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Supporting paper for a speech by Andrew Bailey at the Official Monetary and Financial Institutions Forum

July 2022

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Abstract

The world has undergone substantial structural change over recent decades, with profound implications for the long-run policy landscape. We focus on two key trends. First, the secular decline in risk-free interest rates, suggesting a fall in the long-run global equilibrium interest rate, Global *R**. Using a structural model, we find that declining productivity growth and increasing longevity played the largest roles in explaining this fall. The second trend is the recorded weakness in investment, despite an increasing wedge between the return on capital and the risk-free rate. We use industry-level data for the United Kingdom to investigate the potential structural factors behind this 'missing-investment puzzle', and find a strong role for intangible capital.

Key words: Structural change, equilibrium interest rates, investment.

JEL classification: E22, E43, J11.

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1 Introduction

Monetary policy must respond to a multitude of exogenous forces. Many of those forces have a very visible and direct effect on the outlook for output and inflation over the short and medium term. Others, however, are manifestations of much longer-term structural changes that unfold over many decades. This paper focuses on these longer-term trends and their effects on the broader landscape in which monetary policy operates.

The world has undergone substantial structural change over recent decades. One such example is population ageing: in the United Kingdom, the life expectancy of a 65 year old woman in 1950 was around 80 years old. By 2015 the equivalent life expectancy was close to 86. Moreover, this 6-year increase in life expectancy was not unusual in the global context: the equivalent figures for Germany, Italy and Japan are 7, 8 and 10 years, respectively. Another example is technological change: firms are increasingly moving away from using physical capital, like machinery, equipment and computer hardware, towards intangible capital, like R&D, software and branding. Intangible capital made up 65% of UK firms' investment in the mid-1990s, and this is now 75%, an increase of 10 percentage points. We see similar increases in the United States, Japan and Germany, of 8, 7 and 10 percentage points, respectively.[1]

This widespread structural change has profound effects on the economy, and the broader landscape that policymakers navigate. Of particular relevance to monetary policy, are the effects of structural forces in shaping the long-run trends in key variables such as output, investment and real interest rates.

For example, one of the most striking global trends is the well-documented secular decline in risk-free real interest rates, which suggests that there has been a decline in the long-run global *trend* equilibrium interest rate. This is the long-run trend around which the domestic equilibrium interest rate of an open economy, like the United Kingdom, will fluctuate. We refer to this long-run global trend real rate as Global R^*.

In this paper, we first explore the effect of structural changes, such as demographic trends and technological change, on Global R^*. To do so, we employ a structural model of the world economy, in which we purposefully abstract from shorter-term cyclical influences on the equilibrium real interest rate. Among the five potential forces that we consider, we find that the decline in Global R^* has primarily been driven by

[1] Data on life expectancy is from UN World Population Prospects 2019. Data on intangibles is from the 2022 vintage of EU KLEMS. See Appendix A.1 for more details.

the slowdown in productivity growth and population ageing. The effects of these mechanisms are expected to persist going forward.

The long-run decline in the risk-free interest rate is only part of the story, however. A recent literature has emerged showing that the rate of return on capital has not been declining alongside the risk-free rate. In standard economic theory, the wedge between these two rates of return is a key determinant of firms' investment, itself an important factor for the policy landscape, which, over the long run, has implications for productivity and output. In particular, we would expect the observed rise in this wedge to be coupled with a rise in investment. However, no such investment boom has been recorded across high-income countries over recent decades.

We refer to this observed weakness in investment, despite a growing wedge between the return on capital and the risk-free rate, as the "missing-investment puzzle". To understand the structural forces at play, we investigate several candidate explanations for this puzzle, using industry-level data for the United Kingdom. Our results suggest a strong role for intangible investment. Indeed, when accounting for missing intangibles, in both investment and the measure of the return on capital, the missing-investment puzzle in the United Kingdom is substantially reduced in recent years.

Finally, given their important role in explaining the trends in investment, we extend our analysis to understand the potential impact of intangibles on long-run productivity. While intangibles can *explain* the UK missing-investment puzzle, they may have *driven* the concurrent productivity puzzle: industries with highest intangibles intensity have contributed the most to declining labour productivity in the United Kingdom since the global financial crisis.

Our results have important implications for the long-run policy landscape. First, our structural model suggests that both productivity growth and demographic trends have led to permanently lower Global R^*. This means that, without significant reversals in these structural trends, or the emergence of new long-run structural forces pushing in a different direction, Global R^* is expected to remain low. Second, intangible capital appears to account for a significant part of "missing" investment in recent years, suggesting that there has not been a structural missing-investment puzzle in the United Kingdom. However, we should be cautious about the impact of the intangible economy on the broader policy landscape, since intangible-intensive industries appear to have contributed to the recent productivity puzzle. It is important to understand why this may be, and the underlying challenges raised by an intangible-intensive economy.

The rest of this paper is organised as follows. Section 2 shows our analysis of the equilibrium real interest rate, and the path of Global R^* over recent decades. Section 3 discusses the missing-investment puzzle, and the role of intangibles. Section 4 concludes.

2 Global R^*

This section explores the dynamics of Global R^* – the long-run global trend equilibrium real interest rate – over recent decades.

We first describe a simple approach to characterise the forces that act on equilibrium real interest rates at different horizons. We then set out the underlying framework for long-run interest-rate determination, laying out the key factors that can drive the dynamics of the trend real rate. We summarise the results of Cesa-Bianchi et al. (2022), hereafter referred to as CHS, who use a general equilibrium life-cycle model to quantify the impact of each of the drivers. Finally, we discuss how these results relate to the recent literature on demographics and inequality.

2.1 Equilibrium Real Interest Rates

The 'equilibrium' or 'neutral' real interest rate is usually defined as the real interest rate required to close the output gap and sustain the inflation rate at its target. In principle, therefore, the equilibrium real interest rate can be a useful guide for monetary policymakers.[2]

The equilibrium interest rate cannot be directly observed, and must be estimated. Such estimates are typically highly uncertain and so are not used as a mechanical guide to monetary policy.[3] Nevertheless, in the longer run, estimates of the equilibrium real interest rate, and the factors driving it, can help to explain the evolution of interest rates over the past and provide an indication of the outlook over coming years.

A simple framework for analysing the equilibrium real interest rate, r^*, is to decompose

[2] When shocks create a trade-off between stabilising inflation at target and closing the output gap, the equilibrium real interest rate is less useful as a guide for policy.

[3] See Fiorentini et al. (2018) for a detailed discussion of the uncertainty around estimates of equilibrium interest rates.

it into a long-run, or trend, component, R^*, and a shorter-term component, s^*:[4]

$$\underbrace{r^*}_{\substack{\text{Equilibrium}\\ \text{real interest rate}}} = \underbrace{R^*}_{\substack{\text{Trend}\\ \text{real rate}}} + \underbrace{s^*}_{\substack{\text{Shorter-term}\\ \text{component}}}$$

In this framework, r^* fluctuates as a result of shorter-term influences on the economy, s^*. These influences include cyclical shocks to both aggregate demand and supply as well as the effects of financial shocks.[5]

However, over the longer term, these fluctuations occur around the trend real rate, R^*, which can change in response to long-run structural forces. Importantly, for an open economy like the United Kingdom, the trend real rate will ultimately be determined by global forces, because frictions that impede the free international movement of capital are weaker over the long run. This implies that it is the global trend real interest rate, Global R^*, that acts as a long-term anchor for the UK's domestic equilibrium real interest rate. As such, the focus of this paper will be on Global R^*.

The above framework suggests that Global R^* can be measured as a common trend component, within a trend-cycle decomposition of data from a cross-section of countries. Figure 1 shows such an estimate from CHS, obtained by applying the methodology of Del Negro et al. (2019) to a panel of 31 high-income countries from 1900-2015.[6] Between 1900 and 1930, Global R^* is estimated to have been relatively stable at around 2%. After falling during the WW2 period, Global R^* rose again between 1950 and 1980, reaching a peak of close to 2.5% in the late 1970s. Thereafter, Global R^* declined steadily and is estimated to have been close to 0% in recent years. Though there are relatively wide error bands around this central estimate, and the alternative estimates, also reported in Figure 1, exhibit different patterns, there is robust evidence of a steady decline in Global R^*, especially in recent decades.

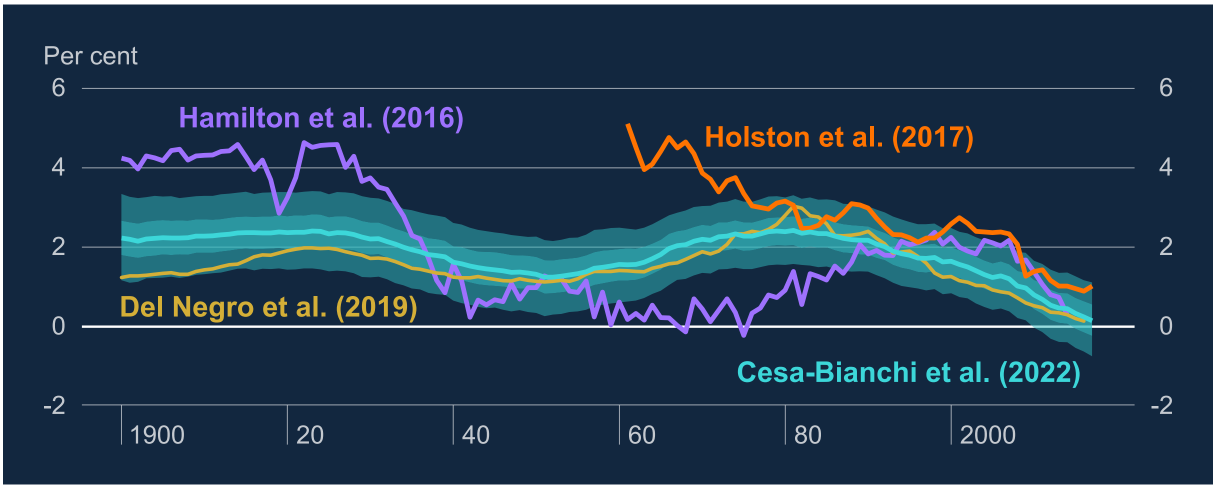
However, these reduced-form empirical estimates do not tell us *why* Global R^* has declined. Understanding the relative importance of the different secular factors that drive Global R^* requires a general-equilibrium structural model. With this in mind, we now lay out the key factors that determine the real interest rates in a neo-classical framework.

[4] This framework was laid out in Bank of England (2018).

[5] For example, the analysis in Bank of England (2018) assesses that during the global financial crisis, headwinds to demand (including heightened uncertainty and tighter financial conditions) prompted a large drop in s^*, which took many years to dissipate.

[6] See Appendix A.1 for details.

Figure 1: Empirical Estimates of Global R^*



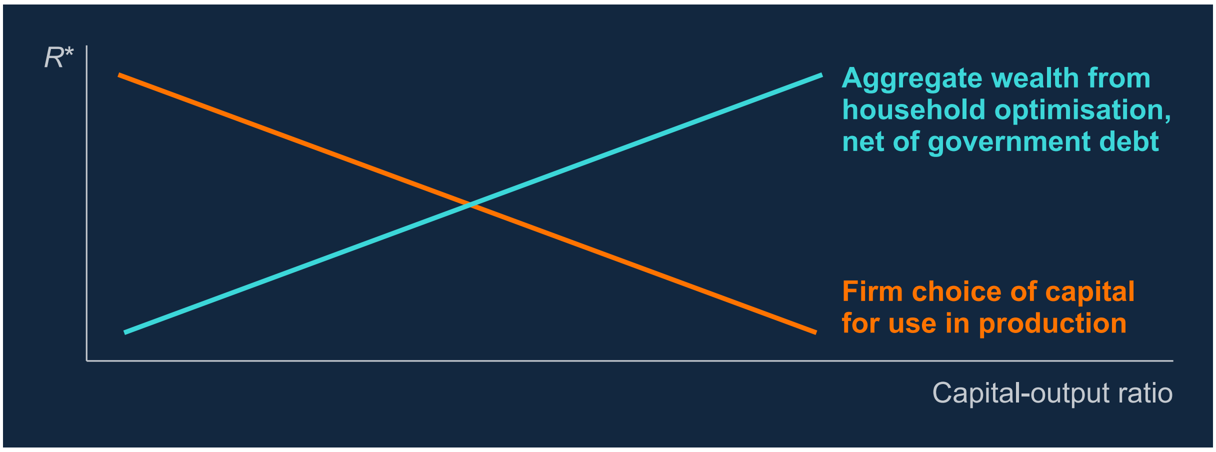
Source: Consumer prices indices, short-term interest rates and government bond yields for the calculation of the Cesa-Bianchi et al. (2022) measure from the Jordà et al. (2017) Macrohistory Database and Eikon Refinitiv. Del Negro et al. (2019), Hamilton et al. (2016) and Holston et al. (2017).

2.2 Interest-Rate Determination

As laid out above, the trend real rate, R^*, is the long-run equilibrium real interest rate. As such, it corresponds to the real interest within a long-run model: a model that abstracts from both shocks and frictions that pertain to cyclical fluctuations.

In the neo-classical framework, the real interest rate, R^*, is the price that ensures equilibrium in the capital market. Figure 2 provides a graphical representation of this, by depicting the two sides of this market: firms and households.

Figure 2: Interest-Rate Determination



Firms Firms require capital to produce, and R^* corresponds to the rate at which firms can borrow to finance investment. The marginal cost of each unit of capital, then, will be determined by this borrowing cost, R^*, adjusted for the effects of depreciation.

Profit maximisation implies that a firm will choose the capital-output ratio that sets the marginal product of capital equal to this marginal cost. If the cost of borrowing falls below the return on capital, firms will be incentivised to borrow in order to invest in capital. The rise in borrowing will raise borrowing rates, and the rise in investment will reduce the marginal return on additional capital, because of diminishing marginal returns, until equilibrium is restored when the two are equalised.

This optimisation, along with the diminishing marginal returns to capital, implies that a higher value of R^* will induce the firm to choose a lower capital-output ratio. This leads to the downward-sloping orange line in Figure 2.

Households Capital also provides a way for households to accumulate and store wealth.

Given their stream of income over their life-cycle, each household will optimally accumulate wealth to smooth consumption and maximise their utility. R^* is the return that the households earn on each unit of wealth. Aggregate wealth in the economy is the sum of per-capita wealth across households.

Within this simple framework, we can consider two ways to store wealth: government bonds and productive capital. As long as the return that the household receives on each of these is the same, households will be indifferent about which they hold, and their optimal behaviour will determine their total wealth, rather than how it is allocated.[7] Assuming that the quantity of government debt is determined by the government's budget constraint, and does not depend on the interest rate, households' holdings of capital is determined by the fact that aggregate wealth must be equal to total government bonds plus capital.

This behaviour typically implies that households will hold more wealth when the return, R^*, is higher.[8] This is shown in the upward-sloping blue line in Figure 2.

[7] More precisely, this is true so long as the *risk-adjusted* returns on different assets are the same, however this simple framework abstracts from risk.

[8] In general, this will depend on a number of specific assumptions about household preferences and life-cycle income, and, in some cases, households may hold less wealth as the rate of return falls. The exposition here only requires that, if this is the case, then the effect is not too strong. Specifically, we require that the blue line in Figure 2, if negatively sloped, is steeper than the orange line. Alternative modelling approaches can also lead to an upward-sloping line as the one presented here – see for example Aiyagari-Bewley-Huggett models, or the model in Moll et al. (2021).

The precise positions of these two lines will depend on several factors, which we can separate into two groups. The first group consists of the parameters of the model, which do not change over time. The second group is the structural factors that may vary over time, and therefore drive the dynamics of R^*.

In particular, CHS consider five key drivers: productivity growth, population growth and longevity (which together capture population ageing), government debt, and the price of capital goods relative to consumption goods. The mechanisms through which each driver affects R^* can be seen through their effects on the position of the two lines in Figure 2.

Productivity Growth: A decline in productivity growth causes the marginal product of a given capital-output ratio to fall, shifting the orange line to the left. All else equal, this lowers both R^* and the capital-output ratio in equilibrium.

Population Ageing: A change in the population age distribution towards older generations, due to either a decline in population growth rates or an increase in longevity, raises aggregate household wealth. This is driven by two effects. First, households expecting to live longer will optimally want to accumulate more wealth to finance consumption during a longer retirement. Second, since, in the data, older households are, on average, wealthier than younger households, a rise in the share of older households in the population also increases aggregate wealth.[9] This shifts the blue line to the right: for a given R^*, the aggregate wealth of households rises. All else equal, this lowers R^* and increases the capital-output ratio in equilibrium.

Government Debt: For a given level of aggregate wealth, a rise in the quantity of government debt lowers household capital holdings. As described above, in equilibrium, household wealth must equal government bonds plus capital, so that the quantity of capital held by households is found by subtracting the quantity of government debt from aggregate wealth. Therefore, if a larger portion of wealth is allocated to government debt, households' holdings of capital declines for all values of R^*. This shifts the blue line to the left. All else equal, this raises R^* and pushes down on the capital-output ratio in equilibrium.

Relative Price of Capital: The effect of a change in the relative price of capital on the firm's optimal capital-output choice will depend on the elasticity of substitution

[9] In the quantitative exercise, CHS calibrate the life-cycle profile of wealth to match this empirical fact. These mechanisms are explored at greater length in Lisack et al. (2021).

between capital and labour. Empirical estimates point to complementarities between the factors of production, so that a decline in the relative price of capital will lead to a decline in the optimal capital-output ratio.[10] This shifts the orange line to the left. All else equal, this lowers both R^* and the capital-output ratio in equilibrium.

2.3 Decomposing the Drivers of Global R^*

While the qualitative effects of the key drivers of equilibrium interest rates can be understood from the simplified framework considered above, a richer structure is required to uncover their quantitative importance.

For that, we draw on the work of CHS, who use a general-equilibrium life-cycle model to provide a structural interpretation of the evolution of Global R^* in response to this set of drivers.

Quantitative Model CHS consider a model of the world as a single large (closed) economy, populated by overlapping generations of finitely-lived households. The model is calibrated so that each time period corresponds to five years, and therefore captures the effects of slow-moving trends, abstracting from business-cycle fluctuations. Consistent with the five-year timing assumption, the model includes fourteen cohorts of households, from age 20-24 to 85-89.

Using data for a panel of 31 high-income countries from 1950 to 2015, they derive the common global trend in each of the five key drivers.[11] These paths for the drivers are then fed through the model as exogenous processes driving the dynamics of the equilibrium. The model is simulated using a novel recursive approach that captures slow-moving beliefs about long-term trends, which is particularly relevant as the simulations span sixty years of substantial structural change. This results in an estimate of the decline in Global R^*, and a decomposition of the contribution of each driver.

The results of these simulations depend on the estimated path of these drivers, as well as the parameters that determine the shape, slopes and positions of the lines in Figure 2. To capture this uncertainty, CHS carry out sensitivity analysis, considering alternative estimates of the path of the drivers, and alternative values of the key

[10] This effect applies to the *value of* the capital-output ratio (that is, accounting for the change in the price), which is what is shown in the figure. It is driven by the fact that the substitution towards the now-cheaper factor of production is not sufficiently large to offset the decline in its price, due to complementarities. These mechanisms are explored at greater length in Sajedi and Thwaites (2016).

[11] In the five-year model period, the next time period would be 2020. However, they exclude any data from 2020 to avoid the large movements induced by the Covid-19 shock. See Appendix A.1 for more details.

Table 1: Change in Global R^* from 1985

Empirical Model	**Median**	**5%–95%**
1985–2015	-1.9	(-2.4, -1.3)
Structural Model	**Baseline**	**Range**
1985–2015	-1.9	(-3.3, -1.1)
Of which:		
Productivity growth	-0.9	(-1.2, -0.3)
Population growth	-0.1	(-0.5, -0.0)
Longevity	-1.0	(-1.8, -0.8)
Long run	-2.9	(-4.3, -1.8)

Note: For the empirical model, the table reports the median estimates of Global R^* together with the 95 percent posterior intervals (five-year averages of annual data). For the structural model, the table reports the estimate of R^* in the baseline simulation, together with the minimum and maximum across the sensitivity tests.
Source: Cesa-Bianchi et al. (2022).

parameters. The simulations are repeated under random combinations of these alternatives, to create a range of potential paths for R^*.

Declining Global R^* Table 1 shows the resulting changes in Global R^*, between 1985 and 2015, comparing across the empirical estimates shown in Figure 1 and the structural model.[12]

We see that Global R^* declines by 1.9 percentage points in both the baseline structural model simulation, and the median empirical estimate. In the model, this ranges from 1.1 to 3.3 percentage points across the alternative simulations in the sensitivity tests, which encompasses the 95% confidence interval around the empirical estimate. Hence there is a robust finding of a decline in Global R^* over this period, despite the uncertainty about the size of the decline.

Decomposing the Drivers The structural model also allows us to decompose this decline in Global R^* into the contribution of each of the five drivers described above. The full decomposition is provided in CHS. As they show, this fall has primarily been driven by changes in productivity growth and population ageing. For brevity, we therefore focus on these key drivers.

[12]Since the model periods correspond to five years, '1985' means an average of 1981-1985. For comparison, we use the same definition in the empirical model.

The individual contributions of these drivers is shown in the lower panel of Table 1. We see that productivity growth contributed around half of the decline in Global R^* in the baseline, and robustly leads to a significant decline across the alternative simulations.

Amongst the two demographics factors, population growth has a small contribution of 0.1 percentage points in the baseline simulations over this time period, though the sensitivity results suggest that the effect could be as large as 0.5 percentage points. Conversely, the key demographic factor is the rise in longevity. This has a large contribution to the decline in Global R^* both in the baseline and across the alternative simulations.

Long-Run Impact While the estimates of the path of the underlying drivers end in 2015, the simulations continue past this date until the model has settled at a new steady state. This is particularly important for the impact of the demographic variables, as the age distribution continues to adjust after population growth rates and mortality rates stop changing. The final row of Table 1 shows that the long-run decline in Global R^* is 2.9 percentage points, implying a further 1 percentage point decline from 2015.

2.4 Comparing Our Results to the Recent Literature

Ageing and the Baby Boom We have shown that population ageing played an important role in the decline in Global R^* over recent decades, and this impact is expected to persist going forward. Importantly, the model does not predict that the retirement of the 'baby-boom generation', which roughly begins in 2015, will lead to significant upward pressure on Global R^*.

This is in contrast to the points raised in Goodhart and Pradhan (2020). Lisack et al. (2021) use a modelling strategy similar to CHS, focusing on the impact of population ageing, and explore in more detail why the conclusions are different. Here we review the key reasons.[13]

First, we include not only changes in population growth, which account for the baby boom, but also increasing longevity. As we showed, longevity is a much larger driver of population ageing, and therefore Global R^*. Unlike the baby boom, which is a transitory shock to population growth rates that fades out as those cohorts exit the population, rising longevity is not expected to reverse.

[13] These points are also explored in Blanchard (2022) and Vlieghe (2021).

Second, one of the key factors behind this result is the empirical finding that retirees continue to hold high levels of wealth.[14] While retirees do dissave, this behaviour is not strong enough to materially lower their stock of wealth, which we have seen is what matters for determining the interest rate. Put differently, while the mechanism explored by Goodhart and Pradhan (2020), with respect to the retirement of the baby-boom generation, is captured in our framework, it is quantitatively small in comparison to the large and permanent impact of population ageing.

Inequality and Other Missing Drivers The modelling framework in CHS brings together five important structural drivers of Global R^*, and decomposes their relative contributions. However, there are several potential additional factors that drive Global R^* that are not captured by these simulations. CHS discuss these at greater length, noting that the net effect of the missing drivers is ambiguous.

Nonetheless, one important missing driver bears more discussion: inequality. A rise in inequality could potentially affect R^* through two main channels: higher precautionary savings caused by higher individual income risk (Auclert and Rognlie, 2018); or changes in the composition of the population towards high-income households, who have the highest savings rates. Mian et al. (2021) show that this latter channel has significantly increased aggregate wealth in the United States in recent decades, consistent with the decline in R^*. Taking these channels into account is likely to contribute to further downward pressure on R^*.

In contrast to our finding on the importance of demographics, Mian et al. (2021) further argue that demographic trends play a smaller role in the increase in aggregate wealth in the United States, relative to rising inequality. They reach this conclusion by comparing the variation in the savings rates and the evolution of income shares, across different income quantiles and across different age groups, showing that the variation across age groups is too small to account for the large observed trend in aggregate wealth. They focus their analysis of demographics on 45-64 year olds, which they identify as the age group with the highest savings rates. One implication of this is that they abstract from longevity and the high wealth levels of retirees, thereby effectively considering only the impact of population growth rates, and the baby boom in particular. In this sense, their finding of a small contribution from this demographic trend is consistent with our results. However, our results further illustrate that increasing longevity has a larger impact on aggregate wealth and therefore R^*.

[14] Lisack et al. (2021) show this in US household survey data, while Auclert et al. (2021) show that this pattern holds across a larger set of countries.

3 The Missing-Investment Puzzle

The analysis so far has focused on the decline in R^*, motivated by the secular decline in risk-free interest rates. However, this is only part of the story. In this section, we show that risk-free rates do not appear to have comoved with the return on capital. We then explore what this means for investment, through the lens of a "missing-investment puzzle". We end the section with a discussion of the implications of these findings on the policy landscape, in particular on productivity.

3.1 R^* vs. the Return on Capital

As laid out in Section 2, in a neo-classical framework, firms' optimisation equalises the marginal cost of capital to its marginal return. In our stylised framework in Section 2.2, we assumed R^* was equal to the marginal cost of capital, adjusted for depreciation, and therefore equal to the return on capital in equilibrium. The quantitative model of CHS, used in Section 2.3, does allow for a wedge between the two, capturing the costs of financial intermediation, but assumes that it is fixed over time. Therefore, in that framework, R^* comoves with the return on capital.

However, in recent decades, risk-free rates and the return on capital do not appear to comove in the data.[15] Figure 3 plots the return on capital and risk-free rates for a group of high-income countries since the 1970s. Following the literature, we define the return on capital as the gross operating surplus (the output of the firm minus their labour costs and capital depreciation), per unit of capital, adjusted for capital gains.[16] Figure 3(a) shows that this measured rate of return on capital for the market sector has remained stable over recent decades, with a drop around the time of the global financial crisis, much of which has now recovered. Over the same period, across the same group of countries, the risk-free rate, measured as the ex-post real rate of return on 10-year government bonds, shown in Figure 3(b), rose until the 1980s, and has since declined.

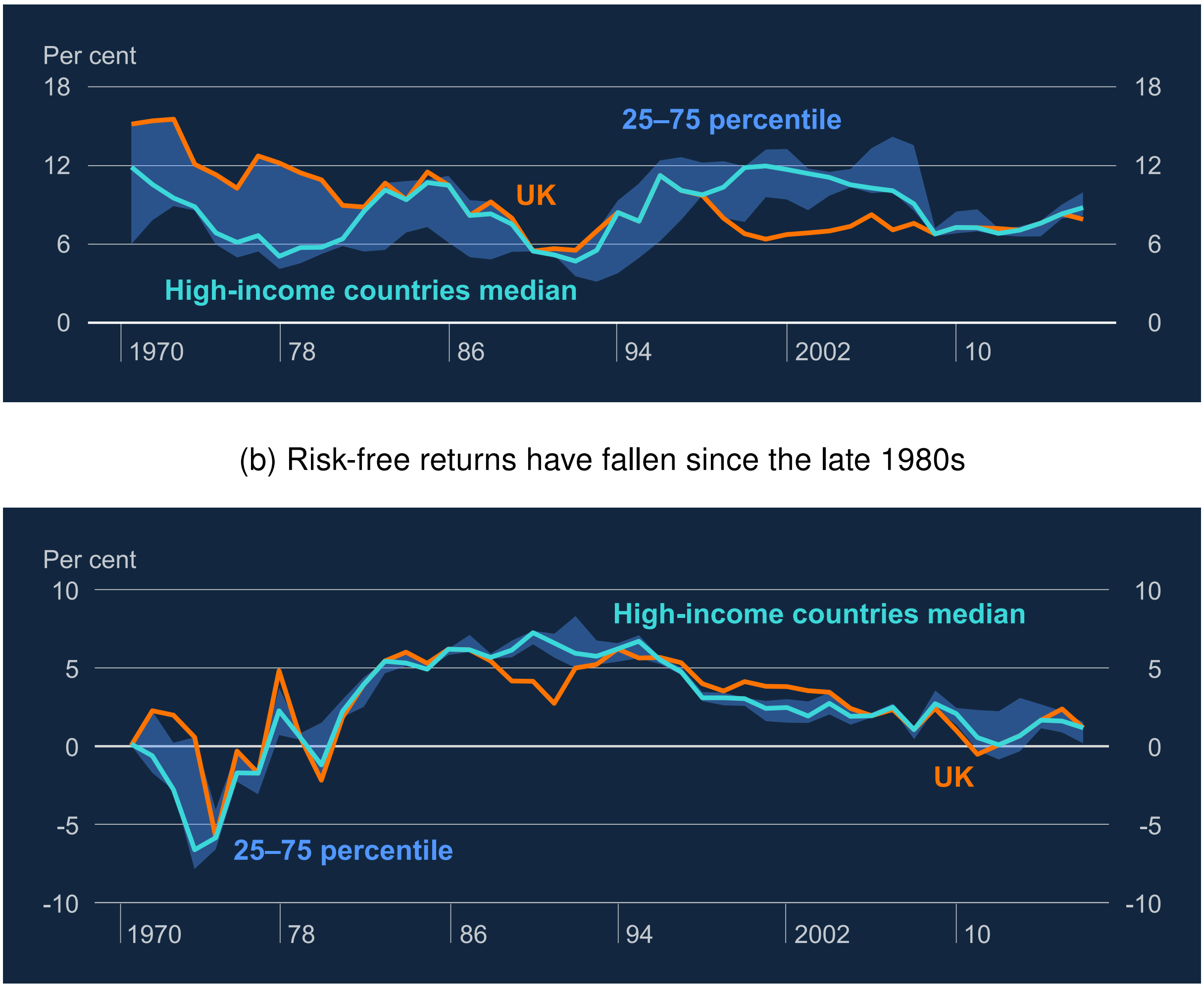
The change in the wedge between these two rates of return is plotted in Figure 4, relative to 1971. We can see that it has a U-shaped pattern: the wedge declines from the 1970s until the 1980s, and then rises materially from the 1990s. Even for the United Kingdom, which has shown a smaller rise in the wedge compared to the average, shown in the orange line, the wedge has risen by roughly 7 percentage points since the trough in 1992. As discussed above, unlike in the data, the equivalent

[15] Caballero et al. (2017) and Reis (2021) also show this for US data.
[16] See Appendix A.2 for full details of the data definitions used.

Figure 3: Return on Capital vs. Risk-Free Rates

(a) Return on capital has been relatively stable

(b) Risk-free returns have fallen since the late 1980s



Note: High-income countries include Finland, Italy, Netherlands, Spain and the United Kingdom. Figure A.3 in Appendix shows that this result is true for a larger sample of countries from 1987. See Appendix A.2 for data definitions.

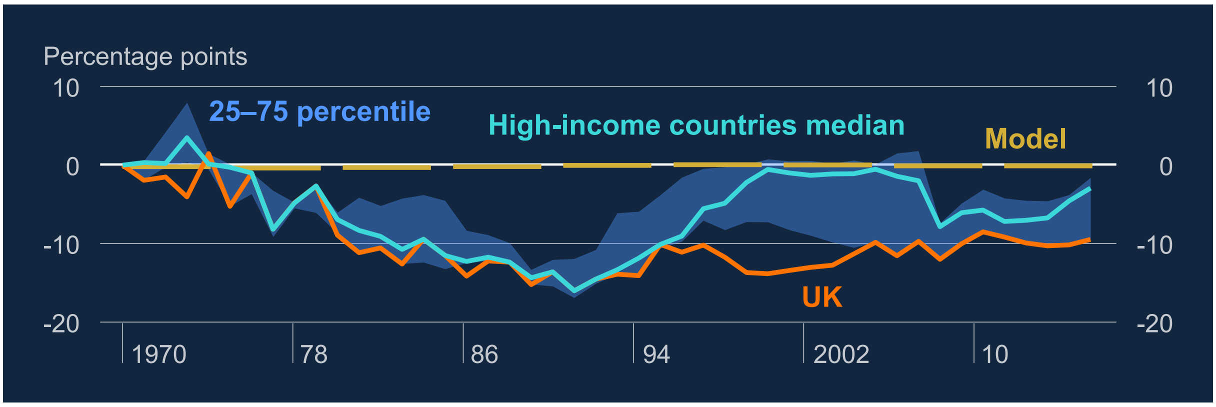
Source: Authors' calculations using EU KLEMS, the Penn World Table 10.0 and the Jordà et al. (2017) Macrohistory Database. See Appendix A.1 for more details.

measure of the wedge in the structural model is stable over time, as shown in the yellow lines in Figure 4.[17]

To understand the importance of this wedge, we relate it to one of the key variables that shapes the policy landscape: investment.

[17] Note that, although the difference between R^* and the rental rate of capital is assumed to be fixed in the model, changes in the relative price of capital lead to small fluctuations in the line in the figure, since the return on capital is measured consistently with the data.

Figure 4: Wedge Between Return on Capital and Risk-free Rates (1971=0)



Note: High-income countries include Finland, Italy, Netherlands, Spain and the United Kingdom. All lines show the wedge between the return on capital and the risk-free rate, as shown in Figure 3, as an index with 1971=0. See Appendix A.2 for data definitions. The yellow lines replicates the same definition in the baseline model simulations of Cesa-Bianchi et al. (2022).
Source: Authors' calculations using EU KLEMS, the Penn World Table 10.0 and the Jordà et al. (2017) Macrohistory Database. See Appendix A.1 for more details.

3.2 Missing Investment

In standard economic theory, the wedge shown in Figure 4 is a measure of firm profitability.[18] As such, this wedge is a key determinant of firms' investment: when profitability is high, firms are incentivised to borrow and invest in capital.[19]

More precisely, this interpretation assumes that firms can borrow at the risk-free rate, so that the wedge is the difference between funding costs and the return on capital. It could, however, be that funding costs have not been declining in line with risk-free rates. This would be the case if, for example, lenders are risk averse and risk or uncertainty has increased over time.[20] Funding costs would then include an increased risk premium over the risk-free rate, to compensate investors for holding risky claims on firms, so that the funding cost that firms face diverges from the risk-free rate over time.

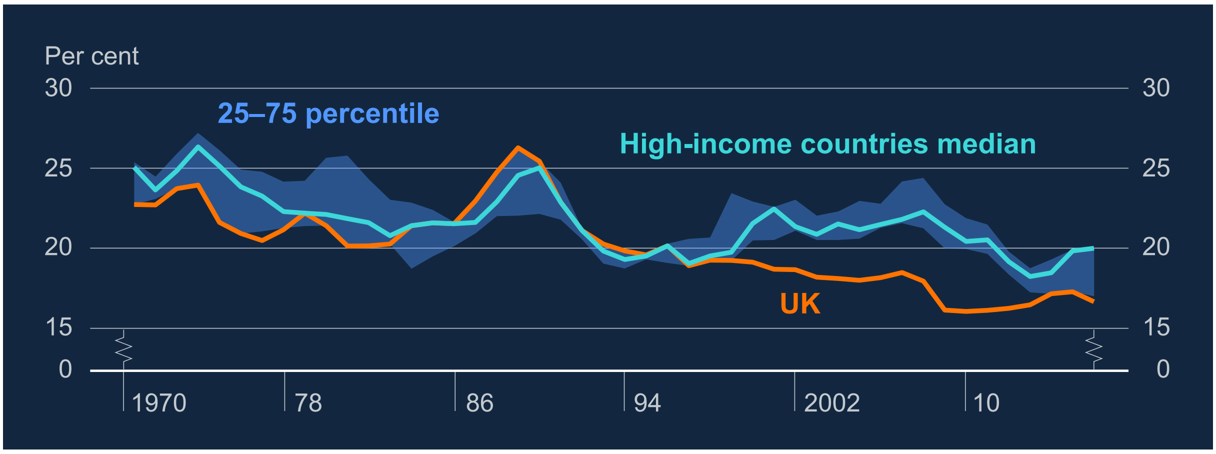
If that was the case, the wedge in Figure 4 may be capturing increased funding costs,

[18] Note that we use 'profitability' to mean excess profitability, ie net of funding costs. Firms' output can be separated into labour compensation, capital payments - covering funding costs - and 'profit' in excess of funding costs. In other contexts, the 'profit rate' refers to the gross operating surplus, which here would be the sum of both the capital and profit shares, per unit of capital.

[19] See Appendix A.2 for more discussion of the economic theory.

[20] See Broadbent (2016) and Vlieghe (2017) for more discussion of risk and uncertainty, and Melolinna et al. (2018) for a study of how these factors have impacted investment in recent years. Note that Haskel and Westlake (2022) also argue that intangible assets are more risky, so that as investment in intangible assets rises, the risk premium may also rise.

Figure 5: Nominal Investment-to-GDP



Note: High-income countries include Finland, Italy, Netherlands, Spain and the United Kingdom.
Source: Jordà et al. (2017) Macrohistory Database, see Appendix A.1 for details.

rather than increased profitability, and we would not expect it to lead to a rise in investment. In Appendix A.2, we compare the risk-free rate to an alternative measure of funding costs, available for the United Kingdom for part of our sample period, and find that they exhibit very similar dynamics.[21] This suggests that the dynamics of the wedge, therefore, do indeed reflect increased profitability.[22]

In light of these results, we interpret Figure 4 as evidence that firm profitability declined between 1970 to the 1980s, and has since climbed up. However, as shown in Figure 5, investment across the same sample of high-income countries has consistently declined or, at best, remained stagnant since the 1970s.

Bringing this together, therefore, we see that in the early part of the sample, both investment and the wedge were declining, as we would expect from standard theory. Since the 1990s, however, while the wedge has risen, investment has not. In other words this highlights a "missing-investment puzzle": not simply that investment has

[21] We focus on the pre-2016 period. We can see, however, that funding costs have started to diverge from the risk-free rate in the more recent period, possibly reflecting an increase in uncertainty following the change in trading arrangements between the United Kingdom and the EU as emphasised in Melolinna et al. (2018). Uncertainty around the future trading relationship and Brexit preparations may have been weighing on business investment and productivity since 2016. This effect may disappear in the long-run as the economy adjusts to the new trading arrangements (Bank of England, 2021).

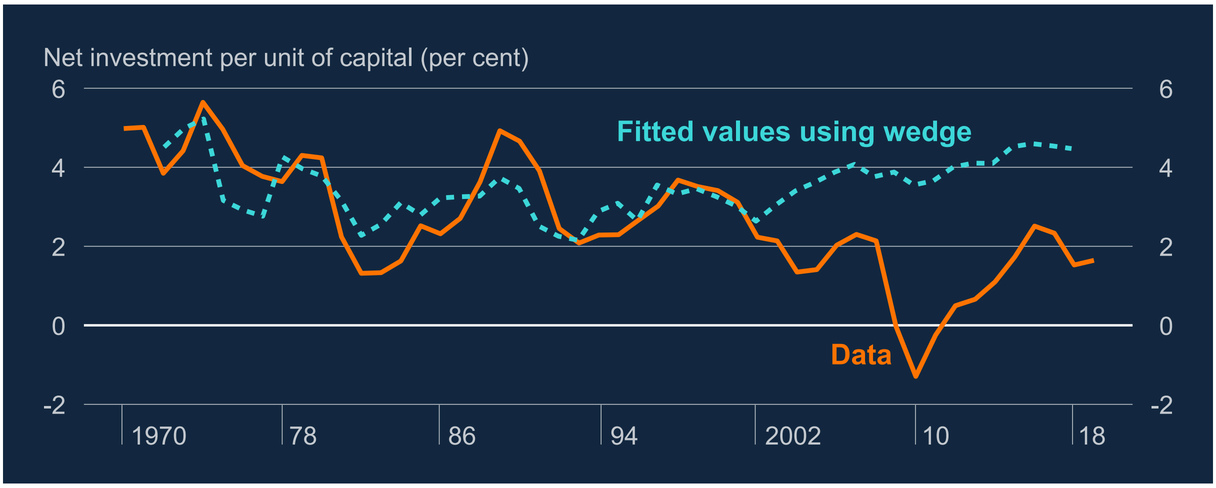
[22] In Appendix A.2 we also look at whether our measure of profitability evolves in line with Tobin's Q. If risk aversion was to increase, markets would price this risk and Tobin's Q would fall. In this case, we might see a divergence between our measure of profitability (the wedge) and Tobin's Q. We find that both the wedge and Tobin's Q move together, as shown in Figure A.2, suggesting that risk premia may struggle to explain the increasing wedge.

been declining, but that there are factors driving lower investment despite high profitability.[23]

To show this formally, we estimate the relationship between the aggregate investment rate and the wedge in the United Kingdom.[24] We measure the investment rate as the ratio of net investment to the lagged capital stock at replacement costs for the market sector. This is shown in the orange line in Figure 6. As with the investment-to-GDP ratio, there is a gradual decline in this investment rate throughout the sample.

Regressing this variable on the measure of profitability shown in Figure 4, we detect a structural break in the relationship in 2001. The dashed blue line in Figure 6 shows the fitted value from the regression estimated from 1970 to 2001. This shows what we would expect investment rates to be had the relationship with profitability been unchanged after 2001.

Figure 6: Missing-Investment Puzzle in the United Kingdom



Note: The orange line shows net investment per unit of capital in the data. The dashed blue line shows the fitted value from the regression of this investment rate on the wedge between the return on capital and the risk-free rate. See Appendix B for full details.
Source: ONS, Jordà et al. (2017) Macrohistory Database and authors' calculations.

We can see that before the structural break, the decline in investment was in line with the fundamentals, captured by the measure of profitability. Since the early 2000s, however, a sizable gap opened up between observed investment and the fitted value from the regression, thereby illustrating the missing-investment puzzle for the United Kingdom.

[23] This puzzle is therefore distinct from the long-discussed underperformance of UK investment with respect to its international counterparts (see, eg, Gieve, 2006).
[24] For more details on our regression analysis, see Appendix B.

3.3 Explaining the Missing-Investment Puzzle

To investigate the candidate explanations of the missing-investment puzzle, we build on the analysis of Gutiérrez and Philippon (2017). They suggest that we can understand the observed decline in US investment in two ways: factors that lower investment by driving down firm profitability, such as expected growth, and factors that lower investment despite high measured profitability. They find a significant role for factors that fall into the latter category, precisely in line with our missing-investment puzzle. The rest of this section focuses on these factors.

We can split the candidate explanations for the missing-investment puzzle into four categories:

Mismeasurement of Capital: If we mismeasure the capital stock, then the empirical measures of both investment and profitability would be mismeasured. For instance, investment by firms has moved increasingly away from physical capital (such as buildings and machinery) towards intangible capital (such as R&D, software, data or branding). Measuring investment in intangible assets is far more challenging than physical assets, and National Accounts have only recently begun to capitalise a few of these intangible assets.[25] Moreover, increasing globalisation can blur the localisation of investment or profits for multi-national firms. Hence, these factors would mean that we are increasingly under-measuring capital over time, which could account for the puzzle.

Competition: The measure of the return on capital that we use, which is based on the gross operating surplus, includes any super-normal profits earned from mark-ups over marginal costs, arising from imperfect competition. An increase in this measure due to an increase in mark-ups, rather than the return on productive capital, would not be expected to lead to a boom in investment, and so could explain this puzzle.[26]

Corporate Governance: If firms are not willing to take up long-term investment opportunities, they would not necessarily take up the arbitrage opportunity offered by high profitability, or would instead borrow cheaply and pay out dividends and buy back shares. Hence, increasing short-termism in corporate governance could also explain the puzzle.

[25] For example, R&D was capitalised only from the 2008 revision of the System of National Accounts, which is the internationally-agreed standard for measuring economic activity.

[26] Note that CHS include a mark-up in their calibration, which is included in the model-implied wedge plotted in Figure 4, but this is held fixed over time.

Financial Frictions: As mentioned above, firms may not borrow at the risk-free rate. Imperfect information or moral hazard between lenders and borrowers (eg, between firms and banks or banks and depositors) leads to the emergence of an external-finance premium, ie a wedge between the risk-free rate and the cost of borrowing of firms. While we showed that the increase in profitability was robust to using other direct measures of funding costs, we can also investigate the impact of factors that determine the external-finance premium, such as the degree of reliance on external financing, or the liquidity or leverage of firms.

Which of these factors is most important is an empirical question, and Gutiérrez and Philippon (2017) investigate this question using industry-level data for the United States. Many candidate explanations, such as the intangible share of capital and financial frictions, vary greatly across industries, so a solely macro perspective may be somewhat incomplete.

While some of these factors can be global in nature, there are also important differences across countries. For example, Gutiérrez and Philippon (2017) find an important role for decreased competition in explaining the puzzle in the United States. While there is a consensus on the increase in market power in the United States (Autor et al., 2017; De Loecker et al., 2020), the United Kingdom does not seem to have experienced such marked trends (Aguda et al., 2022). This suggests that the drivers of the missing-investment puzzle could be different.[27] We therefore employ UK industry-level data to investigate which of the candidate explanations for the missing-investment puzzle is more relevant in the United Kingdom.

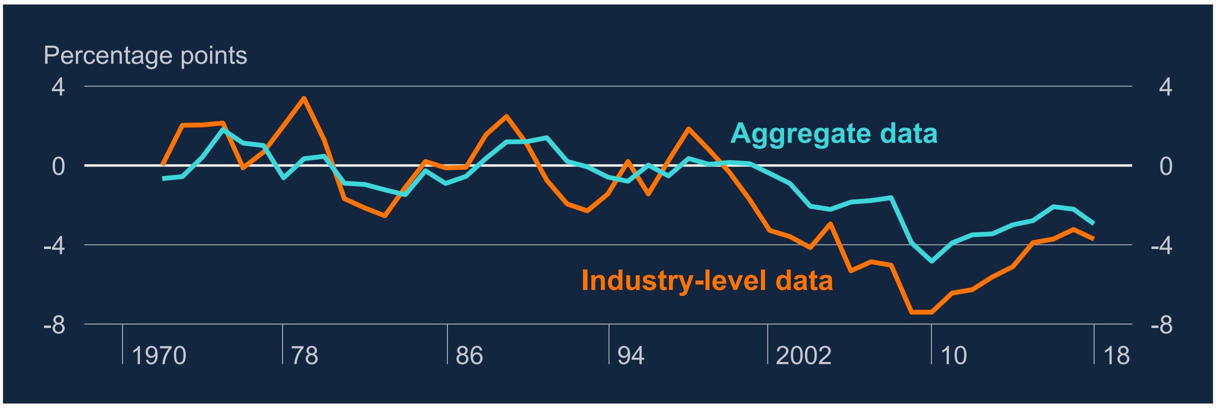
We first check to confirm whether the puzzle is present in the industry-level data. Figure 7 shows the results from a regression of the investment rate on the measure of profitability. In particular, it illustrates the unexplained variation in investment, for both the aggregate data (blue line), and the industry-level data (orange line).

The industry-level data also shows that investment has been low relative to measures of profitability since the early 2000s, indicating a missing-investment puzzle very similar to the one in the aggregate data.

We then investigate which of the list of candidate explanations can account for this unexplained weakness in investment. To do this, we augment our industry-level regression by including proxies for those candidate factors, and assess whether the

[27] Indeed, there is a renewed debate focusing on the secular dynamics behind the United Kingdom's economic underperformance in terms of investment and productivity against its international peers (see, among others, The Economist, 2022).

Figure 7: The Puzzle at the Industry Level



Note: The blue line shows the residuals from the regression described in Figure 6. The orange line shows the year fixed effects from an industry-level regression of investment rates on the wedge, including industry fixed effects, and standard errors clustered at the industry level. See Appendix B for full details.
Source: ONS, KLEMS, Jordà et al. (2017) Macrohistory Database and authors' calculations.

unexplained variation in investment is affected.[28]

Here, we will focus on the key result from this analysis: intangible capital goes a long way to explain the missing-investment puzzle in the United Kingdom.

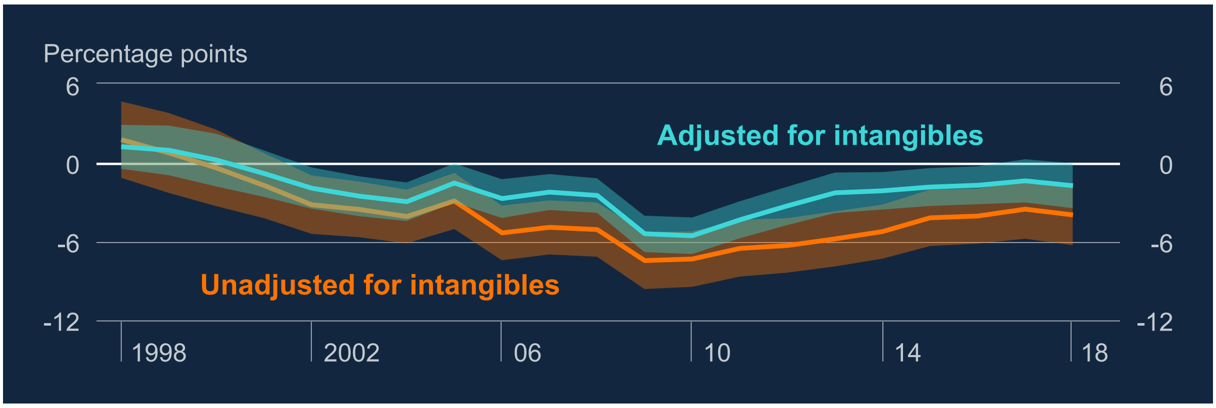
To show this, we use the 2022 vintage of the EU KLEMS data. This vintage not only includes the latest improvements in measuring intangible assets from National Accounts, but also capitalises a broader set of intangible assets building on the work by INTAN-Invest.[29] It is the first vintage of EU KLEMS that includes 7 intangible assets in addition to the 4 that were already included in National Accounts, and as such constitutes the first harmonised and fully integrated industry accounts with such a broad measure of intangibles to date.[30]

We repeat the industry-level regressions, replacing both the measure of investment rates on the left-hand side, and the measure of the return on capital used for the wedge on right-hand side, with these data that are adjusted for intangibles. Figure 8 shows the unexplained variation from the baseline industry-level regressions, as in Figure 7, as well as the new regression adjusted for intangibles. While the missing-investment puzzle can still be seen, it is significantly smaller before 2008, becomes smaller again from around 2013, and is even insignificant towards the end of the

[28] Appendix B provides a detailed discussion of how we investigate each of the different explanations.
[29] INTAN-Invest is a research collaboration dedicated to improving the measurement of intangible assets building on the work by Corrado et al. (2016), and now feeds into the latest EU KLEMS vintage.
[30] See Appendix A.2 for more details on the assets included.

sample. In other words, the puzzle is smaller and almost disappears in recent years, suggesting that the measurement of intangibles can account for an important part of the puzzle.

Figure 8: Explaining the Puzzle with Intangibles



Note: The orange line shows the industry-level puzzle as in Figure 7, and the shaded area around it is the 95% confidence intervals. The blue line shows the same statistic from the regressions in which both investment rates and the wedge are adjusted to include intangibles. See Appendix A.2 for a discussion of the adjustment.
Source: ONS, KLEMS, Jordà et al. (2017) Macrohistory Database and authors' calculations.

The remaining puzzle is mostly concentrated immediately after the global financial crisis. As such, it is unlikely that it reflects structural changes, but rather the effects of the crisis (eg, on financial frictions, see Gopinath et al., 2017). It is worth noting that this result continues to hold even when we include measures of the financial-frictions explanations of the missing-investment puzzle (in particular, external-finance dependence and liquidity). It could be that we need to further explore firm-level data to capture the impact of financial frictions more accurately, or that there are large non-linearities related to the nature of the crisis that the regression framework does not capture. However, this suggests that the remaining puzzle is likely to be more conjunctural than structural.[31]

3.4 Intangibles and Productivity

We have shown that, once we account for intangibles, the UK missing-investment puzzle occurs mostly following the global financial crisis, and seems to have disappeared in recent years. What does this mean for productivity and output?

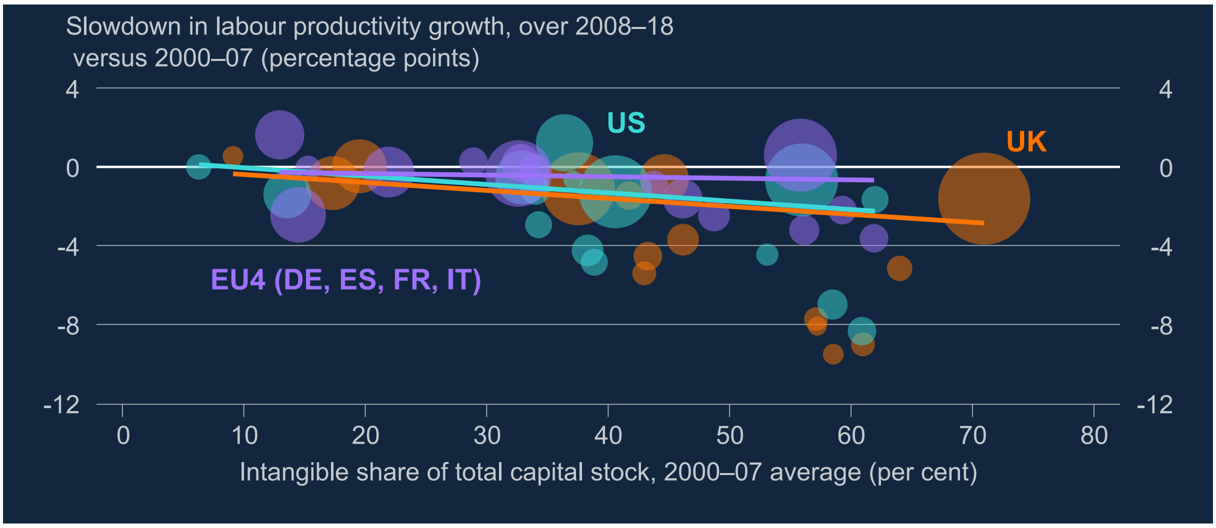
Parallel to this remaining missing-investment puzzle, there was a substantial (missing)

[31] Döttling et al. (2017) similarly found that, contrary to the United States, the missing-investment puzzle in Europe is more conjunctural than structural.

productivity puzzle throughout advanced economies.[32] In the United Kingdom, labour productivity growth declined by as much as 1.3 percentage points in the latest ONS data, when comparing pre- and post-crisis averages (2008-2018 vs. 2000-2007). Does the rise in intangible capital play any role in explaining the productivity puzzle?

Surprisingly, rather than reducing this puzzle, as it did for investment, intangibles appear to be *driving* the productivity puzzle. Figure 9 shows that intangible-intensive industries experience the strongest slowdowns in labour productivity growth since the crisis.[33]

Figure 9: Intangibles May be Driving the Productivity Puzzle



Note: The y-axis shows the change in average labour productivity growth over 2008-2017 relative to the average over the 2000-2007 period. The x-axis displays the average share of intangible assets in total capital. Each ‘bubble’ represents an industry, with the size of the bubbles reflecting its share in total employment within each country, thereby measuring the industry’s contribution to aggregate labour productivity growth. EU4 consists of Germany, Spain, France and Italy.
Source: ONS, KLEMS and authors’ calculations, see Appendix A.1 for more details.

One potential reason for this finding is that investment in intangibles is harder to finance. A growing literature shows that there are unique barriers to intangible investment, such as the fact that these assets are harder to use as collateral.[34] For this reason, it could be that intangible-intensive industries were most affected by the tightening financial conditions after the global financial crisis, which then had long-term scarring

[32] While past data have shown that this slowdown was strongest in the United Kingdom –at around 1.7 percentage points, recent revisions from the ONS in the 2021 Bluebook now suggests that the UK puzzle is of similar extent to the one in other advanced economies. The slowdown is now around 1.3 percentage points in the latest ONS data, smaller than the US data in KLEMS exhibiting a 1.5 percentage point slowdown.

[33] This point is also raised in Goodridge and Haskel (2022).

[34] See Haskel and Westlake (2022) for a literature review.

effects on productivity growth (De Ridder, 2016; Haskel and Westlake, 2022). However, while intangible investment has recovered in recent years, productivity is still low. Could it be that the additional barriers to financing intangibles benefit investment by less productive firms?

Another explanation could be related to the impact of the intangible economy on competition. Intangible technologies tend to require large upfront investments, or so-called fixed costs. This gives firms with high-intangible adoption a competitive advantage, and stops new innovative firms from entering the market. Existing firms become entrenched and have less incentive to innovate, slowing innovation adoption in the long-run (De Ridder, 2019; Aghion et al., 2019). It is difficult, however, to find supporting evidence in UK data. While this mechanism is consistent with the decline in business dynamism and the increase in market power documented in the United States, business dynamism has not been declining as much in the United Kingdom in recent decades.[35] Could it be that these risks have not yet materialised in the United Kingdom?

4 Conclusions

In this paper, we have shown that the substantial global structural changes experienced in recent decades have a profound impact on the long-run policy landscape.

Within our modelling framework, both the secular decline in productivity growth and increased longevity imply permanently lower Global R^*. This means that, without significant reversal in these structural trends, or the emergence of new long-run structural forces pushing in a different direction, Global R^* is expected to remain low.

We have also shown that, in the UK data, the missing-investment puzzle (the apparent weakness in investment despite an increasing wedge between the return on capital and the risk-free interest rate) over the same period, can be largely accounted for by the mismeasurement of intangible capital. Once we control for intangibles, the headwinds that have weakened investment seem to have originated from the persistent effects of the global financial crisis, and appear to have dissipated by 2016.

However, in these same years the United Kingdom has seen a substantial productivity

[35]See, for example, Figure A.5 in Appendix A.2, showing that firm entry and exit rates were stable in the United Kingdom since the early 2000s, as opposed to declining in the United States (Akcigit and Ates, 2021). Gutiérrez and Piton (2020) also show that labour shares have not been falling in the United Kingdom as opposed to the United States. See Appendix A.2 for a more detailed discussion of business dynamism in the United Kingdom.

puzzle. Rather than reducing this puzzle as it did for investment, intangibles may be *driving* the labour productivity puzzle, making the overall long-run impact on output ambiguous. Future research should shed light on the unique challenges from the increase in intangible capital, and how these can be addressed.

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Appendix

A Data Definitions

A.1 Data sources

For the structural and empirical models of Global R^*, Cesa-Bianchi et al. (2022) consider the following list of high income countries used in the analysis: Australia, Austria, Belgium, Canada, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hong Kong, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Lithuania, Netherlands, New Zealand, Norway, Poland, Portugal, Singapore, Spain, Sweden, Switzerland, United Kingdom, United States.

The data for the five drivers of Global R^* is from a combination of Penn World Table 10.0 (relative price of capital), United Nations Department of Economic and Social Affairs (population growth and longevity), Ziesemer (2021) (labour-augmenting productivity) Moreno Badia et al. (2018) (debt to GDP). The data for the calibration of the model is from Caballero et al. (2017) (Real return on capital), US Census (Cohort-specific labour supply), and Penn World Table 10.0 (Capital to output ratio). The data for the empirical model is a combination of Jordà-Schularick-Taylor Macrohistory Database (Jordà et al., 2017) and Eikon Refinitiv for short- and long-term interest rates and CPI inflation.

For the missing-investment puzzle analysis, we use the following main data sources:

- EU KLEMS: our primary dataset is the 2021 vintage of EU KLEMS, which includes industry accounts for all European countries as well as the United States. We apply Gutiérrez and Piton (2020) methodology and use previous vintages to extend our data as far back as possible (1970 for most countries). This 2021 vintage of EU KLEMS includes detailed information on intangibles from 1995, including assets that are not capitalised in National Accounts building on the work by INTAN-Invest.
- ONS: the UK data in 2021 EU KLEMS vintage does not include ONS latest revisions and, specifically, double deflation introduced in the 2021 Bluebook.

For this reason, and like Goodridge and Haskel (2022), we use instead ONS GVA and GVA deflator data by industry division for the United Kingdom.

- Historical data: we complement historical information at the country-level using the Penn World Table 10.0 (Feenstra et al., 2015) for investment-to-GDP ratios, the Jordà-Schularick-Taylor Macrohistory Database (Jordà et al., 2017) for the risk-free rate and CPI inflation. The UK weighted average cost of capital uses data from the Bank of England Millenium of Macroeconomic Data, Bloomberg Finance LP, Tradeweb, Refinitiv Eikon and I/B/E/S both from LSEG and the IMF WEO.

- Firm-level data: we complement data from National Accounts with industry-level indicators built using firm-level data for the United Kingdom. We take most of this data from a large micro dataset of firms' financial accounts, including annual balance sheet, income and cash flow statements, provided by Bureau van Dijk (BvD). This commercial database builds on the publicly available filings of each firm at Companies House, the registrar of companies in the United Kingdom. The database covers much of the corporate universe of the United Kingdom. We use concentration ratios at the industry-level from Aguda et al. (2022), built using the UK Census of firms (ONS BSD dataset). Finally, we use Worldscope covering all listed firms in the United Kingdom for measures of Tobin's Q.

A.2 Variable definitions

Investment and capital stock We first focus on investment-to-GDP ratios for the total economy (Figure 5). We then focus on the investment rates from Figure 6 onwards, defined as investment net of depreciation to the lagged capital stock at current replacement costs. The main series include only assets capitalised in National Accounts, while the intangible adjusted series include additional assets available in KLEMS.[36]

Profitability As already described in the main text, our preferred measure of profitability is the wedge between the return on capital and the risk-free rate. Note that profitability here is thus net of capital cost.

The return on capital is the real internal rate of return (IRR) from the standard Hall

[36] See KLEMS documentation available here.

and Jorgenson (1967) formula measured at the industry level. More specifically, it is:

$$IRR_t = \left(1 + \frac{GOS_t - q_{K,t-1}K_t[\delta_K(1+\hat{q}_{K,t}) - \hat{q}_{K,t}]}{q_{K,t-1}K_t}\right)\frac{1}{1+\pi_t} - 1$$

with GOS the gross operating surplus, δ_K the depreciation rate for asset k, K the capital stock, q its price and $\hat{q}$ the 3-year moving average of its price growth (expected price inflation of capital), π the CPI inflation.

Note that the standard Hall and Jorgenson (1967) formula also includes tax adjustment factor. We abstract from this due to data limitations for a large sample of countries. Using UK data, we find that this tax adjustment only changes marginally the measure of the wedge.

We use the risk-free rate in the baseline analysis assuming it is representative of firms' funding costs. For robustness, we use an alternative measure of funding costs using a weighted average cost of debt and equity from the Bank of England (see Figure A.1). We find that this funding cost comoves strongly with the safe rate, though we can see a recent increase in the WACC in the most recent period, suggesting that the safe rate is a good proxy for funding costs over the period of analysis.

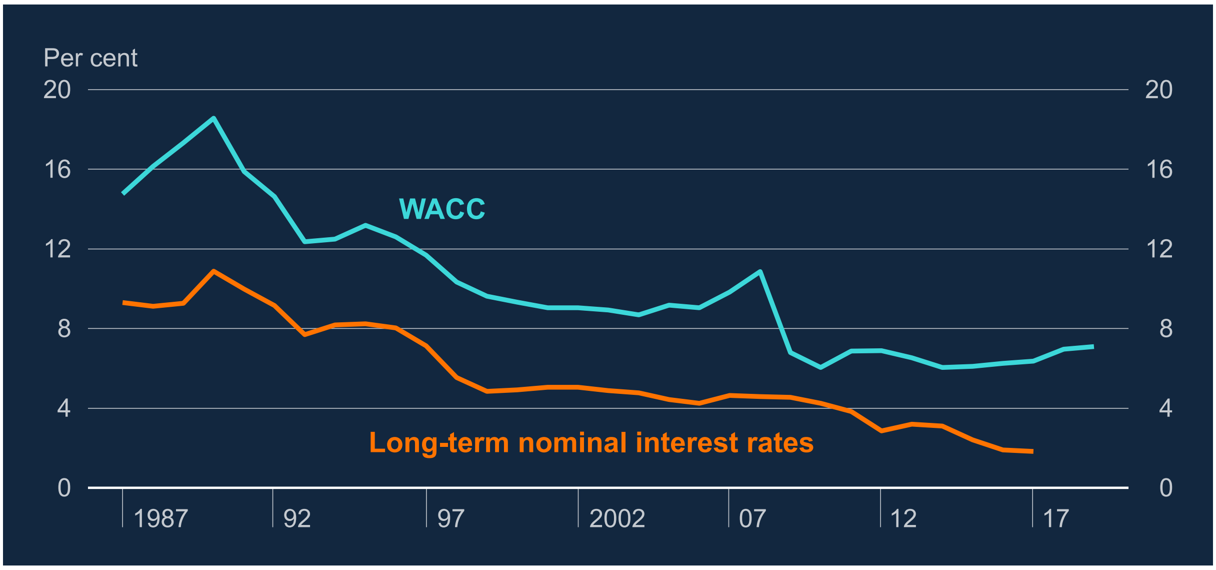
In the workhorse model for firm investment, Q-theory (Jorgenson, 1963; Tobin, 1969), the sufficient statistic for profitability is Tobin's Q, defined as the ratio of market value to replacement cost of capital stock. We confront our measure of profitability, based on the wedge between the internal rate of return and the funding costs of the firms, to Tobin's Q from Worldscope listed firms data. As seen in Figure A.2, Tobin's Q also increases from the early 2000s.

Figure 3 focuses on the sample of countries with data available since the early 1970s. Figure A.3 shows that using a larger sample of countries from 1987 does not change the main result: the return on capital has been flat when the risk-free rate declined steadily.

Intangibles Central to this paper is the role played by intangible investment. National accounts include some intangible assets (Software and databases, R&D, other intellectual property products).[37] However, these measures miss firms' increased spending on some intangible assets such as organisation capital, design, market research, advertising or staff training. While financial markets might value these types of expenses

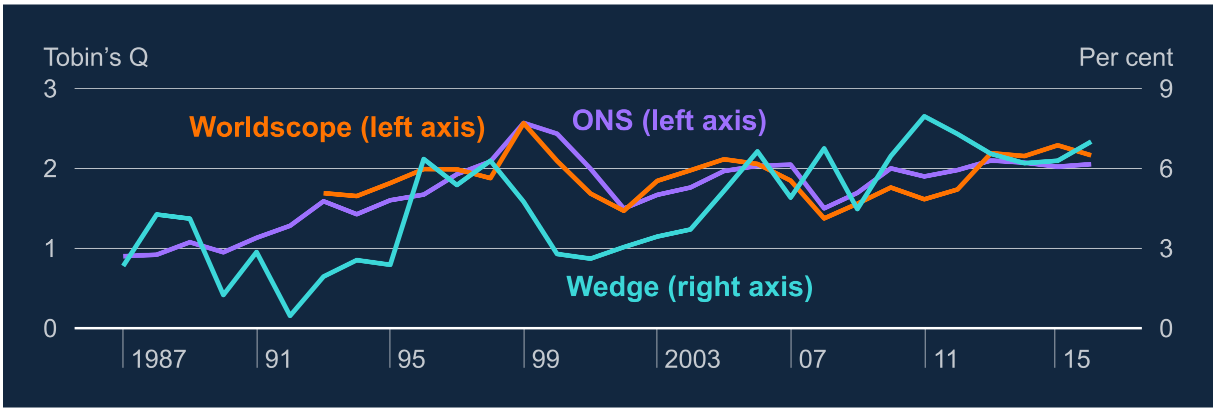
[37] See ESA2010 Annex 7.1 for a definition of those assets.

Figure A.1: Weighted Average Cost of Capital (WACC) vs. Risk-Free Rate



Note: The blue line shows the weighted average cost of debt, bond and equity for private non-financial corporations. The orange line shows ten-year government bond yields. Both series are for the United Kingdom.
Source: Jordà et al. (2017) for the risk-free rate; the Bank of England Millenium of Macroeconomic Data, Bloomberg Finance LP, Tradeweb, Refinitiv Eikon and I/B/E/S both from LSEG, the IMF WEO and Bank calculations for the WACC.

Figure A.2: Tobin's Q in the UK



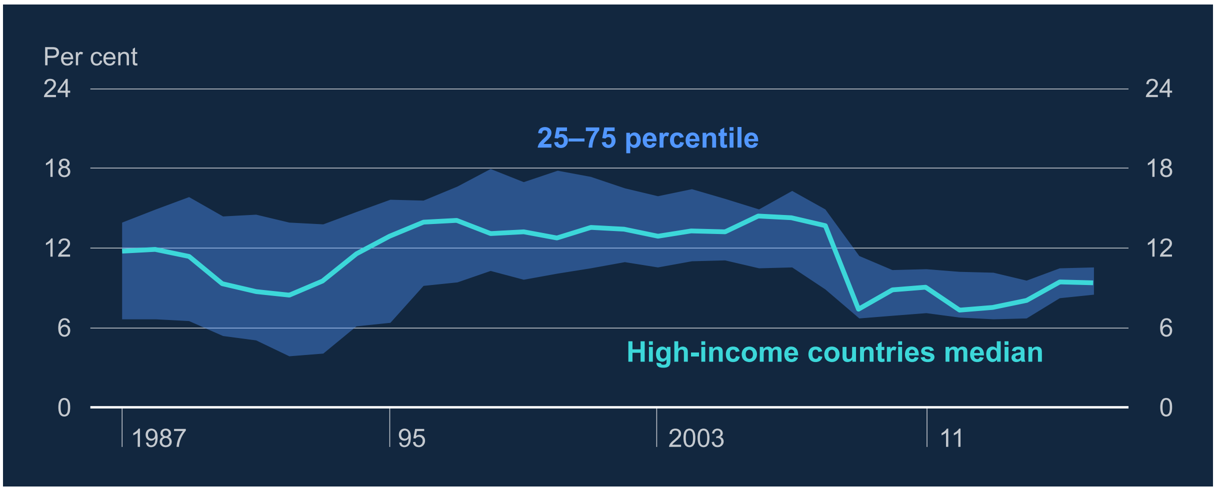
Note: The blue line shows the UK wedge as in Figure 4. The purple line shows Tobin's Q using ONS data, defined as the market value of total equity liabilities over the capital stock (of fixed assets) at replacement costs, for non-financial corporations. The orange line shows Tobin's Q from Worldscope, defined as the ratio of market value of equity, total liabilities, and preferred stock, over total assets.
Source: ONS, Eikon from Refinitiv and authors' calculations.

as investment, they are not capitalised and thus not included in measures of investment.

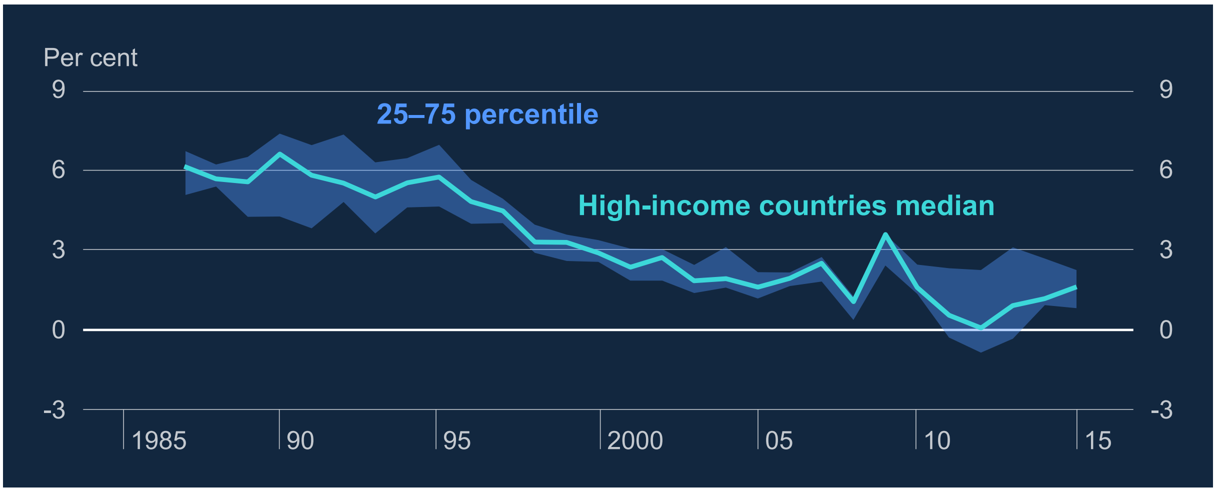
We use the latest EU KLEMS vintage which capitalises 7 of these additional assets

Figure A.3: Return on Capital vs. Risk-Free Rates: Larger Sample of Countries

(a) Return on capital has been relatively stable



(b) Risk-free returns have fallen since the 1980s



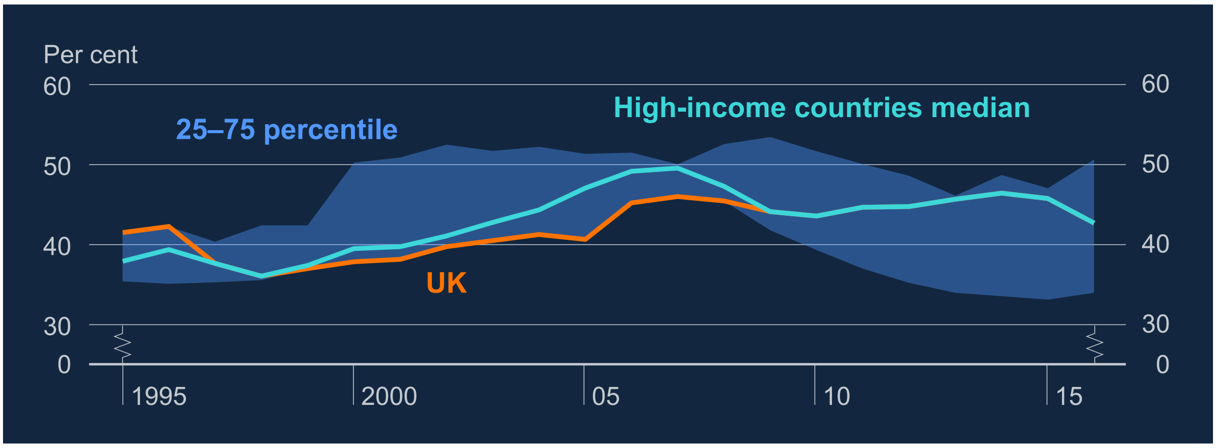
Note: High-income countries still include Finland, Italy, Netherlands, Spain and the United Kingdom; but also France, Japan and the United States. See Appendix A.2 for data definitions.
Source: Authors' calculations using EU KLEMS, the Penn World Table 10.0 and the Jordà et al. (2017) Macrohistory Database.

accounting for about 60% of total intangible investment and almost 40% of total capital.[38] We compute adjusted measures of investment and profitability using this broader investment data. Interestingly, as we can see in Figure A.4, and differently from the corresponding unadjusted Figure 5 in the main text, once we use these adjusted measures, UK investment-to-GDP ratio seems to be in line with its international

[38]The 7 new assets are Industrial Design, New product development costs in the financial industry, Innovative Property, Brand, Organisational Capital, Training and Economic Competencies.

counterparts. As intangible investments has become an ever larger share of total investment, this compositional effect is able to account for some of the missing investment puzzle in the UK. In other words, investment is higher and more in line with profitability once we take into account intangibles, as described in the main text.

Figure A.4: Investment-to-GDP Including Additional Intangibles



Note: High-income countries include Finland, Italy, Netherlands, Spain and the United Kingdom. The chart shows nominal investment-to-GDP including the additional intangible assets in the latest EU KLEMS vintage for the measure of investment. Note that those assets are not included in the measure of GDP.
Source: Authors' calculations using EU KLEMS and the Penn World Tables.

Beyond affecting the (mis)measurement of investment, Moll et al. (2021) show how the capital demand shock associated with the increasing demand for intangible assets in a model with an upward slopping capital supply schedule can affect capital returns more than investment quantities, and lead to a muted increase in investment relative to profitability. Note that the authors focus on automation rather than intangible investment. However, evidence on automation adoption (imports of robots) points to low investment in automation in the UK relative other European countries, suggesting that intangible capital might play a more important role for the UK.[39]

Globalisation Next, we look into measures of globalisation, or the foreign activity of UK firms. In a similar way that firms' spending on intangibles constitutes a challenge for the measure of investment, UK firms could be increasingly investing abroad rather than in the UK and this pattern could translate into a low investment rate in UK data.

[39]A look at Comext data suggests that UK imports of robots as a share of GDP is below its large EU counterparts. For example, they are flat at 0.2% of GDP since the early 2000, while increasing 0.8 to 1.2% in Germany from 2000 to 2015. This could partly reflect the fact that robots are mostly used in manufacturing, which is a small share of GDP in the UK.

Unfortunately, we do not have data on UK firms' investment abroad. However, for our regression analysis, we are able to observe the share of foreign sales out of total turnover for UK businesses in the FAME-BvD dataset.[40]

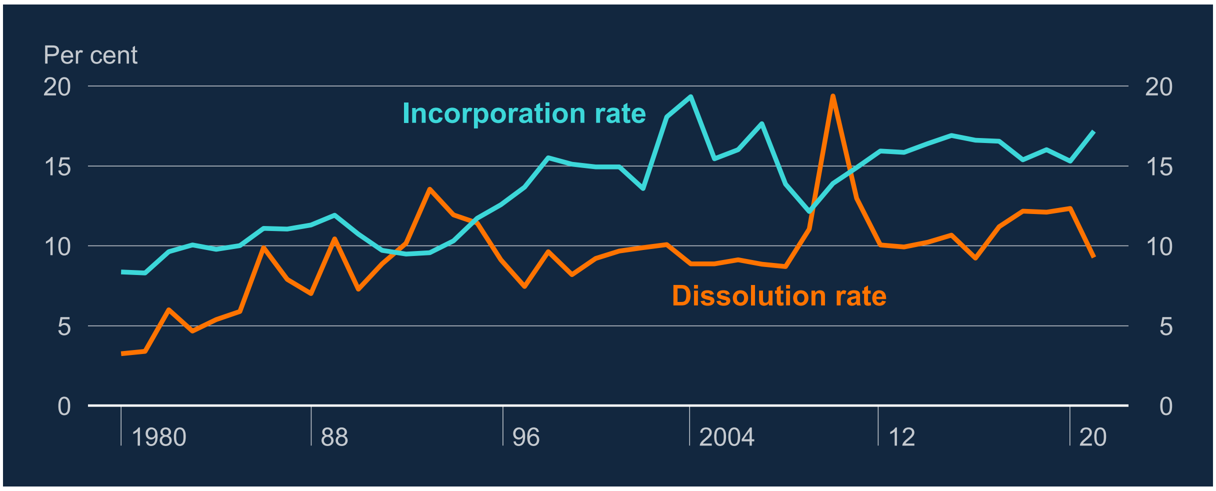
Competition Decreased competition, due to technology or regulation, has been put forward as one of the most important drivers of the US investment puzzle (see, among others, Gutiérrez and Philippon, 2017). This decline in competition is reflected in a decline in business dynamism more generally in the United States (Akcigit and Ates, 2021), with increased concentration, declines in firm entry and exit rates, and a large reallocation of market shares towards low labour share/high capital-intensive or profitable firms leading to a secular decline in the labour share of income.

In contrast, evidence on business dynamism is mixed in the UK. While there is strong evidence for an increase in mark-ups (Aquilante et al., 2019; Loecker et al., 2022), the literature is yet to achieve consensus when it comes to concentration in firms' sales: for example, Aguda et al. (2022) show flat concentration, while Koltay et al. (2022) find rising concentration. Furthermore, the UK labour share is flat since the early 2000s (Gutiérrez and Piton, 2020) and does not seem to reflect the same reallocation of market shares to low labour share firms as in the United States (Gutiérrez et al., 2022). Finally, firm entry and exit have not been falling, as shown in Figure A.5. At face value, all this evidence may suggest a more muted contribution of competition to the investment puzzle for the UK than for the United States.

Financial frictions Forms of financial frictions, such as the lack of sufficient internal funds and difficulties in getting external funding, could prevent firms from pursuing investment projects even when these may be profitable. In this paper we use our firm-level dataset to construct measures of external finance dependence following Rajan and Zingales (1998), looking at how much of a firm's investment in BvD is accounted for by external funding. As in Gutiérrez and Philippon (2017), we also split this indicator into its part accounted by debt and the one by equity. In addition to that, in our analysis we look also at other measures of financial constraintness such as ratios of cash and net current assets to total assets, as well as leverage. We aggregate these indicators to industry-level by considering the median across firms

[40] In other unreported results, we do find some increase in the share of UK listed firms' sales being outside the UK and similarly UK listed firms own an increasing amount of assets abroad in Worldscope data. This could suggest a role for globalisation in the investment puzzle. However, we prefer to use the larger sample from FAME-BvD, as it includes also the vast group of non-listed firms.

Figure A.5: Entry and Exit Rates



Note: Blue line shows UK firm entry as measured by the number of incorporations to the total number of live firms on Companies House register. Orange line shows UK firm exit as measured by the dissolution rate also from Companies House register.
Source: Authors' calculations using Companies House.

within each industry.[41]

Corporate governance Another explanation for the investment puzzle highlighted in the literature covering the United States is the evolution of corporate governance. The hypothesis is that an increasing share of passive actors in the running of businesses may have led to less shareholders' activism and increasing short-termism. Both these forces may then explain the subdued investment despite the observed stable degree of profitability. In contrast with the United States, we do not see a clear increase in payouts or institutional ownership in National Accounts in the UK (Piton and Vatan, 2018).

B Regression Analysis

Aggregate regression In the main text we report results from an aggregate regression of UK net investment per unit of capital (NIpk) on the aggregate wedge (all the variables

[41] Gutiérrez and Philippon (2017) look also into the possible role played by firm-level bank dependence and safe asset scarcity. The former is particularly relevant for businesses without access to capital markets, where financial frictions through banks may mean that bank-dependent firms are responsible for the observed underinvestment (Alfaro et al., 2015). The latter would affect firms' capital costs, but would lead to a disconnect between investment and the wedge only if safe businesses, which should have lower capital costs, cannot or do not wish to exploit those, eg because of product market rents. Unfortunately, we were not able to investigate these avenues in our analysis due to data limitations.

used in the regression analysis are described in Table B.1).

$$NIpk_t = \beta * wedge_t + u_t$$

We detect a structural break in 2001 and thus estimate the model up to that date. As expected the coefficient β on the wedge is positive and significant; given that, we show residuals from this econometric model for the whole sample to document and quantify the UK investment puzzle given profitability, as described in the main text. Notice these results are supported by our industry-level regressions below, where we do not split the sample for structural breaks.

Industry-level regressions We complement our aggregate results looking at industry-level information. We run regressions of net investment per unit of capital on a constructed industry-level wedge, and include both industry and year fixed effects, as well as clustering by industry and year. Notice that, at industry-level, we document and quantify the puzzle following Gutiérrez and Philippon (2017) by reporting the (negative) year fixed effects from this regression.

$$NIpk_{it} = \gamma * wedge_{it} + \delta_i + \delta_t + u_{it}$$

where δ_i and δ_t represent the industry and year fixed effects, respectively.

To show the importance of intangibles in explaining the puzzle, we run a regression of the investment rate on the wedge, both adjusted for the additional intangibles not included in National Accounts ($NIpk^{adj}$ and $wedge^{adj}$, respectively) –again the regression includes also industry fixed effects and clustering at the industry-year level. We interpret the reduction in the estimated drag from the year fixed effects shown in Figure 8 in the main text as evidence of intangibles helping explaining the investment puzzle.

Finally, we use the regression of $NIpk^{adj}$ on $wedge^{adj}$ as our baseline, and include each selected additional explanation one by one to test whether it may help explaining the remaining puzzle.

$$NIpk_{it}^{adj} = \gamma^{adj} * wedge_{it}^{adj} + \theta * explanation_{it} + \delta_i + \delta_t + u_{it}$$

When we include all the selected measures from Table B.1, our sample shrinks considerably: it ends up including only observations from 2000 onwards. For robustness we thus proceed in two fashions.

First, we constrain each regression to match the estimated coefficients for the wedge and industry-level fixed effects from the baseline model using data from the longer sample. Crucially, we allow the year fixed effects to change to understand how the puzzle is affected. This procedure does not seem to suggest that any of our preferred measures contributes substantially to explain the puzzle once intangibles are taken into account.[42]

Second, we restrict the sample to the years common to all variables considered for our explanations, and let the model re-estimate everything each time. Again, this does not change our main result on the important role played by intangibles as opposed to other explanations.

[42] We were able to find, if anything, some evidence of our measure of leverage helping with explaining some of the puzzle. While we follow the literature here focusing on the measures of external finance dependence described in Table B.1, we believe this result is in line with the main conclusion that the investment puzzle in the UK may have been more conjonctural than structural, unlike in the United States. Thus, we find this promising in terms of further future investigations in the link between the puzzle and financial frictions, perhaps pursuing more sophisticated approaches than our simple method here –eg including non-linearities, more indicators or other moments of the within industry distributions.

Table B.1: Summary of Variables for Regression Analysis

Variables	Definitions
Core covariates	
$NIpk$	Investment net of depreciation divided by the lagged capital stock
$Wedge$	Spread between return on capital and the safe rate
$Nipk^{adj}$	Same as NIpk, but adjusted for the additional intangibles missing from National Accounts
$Wedge^{adj}$	Same as wedge, but adjusted for the additional intangibles missing from National Accounts
Additional explanations	
Globalisation	Share of sales abroad out of total sales - median across firms within an industry.
Financial frictions	i) External finance constraints: median across firms within an industry of external finance dependence, ie how much investment is founded by external sources including equity and debt (Rajan and Zingales, 1998).
	ii) Liquidity: median across firms within an industry of the ratios over total assets of net current assets and cash (the latter as bank deposit minus bank overdraft, see Bahaj et al., 2020).
	iii) Leverage: median across firms within an industry of the ratio of debt over total assets.
Competition	i) Concentration ratios, as the percentage of industry-level sales accounted for by the top 5, 10, 20 and 50 firms.
	ii) Herfindahl-Hirschman index defined as $HHI_k = \sum_j s_j^2$ where s_j denotes the share of sales for firm j in a given industry k.