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JEL Classification: D24, E23, E44, F45, O47

Keywords: Productivity Growth, great recession, convergence

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1. Introduction

Across advanced economies, productivity growth slowed after the mid-2000s. The common slowdown in TFP growth since the early-2000s has been widely labeled the "productivity puzzle" (e.g., van Ark and Venables, 2021). In this paper, we examine the slowdown in UK productivity growth since the mid-2000s relative to the experience in the United States and major northern-European countries. Northern Europe turns out to be a reasonable comparison for the UK; the experience of southern Europe is quite different. We focus on the pre-pandemic period.[1]

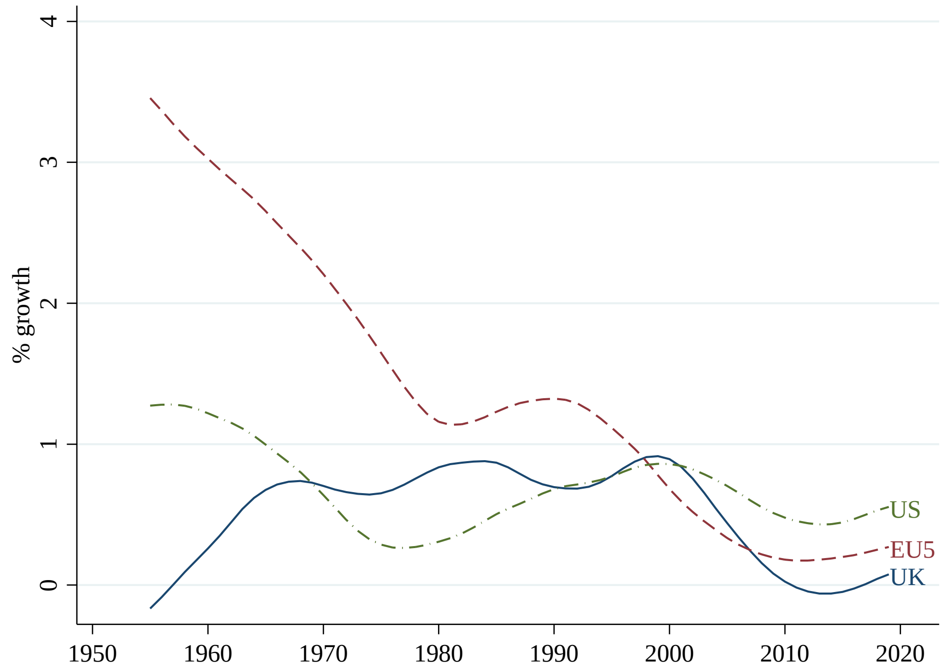
Given that the slowdown was common, our starting point is that the bulk of the UK slowdown is *not* explainable primarily by UK-specific factors. Indeed, given the widely discussed slowdown in total factor productivity (TFP) growth at the U.S. "frontier," we argue that it would be surprising if the U.K. as well as northern Europe had *not* seen a slowdown. The residual UK productivity puzzles are more modest. First, from the early 1990s to 2007, why did UK TFP largely converge to northern-European levels (what we refer to as the EU-5) and close the gap somewhat with U.S. TFP levels? Second, after 2007, why did UK TFP modestly diverge again from U.S. levels (while largely paralleling the EU-5)? To provide proximate answers to these questions, we investigate UK-specific factors from macroeconomic and industry data. Our answer to the first pre-2008 convergence puzzle is the sizeable and essentially complete convergence of UK market services TFP to U.S. levels. Our answer to the second post-2007 divergence puzzle is that it was largely idiosyncratic, reflecting an industry structure that was relatively unfavorable to TFP growth as well as a particularly bad outcome in mining—where the shortfall is understandable and industry-specific, rather than country-specific.

Throughout, we focus primarily on the slowdown in TFP growth. The reason is that slower growth in capital deepening and labor quality are *not* important growth-accounting factors in explaining the labor-productivity slowdown in the UK or elsewhere. Indeed, relatively slow growth in desired capital input (and, thus, in investment) is consistent with slow growth in TFP and labor. As a result, stories that focus primarily on capital deepening are, in our view, focused on a secondary symptom rather than a primary driving factor.

[1] A few of the many papers discussing slow productivity growth since the mid-2000s include Cette et al (2016), Adler et al. (2017), Fernald et al. (2017), and Goodridge et al (2018). Goldin et al. (2021) review the large literature on the topic. Fernald and Li (2021) and Fernald, Li, and Ochse (2021) discuss productivity growth during the pandemic.

Figure 1 provides a longer-term perspective on TFP trends, including the widespread slowing since the mid-2000s.[2] The U.S. trend shows the well-known pattern that TFP growth slowed in the 1970s, picked up again in the 1990s, and then slowed again in the 2000s. In the "EU-5" of northern Europe, TFP growth has, broadly speaking, been slowing since the 1960s. TFP growth in northern-Europe slowed further in the 1990s and slowed yet more in the 2000s. The UK experience is different from either, in that trend TFP growth was broadly constant from the mid-1960s through the early 2000s. The UK trend pace matched the U.S. pace in the 1990s. But, as in the U.S. and EU-5, TFP growth slowed markedly since the mid-2000s.

Figure 1: Trend TFP growth in the UK, Northern Europe, and U.S.



Notes: Source is PWT 10.0 (Feenstra, Inklaar, and Timmer, 2015). EU-5 covers Germany, France, Netherlands, Belgium, and Finland (ordered by size of GDP in 2010). EU-5 TFP is defined as a Törnquist index of TFP, variable RTPNA, weighted by nominal PPP-adjusted GDP, variable CGDP^{O}. Trends are calculated with a biweight filter with bandwidth of 12 years.

In this paper, we view the common slowdown in the 2000s as disappointing, but not necessarily puzzling, from the point of view of conditional convergence. The logic of conditional convergence implies that countries eventually approach a steady-state path where each country has its own *level* of productivity (GDP per hour or TFP) relative to the frontier. The relative steady-state level of

[2] The data are from the Penn World Tables (PWT, Feenstra et al., 2015) and are smoothed with a bi-weight filter. This filter is roughly a 12-year centered moving average that becomes increasingly one-sided at the end points.

TFP depends on conditioning factors such as the efficiency of financial markets (which can affect relative resource misallocation), the availability of skilled managers, or industry structure.[3] If those conditioning factors don't change, countries should all (eventually) tend to grow at similar rates.

This conditional-convergence perspective is already the received wisdom for explaining why TFP growth in Continental Europe started well above U.S. or UK rates and then steadily declined. In the decades after World War II, continental Europe received a convergence "boost" to growth in GDP per hour and TFP as the economy recovered from the destruction and dislocations of the war. As TFP levels got closer to U.S. levels, growth naturally slowed.

Conditional convergence is easier to see in levels than in growth rates. Figure 2 shows the U.S., UK, and EU-5 levels of market-sector TFP since the mid-1980s.[4] The U.S. has remained the frontier economy throughout.

After the early 1990s, the UK roughly parallels the U.S. Looking more closely, as Section 3 discusses, there were some movements in the relative level. The UK market economy was only 84 percent of the U.S. level in 1995 and 2001; but, by 2007, the UK had risen to 89 percent. However, as of 2019, the UK had retreated somewhat to 85 percent—a decline of about 4 percent, or a little over 0.3 percentage points per year from 2007-2019.

The average EU-5 country (the red line) gradually diverged from the U.S. level after 1995, falling from 92 percent of the U.S. level in 1995 to 89 percent in 2007, then further to 87 percent by 2015. Throughout, the UK remained below the EU-5 average, apart from 2005 when they were essentially equal. The UK moved closer to the EU-5 level from the early 1990s to the mid-2000s but, since the mid-2000s, has largely paralleled the EU-5.

Figure 2 shows not only that the U.S. economy was the frontier, but that its growth rate (the slope of the line) has changed over time. The key question for the UK and other countries is what happens when TFP growth at the frontier changes? The neoclassical perspective that underlies the conditional-convergence framework implies that if growth at the frontier changes,

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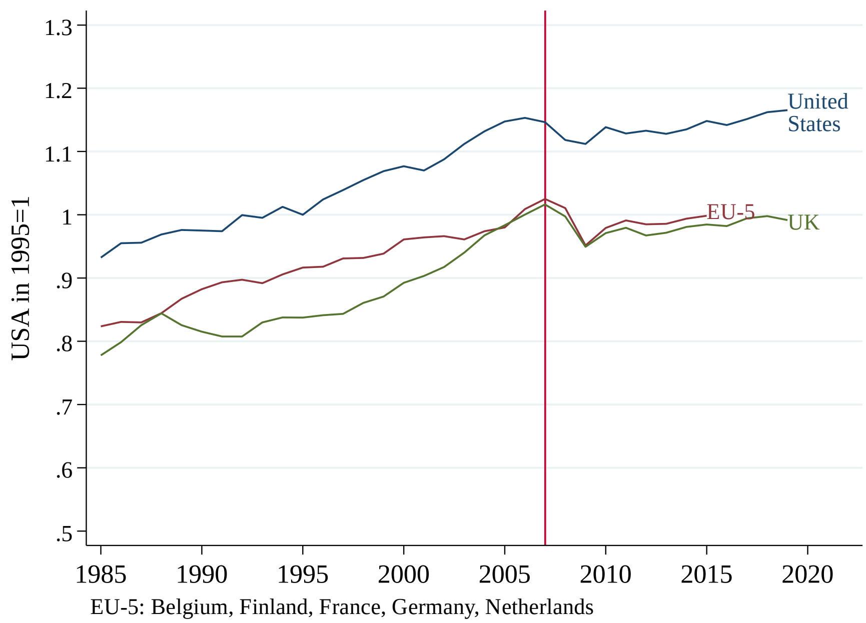
[3] Educational attainment on its own is already be included in TFP. But educational attainment, as well as capital per hour, can contribute independently to why output per hour may differ across countries.

[4] The figure combines estimates of the level of TFP for market industries in 1997 from Inklaar and Timmer (2009) with data on market-sector-industry TFP growth rates before and after 1997. The figure uses the published market-sector data from ONS for the UK; from the joint BEA-BLS dataset for the United States; and from EU-KLEMS (2012 and 2017) for continental Europe. See the appendix for more details. We note that the U.S. market-sector TFP growth rate in the joint BEA-BLS data is somewhat lower than the BLS (or Fernald, 2014) *business*-sector TFP growth rate since the mid-1990s, mainly because output growth is lower. These differences presumably reflect coverage differences. We note also that Northern Europe is more comparable to the UK than all of Europe, given the substantial deterioration in TFP levels in Italy and Spain since the 1990s; Fernald and Inklaar (2020, Chart 3) show a figure like Figure 2 that breaks out southern Europe, as well.

growth everywhere should change, perhaps with a lag. The reason is that the model assumes that the ideas and innovations that drive TFP growth diffuse across countries. Consistent with this view, the International Monetary Fund (2015, Box 3.2) uses cross-country panel data from 1970 to 2007 and finds a statistically significant link between changes in U.S. TFP growth and in TFP growth for other advanced economies. The peak effect occurs in three to four years.

Figure 2. Convergence and divergence of market economy TFP levels



Notes and sources: Data run 1985 through 2019. Market-sector TFP growth for UK aggregated from ONS productivity data, for US aggregated from BEA-BLS Integrated Production Accounts, for EU-5 from EU KLEMS 2017, combined with EU KLEMS 2012 (before 1995) PPP-adjusted TFP levels are based on Inklaar-Timmer (2009) for 1997. The red EU-5 (Northern Europe) line is the GDP-weighted average of the five individual countries. The red-shaded area shows the range across the EU-5.

The UK experience is broadly consistent with this hypothesis that TFP growth follows frontier growth with a lag. When U.S. TFP growth picked up in the mid-1990s, UK TFP growth also picked up within a few years. And when U.S. TFP growth slowed in the mid-2000s, UK TFP growth also slowed within a few years. [5]

Of course, as Figure 2 shows, northern European TFP growth did *not* see the same pickup in the 1990s. A large literature has examined why continental Europe lost ground relative to the

[5] It oversimplifies to imply that ideas flow solely from the U.S. frontier to other countries; and though the U.S. is the overall market-sector leader, it is not always the frontier for individual industries. This doesn't change the basic point that no country is an island (even though Britain is an island). We discuss the frontier slowdown further in Section 4.

frontier. That literature takes as its starting point the premise that if growth rises at the frontier, that other countries should equally benefit. The puzzle then was that Europe did not see a contemporaneous (or even slightly lagged) speedup.[6] But as both Figure 1 and Figure 2 show, EU-5 TFP growth did slow after the mid-2000s—and by about as much as the U.S. slowdown.

The mid-2000s slowdown in the United States is not per se our focus. But in our view, it is nevertheless central for understanding the experience of the UK, northern Europe, and elsewhere. Our preferred story—and what we consider to be the leading story—for the U.S. TFP growth slowdown is a slowing trend that predated the Great Recession (Fernald, 2015; Fernald et al, 2017). The temporary mid-1990s boost to U.S. TFP growth from the production and use of information and communications technology (ICT) ended a decade later. The trend then reverted to a slower pace. (We discuss other stories in Section 4.)

In other words, the "productivity puzzle" of a common slowdown is a single puzzle at the productivity frontier—for which we think there are good stories. From this perspective, the UK and EU-5 slowdowns in the 2000s are largely the expected result of a frontier slowdown.

Of course, there are residual puzzles, in that growth rates are not exactly equalized. For the UK, we highlight two features of the data. First, why (in a proximate) sense, was the UK converging to EU-5 and US levels prior to 2008? Second, why has it diverged again after 2007?

To understand the magnitude of the shortfall, consider three counterfactuals.

- First, if UK TFP growth had continued to grow at its 1995-2007 pace, then UK market-economy TFP in 2019 (pre-pandemic) would have been 22 percent higher than it was, where this percentage difference and subsequent ones are calculated as 100 times log differences. Many discussions of UK productivity assume this is the correct counterfactual. However, this pre-2007-trend counterfactual overstates what we need to explain via UK-specific stories, because the U.S. frontier as well as other advanced economies also slowed.
- Second, if the UK had continued to converge towards the U.S. level at a pace of 0.5 percentage points per year, then the UK level in 2019 would have been 10 percent higher than it was.

[6] See Timmer et al (2010) for a comprehensive discussion, with additional references.

- Third, if the UK had simply maintained its 2007 TFP position at 89 percent of the U.S. level, then UK TFP in 2019 would have been 4 percent higher than it was.

The second or third counterfactuals—where the UK either kept converging, or else stayed constant relative to the US—appear to us to be the relevant ones to consider. Thus, idiosyncratic UK stories need to explain a cumulative growth shortfall of 4 to 10 percent, *not* 22 percent.

That the UK would continue to converge was never guaranteed, and our discussion of subsectors below suggests that continuing post-2007 convergence is an aggressive counterfactual. Hence, we think the relevant shortfall is the more conservative 4 percent cumulative shortfall. In the realm of "productivity puzzles," this is small—especially given the year-to-year volatility of TFP: the annual standard deviation of UK market economy TFP growth since 1995 has been 1.6 percent. Visually, Figure 2 suggests that the UK broadly maintained its comparative position in the face of a sizeable shocks (notably, the synchronized productivity slowdown, the Great Recession, and Brexit). We also note that the post-2007 performance of UK and EU-5 productivity was quite similar. As we discuss, much of the 4-percent shortfall is explained by a somewhat unfavorable industry structure as well as a few idiosyncratic industries—supporting our view that UK-specific factors are not of primary importance.

Examining broad subsectors sheds some light on the residual TFP puzzles. We highlight three subsector patterns in Section 3. First, in the pre-2007 period, the UK market-services sector saw substantial and essentially complete convergence to U.S. levels; it has largely maintained its relative position ever since. Indeed, market-services drove the pre-2008 convergence in the overall market economy, since other sectors were not converging, or were even diverging, before 2008. Since we see little a priori reason to expect that, after convergence was achieved, UK market services TFP would continue to grow faster than the US pace, we view the second counterfactual above—of continuing overall convergence—as overly aggressive.

Second, and in contrast, manufacturing TFP in the UK and the EU-5 lost substantial ground relative to the U.S. frontier from the mid-1990s to 2007. However, the manufacturing divergence ended at that point: UK manufacturing TFP has actually risen faster than US TFP since.

Third, given that neither manufacturing nor market services (which together account for about 85 percent of the market economy) explain why the UK slowed more than the U.S. after 2007, that residual slowdown is necessarily accounted for by other sectors, or by relative output shares. Both play a role. The UKs industry structure was somewhat unfavorable to growth after

2007; and mining, most notably, performed much worse in the UK than the U.S. The mining results, certainly, are intuitive, given that North Sea oil has become more challenging (and expensive) to extract, even as US mining TFP has surged because of fracking.[7]

This paper is structured as follows. Section 2 documents that the common labor-productivity slowdown was a TFP slowdown. In our growth accounting, we do not see weak capital formation as an important independent channel for explaining weak growth in labor productivity. Section 3 looks at manufacturing versus market-services sectors. Section 4 delves into the argument that the U.S. slowdown at the frontier pre-dated the Great Recession and reflected a waning in the IT boost that began in the mid-1990s. It also assesses whether the common slowdown reflected the effects of the Great Recession. Section 5 and 6 discuss some alternative factors that might have affected the productivity statistics; the main finding is that the UK's industry structure was somewhat worse for measured growth than the U.S. or EU-5 structure. Section 7 concludes, drawing some lessons for the debates.

2. Key facts and conceptual framework

This section shows that weak TFP growth is the key to understanding weak labor productivity growth in the United Kingdom as well as in the United States and Europe. Specifically, we find that, although a shortfall of capital formation appears to be a proximate contributor to the growth slowdown, it does not appear to be an important *independent* contributor. Rather, the role of capital is mainly as a symptom of weak TFP growth.

Accounting for labor productivity growth: TFP and capital deepening

Table 1 shows two growth-accounting decompositions since 1985 for the total economy (using the Penn World Tables) and for the market economy (using various sources).[8] In both cases, we show the United States, the United Kingdom, and northern Europe. We focus on northern

[7] See, for example, Barnett et al. (2014), p. 118.

[8] The market economy excludes real estate (industry code L), public administration and defense (O), education (P), and health and social work (Q). We compute UK, US, and EU-5 market-economy aggregates as Törnqvist indices across market-economy industries. Using Törnqvist indices excludes labor and capital reallocation terms from market economy TFP (they are in factor contributions instead). The EU-5 aggregates use appropriate (PPP-adjusted) Törnqvist indices to aggregate output, capital, hours, TFP, and labor composition across countries.

Europe as a comparison because it is the most similar to the UK (and it is a grouping for which EU KLEMS has complete growth-accounting data).[9]

Line 1 of each block shows labor productivity growth by subperiod. In all countries, the pace of productivity growth is much slower in the 2007-2019 period than earlier.

The table then shows two growth-accounting decompositions of labor productivity. Both start from the basic growth-accounting identity that implicitly defines TFP growth, $\Delta \ln TFP_t$:

$$\Delta \ln Y_t = \alpha_t \Delta \ln K_t + (1-\alpha_t)(\Delta \ln H_t + \Delta \ln LC_t) + \Delta \ln TFP_t. \quad (1)$$

In this equation, $\Delta \ln Y_t$ is output growth, $\Delta \ln K_t$ is capital input growth, $\Delta \ln H_t$ is hours growth, and $\Delta \ln LC_t$ is labor composition growth. α_t is the nominal share of payments to capital in revenue (which, in practice, we take to be the average in years $t-1$ and t), and $(1-\alpha_t)$ is labor's share. We assume the factor shares sum to one.[10]

Equation (1) can be rearranged to yield the standard growth-accounting decomposition of labor productivity growth:

$$\Delta \ln Y_t - \Delta \ln H_t = \alpha_t(\Delta \ln K_t - \Delta \ln H_t) + (1-\alpha_t)\Delta \ln LC_t + \Delta \ln TFP_t. \quad (2)$$

A challenge with interpreting equations (1) or (2) is that capital growth, and capital deepening (capital per hour worked), are endogenous. For example, in the Solow (1956) growth model, all growth in output per hour comes from TFP growth. But the Solow (1957) identity in equation (1) would attribute some of that growth to increases in capital per hour. Perhaps most relevantly, a slowdown in trend TFP growth naturally leads to slower growth in capital per hour, because firms don't need as much capital with slower growth.[11]

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[9] We merge the 2017 vintage of EU KLEMS with the 2012 vintage (see www.euklems.net). The 2019 vintage (Stehrer, 2019; see www.euklems.eu) starts in 1995 but is inconsistent in terms of definitions with the 2012 vintage, so it is not appropriate to merge them. More concerningly, the capital data in the 'statistical database' of the 2019 vintage (which, like other sources, includes only national accounts intangibles) differs from other sources—growing more slowly since 1995. Given these differences, we do not recommend using the 2019 vintage of the EU KLEMS data. A first look at the 2021 version, which was released on December 20, 2021 (https://euklems-intanprod-llee.luiss.it/) suggests growth patterns similar to those in 2019, but a more detailed comparison could not be completed at this time.

[10] Under standard conditions of constant returns to scale, perfect competition, and perfect factor mobility (Solow, 1957), TFP growth defined by this equation represents the outward shift in society's production possibilities frontier from technological change. A large literature discusses how to interpret TFP growth when these conditions fail (e.g., Basu and Fernald, 2002; Oulton, 2016). For our purposes, we simply take equation (1) as defining aggregate TFP growth as the part of aggregate output growth not explained by revenue-share-weighted input growth.

[11] In the Solow (1956) model, for example, steady-state capital per hour grows at the rate of labor-augmenting technical progress, which in turn equals TFP growth divided by labor's share. So slower growth in TFP leads to slower growth in capital per worker; this is true in the transition as well as in steady state. Oulton (2019) suggests a model in which the post-2007 world saw output growth constrained by demand for exports. In this "bad regime," the neoclassical

Table 1: Growth Accounting for the UK, US, and EU

(percent or percentage points per year)

A: Capital-output decomposition

	1985–1995			1995–2007			2007–2019		
	UK	EU-5	US	UK	EU-5	US	UK	EU-5	US
Total Economy (PWT 10.0)									
(1) Labour productivity growth	2.20	2.89	1.47	2.17	1.59	2.20	0.13	0.56	1.11
p.p. contributions from:									
(2) Capital/output (α/(1-α) (ΔlnK - ΔlnY))	0.44	0.10	0.17	-0.39	0.06	0.37	0.28	0.20	0.20
(3) Labour composition	0.83	0.58	0.38	0.70	0.39	0.31	0.29	0.32	0.21
(4) TFP growth (ΔlnTFP/(1-α))	0.92	2.21	0.92	1.86	1.14	1.52	-0.44	0.04	0.71
Market economy (UK: ONS, US: BEA-BLS, EU-5: EU KLEMS 2012+2017, until 2015)									
(1) Labour productivity growth	3.80	2.58	2.01	2.82	2.14	2.75	-0.17	0.54	1.21
p.p. contributions from:									
(2) Capital/output (α/(1-α) (ΔlnK - ΔlnY))	0.55	0.46	0.39	-0.24	0.28	0.54	0.01	0.38	0.59
(3) Labour composition	0.49	0.71	0.35	0.51	0.21	0.26	0.59	0.53	0.22
(4) TFP growth (ΔlnTFP/(1-α))	1.21	1.40	1.08	2.51	1.65	1.81	-0.31	-0.37	0.24

B: Capital-labor decomposition

	1985–1995			1995–2007			2007–2019		
	UK	EU-5	US	UK	EU-5	US	UK	EU-5	US
Total Economy (PWT 10.0)									
(1) Labour productivity growth	2.20	2.89	1.46	2.17	1.59	2.20	0.13	0.56	1.12
p.p. contributions from:									
(2) Capital/worker	1.23	1.08	0.67	0.69	0.64	1.07	0.22	0.34	0.57
(3) Labour composition	0.47	0.38	0.23	0.41	0.24	0.19	0.17	0.20	0.12
(4) TFP growth	0.50	1.43	0.57	1.08	0.71	0.94	-0.26	0.02	0.42
Market economy (UK: ONS, US: BEA-BLS, EU-5: EU KLEMS 2012+2017, until 2015)									
(1) Labour productivity growth	2.86	2.58	2.01	2.80	2.14	2.75	0.12	0.54	1.21
p.p. contributions from:									
(2) Capital/worker	1.82	1.28	0.77	0.86	0.98	1.20	-0.05	0.43	0.69
(3) Labour composition	0.30	0.43	0.35	0.33	0.13	0.26	0.38	0.34	0.22
(4) TFP growth	0.74	0.86	0.89	1.61	1.03	1.29	-0.21	-0.23	0.29

Notes: The text describes the growth-accounting decompositions shown in lines 2 through 4. Panel A follows equation (1), which expresses capital deepening in terms of the capital-output ratio. Panel B follows equation (1), which expresses capital deepening in terms of the capital-labor ratio. The EU-5 data aggregate output, capital, hours, labor composition, and TFP as appropriate PPP-adjusted Törnquist indices for Germany, France, the Netherlands, Belgium, and Finland—the five northern European countries with full EU-KLEMS growth-accounting data. Because of data availability in EU-KLEMS, the EU-5 market-economy measures in the bottom panel end in 2015, whereas all other data shown end in 2019. See the data appendix for further details

Fernald et al (FHSW, 2017) suggest using a complementary decomposition of labor productivity in terms of the capital-output ratio. This approach, which is widely used in the economic-growth literature, (partially) adjusts for the endogeneity of capital. In particular, a rearrangement of the above equations yields the following:

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relationships do not hold (even though the production structure of the model is neoclassical). But in that bad regime, the capital-output ratio would fall, unlike what the data show after 2007.

$$\Delta \ln Y_t - \Delta \ln H_t = \frac{\alpha_t}{1-\alpha_t}(\Delta \ln K_t - \Delta \ln Y_t) + \Delta \ln LC_t + \frac{\Delta l \ln TFP_t}{1-\alpha_t}. \quad (3)$$

This expression is useful because, even though capital formation ($\Delta \ln K_t$) is endogenous, in many models the capital-output ratio is stationary in steady state (through possibly with a trend due to trends in the relative price of investment goods). Slower growth in technology and labor naturally lead to a lower path for both capital and output—but, in neoclassical models, even though the capital-labor ratio declines, the capital-output ratio does not decline. Thus, if we observe a decline in the capital-output ratio, it is consistent with special influences that have reduced capital relative to output. Such influences could reflect, say, unusual credit constraints or heightened uncertainty that reduce investment (and, over time, capital) more than you would expect just from a weaker and slower-growing economy.

Returning to Panel A of Table 1, lines 2 to 4 show the decomposition from equation (3). In both the PWT and for the market sector, the contribution of the capital-output ratio (row 2) is not notably lower in the post-2007 period (column 3) than in the preceding period. This is particularly true in PWT, where the capital-output ratio was declining sharply from 1995-2007, but then rose steadily after 2007. The pattern is qualitatively similar in the market economy, in the bottom panel, though not as strong. Even there, the capital-output ratio fell in the 1995-2007 period. It was then essentially flat in the post-2007 period. Thus, there is no evidence that the shortfall in labor-productivity growth reflected a shortfall of capital accumulation.

Line 3 shows the contribution of labor composition. In the PWT, slower growth of labor composition does contribute notably to the UK labor-productivity slowdown after 2007; it contributes less to the slowdown in the EU-5 or the US data. In the market economy, the ONS's UK data shows that labor composition slightly mitigates the labor-productivity slowdown, in that it added a bit more post-2007 than in the 1995-2007 period. The same is true, to a greater or lesser extent, for the EU-5 and the US.

Putting the capital-output and labor-composition contributions together shows that the reduced contribution of TFP (row 7) explains essentially all the slowdown in labor productivity growth for all three economies. For the UK, most saliently, the slowdown in the total economy TFP contribution of 2.30 percentage points (from 1.86 percent from 1995-2007 to -0.44 percent 2007-2019) *more than* explains the labor-productivity slowdown of 2.03 percent. For the market economy, TFP explains 2.82 percentage points of the labor-productivity slowdown of 2.99 percent.

Note, again, that the TFP contribution in row 7 is $\Delta \ln TFP_t/(1-\alpha_t)$, which expresses technology growth in labor-augmented form. By dividing by labor's share of income, it exceeds the direct effect of TFP growth. The economic effect this captures, in neoclassical models, is the induced capital growth that results from TFP and/or labor growth.

Panel B shows the "standard" growth-accounting decomposition from equation (1), which does not account for fact that capital growth is endogenous. Even then, the decomposition continues to show that changes in TFP are the main contributor to the slowdown after 2007. For example, (standard) market-sector TFP growth in the UK slows by 1.82 percent per year after 2007 (from 1.61 percent 1995-2007 to -0.21 percent after 2007), which accounts for the vast majority of the 2.68 percent slowdown in market economy TFP growth in line (1). With this decomposition, it does appear that reduced capital-deepening (capital per hour) plays some role. But, again, since capital is endogenous, this is exactly what we expect to see when TFP growth slows down. The slowdown in the contribution of capital per hour appears is in line with what standard growth models would predict.

Our view that capital deepening does not have an important independent role in explaining the U.K., U.S. or European labor-productivity slowdown may seem surprising. It is "conventional wisdom" that investment in many countries fell sharply after 2007 and was slow to recover. But the relevant input for production is capital, and capital input growth responds relatively slowly to changes in investment. And for productivity, it is capital growth *relative* to growth in output (in our decomposition) or labor (in the standard decomposition) that matters. And both labor and output growth were subdued in the aftermath of the Great Recession. Thus, from this perspective, the weakness in investment plausibly follows from the weakness in other factors that slowed growth, rather than the reverse. That is, weak investment is a symptom of other underlying issues, not an independent cause of the slowdown. (Appendix B provides further graphical evidence on the dynamics of capital.)

Of course, even if capital doesn't explain the slowdown in labor productivity growth after 2007, it could contribute to a gap between UK labor productivity and the frontier. We focus on the market-sector TFP gap in the next section. But we will note here that, using data from the Penn World Tables, there is a larger gap between the level of UK and U.S. labor productivity than there is between the level of UK and U.S. TFP. (In 2019, in the PWT, overall UK TFP was 77 percent of the US level; UK labor productivity was 74 percent of the US level.)

Based on Table 1, panel A, we do not view capital formation as a major additional contributor to weak labor productivity growth as of 2019. Hence, we focus most of the rest of our analysis on TFP.

3. TFP levels across industry groups

We now dig into some of the details of market-economy TFP growth. Overall, the UK was converging towards U.S. levels before 2007 because of rapid and essentially complete convergence in market services. Indeed, for manufacturing, the puzzle is the slow relative growth before 2008, rather than the performance since that time. Since 2007, much of the modest shortfall of relative UK TFP growth appears idiosyncratic, reflecting factors such as mining and finance—both of which have measurement issues that suggest we should not overinterpret these shortfalls.

Figure 2, discussed already in the introduction, compares market-economy TFP levels across regions over time. The top left panel of Table 2 shows some of the numbers that underlie that figure. (Note that, in contrast to Table 1, TFP is *not* scaled by $1/(1-\alpha)$). UK market economy TFP grew by an average of 1.6 percent per year from 1995-2007, compared with U.S. growth of only 1.1 percent and EU-5 growth of 0.9 percent. After 2007, all growth rates slowed substantially, with the UK and EU-5 growth rates turning negative.

Table 2: Growth and comparative levels of TFP in UK, US and EU-5 market economy

	Market economy			Manufacturing			Market services		
Average annual TFP growth	1995-2007	2007-2015	2007-2019	1995-2007	2007-2015	2007-2019	1995-2007	2007-2015	2007-2019
United States	1.1	0.0	0.1	3.8	-0.5	-0.2	0.7	0.1	0.2
EU-5	0.9	-0.3	.	2.4	0.1	.	-0.1	0.0	.
UK	1.6	-0.4	-0.2	2.3	0.4	0.1	2.0	-0.2	0.0
Relative TFP level (USA=1)	1995	2007	2015	1995	2007	2015	1995	2007	2015
United States	1	1	1	1	1	1	1	1	1
EU-5	0.92	0.90	0.87	0.95	0.81	0.85	1.02	0.93	0.88
UK	0.84	0.89	0.86	0.92	0.77	0.83	0.87	1.02	1.00

The bottom panel shows that the UK relative TFP level rose from 84 percent of the U.S. level in 1995 to 89 percent in 2007 before retreating to 86 percent in 2015. Not shown, the UK level retreated a bit further to 85 percent by 2019, or a decline of 4 percent relative to the U.S. frontier from 2007 to 2019. The UK nevertheless remains a bit above its 1995 relative level, which is not the case for the EU-5. This group of countries gradually lost ground, dropping from 92 percent of the US level to 90 percent in 2007 and 87 percent in 2015. After 2007, the EU-5 and UK are very similar in levels as well as growth rates.

From a conditional convergence perspective, it is not at all clear that the UK has much of an overall productivity puzzle: Frontier growth slowed, so the UK did as well. We discuss the U.S./frontier slowdown further in Section 4. It is, of course, unfortunate that the U.S., UK and other advanced economies saw a productivity slowdown. And the UK would have benefited had it been able to further close the productivity gap. But it would have been a surprise if the sharp global slowdown were *not* associated with a UK TFP slowdown, possibly with a lag.

Relative to the U.S., the residual "puzzles" for the UK are (i) the 0.5 percentage-point per year convergence that took place from 1995 to 2007 and (ii) the 0.3 percentage point divergence that took place since then. We look at subsectors to gain insight, at least in an accounting sense, into the sources of this convergence and divergence. We separately distinguish manufacturing and market services. In recent years in the UK, manufacturing accounts for approximately 15 percent of market economy value added and market services for almost 70 percent. The remaining 15 percent consists of agriculture, mining, utilities, and construction.

The middle and right blocks of the table show manufacturing and market-services TFP. The market services and (for the US and EU-5) manufacturing numbers are Törnqvist aggregates of the more underlying industries. In the UK data, total manufacturing is the most detailed level of data available from the ONS.

For all three regions, TFP growth in both manufacturing and market services essentially disappears after 2007, in some cases turning negative. Manufacturing TFP growth slows sharply after 2007 in all three regions, especially in the United States (where the slowdown is more than 4 percentage points). For market services TFP growth, the US and UK also slow sharply after 2007, particularly the UK. For market services, the EU-5 is a little different, in that it shows a pickup in growth after 2007…from -0.1 percent from 1995-2007 to 0.0 percent 2007-2015! Timmer et al. (2010) emphasized and discussed the very poor market-services performance in Europe.

Figure 3A and B show the corresponding levels figures for manufacturing and market services; the bottom panel of Table 2 show selected levels numbers. We highlight two important takeaways from these figures. First, in the pre-2007 period, the UK saw substantial and essentially complete convergence in market-services TFP, and it has largely maintained its position ever since. Second, manufacturing TFP in the UK and the EU-5 lost ground relative to the U.S. frontier from the mid-1990s to 2007.

First, starting with market services, UK market-services TFP was only 87 percent of the U.S. level in 1995; but it rose to 102 percent of the U.S. level by 2007. Growth performance since then has been comparably weak in all three regions (though a little lower in the UK). The UK remained at 100 percent of the U.S. level in both 2015 (in the table) and 2019.

As we discuss further below, the UK market services sector was the only broad sector that was converging to US levels in the 1995-2007 period. Correspondingly, the strong market-services convergence drove the first residual UK puzzle, which was the modest pace of overall market economy convergence before 2007.

We see little a priori reason to expect that, after convergence was achieved, UK market services TFP would have continued to grow faster than the US pace. Hence, it is no surprise from this perspective that overall convergence ended. Although there was a small retreat after 2007 (from 102 percent to 100 percent), those changes explain little of the residual post-2007 relative market-economy slowdown.

Second, turning to manufacturing, both the UK and the EU-5 lost ground relative to the U.S. frontier from the mid-1990s to 2007. Even though UK manufacturing TFP growth was relatively fast (2.3 percent) from 1995-2007, and comparable to the EU-5 pace (2.4 percent), neither could keep up with the rapid U.S. pace (3.8 percent). Hence, the UK fell from 92 percent of the U.S. level in 1995 to only 77 percent in 2007.

Although the ONS figures we rely on for the UK do not break out individual manufacturing industries, this shortfall is not a major puzzle. We know that the U.S. has a much larger IT-producing industry than the UK or EU-5 (Timmer et al., 2010). In the U.S. industry data, the “computer and electronic products” industry contributed 2.4 of the 3.8 percent TFP growth in the US, making this difference in economic structure and prime candidate for the difference in manufacturing productivity growth. In any case, the manufacturing divergence ended after 2007, and the UK has made up a modest amount of ground relative to the U.S. but is at only 83 percent of the U.S. productivity level by 2015.

Given these first two observations, neither market services nor manufacturing can fully account for the post-2007 slowdown in market economy TFP relative to the United States. Thus, the remaining 15 percent of the economy must explain that residual slowing, i.e., the modest 0.3 percent (34 basis point) per year post-2007 divergence from the market-economy U.S. TFP level.

Given the heterogeneity of this group, which comprises agriculture, mining, utilities, and construction, we do not aggregate them explicitly in Table 2. But our third observation is that, within this group, mining particularly stands out for its sizeable contribution to the residual post-2007 divergence of UK relative to US productivity. Although we do not have detailed growth accounting for mining subsectors, oil and gas extraction is clearly an important contributor. And here, the divergence relative to the U.S. is intuitive. For the UK, North Sea oil is becoming more challenging and expensive to extract. As Barnett et al (2014, p. 118) note, "North Sea oil and gas extraction output has been in secular decline since around 2003." Quantitatively, mining TFP growth was quite negative from 1995 to 2007 (-5.7 percent per year) as well as 2007-2019 (-6.5 percent per year). In contrast, for the U.S., fracking was an important contributor to a pickup in mining TFP growth from 1.9 percent during 1995-2007 to 3.3 percent thereafter. We discuss the quantitative contribution of mining to the slowdown further in Section 5.

As Byrne, Fernald, and Reinsdorf (2016) discuss, standard measures of mining TFP do not control for variation in the quality of the natural resources being extracted (see also Brandt, Schreyer, and Zipperer, 2017). Correcting for natural-resource quality would suggest that "true" oil-extraction TFP is mismeasured, with growth presumably biased downwards, in both the UK and the U.S. The observed decline in UK extraction TFP reflects the declining quality of North Sea deposits. Hence, the same observed inputs produce less output. In the U.S., fracking allowed oil and gas to be extracted *despite* a shift to very low-quality deposits, and measured TFP (which excludes the shift to low natural resource quality) was also biased downward.

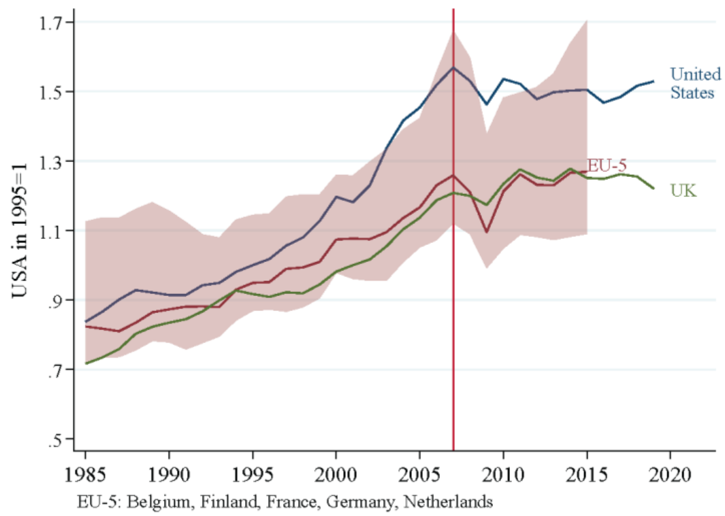
Whether the downward bias in mining is more pronounced in the UK or U.S. is beyond the scope of this paper. Certainly, it would be interesting to understand the nuances of mining TFP better. But from a macroeconomic perspective, it appears to be a relatively self-contained issue, rather than a broader issue regarding UK competitiveness. At least this portion of the residual shortfall in UK TFP growth is not, per se, a reflection of a systematic, country-specific problem.

To summarize this section, an investigation of subsectors sheds light on why TFP was converging before 2007: because of market services convergence, which offset a divergence in manufacturing as well as mining. Indeed, for manufacturing, the puzzle is the slow relative growth before 2008, rather than the performance since that time. Since 2007, the modest shortfall of relative UK TFP growth appears to reflect idiosyncratic industry issues in mining, where measurement challenges suggest we should not overinterpret the shortfalls. We return to (and to some extent quantify) the idiosyncratic industry issues in Section 5, where we also discuss industry weights.

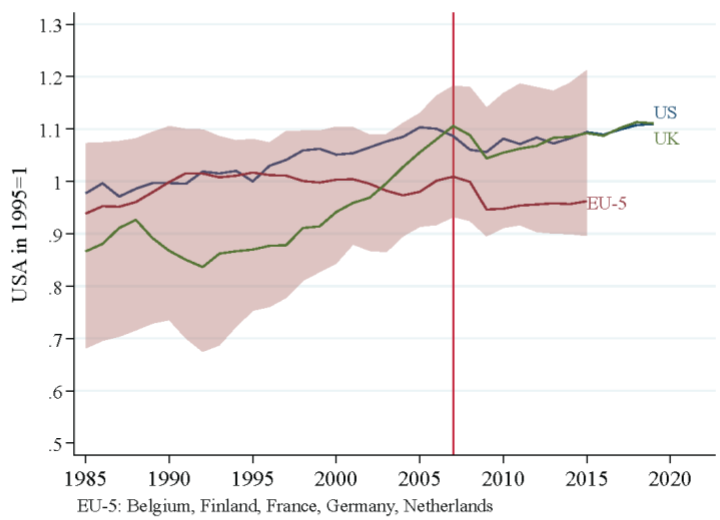
Of course, there is still a levels shortfall outside of market services. The key to achieving TFP growth above the global frontier pace is to promote convergence in those areas. Manufacturing, in particular, appears to offer substantial potential for further catchup.

Figure 3: Convergence and divergence for manufacturing and market services

A. Manufacturing TFP level (UK from ONS)



B. Market Services TFP level



See notes to Figure 2.

4. Why did the U.S. frontier slow?

Our story for the overall UK and EU slowdown in the 2000s is the common global productivity slowdown. We have emphasized frontier TFP growth, where we have implicitly or explicitly taken the U.S. as the frontier. Since there is no reason to expect a frontier slowdown to lead to *faster* convergence by other regions, that slowdown naturally led to a slowdown everywhere.

We take the U.S. as the frontier because it is the overall market economy TFP leader. Of course, ideas can flow in both directions across borders and the U.S. is not always at the frontier in individual industries. But this does not change the basic point that countries do not exist in autarky. Innovations in one region of the world can flow to other regions. Conversely, if a productivity slowdown in one region reflects slower growth in new innovations, then it is likely to be associated with a productivity slowdown elsewhere. There is a large literature looking at the U.S. slowdown, and our central premise is that it makes no sense to separately investigate why the UK or continental Europe slowed. Therefore, this section focuses on the U.S. slowdown, but the same forces (the ICT revolution and its end; or the Great Recession) inevitably affect everyone.

As we noted in the introduction, the leading hypothesis for the U.S. TFP slowdown since the mid-2000s is a sharply slowing trend. In our view, the slow trend at the frontier appears largely independent of the Great Recession (Fernald et al., 2017): The mid-1990s productivity boom ended several years, at least, prior to the Great Recession—somewhere between 2004 and 2006 (see Fernald, 2015; Fernald et al., 2017; and updated estimates from Kahn and Rich, 2007). For example, U.S. TFP growth from the end of 2004 through 2007 was even slower than it was from the end of 2007 through 2019. In addition, the U.S. slowdown was observed before the recession, and professional forecasters were already at least partially accounting for it (Fernald et al., 2017). The standard story is that ICT had provided an exceptional boost to trend TFP growth in the mid-1990s and early 2000s. The waning trend plausibly reflected a pause in (if not the end of) those exceptional gains.[12]

Consistent with this view, Bloom et al. (2020) argue that "ideas are getting harder to find." Closely related, several recent papers highlight how information technology itself might endogenously lead to a slower pace of innovation and growth throughout the economy. These

[12] There are complementary stories that emphasize regulation. For example, Fernández-Villaverde and Ohanian (2018) argue that regulation and a lack of competition have led to weak growth in Europe as well as the United States. That said, Fernald et al. (2017) find no quantitative evidence that regulatory changes have a first-order impact on U.S. TFP growth. Philippon (2019) argues that Europe is now more competitive than the United States.

stories put the slowing U.S., UK, and European productivity trend in the context of other recent developments, such as declining dynamism, rising dispersion of firm-level productivity in many countries (e.g., Andrews, et al., 2019), and the growing importance of superstar firms (Autor et al. 2019).

For example, de Ridder (2019) argues that intangibles linked to IT hardware and software are a form of fixed costs. Successful firms expand, which allows them to spread these fixed costs over more production. The initial expansion of these successful high-intangible firms, in turn, increases productivity growth even as concentration rates rise. But over time, another effect dominates: It is challenging (for new entrants or for existing low-intangible incumbents) to compete with the high-intangible incumbents. So innovative activity, firm turnover, and aggregate productivity growth slow.

Aghion et al (2019) provide a related endogenous growth argument linked to information technology. In their story, improvements in information technology initially boosts productivity by increasing managerial scope, which allows high-productivity/high-markup firms to expand. But the expansion of these high-productivity firms eventually deters innovation and undermines long-run growth. The reason is that a potential innovator would have to compete with a high-productivity incumbent. That prospect lowers the expected the returns to innovation. Though the de Ridder and Aghion et al. stories differ substantially in their details, both suggest indirect reasons for why information technology—a general purpose technology—might now be leading to reduced innovative activity at the frontiers of the global economy.[13]

These same micro-founded growth stories should apply equally to the UK and Europe. Of course, diffusion lags mean that the timing of the slowdown need not be the same. If we take as given the three- to four-year lag estimated by the IMF (2015), then the U.S. slowdown that appeared in the mid-2000s would hit the UK and Europe right around the time of the Great Recession.

Our story is very much a "supply side" explanation for the slowdown. A variant of the "common slowdown" view is that the Great Recession itself was the common shock that hit the global economy and led to the slowdown in TFP growth. As already discussed, this version of the story does not naturally match the pre-Great Recession timing of the U.S. slowdown. But even if

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[13] Andrews et al., (2019) find, in firm-level data, that TFP growth of frontier firms slowed after about 2007. But their emphasis is on a different channel: the growing dispersion between the "best firms" and the rest, which they interpret as a growing technology diffusion problem.

the Great Recession was not the main shock, it could have played a more important role in some regions or industries.

There is no question that the crisis was a traumatic and disruptive event across advanced economies. Fatás and Summers (2018) find a permanent effect of the crisis on potential output in many or most countries. There are many channels through which such hysteresis could work (see Fatás and Summers, 2016, for example). Labor-market channels are perhaps the best established, as unemployed workers could lose skills and lose labor-market attachment. Such stories imply that the Great Recession could have caused hysteresis even if the path of TFP were largely unaffected. That said, a number of papers do highlight potential TFP channels, as well (e.g., Adler et al, 2017). Possible channels include increased misallocation of resources in some economies (e.g., Gopinath et al. 2017); increased credit frictions that reduce investment in intangibles such as R&D, organization capital, and training (e.g., Duval et al., 2017); or other reduced incentives to innovate (e.g., Bianchi et al., 2018; Anzoategui et al., 2019; Garga and Singh, 2020).

In our view, the evidence is far from clear for advanced economies that the level or growth rate of *TFP* is typically affected permanently by recessions. For example, the 1930s Great Depression appeared to be an extraordinarily innovative period.[14] More broadly, Oulton and Sebastiá-Barriel (2017) look at growth-accounting variables following financial crises. They find that, for advanced economies, the long-run level of TFP is typically not significantly affected. In their estimates, advanced-economy GDP per capita is permanently lower after a financial crisis because employment per capita is permanently lower, whereas capital per worker as well as TFP are unchanged.[15]

Still, for developing economies, or for the sample that includes all countries, Oulton and Sebastiá-Barriel (2017) do find that financial crises appear to permanently reduce both TFP and capital per worker, as well as employment per capita. Oulton and Sebastiá-Barriel data end in 2010, so updated data might show more of an effect. Furceri and Mourougane (2012) discuss GDP effects through hysteresis in labor markets or persistent effects on capital deepening if there are changes in risk premia. They also find that impact of financial crises varies according to structural

[14] Field (2003) and Alexopoulos and Cohen (2009) argue that the 1930s were the single most innovative U.S. decade of the 20th century. Gordon (2016) and Bakker et al. (2019) provide (different) updated time series estimates of U.S. TFP growth to argue that, while the 1930s were an innovative period (with faster TFP growth than the decades preceding it), it was less innovative than the decades that followed (during and immediately after World War II).

[15] In standard neoclassical growth models, a permanent change in the level of employment would *not* affect steady-state capital per worker. Of course, changes in risk premia or other factors affecting the relative cost of capital to labor would affect capital per worker and the capital-output ratio.

features such as the degree of openness, macro-economic imbalances, financial deepening, and the quality of governance. Relatedly, Jordà et al. (2020) find that monetary contractions typically have long-lasting effects on TFP and capital deepening.

Unfortunately, it is very hard in practice to differentiate our 'slowing underlying trend' view from the view that the productivity slowdown outside the United States was, in fact, primarily a result of the Global Financial Crisis and/or the slow growth that followed. For example, given lags from the U.S. productivity slowdown, both hypotheses predict that univariate break tests on UK or European data should show breaks around the time of the Great Recession. Conversely, even if break tests suggest a change in growth rates around the time of the Great Recession, this does not necessarily imply that the "shock" was the recession or financial crisis.[16] Of course, if the shock had a differential (worse) effect in the UK or EU-5 than in the US, then the relevant statistical test for this hypothesis is whether there was a break in growth relative to frontier growth. As we discuss in Appendix C, formal break tests find at most weak evidence of a break following the Great Recession in industry or market economy TFP, and even less evidence of breaks in relative TFP. The weak power of break tests, though, means that the evidence is not dispositive either way.

From the point of view of the UK productivity puzzle, both our preferred story (a frontier TFP slowdown) or the Great Recession alternative (which slowed global TFP growth) imply that we should not be focusing on idiosyncratic UK stories. Rather, as we have argued throughout, the overall UK slowdown is not a surprise given the global slowdown.

Still, considering the subsector results in Section 3, we can think concretely about how the Great Recession might have affected relative UK TFP. First, for market services broadly, it is not obvious that even in the absence of the Great Recession, market services TFP would have continued to grow faster in the UK than the US, given that convergence had been achieved. Second, looking more narrowly within market services, the Great Recession could most obviously have affected finance disproportionately, given increased regulatory burdens and changing business models. Third, within manufacturing, the Great Recession could have somehow led to a slowdown in *US* productivity growth. Those are the places to look to as additional factors on top of an already-slowing TFP trend.

[16] Oulton (2020) looks at HP trends estimated across countries using data through 2007. He finds that the data show only limited evidence of a pre-GFC slowdown in trend TFP growth. Given lags from the U.S. slowdown, this finding is completely consistent with our view—it is what we would expect and predict. Our perspective is that one should focus on explaining the frontier, where we can bring considerable evidence to bear on the timing. E.g., Fernald (2015) looks at time series, cross-industry, and cross-region evidence to link the pre-GFC slowdown to information technology production and use.

5. Counterfactual industry structure

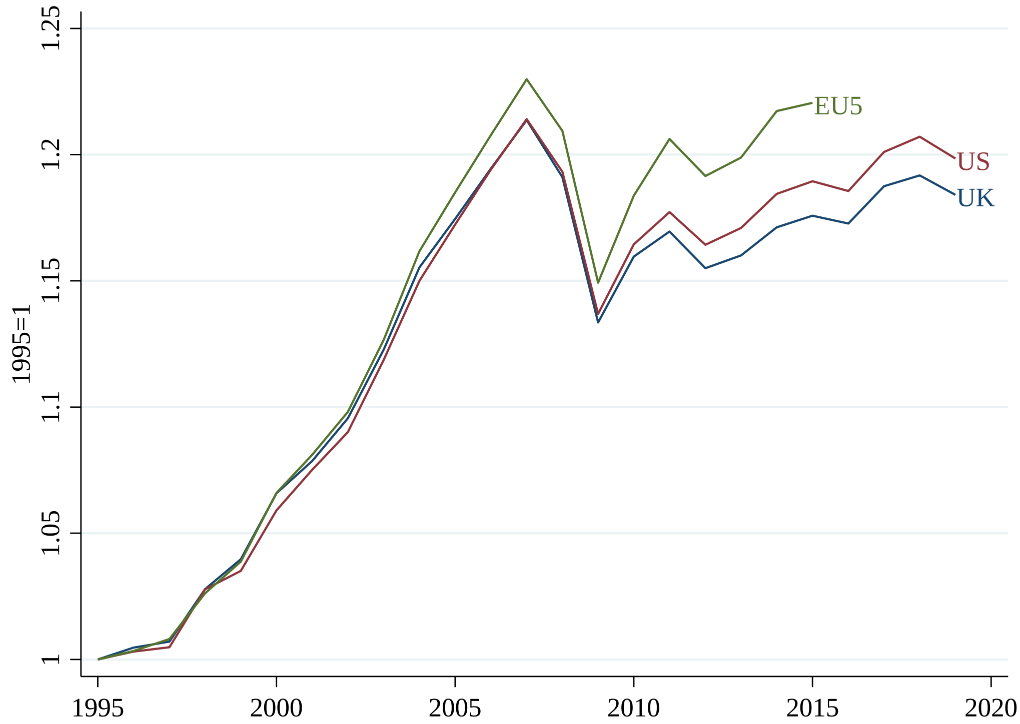
This subsection considers the role of differences in industry structure and quantifies the industry contribution to the "residual" post-2007 slowdown. The UK has a relatively small manufacturing sector compared to the US or many European countries and since manufacturing industries tend to show faster productivity growth than non-manufacturing industries, this may hold back aggregate productivity growth. We recalculate UK market economy growth using the U.S. and EU-5 sectoral weights. These calculations show that the UK industrial structure was somewhat unfavorable to overall TFP growth. Indeed, using US weights reduces the residual (relative to the U.S.) slowdown by almost a third relative to using UK weights. Much of what is left can be accounted for by the shortfall in mining discussed in Section 3.

Figure 4 shows three alternative Törnqvist market-economy indices, normalized to equal 1 in 1995. The blue line, which lies below the others after 2010, is based on the UK value-added shares. This line corresponds to the UK market-economy data discussed previously. The red line weights UK industry TFP growth using U.S. shares. This line lies almost on top of the UK line through 2009. But after 2009, a gap opens up, and the US-weighted line lies a bit above the UK-weighted line. The green line uses EU-5 industry value-added shares and lies above the others—with a gap opening up from 1995-2007 and then a further gap through 2015.

Qualitatively, all three lines are similar. But the slowdown after 2007 is modestly attenuated with the EU-5 or U.S. weights. Growth would have been about 0.3 percentage point faster on average from 2007-2015 with the EU-5 weights, cumulating to about 2.4 percent higher TFP by 2015. With U.S weights, growth would have been about 0.10 percentage points per year faster from 2007-2019, cumulating to a 1.1 percent higher TFP level by 2019. Another way to look at this is that, using UK weights, the TFP shortfall relative to the U.S. after 2007 was 34 basis points a year. Using U.S. weights, however, the TFP shortfall was only 24 basis points.

The faster counterfactual growth under US or EU-5 sectoral shares is primarily due to a greater importance of manufacturing than in the UK. From 2007 to 2015, manufacturing's share of market economy value added averaged 15.5 percent in the UK, compared with 18.2 percent in the U.S. and 25.0 percent in the EU-5.

Figure 4: U.K. TFP with Counterfactual Sectoral Weights



Notes: Törnqvist aggregates over market-sector industries with alternative sectoral weights.

Thus, unfavorable sectoral weights can explain some of the poor UK TFP performance relative to the United States (our main comparison). Even using U.S. weights, however, there is still a 24-basis point shortfall in TFP growth after 2007. Looking at underlying industry contributions, with U.S. weights, shows a range of positive contributors to the shortfall, and a range of negative contributors. But one industry stands out, as discussed already in Section 3: Mining. Mining contributes 21 basis points of the U.S.-weighted shortfall of 24 basis points. As already discussed, the mining shortfall is largely idiosyncratic to that industry.

Other industry contributions to the post-2007 slowdown are smaller in magnitude and largely cancel out. The only ones that contribute more than 10 basis points in absolute value to the post-2007 UK slowdown are (i) wholesale and retail trade, where the UK speeds up relative to the U.S., adding 13 basis points to UK relative TFP; and (ii) finance, where the UK slows down, subtracting 12 basis points from relative UK TFP. Again, these appear plausibly to be idiosyncratic industry stories. US wholesale and retail trade pulled ahead before 2007; the UK appeared to catch up with a sufficient lag that it showed up after 2007. UK finance was hit hard by the financial crisis and, potentially, by the risk of Brexit.

The role of unfavorable industry structure raises the question of whether policy should aim to change the industry structure. Our first response to this question is to note that improved industry structure is no panacea. Even with the EU's favorable market structure, UK TFP would have slowed down sharply after 2007.

Second, in the absence of market failures, subsidizing manufacturing development, say, could easily reduce future UK welfare and might not even raise TFP growth. To a large degree, relative TFP across industries translates into relative prices. So if the UK specializes in slower-TFP-growth services, UK consumer welfare can benefit from a terms of trade improvement by importing ever-cheaper manufactured goods. Suppose subsidies to domestic manufacturing succeed in raising measured UK TFP growth. Then the UK would presumably lose (some or all of) the terms of trade gains: It might even start exporting the ever-cheaper manufacturing goods, while importing products whose prices were not falling. In the absence of market failures, the terms-of-trade losses combined with the rising tax burden would be expected to offset the gains. And of course, the marginal manufacturing firm that enters only because of the subsidies may well be less productive than the average, thereby reducing manufacturing TFP growth (even if the value-added share of manufacturing increases).

Of course, this doesn't mean that all industrial policies to support growth are doomed to fail to boost welfare. Recently, there has been increased academic and policy interest in the question of what industrial policies might work (e.g., Aiginger and Rodrik, 2020; Chang and Andreoni, 2020). Most obviously, there can be a range of market failures that policy might help overcome. Potential rationales include:

- Policy may help reduce uncertainty, which can promote investment in technologies and worker skills;
- Some technologies may have increasing returns or learning-by-doing, such that a guaranteed market (via temporary protectionism or guaranteed government procurement) may provide welfare gains;
- Policy may help overcome informational frictions;
- Policy may help overcome coordination problems. And of course, policy certainly plays an important role through institutions (such as rule of law and competition policy) and through investments (such as education, infrastructure, and research and development).

Our study does not provide any particular insight into whether, or how, these rationales apply to the UK. Still, stepping back, it is important to remember that the TFP slowdown occurred across advanced economies. Even in continental Europe, with its “favorable” industry shares, TFP growth slowed.

In sum, the “unfavorable structure” finding of this section reinforces our view that we should not overstate the puzzle of the residual UK TFP slowdown after 2007. The 4 percent cumulative TFP growth slowdown relative to the U.S. is small enough that it can be substantially explained by industry structure and the idiosyncrasies of declining North Sea oil.

In our view, the most promising policy steps are <u>not</u> those that are aimed at somehow improving the industry structure. Rather, we would focus first on general (almost generic) steps to create an innovative-friendly environment. Such policies can also help close the gap in productivity levels, most obviously in manufacturing.

In terms of creating an innovation friendly environment, government policies can play an important role (Aghion, Antonin, and Bunel, 2021). One set of policies involves creating sound institutions, such as the rule of law, efficient bankruptcy procedures, and appropriate antitrust/competitiveness policies. These policies ensure that entrepreneurs and innovators can appropriate the gains from their innovations, without allowing them to subsequently create barriers that restrict competition. A second set of policies involves promoting investments, most obviously in education, infrastructure, and research and development. Some of those investments may boost innovation and TFP—our main focus—but even apart from that, they can help close labor productivity gaps.

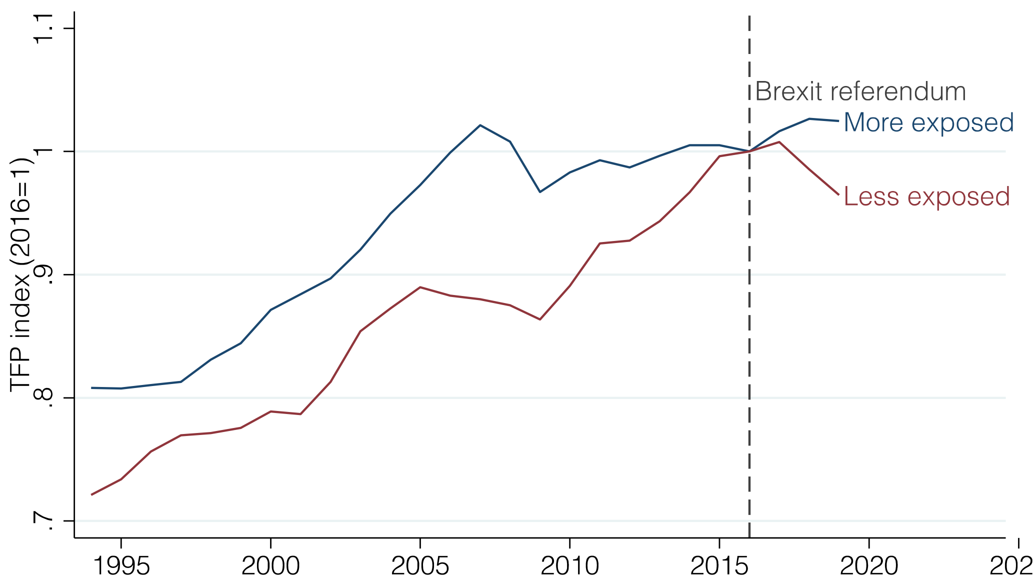
6. Brexit, market power, and intangibles

In this section we consider several other factors that could amount to a UK-specific growth problem. Specifically, we consider whether Brexit may have already dampened productivity growth in the most-affected industries, and we consider rising market power and intangible investment, which have been highlighted in the broader productivity growth literature, but where the UK might be in a special position. However, we find no clear evidence for a ‘smoking gun’ that might account for the slower UK productivity growth performance.

A. Brexit

By many accounts, Brexit is likely to be a drag on the UK economy, by making the UK economy less efficient. An initial pass at the data does not suggest that more-exposed industries have performed worse since the 2016 referendum. Figure 5 divides industries into more- and less-Brexit-exposed industries, based on export shares. Since the referendum, more-exposed industries have actually shown stronger productivity performance than less-exposed industries. Of course, we don't know the counterfactual. And the drag from Brexit could gradually accumulate over the years to come.

Figure 5: Brexit exposure



Sources: ONS Productivity Data (industry TFP growth), ONS Blue Book (industry value added) OECD TiVA (exposure measure)
Notes: Figure shows TFP growth across industries that are more or less exposed to Brexit. More exposed are those industries where domestic value added exports as a share of industry value added is above the median share across industries. TFP growth is aggregated over more and less exposed industries as a Törnqvist index.

B. Market power and intangibles

Two further issues that have received a lot of attention in recent literature are an apparent rise in market power, and the increasing share of intangibles in investment and output. These could matter if they are more important for the UK than for the United States. We find little evidence so far that either of these stories can explain the slowdown in U.K. productivity growth—at least in a direct sense.

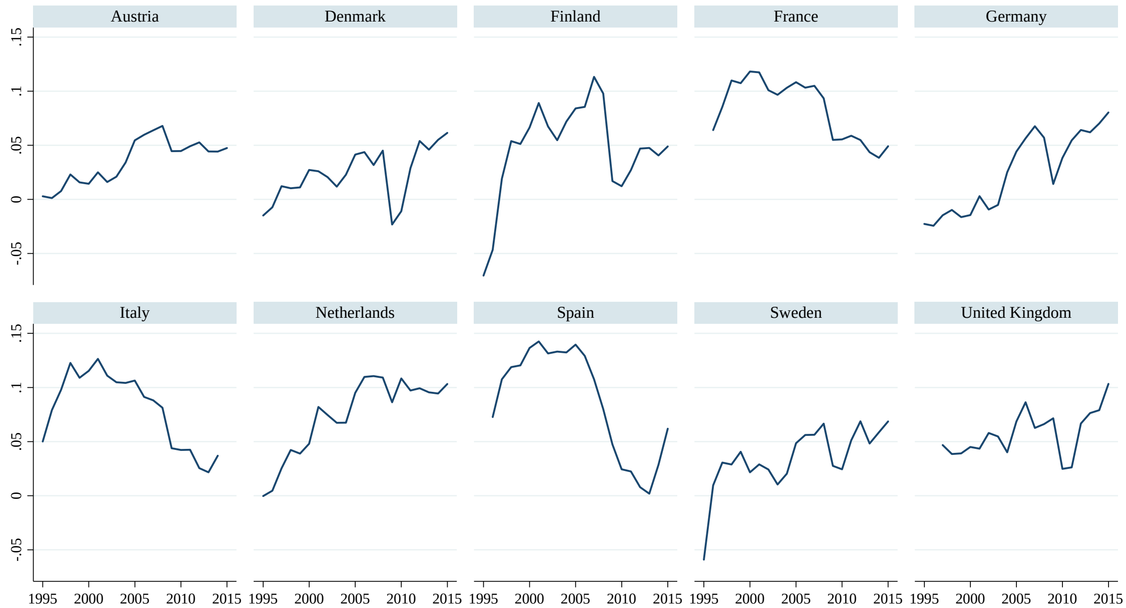
As Karabarbounas and Neiman (2018), among others, point out, rising market power and rising intangibles could both explain apparently increasing economic profits in the data (what Karabarbounas and Neiman call "factorless income"). The link can be direct when rising market power leads to pure economic profits. (It does not need to, if the rising market power is needed to offset rising returns to scale, say, from fixed costs.[17]) With intangibles, the issue is that the returns to intangibles show up in residual payments to capital, but our usual measures of the capital stock might not include those intangibles. Concretely, Apple had a market capitalization of $1.4 trillion in late January 2019, but it has few tangible assets. Its cash flow derives from a return on its enormous stock of intangible design and marketing skills.

Both stories have implications for measuring innovation, as well. First, if here are pure economic profits, then the typical default of estimating capital's factor share as a residual is misleading—that residual includes pure profits as well as the implicit rental cost of capital services. Second, if the story is rising (unmeasured) intangibles, that has implications for measurement of both output (producing the intangible assets) and inputs (the accumulated intangibles stock).

Figure 6 takes a first look at this story by looking at the implicit "excess" return to measured capital in the EU KLEMS dataset—namely, the internal nominal rate of return to measured capital relative to a 10-year government bond yield. (We are missing the US, but it shows a sharp increase). That is, for each country, there is an implicit nominal return in the user-cost formulas (with one user cost equation for each type of capital) such that the sum of the implicit capital rental payments exhausts non-labor factor costs in value added. To adjust for inflation and for the overall level of interest rates, we subtract the nominal government bond yield. The rates in the figure just can be interpreted as reflecting risk, financial frictions—or pure profits.[18]

[17] Ho and Ruzic (2020) find, for U.S. manufacturing plants, that profit rates are rising despite constant markups. In their estimates, returns to scale have fallen over time.
[18] Analysing the overall labor or capital share is subject to an even longer list of potential alternative explanatory factors. See also Barkai (2020) for a related approach for US data.

Figure 6. Market power: increase in apparent profits in UK and elsewhere



Source: IRR: EU KLEMS 2017, calculations by Daan Freeman. Government bond yields: ECB
Notes: Figure shows for each country the internal rate of retun on fixed assets minus the 10-year government bond yield.

In the figure, 7 out of the 10 countries shown saw an increase in this premium over the sample. This increase could be consistent with rising economic profits. These include the United Kingdom.

Still, if we interpret rising internal rates of return as reflecting rising market power, it implies that measured TFP growth did not necessarily track innovation and technology. In the simplest case of constant returns, the issue is that we are underweighting labor and overweighting capital. One could investigate this directly by imposing a premium over the government bond rate in calculating the implicit rental cost and factor shares.

We have not done that, but as a first test, we can see how large a difference it would make to shift weight towards labor and away from capital in the UK data. Specifically, as a benchmark, we simply impose that because of rising economic profits, the true capital share of value added revenue falls 10 percentage points after 2005—a quite large effect—with labor's share rising 10 percentage points.[19] Under the assumption of constant returns, this increases the implied growth rate of aggregate technology by $0.1 \times (\Delta \ln K_t - \Delta \ln H_t - \Delta \ln LQ_t)$. In the ONS data for the

[19] This is only to gauge the plausible magnitude of the effect. With markups, other issues arise, including the fact that aggregate technology cannot in general be expressed just as a function of aggregate output and aggregate capital and labor. The distribution of output and inputs across firms and industries also matters. See, for example, Basu and Fernald (2002).

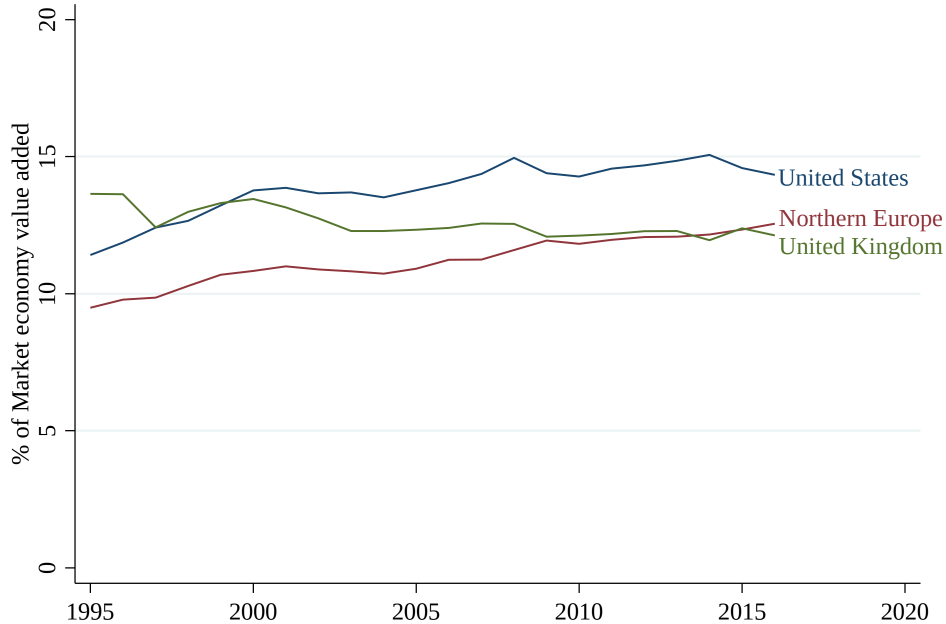
market sector, the term in brackets from 2007 to 2019 is negative (-0.7 percent per year)—implying that true technology growth would be about 7 basis points per year worse than measured. In the U.S. BLS data for the business sector, the term in brackets is positive (+1.3 percent per year), so true technology growth would be a bit faster than measured. Together, the UK and U.S. calculations imply that pure profits would increase the UK-U.S. divergence by about 0.2 percentage points per year. This increase in profits is large (though perhaps plausible), but even then, it goes the wrong way to explain why UK TFP growth was weaker than U.S. TFP growth since 2007.

Non-constant returns to scale could also matter since output elasticities differ from factor shares. With increasing returns to scale ($\gamma > 1$, where γ is the degree of returns to scale), measured TFP growth will mechanically fall if share-weighted input growth, $\Delta\ln(X)$, falls. In the ONS data for the market sector, share-weighted capital and labor growth slowed by 0.4 percentage points from 1995-07 to 2007-19.[20] If the typical industry γ were 1.1, then TFP growth would fall by $(\gamma - 1) \times 0.4$ percentage points per year, or $0.1 \times 0.4 = 0.04$ percentage points per year. Of course, the same logic would apply somewhat prior to 2007, and would also apply to the United States (where profit rates appear to have risen notably after 2000). So, it is unclear that it could explain any of the shortfall relative to the U.S. over this period. That said, most estimates suggest that returns to scale γ are not too far from one (e.g., Basu and Fernald, 1997, and Inklaar, 2007). Hence, even this small estimate is probably an upper bound.

Another interpretation of Figure 6 is that it is capturing intangible investments. Indeed, one channel through which a recession might cast long shadows is through reduced intangible investments—that is, reduced investments in the future. Some of these investments are measured in the national accounts, but others are not. As a pure measurement issue, if intangibles are not measured, there is missing investment output as well as missing intangible capital input.

[20] Table A5 of the ONS data, see Appendix A.

Figure 7. U.K. intangible investment rate edging down



Source: INTAN-Invest Database, January 2019, Corrado et al. (2016).

The intuition is clear. Figure 7 looks at the share of intangible investments relative to market-sector value added. Intangibles here are as measured in the INTAN-Invest database of January 2019 (Corrado et al., 2017), which attempts to measure many of the harder-to-measure types of intangibles (organizational change, training, and branding, for example). The intangibles share has been rising in virtually all countries, but there is no obvious change in trend before and after 2005. In particular, for the UK, the share of intangible investment in value added has modestly closed the gap with the U.S. after 2007.

As a caveat, this argument captures only the direct effect of intangibles on the accounting. The indirect effects are less clear. For example, Corrado et al. (2019) find a similar result for the direct growth-accounting effects. However, they argue that spillovers to growth from the accumulated stock of intangibles can explain much of the mid-2000s U.S. TFP slowdown. To get this result, they assume very large and immediate positive spillovers from a broad class of intangibles—well beyond R&D—such as advertising, training, and organizational capital. We are less persuaded that spillovers to this large class of intangibles is as large as assumed by Corrado et al. (2019). For example, the argument for spillovers from organization capital are weaker than for R&D as organization capital tends to be more tacit, and the evidence is likewise weaker (e.g. Chen and Inklaar, 2016).[21]

[21] As noted in Section 4, de Ridder (2019) suggests intangibles can also matter indirectly as a barrier to entry.

7. Discussion and implications for the future

Across advanced economies, growth in labor productivity and total factor productivity is notably lower than it was 20 to 30 years ago. In this paper, we focus primarily on the UK TFP experience, viewed through the lens of conditional convergence. From this perspective, the bulk of the UK TFP slowdown reflects a slowing frontier trend. The residual puzzles are small. The UK was converging towards the US TFP level in the pre-Great Recession period, driven by market services. In the post-2007 period, the modest UK divergence appears fairly idiosyncratic—mechanically driven, most obviously, by mining, where appropriate measurement is a challenge and there have been substantial idiosyncratic shocks. Hence, we put little weight on the modest post-2007 divergence.

Of course, outside market services, the level of UK productivity remains well below the US level. Policymakers care about the level of productivity, and they should not be happy with keeping a roughly stable position relative to the United States. The fact that the level of UK TFP remains below the frontier highlights the theoretical possibility that growth could be quite rapid if the UK could achieve renewed convergence dynamics. Addressing the issues discussed in van Ark and Venables (2021), such as misallocation across firms and regions, could promote these favorable dynamics. In this regard, our sectoral results suggest that the major shortfall is in manufacturing, rather than in market services.

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Appendix A: Data

In the main text, we focus on the total economy from the Penn World Tables (PWT) and we compile market economy series based on the productivity data from the Office of National Statistics for the UK, the BEA-BLS production account for the US and EU KLEMS 2012+2017 for the EU-5. This appendix discusses the **variables** we use in greater detail.

PWT

We rely on PWT, version 10.0, available for download via www.ggdc.net/pwt, along with further documentation. See Feenstra et al. (2015) for the overall documentation of the database. The variables we use are shown in the following table.

Appendix Table 1: PWT Variables for Figures and Tables

Variable description	Variable code(s)
Figure 1	
TFP	$RTFPNA$
Weighting	$CGDP^o$
Table 1	
Labor productivity (GDP per hour)	$RGDPNA/(EMP \times AVH)$
Capital/hour	$RKNA/(EMP \times AVH)$
Labor composition	HC
TFP	$RTFPNA$
Capital/output	$RKNA/RGDPNA$
Weighting of GDP	$CGDP^o$
Weighting of capital	$(1 - LABSH) \times CGDP^o$
Weighting of labor	$LABSH \times CGDP^o$
Figure 8A	
Capital/output	$RKNA/RGDPNA$
Weighting	$CGDP^o$
Figure 8B	
Investment/GDP	v_{gfcf}/v_{gdp} (NA data file)
Weighting	$CGDP^o$

EU KLEMS

For the EU-5 (ordered by GDP, Germany, France, the Netherlands, Belgium, and Finland), we combine the EU KLEMS releases of 2012 and 2017 to enable a longer time series analysis. We use the 2017 time series for however long available. For nearly all variables, we then use the 2012 time series for extrapolation to each available year t (country and industry subscripts are omitted for clarity):

$$\tilde{x}_{2017,t} = x_{2012,t} \times \frac{x_{2017,\tau}}{x_{2012,\tau}} \tag{A1}$$

Here τ is the first year for which data are available in the 2017 release and x is the relevant variable, such as value added at current prices (VA) or the index for total factor productivity ($TFPva\_I$). The only exceptions to the extrapolation in equation (A1) are the contributions to value added growth of hours worked ($VAConH$), of labor composition ($VAConLC$), of ICT capital ($VAConKIT$) and of non-ICT capital ($VAConKNIT$). For these variables, we use the 2012 values as given.

Appendix Table 2: EU KLEMS Variables for Figures and Tables

Variable description	Variable code(s)
Table 1	
Labor productivity	VA_QI/H_EMP
Capital/hour	CAP_QI/H_EMP
Labor composition	LAB_QI/H_EMP
TFP	Based on equation (1) in the main text
Capital/output	CAP_QI/VA_QI
Weighting across market industries	VA
Weighting across countries	See Appendix Table 1
Figure 2, Figure 3, Figure 4, and Figure 5	
TFP	Aggregate across industries (and countries) as for Table 1
Figure 6	
Internal rate of return	Computed based on capital input files, giving capital stocks, deflators and depreciation rates

ONS

The UK Office of National Statistics (ONS) publishes a quarterly productivity dataset. For this paper, we relied on the data released on April 14, 2021.[22] To compute Törnqvist aggregates across sectors, we collected value added at current prices by detailed industry, using the data published on November 11, 2021.[23] The ONS productivity data refer only to market activities, so, for example, exclude public health and education. The data with the proportion of market sector value added by detailed industry was also available from the ONS, we use the data released on February 19, 2020.[24] For years not covered in these data, we assume constant proportions. In the table, below, we reference the Tables used from the ONS productivity dataset.

Appendix Table 3: ONS productivity tables used

Variable description	ONS Tables
Value added quantity index	A1
Hours worked index	A2
Labour composition index	A3
Capital services index	A4
Total factor productivity index	A6
Labour share in value added	A8

BEA-BLS

For the US, the BEA and BLS jointly publish a production account, with industry-level estimates of output, inputs and productivity. We combined two series, namely the current series covering the period 1987–2019 and the historical series for the period 1963–2016. To combine these, we assume that growth rates of output and inputs before 1987 are as given in the historical series. Value added and labour shares computed from the historical series are used before 1987 directly from the historical series.

The BEA-BLS data provide an 'integrated MFP index', which is a TFP index based on gross output. We transform that to a value-added basis by dividing 'integrated MFP' growth by the two-period average value added-to-gross output ratio.

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[22] https://www.ons.gov.uk/economy/economicoutputandproductivity/productivitymeasures/datasets/multifactorproductivityexperimentalestimatesreferencetables/current

[23] https://www.ons.gov.uk/economy/grossdomesticproductgdp/datasets/ukgdpolowlevelaggregates/current

[24] https://www.ons.gov.uk/economy/grossvalueaddedgva/adhocs/11301marketsectorgrossvalueaddedproportions

Appendix Table 4: BEA-BLS tables used

Variable description	BEA-BLS Tables
Gross output at current prices	GrossOutput
Value added at current prices	ValueAdded
Value added quantity index	VA_Quantity
Hours worked index	Labor_Hours_Quantity
Labour input index	Labor_Input_Quantity
Capital services	Computed implicitly from growth of value added, labour input and total factor productivity
Total factor productivity index (gross output basis)	Integrated_MFP_Index
Labour share in value added	(Labor_Col_Compensation+ Labor_NoCol_Compensation)/ValueAdded

Appendix B: Capital-output ratios

As discussed in Section 2 and shown in Table 1, capital does not appear to be an independent contributor to slow growth in UK, US, or EU-5 labor productivity after 2007. This section appendix discusses this point graphically.

Appendix Figure 1A plots the capital-output ratio in the PWT data. For visual clarity, the plot is in levels (the integral of $\Delta \ln K_t - \Delta \ln Y_t$), normalized to 2007 = 1. The U.S. and northern European capital-output ratios have an upward trend before the Great Recession, consistent with positive investment-specific technical change. During the recession itself, the capital-output ratios shoot upwards because output falls. (The capital-hours ratio, not shown, shows a qualitatively similar pattern, because hours worked fall. The upward trend is more pronounced with the capital-hours ratio.) Following the recession, the capital output ratio naturally flattens out as output returns to its post-recession normal. By the end of the sample, the U.S. and northern-European capital-output ratios lie roughly in line with their pre-recession trends. That is, there does not appear to be any broad-based shortfall in capital relative to output.

The United Kingdom shows a markedly different pattern—with the differences most apparent *before* the GFC. The pre-GFC trend in the capital-output ratio was downwards. Indeed, after the GFC, the capital-output ratio lies consistently *above* its pre-recession trend.

That capital deepening explains little or none of the U.K., U.S. or European labor-productivity slowdown may seem surprising. It is "conventional wisdom" that investment in many countries fell sharply after 2007 and has been slow to recover. Figure 8B shows the nominal ratio of gross investment to output for the U.K., U.S., and northern Europe (the EU-5).[25] The UK share of investment is uniformly lower than in the U.S. or EU-5 since 1990. That UK share was trending steadily down for decades before the Great Recession. During and immediately after the recession, the share fell further. But it then rebounded. By the end of the sample, the UK share was at, or above, its pre-recession levels (despite slower growth in TFP, which would be expected to reduce demand for capital goods).

One notable feature of the data is that the capital-output ratio is strongly countercyclical (rising in recessions). In Figure 8A, this shows up in the temporary increase from 2007 to 2010. Output fell but capital did not decline (in part because we do not typically observe the workweek

[25] Ideally, we would show Figure 3B in terms of nonresidential investment. For the UK, the picture looks fairly similar, albeit at a lower level.

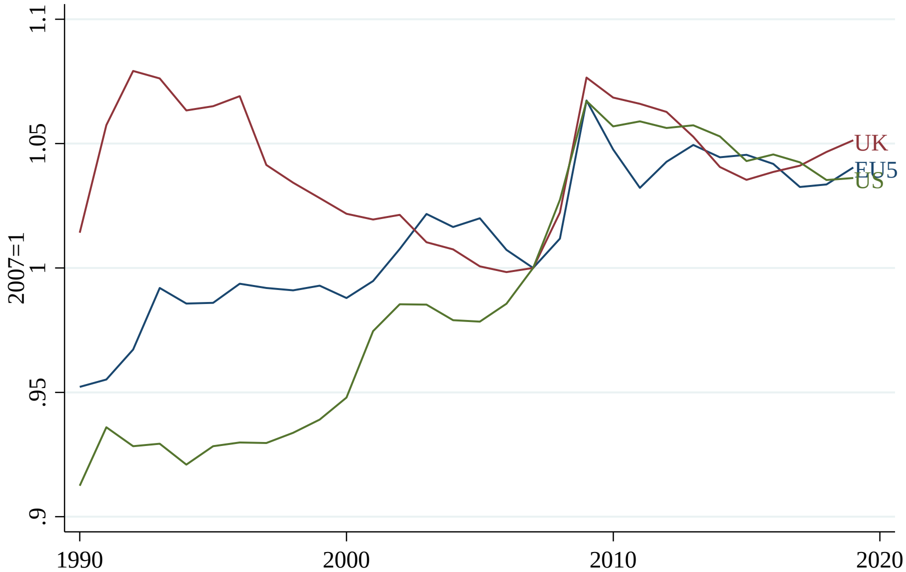
of capital).[26] Returning to Table 1, it shows up as a sharp rise in the contribution of the capital-output ratio in the 2007–11 period (row 5, column 6). The contribution then barely grows in the subsequent period (from 2011 to 2015 for EU KLEMS, or 2011 to 2017 in PWT). Some observers have focused on the post-2010 period, both in Europe and the United States, to argue that subdued capital formation was behind weak labor productivity growth. In a narrow sense, it is true that during this period, capital deepening added less than usual.

But the figure makes clear that this is a cyclical effect. Capital deepening naturally added more, in an accounting sense, during the recession itself. But, intuitively speaking, firms came out of the recession with spare capacity (i.e., capital) relative to demand or relative to labor. Over time, they have brought capital back into line with demand and labor—which meant, for a time, having less capital deepening. Our preference is to look at the entire period from 2007 on—as shown in the 2007-19 columns of the table; or at Figure 8A—where a shortfall of capital deepening was not an important reason for the shortfall in labor productivity growth. [27]

[26] Fernald et al. (2017) adjust for this countercyclicality in U.S. data using the unemployment rate, which is approximately stationary. Fernald (2014) also has a utilization adjustment that, in principle, applies to a composite of capital and labor.

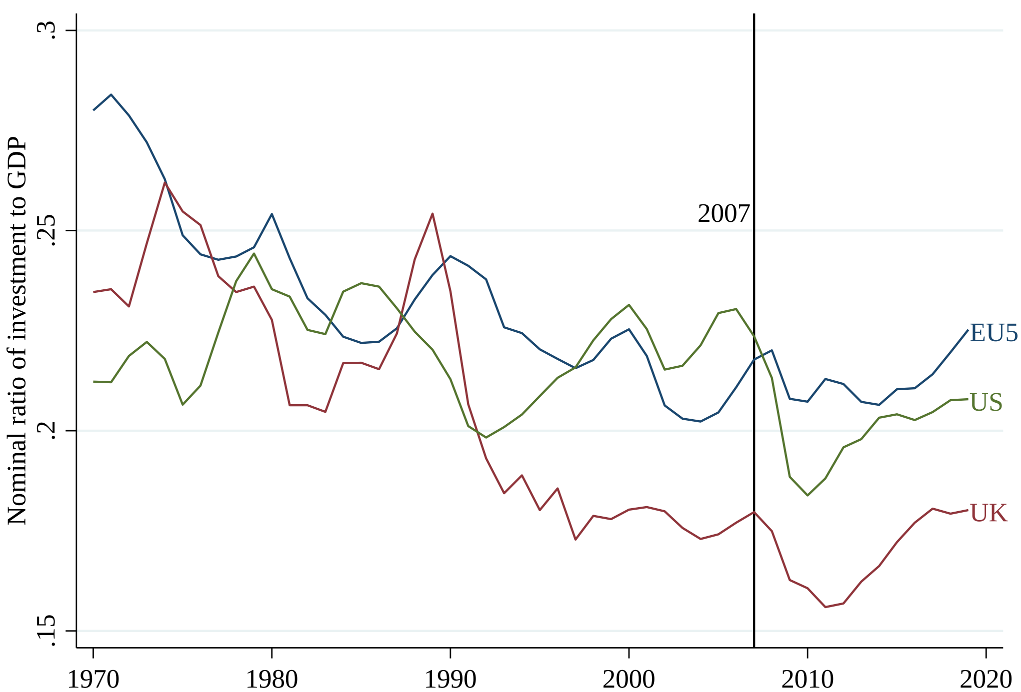
[27] As noted, the cyclical dynamics of capital deepening will add additional cyclical dynamics to labor productivity, above any cyclical dynamics in TFP. Specifically, this suggests a reason not to focus narrowly on labor productivity growth after 2010, when capital-output ratios were gradually returning to steady state from cyclically elevated levels.

Figure 8A. Capital-output ratio not falling short of trend



Source: Penn World Table 10.0 (Feenstra, Inklaar and Timmer, *AER* 2015), variables RK^{NA} and $RGDP^{NA}$.
Notes: Figure shows the capital-output ratio in the UK, EU-5 and US for 1990–2019. The capital-output index is normalised to 2007=1.

Figure 8B: Investment share fell after GFC but has since bounced back



Source: Penn World Table 10.0 (Feenstra, Inklaar and Timmer, *AER* 2015).

Appendix C: Evidence from break tests

We use industry data for the US, UK, and EU-5 to see if we can find, statistically, crisis-induced breaks in trend. Unfortunately, break tests can lack power. Given the sizeable subsample changes in trend discussed in the text and shown in Table 1 and Figure 1 and Figure 2, the evidence for breaks is not statistically overwhelming even though the apparent breaks are economically sizeable. As is well known, these tests lack power.

Previous literature has found statistically significant breaks in U.S. data in the years right before the Great Recession, with estimates ranging from 2004 to 2006. Updated estimates from Kahn and Rich (2007), using multivariate methods, date the U.S. labor-productivity slowdown to 2004Q4. Fernald et al. (2017), using univariate methods, date the U.S. TFP slowdown to 2006Q1 (with little probability that it was 2007Q4 or later). In both cases, the focus is the business economy (Fernald et al) or nonfarm business economy (Kahn and Rich), and the breaks are statistically significant.

Appendix Table 5 shows tests for breaks at unknown dates for our industry data for the U.S., UK, and EU-5. For example, for the one break version, the regression specification is

$$\Delta lnTFP_{c,i} = c_{c,i} + c_{c,i}^{1}|\text{year}{>}\tau_1 + \varepsilon_{c,i}$$

where c indexes countries (or regions) and i indexes industries. The null hypothesis is that $c_{c,i}^{1} = 0$ for all choices of dates τ_1. (The two-break test adds a second break in trend growth to this equation.) In other words, we assume TFP growth is a random walk and test for changes in the constant (the drift term). The estimation was done in Matlab following the Quandt approach in Fernald et al. (2017, Table 6). (Allowing for a third break made little difference to results shown.)

Appendix Table 6 shows break tests for UK and EU-5 industry TFP growth *relative* to the corresponding US industry. The reason, as noted in the introduction and Section 4, is that even if UK and EU-5 data show apparent breaks around the time of the Great Recession, it doesn't mean that the Great Recession was the cause. We would expect a U.S. pre-recession slowdown to also be associated with a slowdown in the UK and elsewhere around the time of the Great Recession. That said, the recession itself could be an additional contributor to the slowdown. After all, the UK and EU-5 both lost ground since 2007 relative to the U.S. frontier.

Results are at best suggestive and rarely rise to the 10 percent level of significance. In Appendix Table 5, only the EU-5 shows a statistically significant market-economy slowdown around the time of the Great Recession. It is not clear why the U.S. data we use (from the BEA-BLS dataset) shows less strong results than those obtained in other studies that use business-sector or non-farm business data. Fernald et al (2017) use cyclically adjusted data, which may make a difference by smoothing the data around recessions. Kahn and Rich (2007, updated) use a multivariable approach. It's also possible that coverage differences make a difference, or the use of annual versus quarterly data (though length, rather than frequency, is more likely to matter for detecting breaks).

Looking at Appendix Table 6, for the UK, only finance and insurance shows a statistically significant relative break. Mechanically, this reflects the catchup in finance and insurance prior to the financial crisis, followed by some loss of ground. Given the magnitude of the shocks to finance (the crisis and Brexit, most obviously), as well as the challenges measuring nominal and real value added in finance, we do not put a lot of weight on this result.

For the EU-5, manufacturing shows a statistically significant *speed up* relative to U.S. manufacturing around the time of the Great Recession. "Other" (non-manufacturing and non-market services) shows a statistically significant relative slowdown after 2009. None of the component pieces (agriculture, mining, utilities, or construction) are significant on their own, so aggregating helps for identifying the break. Other breaks that appear significant are not around the time of the Great Recession.

Appendix Table 5: Break tests at unknown date for Industry TFP Growth, 1971-2019

		United States		United Kingdom		EU-5	
		One break	Two breaks	One break	Two breaks	One break	Two breaks
	Market sector	0.523	0.288	0.194	0.359	**0.085**	0.278
		2006	1982 2005	2007	1997 2007	**2007**	1990 2007
	Market services	**0.047**	0.126	0.796	0.301	0.243	0.304
		1978	1978 2005	1992	1997 2007	1991	1991 2007
C	Manufacturing	0.275	0.244	0.148	0.247	0.226	0.211
		2007	1982 2007	2011	1981 2011	2007	1993 2007
	Other (not manuf or mkt serv	**0.042**	**0.057**	0.229	0.374	0.127	0.218
		1983	**1983 1992**	1987	1978 1987	2004	1992 2004
A	Agriculture	0.544	0.281	0.598	0.333	0.104	0.211
		2005	1983 1992	2002	2002 2010	2009	1992 2009
B	Mining	0.029	0.106	0.577	0.341	**0.071**	0.243
		1982	1982 1994	1996	1978 1996	**2010**	1994 2010
D_E	Utilities	0.205	0.4	**0.087**	0.237	0.269	0.428
		1983	1983 2000	**2004**	1984 2004	2004	1991 2004
F	Construction	0.746	0.281	0.746	0.353	0.224	0.487
		1982	1982 1992	1988	1981 1989	1992	1992 2006
G	Wholesale and retail trade	0.148	0.257	0.412	0.397	0.37	0.462
		2003	1990 1998	1980	1980 1988	2006	1999 2006
H	Transportation	0.332	0.417	**0.052**	0.202	0.154	0.307
		1992	1982 1992	**2007**	1979 2007	2007	1997 2007
I	Accomm. and food serv.	0.468	0.265	0.523	**0.09**	0.447	0.195
		1978	1979 1987	1988	**1988 1997**	2010	1996 2001
J	Information	0.549	0.218	0.321	0.204	0.198	0.228
		2000	1981 2000	1997	1987 1997	1994	1994 2002
K	Finance and Insurance	0.505	0.535	0.474	0.109	0.684	0.154
		2008	2000 2008	1986	1995 2006	1994	1999 2004
M_N	Prof. and scientific serv.	0.107	0.237	0.864	0.391	0.329	0.152
		2009	1990 2000	1997	1985 1993	2009	1995 2009
R_S	Other serv. (incl arts and ent.)	**0.034**	0.136	0.653	0.834	0.135	0.244
		1997	1997 2011	1999	1996 2005	1992	1992 1999

Notes: Table shows p-values of the null of no break in trend TFP growth against the alternative of either one or two breaks. Below each p-value are years associated with the breaks. In each column, the first set of numbers for each industry are p-values against the null of a constant mean growth rate and are heteroskedasticity and autocorrelation robust. Bold indicates significance at the 10% level. The second set of numbers in each column are estimated dates after which the mean growth rate changes. TFP growth is annual data for market industries as discussed in the appendix. Estimation runs 1971-2019 for the U.S. and UK, and 1985-2015 for the EU-5. For estimation details of the Quandt tests, see Fernald, Hall, Stock, and Watson (2017).

Appendix Table 6: Break tests at unknown date for *relative* industry TFP Growth

		United Kingdom		European Union	
		Single	Two-break	Single	Two-break
	Market sector	0.561	0.278	0.474	0.281
		2008	1999 2008	1991	2003 2008
	Market services	0.354	0.302	0.273	0.154
		1992	1992 2008	1991	1995 2005
C	Manufacturing	0.486	0.441	**0.044**	**0.061**
		1993	1994 2004	**2009**	**2001 2009**
	Other (not manuf or mkt serv)	0.404	0.2	**0.061**	**0.096**
		2004	2007 2013	**2008**	**1994 2008**
A	Agriculture	0.691	0.475	0.313	0.386
		2010	2002 2009	1993	1999 2005
B	Mining	0.589	0.347	0.231	0.484
		2000	1991 2000	2010	1990 2010
D_E	Utilities	0.158	0.25	0.672	0.459
		2003	2005 2011	2005	2000 2005
F	Construction	0.487	0.517	0.379	0.182
		1995	2000 2007	2008	1996 2008
G	Wholesale and retail trade	0.314	0.206	0.365	0.159
		2000	1994 2000	1998	1991 1998
H	Transportation	0.446	0.249	0.156	**0.058**
		2002	1992 2002	2002	**1992 2002**
I	Accomm. and food serv.	0.472	0.649	0.527	0.241
		1998	2000 2010	2004	1991 2004
J	Information	0.6	0.428	0.465	0.256
		1996	1994 2000	2001	1994 2000
K	Finance and Insurance	**0.035**	**0.024**	0.395	0.245
		2008	**2002 2008**	2008	2003 2008
M_N	Prof. and scientific serv.	0.183	0.178	**0.08**	**0.088**
		1992	1992 2007	**1995**	**1990 1995**
R_S	Other serv. (incl arts and ent.)	0.39	0.39	0.118	0.228

Notes: Table shows p-values of the null of no break in *relative* trend TFP growth (relative to the corresponding U.S. industry or industry group) against the alternative of either one or two breaks. Below each p-value are years associated with the breaks. In each column, the first set of numbers for each industry are p-values against the null of a constant mean growth rate and are heteroskedasticity and autocorrelation robust. Bold indicates significance at the 10% level. The second set of numbers in each column are estimated dates after which the mean growth rate changes. TFP growth is annual data for market industries as discussed in the appendix. Estimation runs 1971-2019 for the UK and 1985-2015 for the EU-5. For estimation details of the Quandt tests, see Fernald, Hall, Stock, and Watson (2017).