Excluded)			
1998-2008	0.967%	0.951%	0.016%
2008-2015	0.475%	0.488%	-0.013%
Netherlands - Whole Economy Sector (20 Industries)			
1998-2008	1.447%	1.589%	-0.141%
2008-2015	0.865%	0.969%	-0.103%
19 Industries (Industry L Excluded)			
1998-2008	1.591%	1.830%	-0.239%
2008-2015	0.728%	0.772%	-0.043%
Denmark - Whole Economy Sector (20 Industries)			
1998-2008	1.616%	1.362%	0.253%
2008-2015	0.301%	0.447%	-0.146%
19 Industries (Industry L Excluded)			
1998-2008	0.743%	0.851%	-0.108%
2008-2015	0.859%	0.923%	-0.063%
Germany - Whole Economy Sector (20 Industries)			
1998-2008	0.614%	0.534%	0.079%
2008-2015	0.961%	1.005%	-0.043%
19 Industries (Industry L Excluded)			
1998-2008	1.559%	1.406%	0.153%
2008-2015	0.281%	0.325%	-0.044%

(continued)

Table AIV 2. Continued

	$\Delta\ln(V/H)$ (1)	$\sum_i \bar{\omega}_i \Delta\ln(V_i/H_i)$ (2)	R (3)
Italy - Whole Economy Sector (20 Industries)			
1998-2008	-0.020%	-0.232%	0.212%
2008-2015	-0.039%	-0.001%	-0.038%
19 Industries (Industry L Excluded)			
1998-2008	-0.002%	-0.150%	0.147%
2008-2015	-0.227%	-0.189%	-0.038%
Portugal - Whole Economy Sector (20 Industries)			
1998-2008	0.788%	0.834%	-0.045%
2008-2015	0.538%	0.338%	0.199%
19 Industries (Industry L Excluded)			
1998-2008	0.908%	1.020%	-0.111%
2008-2015	0.361%	0.070%	0.290%
Austria - Whole Economy Sector (20 Industries)			
1998-2008	1.880%	1.847%	0.032%
2008-2015	0.290%	0.360%	-0.070%
19 Industries (Industry L Excluded)			
1998-2008	1.910%	1.931%	-0.021%
2008-2015	0.203%	0.237%	-0.033%
Greece- Whole Economy Sector (20 Industries)			
1998-2008	0.573%	-0.382%	0.956%
2008-2015	-0.749%	-1.368%	0.619%
19 Industries (Industry L Excluded)			
1998-2008	0.604%	0.905%	-0.300%
2008-2015	-2.206%	-2.211%	0.050%
Sweden - Whole Economy Sector (20 Industries)			
1998-2008	2.039%	2.096%	-0.056%
2008-2015	0.352%	0.462%	-0.110%
19 Industries (Industry L Excluded)			
1998-2008	2.220%	2.273%	-0.053%
2008-2015	0.292%	0.492%	-0.199%
Ireland - Whole Economy Sector (20 Industries)			
1998-2008	1.740%	1.833%	-0.092%
2008-2015	5.865%	5.641%	0.223%
19 Industries (Industry L Excluded)			
1998-2008	1.815%	2.259%	-0.444%
2008-2015	6.372%	6.381%	-0.009%
Czechia- Whole Economy Sector (20 Industries)			
1998-2008	3.962%	3.803%	0.158%
2008-2015	0.793%	0.774%	0.018%
19 Industries (Industry L Excluded)			
1998-2008	4.073%	4.078%	-0.004%
2008-2015	0.750%	0.742%	0.007%
Estonia- Whole Economy Sector (20 Industries)			
1998-2008	5.794%	5.651%	0.143%
2008-2015	1.522%	1.351%	0.171%
19 Industries (Industry L Excluded)			
1998-2008	5.940%	5.680%	0.260%
2008-2015	1.427%	1.157%	0.270%

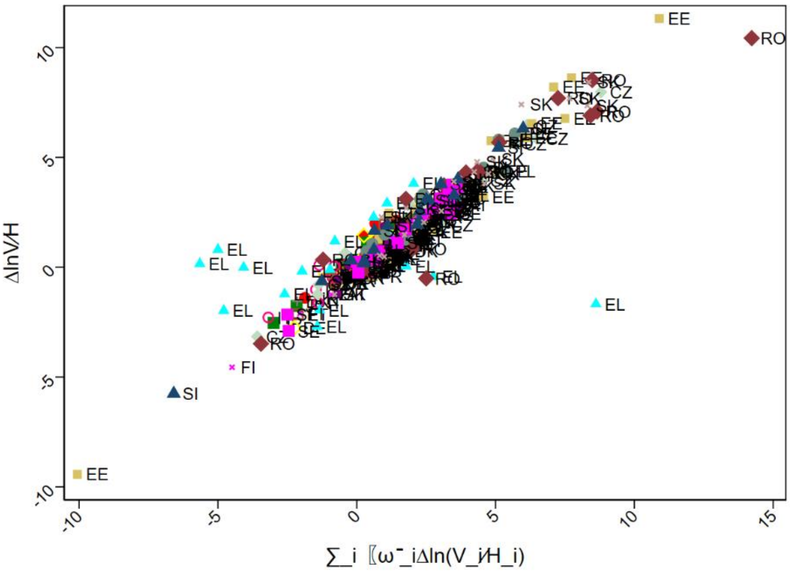
(continued)

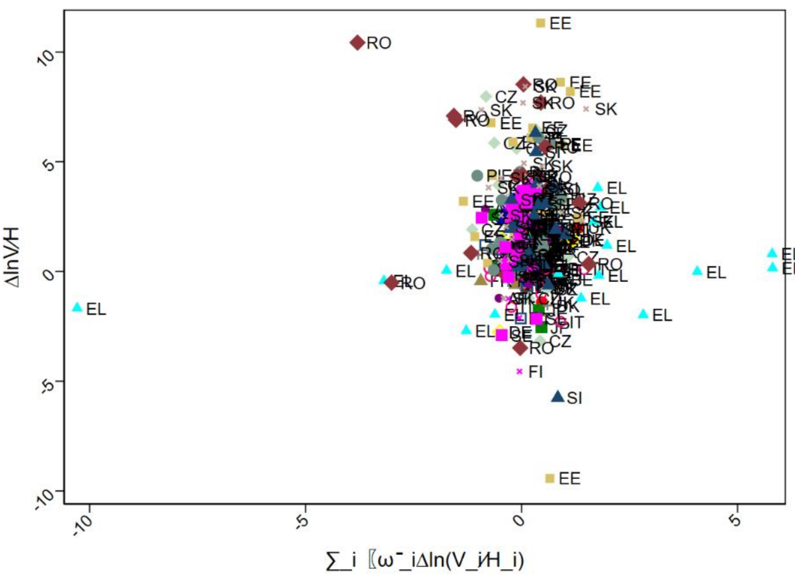
Table AIV 2. Continued

	$\Delta\ln(V/H)$ (1)	$\sum_i \bar{\omega}_i \Delta\ln(V_i/H_i)$ (2)	R (3)
Finland- Whole Economy Sector (20 Industries)			
1998-2008	1.859%	1.927%	-0.067%
2008-2015	-0.438%	-0.304%	-0.133%
19 Industries (Industry L Excluded)			
1998-2008	1.968%	2.159%	-0.191%
2008-2015	-0.633%	-0.346%	-0.287%
Poland- Whole Economy Sector (20 Industries)			
1998-2008	2.359%	1.787%	-0.098%
2008-2015	2.313%	2.190%	0.122%
19 Industries (Industry L Excluded)			
1998-2008	2.488%	1.768%	0.057%
2008-2015	2.409%	2.367%	0.042%
Romania - Whole Economy Sector (20 Industries)			
1998-2008	4.575%	4.565%	0.009%
2008-2015	2.786%	3.825%	-1.038%
19 Industries (Industry L Excluded)			
1998-2008	4.543%	4.835%	-0.292%
2008-2015	3.318%	3.781%	-0.463%
Slovenia - Whole Economy Sector (20 Industries)			
1998-2008	2.759%	2.277%	0.482%
2008-2015	0.409%	0.211%	0.197%
19 Industries (Industry L Excluded)			
1998-2008	2.934%	2.988%	-0.053%
2008-2015	0.324%	0.268%	0.056%
Slovakia - Whole Economy Sector (20 Industries)			
1998-2008	5.196%	4.984%	0.212%
2008-2015	1.815%	2.137%	-0.322%
19 Industries (Industry L Excluded)			
1998-2008	5.445%	5.249%	0.195%
2008-2015	1.999%	2.247%	-0.248%

Notes: Data are average growth rates per year for 1998-2015. Data are decomposition of labour productivity in per hour terms based on Eq.(8).
Sources: ONS, EU KLEMS National Account Data files, and authors' calculation. We remove industries public administration, defence, education, human health and social work activities, arts, entertainment, recreation; other services and service activities, etc., and activities of extraterritorial organizations and bodies from our aggregation exercise. Industries L represents real estate activities.

Figure AIV 1. Industry Labour Productivity $\Delta \ln(V/H)$, Within Productivity $\sum_i \bar{\omega}_i \Delta \ln(V_i/H_i)$, and Reallocation R across 21 Countries 1998-2015





Notes: Data show correlation between aggregate Productivity $\Delta \ln(V/H)$ and Within Productivity $\sum_i \bar{\omega}_i \Delta \ln(V_i/H_i)$, and Within Productivity $\sum_i \bar{\omega}_i \Delta \ln(V_i/H_i)$, and Reallocation R.
Source: ONS, EU KLEMS database and authors' calculations.