NBER WORKING PAPER SERIES

THE ECONOMIC IMPACT OF BREXIT

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Working Paper 34459
http://www.nber.org/papers/w34459

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
November 2025, Revised June 2026

The views expressed do not necessarily represent those of the National Bureau of Economic Research, the Bank of England, the Deutsche Bundesbank or their Committees. The authors would like to thank the Economic and Social Research Council for financial support under grant numbers ES/P010385/1, ES/X013707/1, ES/V004387/1. We are grateful for feedback from presentations at the Bank of England, the Banque de France, Banca D'Italia, Central Bank Business Surveys Conference, Chicago, Columbia, UC Davis, Duke, Edinburgh, ESCB Research Cluster Workshop, ESCoE, European Investment Bank, Imperial, IMF, KCL, Michigan, MIT, Philadelphia Fed, Princeton, QMUL, Queen Mary, Sciences Po, Stanford, Wharton and Yale. Corresponding Author: philip.bunn@bankofengland.co.uk. This paper updates and significantly extends our earlier work on the impact of Brexit that was previously published in Bloom et al. (2019).

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November 2025, Revised June 2026
JEL No. E0

ABSTRACT

This paper examines the impact of the UK's decision to leave the European Union (Brexit) in 2016. Using a decade of data since the referendum, we combine estimates using macro data with estimates using micro data collected through our Decision Maker Panel survey. These suggest that by the end of 2025 Brexit had reduced UK GDP by 6% to 8%, with the impact accumulating steadily over time. We estimate that investment was reduced by 12% to 13%, employment by 3% to 4% and productivity by 3% to 4%. These negative impacts reflect a combination of elevated uncertainty, reduced demand, diverted management time, and increased misallocation of resources from a protracted Brexit process. Comparing these with contemporary forecasts shows that these forecasts were relatively accurate in the short to medium term, but they underestimated the impact over a decade.

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Aggregate data for main figures in this paper can be downloaded from is available at https://bit.ly/4epshv5

1 INTRODUCTION

A decade on from the UK's decision to leave the European Union (Brexit), this paper uses a combination of macroeconomic and microeconomic data to study the economic impact of Brexit. The Brexit process started when the "Leave" campaign won the June 2016 UK EU Membership Referendum by 51.9% to 48.1%. But the complexity of this process meant that it was not until 31 January 2020 that the UK formally left the EU, with a transition period running until 31 December 2020, and negotiations on Northern Ireland stretching into 2023. As such, it was not until 2024 that the Brexit process was winding down, necessitating analysis of 10 years of data.

We estimate that by the end of 2025, the Brexit process had reduced UK GDP by 6% to 8%, investment by 12% to 13%, employment by 3% to 4%, and productivity by 3% to 4%. These effects accumulated gradually over time. We identify four main channels through which Brexit has affected the UK economy. First, the UK's decision to leave the EU generated a persistent increase in uncertainty, weighing on investment in particular. Second, investment and employment growth were affected by lower expected demand for goods and services. Third, productivity growth *within firms* was affected by lower innovation and IT investment, and by management time and resources being used to prepare for Brexit. Finally, productivity growth *between-firms* was reduced as the more productive, internationally exposed, firms were more negatively impacted.

The identification strategy for estimating the impact of Brexit exploits the fact that the vote for Brexit was a largely unexpected event. The betting markets put the odds on the UK voting to leave the EU at around 30% in the months before the vote.[1] Using this discrete event, we employ both a macro and a micro identification strategy.

The macro-level estimation compares the UK's performance after 2016 to a set of up to 33 comparable countries. There is no single best way to weight the comparator countries together, so we consider the average of five different approaches: a simple unweighted average, a GDP

[1] For example, see Bell (2016). Financial markets similarly did not seem to expect Brexit. The 7% drop in the Pound (Sterling ERI) the day after the Brexit vote was the largest one day move in the Dollar, Pound, or Euro since the end of Bretton Woods. Davies and Studnicka (2018) show that, in the two trading days following the EU referendum, companies that rely more heavily on European global value chains reported more negative returns.

weighted average, a gravity weighted average, a trade weighted average and a synthetic control estimator. We show that the UK has performed materially worse than other countries since 2016 across all five approaches.

The micro-level analysis uses firm-level data to estimate a set of classic difference-in-differences regressions. Brexit had a heterogeneous impact on businesses according to their pre-referendum exposure to the EU, providing variation across firms to help identify the effects. We draw on data from the Decision Maker Panel (DMP), which is a major new survey of over 2,000 UK firms a month that we set up to help evaluate the impact of Brexit. The DMP data are combined with data from company accounts. Our Brexit exposure measure averages across six different individual pre-2016 firm-level exposure metrics: EU export share, EU import share, EU migrant labor share, EU regulatory exposure, EU directors share and EU firm ownership.

Our macro-based estimates of the impact of Brexit are typically larger than the micro-estimates. One source of the difference is likely to be negative spillover effects via demand and supply chains. In the micro estimation, firms with no direct prior exposure to the EU were nonetheless likely to have still been negatively impacted by the Brexit process, which would lower the size of the estimated treatment impact. As such, the stable unit treatment value assumption is likely violated. We develop a general equilibrium model to help reconcile the macro and micro-based estimates and show that a larger macro impact is consistent with negative spillovers via demand and supply chain linkages outweighing more positive spillovers through the labor market. However, we still prefer using both micro and macro estimation strategies, as the macro approach cannot entirely separate out the impact of other factors such as the Covid-19 pandemic, which affected the UK in 2020-2021, in the middle of the Brexit process. Covid differentially affected countries and there were distinct policy responses in each country, including the UK's generous employment support scheme, which clouded the macro picture at this point. On balance, we believe that the range of micro and macro estimates gives the most reliable assessment of the economic impact of Brexit. Reassuringly, both yield relatively similar time profiles and magnitudes of estimated impacts.

We also compare our results to the predictions made for the impact of Brexit on GDP made by a set of 25 academic and professional economists around the time of the referendum. Our results

imply these forecasts were too pessimistic in the short term, but too optimistic over the longer term. The forecasters' average long-run forecast for the impact of Brexit was a reduction in GDP of around 4%. However, we note that our longer-run estimate of the impact of Brexit on GDP is more negative at 6% to 8%. This could be due in part to the protracted nature of the Brexit process, which was not expected when the initial predictions were made. Despite this we see these forecasts as being surprisingly accurate in predicting the impact of Brexit, particularly those made by academics, banks and consultancies.

We see three motivations for this paper. First, the UK's exit from the European Union is a major economic and political event and worth studying directly. The UK is the world's sixth largest economy and the European Union is the world's largest trading bloc; no other country has attempted to exit the EU trading bloc with the ensuing disruption to trade and movement of people. Second, the UK's experience of Brexit has some parallels with the implementation of tariffs and immigration controls in the United States in 2025, which has disrupted trade and migration and increased economic policy uncertainty. Our results suggest the economic costs of this could be substantial, but may accrue more slowly than predicted.[2] Finally, the recent expansion in the micro-literature of social science predictions (DellaVigna and Pope, 2018) has few parallels in macroeconomics. The impact of Brexit provides a novel case study, since its impacts were publicly predicted by 25 economists on the eve of the vote in May and June 2016, and those forecasts can be benchmarked against their realizations a decade later.

This paper links to three strands of literature.

First is the literature on the impact of Brexit. Several papers tried to assess the potential impacts of Brexit either prior to the referendum or shortly afterwards, including HM Treasury (2016), IMF (2016), Van Reenen (2016), Dhingra et al. (2017) and Sampson (2017). Brexit was typically assumed to lead to an increase in trade barriers that would lower future trade and productivity. Other papers have used post-referendum data to try and estimate the effects of Brexit, typically finding negative impacts on variables such as GDP, employment and investment, including Born

[2] A similar point is made by Gopinath (2026).

et al (2019), Dhingra and Sampson (2022), Springford (2022), Haskel and Martin (2023) and Alabrese et al. (2026).

Relatedly, Freeman et al. (2024) estimate that the move to a new trading arrangement with the EU in 2021 led to an immediate, sharp drop in both UK exports of goods to the EU and imports of goods into the UK from the EU. Crowley et al. (2020) show how uncertainty about future market access reduced the entry of UK firms into trading partners' markets. Keiller (2024) uses firm-level investment and administrative trade data to estimate that Brexit reduced manufacturing sector investment by 7%. Other papers consider the effects of Brexit on foreign direct investment (Breinlich et al., 2020; McGrattan and Waddle, 2020), firms' use of subsidiaries (Crowley et al., 2026), global value chains (Vandenbussche et al., 2022), labor market outcomes (Costa et al., 2019), prices (Breinlich et al., 2022; Di Pace and Masalo, 2025), stock markets (Breinlich et al., 2018; Davies and Studnicka, 2018) and immigration (Portes and Springford, 2026). Broadbent et al. (2024) model Brexit as a shock to future productivity in the tradables sector, which is offset in the short run by depreciation in the exchange rate.

We contribute to the literature on the impact of Brexit in two ways. First, by collecting our own monthly panel microdata in the Decision Maker Panel (DMP) to directly measure firm-by-firm Brexit exposure and impacts. The DMP is one of the largest business surveys in the UK, surveying firms from a range of industrial sectors and geographies every month. The sample of around 7,000 firms that we use in this paper accounts for around 10% of UK private sector employment. With this data we can observe immediate responses, expected changes, the dispersion of firms' expected responses and answers to Brexit-specific questions such as the amount of senior executives' time diverted to deal with Brexit. Second, we bring together the macro and micro-type approaches with a comprehensive study that assesses the overall impact on the UK economy.

The second related literature connected with our paper refers to trade reforms, including papers like Harrison (1994), Pavcnik (2002), Melitz (2003), Amiti and Konings (2007), Goldberg et al. (2009), Topalova and Khandelwal (2011), Bloom et al. (2016), Limão and Maggi (2015), De Loecker et al (2016), Goldberg and Pavcnik (2016), Handley and Limão (2017), Crowley et al (2018) and Dhingra et al (2022). These generally show that freer trade has a positive impact on

growth – from a combination of higher productivity, improved reallocation, higher quality inputs and higher levels of innovation. When trade reforms reduce uncertainty – for example, by making temporary agreements permanent – additional positive investment and employment impacts are usually observed. The withdrawal of the UK from the EU single market and customs union can be seen as a "reverse" trade reform – increasing trade barriers and generating uncertainty. There are few examples of this type of trade fragmentation, and therefore we add to the literature by studying this.

Third, our paper relates to the literature on the effects of uncertainty more generally, for example, Bernanke (1983), Dixit and Pindyck (1994) and Fernandez-Villaverde et al. (2011). The long-lasting nature of the Brexit uncertainty shock makes it different to most uncertainty shocks, which tend to be short-lived. Studying Brexit's impact can show how firms respond to persistent uncertainty over the best part of a decade. Hassan et al. (2024) use data from earnings calls to measure Brexit uncertainty and show how that led to lower hiring and investment in listed firms across the world. Graziano et al. (2021) consider the effects of Brexit-induced trade policy uncertainty on trade in goods. Ahmad et al. (2023) extend this to services. Faccini and Palombo (2021) show the longer-term nature of the uncertainty created by Brexit may have induced a gradual and persistent economic impact.

The structure of this article is as follows. Section 2 provides a brief timeline of the key events in the Brexit process. Section 3 sets out our macro estimates of the impact of Brexit. Section 4 focuses on the micro estimates. It first provides an overview of the Decision Maker Panel survey that we draw on, sets out the methodology and then presents the micro results. Section 5 compares the macro and micro results and sets out a model to help reconcile the two estimates. Section 6 compares our estimates to earlier forecasts for the impact of Brexit, before Section 7 concludes.

2 BACKGROUND ON THE BREXIT PROCESS

The Brexit process was long, legislatively complex and uncertain, and we estimate the total effect of this Brexit process, including uncertainty, transition, and the eventual trading regime. We provide a brief overview of this as a background to the paper and our identification strategy.

In January 2013, Prime Minister David Cameron promised to hold a referendum on the UK's membership if his Conservative Party won the 2015 General Election. They subsequently won the May 2015 election, and in February 2016, set the date for a referendum that was held on 23 June 2016. The UK voted to leave the EU by 51.9% to 48.1%, despite betting markets implying that there was only around a 30% chance the UK would vote to leave in the days immediately beforehand. The day after the referendum the UK pound depreciated 8%, and monetary policy in the UK was subsequently eased.

David Cameron resigned immediately after the Brexit referendum and was succeeded as Prime Minister by Theresa May. In March 2017, Article 50 was triggered, which formally began the process for the UK leaving the EU. This allowed two years for negotiations around the UK's future relationship with the EU, but the process was complex. At the Salzburg Summit in September 2018, EU leaders rejected Theresa May's 'Chequers proposals' as the two sides struggled to agree a deal that would allow the UK to leave the customs union and avoid a hard border between Northern Ireland and the Republic of Ireland. In November 2018, a draft withdrawal agreement was eventually reached, but this was rejected six times by the UK Parliament in early 2019. This led to the resignation of Theresa May, and Article 50 was temporarily extended.

Boris Johnson replaced Theresa May as Prime Minister in December 2019. A renegotiated withdrawal agreement was passed soon after by the UK Parliament, and the UK formally left the EU on 31 January 2020, with a transition period running until the end of 2020. During this transition period, the UK remained a member of the single market and customs union. The withdrawal agreement set out the broad terms on which the UK would leave the EU, but not the details of the future trading arrangements.

The new TCA (Trade and Cooperation Agreement) setting out the post-Brexit trade arrangements between the UK and the EU was finally agreed on 24 December 2020, only a week before the end of the transition period, and it came into effect on 1 January 2021. However, there was still a phased implementation of some aspects, including the Northern Ireland protocol, with further changes agreed in February 2023 as part of the Windsor Framework. Under the TCA, there were no tariffs or quotas on trade between the UK and EU, but the UK was no longer part of the EU single market or customs union. There are also ongoing parts of the Brexit process still being discussed in 2026, including issues around fishing rights, farming exports, defense and energy policy.

3 MACRO ESTIMATES

3.1 Macro-level methodology for evaluating the impact of Brexit

Our macro analysis is based around comparing the aggregate performance of the UK economy to a set of comparable countries in the period before the Brexit referendum versus the period afterwards. Our aim is to estimate how the UK economy might have evolved in the absence of Brexit. To do so, we compare the UK with a set of 33 comparator countries: the EU-27; Iceland, Norway and Switzerland, which are members of the European Free Trade Association; and Canada, Japan and the United States, which are major UK trading partners and fellow G7 economies. Our data were collected from the OECD, World Bank and national statistical offices. They cover the period from 2006 Q1 to 2025 Q4. We carry out this analysis for GDP per capita, business investment, employment and labor productivity.

There is no single best way to weight the comparator countries together, so we consider five different approaches to show that our results are robust to the choice of weighting methodology: (i) simple unweighted, (ii) GDP weighted; (iii) GDP/air distance (gravity) weighted; (iv) UK trade weights; and (v) a formal synthetic control. To generate a distribution we also carry out a bootstrapping exercise using the unweighted data, in which we randomly draw 1,000 samples of 33 countries with replacement.

One limitation of this macro-based approach of comparing the UK to a weighted average of similar countries is that factors other than Brexit could also be important in explaining why the economic performance of the UK has deviated from that of other countries. In particular, our sample period contains the Covid-19 pandemic. This will have had different effects on different countries. If the UK were more affected than other countries, that could incorrectly be attributed to Brexit. In some of our analysis we smooth through 2020, the height of the pandemic, and we focus on where the UK lies at the end of the sample period, when only differences in the long-term effects of the pandemic would be relevant. However, other factors such as differences in fiscal policies, could also contribute to cross-country differences in economic performance. This is why it is important to consider these macroeconomic estimates alongside the evidence from firm-level data.

A second caveat to this approach of comparing the UK to other countries is that Brexit may have had an impact on those comparator countries, not just the UK. This could particularly be the case for other countries in the EU, which faced higher barriers to trading with the UK after Brexit. This would violate the stable unit treatment value assumption (SUTVA) which is necessary for making causal inferences. It is likely that the impact on other countries was negative on average (IMF, 2016b), which would result in an understatement of the true impact of Brexit on UK output growth. This highlights the value of taking multiple approaches, including our micro-based approach, where identification of the Brexit effects should be stronger, before drawing conclusions.

Prior macro estimations of the impact of Brexit have typically used a synthetic control, as proposed by Abadie and Gardeazabal (2003). Using this approach, Born et al. (2019) calculated that the Brexit vote has caused a UK output loss of 1.7% to 2.5% by 2018. Springford (2022) estimated that Brexit had lowered UK GDP by 5.5% by mid-2022. Alabrese et al. (2026) estimate an output loss from Brexit of around 8% by 2023. These 'doppelganger type' exercises work by trying to match, in this case, UK GDP growth to that of other countries in a pre-referendum control period. In the construction of our synthetic control estimate we use pre-referendum data from 2006 Q1 to 2016 Q1 (41 periods), to obtain optimal weights that minimize the prediction error in the pre-referendum period. [3] However, the weights assigned to individual countries can be sensitive to the

[3] The weights assigned to different countries in our GDP per capita synthetic control exercise are USA: 60.5%, Estonia: 9.5%, Finland: 1.6%, Greece: 11.1%, Italy: 5.6%, Ireland: 4.1%, Lithuania: 4.2%, and Iceland: 3.5%.

control period and exact assumptions made. So, we report our five weighting methodologies, starting with our baseline of the unweighted average of all 33 countries, to show the range of estimates across different approaches.

3.2 Macro results

Figure 1 shows UK GDP compared to that of other countries since the Brexit referendum. Our analysis focuses on GDP per capita. This helps to account for any differences in population growth trends across countries and any impacts on migration. It illustrates that UK GDP was growing at a similar rate to other comparable countries in the period prior to the Brexit referendum, regardless of how those other countries are weighted together.

Since the vote for Brexit in 2016 Q2, UK GDP has grown by less than other comparable countries. This result holds across all our alternative weighting methods for constructing the comparison group. Relative to the distribution around the unweighted average, the UK sits near the bottom, at roughly the 10th percentile.[4] Depending on the comparator metrics used, UK GDP per capita is estimated to have grown by between 5% and 10% less than other similar countries between the Brexit referendum and the year to 2025 Q4, rising by just 6% in absolute terms over this period. The smallest implied impact comes from GDP/air distance weighting the comparator countries, which places a heavy weight on large, nearby Northern European countries that experienced relatively slow growth post 2016. In part, this could have been due to Brexit spillovers. The largest estimated impacts come from the unweighted average and synthetic control. The synthetic control places more weight on faster growing countries (since the UK was relatively fast growing prior to Brexit), in particular the US. Taking the average across our five weighting approaches, UK GDP per capita is estimated to have been 8% lower than other similar countries over the year to 2025 Q4.[5] We use this average as our central estimate of the effect of Brexit from macroeconomic data.

[4] Figure A1 in the Appendix shows the UK relative to all 33 comparator countries individually.

[5] If we carry out a similar analysis on headline GDP data rather than GDP per capita, the estimated Brexit impact is 7% rather than 8% (Figure A2). This is because UK population growth has been slightly stronger than in other countries since 2016, although as is shown on Figure A2, the UK is still towards the centre of the range of comparator countries for population growth since 2016. Portes and Springford (2026) estimate that the introduction of the post-Brexit immigration system in 2021 increased migration from non-EU countries and led to a 0.6% increase in total foreign-born employment in the UK by 2024. These immigration changes can be viewed as either a direct consequence of the vote for Brexit or a separate, albeit related, policy change. By focusing on GDP per capita we are implicitly

Investment, employment and labor productivity are all estimated to have grown by less in the UK than in other comparable countries since 2016. Figures 2, 3 and 4 plot similar comparisons for the UK relative to other countries for business investment, employment and labor productivity respectively. UK business investment is estimated to have been, on average, 13% lower than that of comparable countries, with a range of 8% to 22% across the five weighting metrics. The largest 22% estimate comes from the synthetic control, which places a larger weight on faster growing countries like the US, as UK investment was growing strongly pre-Brexit. UK employment is estimated to have been, on average, 4% lower than other similar countries over the year to 2025 Q4, with the individual estimates ranging from 2% to 5%. For labor productivity, it is estimated to be 4% lower, with a range between 2% and 6%. The differences for employment and labor productivity are therefore smaller than for investment, but have grown steadily larger over our sample period.

To test the robustness of our estimates for GDP per capita, we drop each one of the individual 33 countries and rerun our estimation. We see that for our preferred unweighted average this makes almost no difference, as shown in the left panel of Figure A3. The synthetic control estimator is robust to dropping each country individually except for the US, which if dropped roughly halves the predicted impact (see Figure A3 right panel). In Figure A4 we show the robustness to dropping individual countries across all five estimators, focusing on Germany and the US, which individually have the largest impact.[6] Dropping Germany, a large nearby slower growing country, increases the estimated negative impact of Brexit from 6% to 11%, with a 9% average. Dropping the US, a large faster growing country, reduces the estimated impact of Brexit from 4% to 10%, with an average of 6% across the five metrics.

treating any population changes as independent of Brexit. This helps make our macro results more comparable to our micro estimates which will not capture the effects of the immigration policy changes that contributed to increased non-EU migration.

[6] We also carry out a permutation test where we use the same synthetic control method for each individual country in our sample as if they had instead been the impacted by a large and unexpected event in 2016 Q2 (Figure A5). The UK lies at the bottom of the range of estimates for GDP and investment, although less so for employment and productivity.

This highlights that while the choice of country and estimation approach can influence the predicted impact, whichever approach we follow generates a material predicted impact of Brexit on UK GDP per capita ranging from 4% to 11%.

In summary, our analysis of cross-country macroeconomic data shows that the UK has performed steadily worse than other countries since 2016. Given its relatively strong performance prior to Brexit, and the absence of any other major events or changes that particularly impacted the UK over this period, it seems reasonable to assume this is primarily a Brexit effect. This helps to motivate our firm-level analysis, where we can more clearly identify the causal effects of Brexit, and which we turn to in the next section.

4 MICRO ESTIMATES

We also use firm-level panel data to evaluate the impact of Brexit in section 4.1. Our analysis makes use of data from the Decision Maker Panel (DMP) survey, a major new survey of firms that we set up in 2016 to study the Brexit process, which we describe after outlining our estimation strategy.

4.1 Micro-level methodology for evaluating the impact of Brexit

To estimate the causal impact of Brexit using firm-level data, we use a difference-in-differences approach. This exploits two important factors. First, that the vote for Brexit was a surprise, with betting odds giving Brexit about a 30% chance of success through the six-month period prior to the June 2016 vote. With little pre-referendum anticipation effect, the changes between more and less EU-exposed firms after 2016 should primarily reflect the impact of the Brexit vote and the subsequent process of the UK leaving the EU. Second, Brexit is likely to have had a heterogeneous impact on UK firms according to their pre-referendum exposure to the EU, providing important variation across firms to help identify its effects.

Our difference-in-differences analysis estimates changes in trends after the Brexit referendum that are correlated with prior EU exposure. The estimate takes the form of equation (1) below:

$$Y_{it} = \beta\, E_i \text{ x } Post_t + f_i + m_t + e_{it} \quad (1)$$

Where Y_{it} is an outcome variable (e.g. investment, employment or TFP growth); E_i is EU exposure of firm i; $Post_t$ is a dummy variable that takes the value of zero before the Brexit referendum and one afterwards; f_i are firm fixed effects and m_t are time fixed effects.[7] Standard errors are also clustered at the firm level.

EU exposure is based on six different firm-level metrics. These capture different dimensions of firms' exposure to the EU immediately *prior* to the 2016 referendum. The six variables we use are: (i) percentage of sales that were exports to the EU; (ii) percentage of costs that were imports from the EU; (iii) percentage of the workforce who were migrants from the EU; (iv) percentage of sales covered by EU regulations; (v) percentage of directors who were EU nationals; (vi) whether the firm was EU owned. Data on the first four exposure metrics were collected in the DMP survey and refer to 2016 Q1.[8] The last two exposure measures are based on data from the Bureau van Dijk FAME database and are for 2015 (these data are only available annually).[9]

We take the simple average of the six EU exposure metrics as our preferred measure of pre-referendum exposure to the EU.[10] Each of the six measures is defined on a 0 to 1 scale. The Brexit process was complex and likely to have affected firms in many different ways. So, by using a broad measure of exposure, we aim to capture these different impacts as comprehensively as possible. This is an advantage of our primary data collection, in that we are able to capture a range

[7] We focus on estimates in *growth* space because we find evidence of significant differences in the growth rates of our outcome variables in the pre-referendum period between firms with high and low levels of exposure to the EU.

[8] The exact questions asked were: 'Approximately what percentage of your total sales revenue was accounted for by exports of goods and services from the United Kingdom to EU and non-EU countries immediately prior to the EU referendum (2016 Q1)?'; 'Approximately what percentage of your total costs (including labor costs) was accounted for by goods and services imported from EU and non-EU countries immediately prior to the EU referendum (2016 Q1)?'; 'Approximately what percentage of your employees were immigrants from the rest of the EU immediately prior to the EU referendum (2016 Q1)'; and 'Approximately what percentage of your sales was affected by EU regulations immediately prior to the EU referendum (2016 Q1)?'. For the export and import questions, firms were asked to provide a number between 0 and 100. For the EU migrants' question, respondents were asked to select from: (i) Less than 1%; (ii) 1% to 5%; (iii) 6% to 10%; (iv) 11% to 20%; (v) 21% to 50%; (vi) More than 50%; (vii) Don't know. For the EU regulation question, respondents were asked to select from: (i) None; (ii) 1-10%; (iii) 11-50%; (iv) More than 50%; (v) Don't know. For questions where firms were asked to select a range, midpoints were used to assign a numerical value to these responses. These questions were initially asked to all firms in the panel in 2017 and were subsequently asked a number of times to collect data from firms who joined the panel at a later date or who did not originally respond. If firms responded more than once to any of these questions, their first response is used.

[9] FAME is provided by Bureau Van Dijk using data on the population of UK firms from the UK Companies House.

[10] We also show in the Appendix that our results are robust to taking the first principal component of the six exposure measures rather than the simple average. We also show our results are robust to dropping any single exposure measure.

of exposure paths to the EU. As we show in Section 4.3 below, these data also match up well against other firm accounts and ONS industry data, indicating that the data collected in the DMP survey are of high quality.

To try to understand the channels through which Brexit affected firm outcomes, we also run another set of regressions that replace pre-referendum EU exposure with proxies for the first and second moment impacts of Brexit. These data were also collected in the DMP survey. Firms were asked about both the expected eventual impact of Brexit on their sales and about the importance of Brexit as a source of uncertainty. More details on these data are provided in Section 4.4. However, we focus on the prior EU exposure approach in our main set of results because these metrics are more likely to be exogenous to subsequent firm performance and therefore offer a more robust methodology.[11]

In our micro analysis DMP data are matched to accounting data using Companies House registration numbers, with data organized in financial years.[12] We define the pre-referendum period as financial years 2011/12 to 2015/16.[13] The post-referendum period is defined as 2017/18 to 2024/25. We exclude 2016/17, as this contains a mix of pre and post referendum data, which varies depending on when firms' accounting years end. We also consider the effects of Brexit on the propensity of firms to apply for patents, using data from PATSTAT database. PATSTAT is a comprehensive, statistical database of patent information, primarily maintained by the European Patent Office.[14]

As well as being able to better identify the causal effects of Brexit, another advantage of our micro approach is that it is also possible to include controls for the Covid pandemic. The DMP survey

[11] For example, there is at least a risk firms who have performed less well in the post-referendum period for reasons other than Brexit may report greater Brexit impacts subsequently in their survey responses.
[12] Years are defined from July to June in next calendar year to align with post-Brexit years (given the Brexit vote occurred in late June). So, for example, 2017/18 would be July 2017 to June 2018. Firms are allocated to the year that mostly closely aligns with their accounting year. For the outcome variables, we use data from company accounts, and for investment and employment only, we use DMP data if accounts data are not available (about 5% of observations).
[13] We do not extend this back further to avoid having the 2008-10 financial crisis as part of our control period. We only estimate our regressions up to 2024/25 because of lags in the availability of accounting data.
[14] We thank Ralf Martin (Imperial), Arjun Shah (King's College London), Anna Valero (LSE) and Dennis Verhoeven (KU Leuven) for their assistance with enabling the data on patents to be linked to the DMP. See Dechezleprêtre (2023) for more detail on the PATSTAT data.

asked firms to estimate the impact of Covid on a number of different aspects of their business, such as sales, employment and investment, in different periods. We include these firm-level data on the impact of Covid as controls in our regressions, and these are summarised in Figure A6 in the Appendix.

4.2 Overview of the Decision Maker Panel (DMP) survey

Our micro data analysis draws heavily on data from the Decision Maker Panel (DMP). The DMP is a large and representative monthly online panel survey of UK businesses that we founded in 2016. It is run by the Bank of England, King's College London and the University of Nottingham and is supported by funding from the Economic and Social Research Council. It is similar in style to the U.S. Survey of Business Uncertainty run by the Federal Reserve Bank of Atlanta (Altig et al., 2022). Bunn et al. (2024a) provides a detailed overview of the DMP survey and further information on the survey methodology. More information, including aggregated data, is available on the survey website: www.decisionmakerpanel.co.uk. Below we summarize the information about the survey that is most relevant to our study.

The motivation for founding the DMP survey was to help assess the impact of Brexit on UK firms. Since then, it has been used to study the effects of other key events that have had significant economic impacts, such as the Covid-19 pandemic (Altig et al., 2020; Bloom et al., 2025), and the subsequent increase in inflation (Bunn et al., 2024b, Yotzov et al., 2026). The timely and quantitative nature of the survey have made the data useful for both informing policy decisions and creating opportunities for high-quality research.

The survey contains regular questions about recent developments in business conditions and about firms' expectations for how those conditions will evolve over the next year. The expectations questions ask firms about the distribution of their expectations, not just the single most likely outcome. This allows an assessment of the uncertainty surrounding those expectations. The regular questions cover sales, prices, employment, wages and investment.[15]

[15] The surveys have a rotating three-panel structure – each member is randomized at entry into one of the three panels (A, B or C). Each panel is given one third of the questions in any given month, so that within each quarter all firms

Each survey also includes some special questions on topical issues. Some special questions are asked only once, others may be asked a number of times. This paper primarily makes use of the special questions relating to Brexit. The key special questions that we use are about pre-referendum exposure to the EU (through exports, imports, use of migrant labor and importance of EU regulation) and questions on Brexit uncertainty and the expected impact of Brexit on sales.

The panel grew quickly after its launch and now receives between 2,000 and 2,500 monthly responses, making it one of the largest regular business surveys in the UK (Figure A7 shows the sample size over time). The response rate is in the region of 50-55% for active respondents, defined as those who have responded to at least one survey in the last twelve months. The DMP currently covers around 4% of total UK private sector employment in each monthly survey, rising to about 6% for employees in private sector businesses that have more than 10 employees. Around 15,000 unique firms had responded to at least one of the monthly online surveys by May 2026, with the average firm responding 16 times. In this paper, we focus on the sub-sample of just over 7,000 firms that have answered all of the key special questions on Brexit exposure. This provides a large and representative sample for our analysis: these firms account for around 2.7 million employees, which is approximately 10% of UK private sector jobs.

The sampling frame for the DMP consists of active UK businesses with ten or more employees, as listed in the Bureau van Dijk FAME database. As of February 2026, the sampling frame contained approximately 79,000 firms. Firms are randomly selected from this sampling frame and invited by telephone to join the panel by a recruitment team based at the University of Nottingham. This approach helps to ensure that the survey provides a representative view of the UK economy.

When the DMP recruitment team initially contacts firms, they request to speak with the Chief Financial Officer (CFO) and, if unavailable, the CEO. Consequently, an average of 79% of respondents hold these senior positions (66% are CFOs and 13% are CEOs). Given that the median firm in the survey employs about 70 people, these CEOs and CFOs should have a good

rotate through all questions. This helps to keep the survey short for respondents whilst yielding a regular monthly flow of data. There is also an introductory survey on firm characteristics that firms are given for their first survey before they enter the regular panel. Most firms take between 5 and 10 minutes to complete the monthly surveys with a median completion time of just under 8 minutes.

understanding of the direction and performance of the business, and have the ability to answer numerate questions. The recruitment team also follow up with firms who stop responding to try and re-recruit them back into the survey to improve the length of the panel time series.

The DMP survey covers all industrial sectors of the UK economy and all regions. It also covers large, medium-sized and small businesses; only firms with fewer than ten employees are not covered. As well as private businesses, the survey also includes charities and other not-for-profit organizations. Aggregated survey data are weighted using employment data to match the UK Inter-Departmental Business Register (IDBR) by industry and firm size. The DMP survey matches the industrial composition of the UK economy well (Figure A8). Table A1 provides some descriptive statistics on the firms in the DMP survey. The DMP data align closely with firm-level accounts data on overlapping items (e.g. sales and employment) in levels and growth rates (Figure A9). The DMP also line up well when quarterly sales and employment growth are aggregated across all respondents and compared to quarterly UK GDP and employment growth (Figure A10).

An important consideration for our study is whether the Brexit referendum itself had an impact on which firms respond to the DMP survey. The linear response regressions in Table A2 show that whether a firm in the sampling frame has ever responded to a DMP survey is independent of the percentage of people voting to leave the EU in the local authority where that firm has its headquarters. Figure A11 confirms this lack of correlation - the scatter plot reveals no discernible pattern between response rates and local Brexit vote share.[16] The response rate analysis also shows that larger firms are more likely to respond to the DMP survey, although the magnitudes of these effects are not substantial.

A second validation check involves looking at DMP respondents' personal views on Brexit. In the DMP survey, only 22% of panel members had a positive personal view of Brexit at the time of the referendum (Figure A11). This is lower than the 52% of the population who voted to leave the EU in the referendum. However, this figure of 22% aligns with data from the British Election Survey where 23% of respondents with CFO characteristics (managers with a degree and income over

[16] The DMP recruitment team are located in Nottingham, a Brexit supporting region, which offsets the involvement of the Bank of England and King's College in London, which are both based in London, a Remain supporting region.

£50,000 a year) reported that they had voted for Brexit. CFOs responding to the DMP survey therefore appear to share similar views on Brexit with the wider population of CFOs.

4.3 Firms' exposure to the EU

Our micro analysis centers around a broad measure of pre-referendum exposure to the EU, which takes the average of six different firm-level metrics covering the importance of EU exports, imports, migrant labor, EU regulation, directors who are EU nationals and firm ownership. The first four variables are data from the DMP survey, with the last two coming from Bureau van Dijk.

In the DMP survey, businesses reported that exports to the EU made up around 7% of their sales in 2016 Q1, imports from the EU accounted for 9% of costs, 9% of employees were nationals of other EU countries and 17% of sales were affected by EU regulation. On average, 7% of directors of firms in our sample were EU nationals in 2015, and 4% of firms were EU owned.[17]

DMP export and import data can be benchmarked against Office for National Statistics (ONS) data from the input-output tables. These match up well on both exports and imports (Figure 5). Breaking the DMP versus ONS data down by industry, Figure 5 shows that they are well correlated. The proportion of workers who were EU migrants in 2016 Q1 in the DMP survey also matched up well with estimates for 2015 from the ONS Labour Force Survey (9% vs 8%), with a strong correlation at the industry level.[18]

Combining the six individual metrics together, Figure 6 shows a wide spread in the distribution of firms' pre-referendum exposure to the EU. Just under 20% of firms had no direct exposure to the EU across any of the dimensions, while the other 80% had exposure across one or several of the aspects. This heterogeneity in exposure provides an important source of variation to help identify the effects of Brexit in our micro-level analysis. Taking all the measures together, the industries that are estimated to have had the highest prior exposure to the EU are manufacturing/production,

[17] Figure A12 plots the distribution of each of these individual exposure metrics, and Table A1 includes some descriptive statistics.
[18] There is no comparable data available from other sources on the importance of EU regulation, the share of directors who are EU nationals and on EU ownership.

wholesale and retail, and finance and insurance (Figure 6) – all relatively tradeable goods and services. The least exposed industries are more concentrated in non-tradables, including recreational services, health and other services (which is mainly personal services, for example, nail bars, barbers etc).

4.4 Survey data on the first and second moment impact of Brexit

One of the initial motivations for setting up the DMP survey was to collect data on the uncertainty created by the UK's decision to leave the EU. There were many different aspects to this uncertainty. In addition to uncertainty around what the UK's eventual relationship with the EU would look like, there was also uncertainty about future market access, the availability of migrant labor, product regulation, the speed of transition, and whether the UK would leave the EU at all. The uncertainty created by Brexit was also much more long-lasting than most typical uncertainty shocks.

To monitor the uncertainty generated by Brexit, we created a Brexit uncertainty index (BUI). We define this as the percentage of firms who reported Brexit as one of the top three sources of uncertainty for their business in each period.[19] This BUI is plotted in Figure 7. This also correlates strongly with a Brexit media index, which captures the percentage of stories in UK newspapers that mention Brexit, and which is also shown in Figure 7.

The vote for Brexit generated a large, broad and long-lasting increase in uncertainty. After the June 2016 vote, just under 40% of firms rated Brexit as one of the three main drivers of uncertainty (Figure 7). This rose even higher after the September 2018 Salzburg summit when the EU did not accept the UK's Brexit proposal, which increased the chance of a no-deal Brexit. It remained at around 55% in the first quarter of 2019 as the UK Parliament rejected the proposed withdrawal

[19] Firms were asked 'How much has the result of the EU referendum affected the level of uncertainty affecting your business?' with four possible responses: (i) 'Not important', (ii) 'One of many drivers of uncertainty', (iii) 'One of the top two or three drivers of uncertainty', and (iv) 'The largest current source of uncertainty'. Our Brexit Uncertainty Index (BUI) is defined as the share of firms which choose options (iii) or (iv) – that is rating Brexit as, at the least, one of the three most important sources of uncertainty for their business. In our regression analysis, we define Brexit uncertainty on a 0 to 3 scale to make use of the additional granularity in these data. This variable is defined as 0 for those who answered, 'Not important', 1, for 'One of many drivers of uncertainty', 2, for 'One of the top two or three drivers of uncertainty', and 3, for 'The largest current source of uncertainty'. This measure is very highly correlated with the simpler metric of just focusing on Brexit being in the top 3 sources of uncertainty.

agreement in the run-up to the initial end March 2019 deadline for the UK leaving the EU. Uncertainty remained high throughout 2019 as the UK's exit from the EU was delayed, and only started to fall after the election victory of Boris Johnson in December 2019, which paved the way for the UK to leave the EU in January 2020. However, the share of firms reporting that Brexit was an important source of uncertainty did not fall consistently below 40% until the second quarter of 2021, after the new trade agreement had come into effect. This was almost five years after the original referendum. After 2021, Brexit related uncertainty gradually declined, although in September 2025, Brexit was still an important source of uncertainty for around 16% of firms. Media coverage of Brexit also followed a similar pattern around these key Brexit events and has continued to decline gradually into 2026.

At the firm level, Brexit uncertainty was highly correlated with prior exposure to the EU. Table 1 reports some simple regressions looking at the relationship between each of our six EU exposure measures and average Brexit uncertainty per firm. All six measures are statistically significant when included individually, and when combined, five of the six still have a coefficient that is significant. The R^2 when including our six-measure average of EU exposure measures (column 8) is almost double that of any regression with only a single metric. This highlights the broad nature of the uncertainty created by Brexit, and the value of using multiple exposure measures rather than just focusing on one dimension of EU exposure or just on trade exposure.

The DMP survey has also collected information on how firms viewed the long-term impact of Brexit on their sales. They were repeatedly asked to assign probabilities to the likelihood of Brexit having a large (greater than 10%) or small (up to 10%) positive or negative impact on long run sales, or no impact at all.[20] On average, firms attached a probability of just under 15% to large negative impacts, just under 25% to small negative effects, around 50% to no impact and 12% to

[20] The exact question wording was: 'How do you expect the eventual Brexit agreement to affect your sales once the UK has left the EU, compared to what would have been the case had the UK remained a member of the EU? What is the percentage likelihood (probability) that it will: (i) Have a large positive effect on sales at home and abroad, adding 10% or more to sales ; (ii) Have a modest positive effect on sales at home and abroad, adding less than 10% to sales; (iii) make little difference; (iv) Have a modest negative effect on sales at home and abroad, subtracting less than 10% from sales; (v) Have a large negative effect on sales at home and abroad, subtracting more than 10% from sales.' Responses across the five categories had to sum to 100%. In calculating a continuous variable for the expected long-run sales impact we assume that an impact of less than 10% corresponds to 5%, on average, and more than 10% equates to an average impact of 20%.

a positive impact (Figure A14). Assigning midpoints to these responses implies that firms thought Brexit would lower sales by about 2.5% on average. In a separate question, they estimated that Brexit had also raised their unit costs by around 4%. DMP data on the long run expected impact of Brexit on sales are well correlated with our EU exposure metrics (Table A3) and Brexit uncertainty (Figure A15).

4.5 Micro results on investment and employment

As explained in Section 4.1, we estimate the impact of Brexit at the micro level using firm-level data and a difference-in-differences approach. This tests whether firms that were more exposed to the EU did worse after 2016, controlling for time and firm fixed effects. Table 2 reports the results for investment and employment.[21] The results imply that, after the vote for Brexit, investment and employment in UK firms were both lower for firms more exposed to the EU.

Column (1) of Table 2 shows that firms with a higher level of pre-referendum exposure to the EU (based on our six-measure average) experienced higher investment growth in the pre-referendum period. The size of this difference is large – the coefficient of 8.9 implies that a firm with prior EU exposure of 0.1 (the mean value) rather than zero would have had, on average, 0.9% faster investment growth per year before the referendum. This was likely because more EU exposed firms tend to be more globalized and trading, and so typically faster growing. But after 2016, investment growth was lower for more EU exposed firms, with the coefficient of -5.6 suggesting that prior EU exposure of 0.1 rather than zero would be associated with about 0.6% lower annual growth of investment. The equation in column (1) includes time fixed effects to capture other macro factors that affect all firms, but it does not include firm fixed effects.

In column (2), we add firm fixed effects. The coefficient on the post-referendum exposure interaction is then interpreted as showing the change relative to the pre-referendum period, which is equivalent to the difference between the coefficients in column (1). This interaction has a negative and highly significant coefficient of -14.6. It implies that firms with EU exposure of 0.1 rather than zero would have had 1.5 percentage points lower annual investment growth post-Brexit.

[21] Figure 8 also shows these results in descriptive form.

In column 3, we add a control for firms' estimate of the impact of Covid-19 on their investment growth, which while highly significant, makes little difference to the Brexit effect because Covid and Brexit exposure have little correlation across firms.

To estimate the impact of Brexit on aggregate investment from our micro results, we use the regression in Table 2 to calculate how different investment growth would have been in each year if all firms were assumed to have zero EU exposure. The growth impacts are then cumulated to estimate the impact on the level of investment. The results imply that business investment was 12% lower by financial year 2024/25.[22] The implied aggregate effects are plotted on Figure 9. Whilst there is some volatility from year to year, the effect on investment builds up gradually over time, rather than arising immediately after the referendum.

Tables A5 and A6 report a set of robustness checks around our investment results. Table A5 shows our results are robust to taking the first principal component of our six EU exposure measures rather than a simple average. It also shows that our investment results are robust to leaving out any one of the six EU exposure metrics. Looking at how the Brexit effects vary across different types of firms (Table A6), for a given level of exposure, the point estimates are larger for firms that were more constrained by lower cashflow, larger firms, and firms in manufacturing, retail and finance (industries with the highest level of prior EU exposure and whose goods and services are most tradable). However, these differences in the point estimates are generally not statistically significant between the different subsamples.

Turning to employment, we find that employment growth was significantly lower in firms with higher exposure to the EU after the Brexit referendum. Column (4) of Table 2 illustrates how firms with higher EU exposure had faster employment growth between 2011 and 2015, but lower growth after 2016. This still holds after including firm fixed effects and a control for the effects of the Covid pandemic, as shown in columns (5) and (6). The results imply that a firm with the mean Brexit exposure of 0.1 rather than zero experienced average employment growth that was around 0.4 percentage points a year less than it would have otherwise done after 2016. This translates into an impact of around 3.5% on the level of private sector employment by 2024/25, and 3% in whole

[22] In Table A4 of the Appendix we also report the effects estimated separately for each individual year after 2016.

economy space (assuming no impact on public sector employment which is not covered by our firm-level data). As with investment, the Brexit effects on employment are estimated to have accumulated gradually over time since the referendum (Figure 9).

Lower investment could reflect first moment effects on sales and trade and/or second moment effects of higher uncertainty. Unpacking these two effects is challenging, not least because the two effects are likely to be well correlated. To investigate this, Table A7 in the Appendix replaces the EU exposure post-Brexit interaction with post-Brexit interactions for the expected impact of Brexit on long-run sales and average Brexit uncertainty. Whilst these self-reported metrics are prone to endogeneity concerns, the results imply that higher uncertainty can explain more of the investment impact and lower sales can explain more of the employment impact.[23]

4.6 Micro results on productivity

The vote to leave the EU could have affected aggregate productivity through effects on productivity *within* individual firms, or because output was reallocated *between* firms with varying levels of productivity. In this section, we examine both effects, although we focus more on the within-firm effects, where we find that the Brexit effects have been largest. We follow the framework of Baily et al. (1992) to separate out these different channels:

$$\Delta\Pi_t = \sum_{\mathrm{i}\in\mathrm{Surv}} \bar{\varphi}_i \Delta\pi_{\mathrm{i,t}} \qquad \text{… within firms}$$

$$+ \sum_{i\in Surv} \Delta\varphi_{i,t}(\overline{\pi}_{\mathrm{i}} - \overline{\Pi}) \qquad \text{… reallocation between surviving firms}$$

$$+ \sum_{i\in\Delta Entry} \varphi_{i,t}(\overline{\pi}_{\mathrm{i}} - \overline{\Pi}) \qquad \text{…. reallocation to new firms}$$

$$- \sum_{i\in\Delta Exit} \Delta\varphi_{i,t-1}(\pi_{i,t-1} - \overline{\Pi}) \qquad \text{…. reallocation from exiting firms}$$

[23] Lower labor supply may also have played a role for employment. Inward migration to the EU fell after the referendum (Figure A16).

Here $\pi_{i,t}$ is productivity in firm *i* at time *t,* Π_t is aggregate productivity at time *t,* $\varphi_{i,t}$ is the employment share of firm *i* at time *t* and a bar over a variable indicates the average of the variables across times *t*-1 and *t*. Δ is the change that is due to the vote for Brexit. Δ*Entry* and Δ*Exit* denote changes in firm entry and exit that are associated with Brexit. We first consider the effects of Brexit on within-firm productivity, before moving on to the between-firm effects.

In Table 3, we report our micro estimates of the impact of Brexit on TFP, our preferred measure of firm-level productivity, *within firms*. Column (1) shows that firms with higher pre-referendum exposure to the EU had faster TFP growth prior to the referendum, but lower TFP growth afterwards. This is also shown in Figure 8. Adding in firm-fixed effects in columns (2) and (3) again changes the interpretation of the coefficient on the exposure/post-referendum variable to be the change in the relationship after 2016. This confirms that firms with higher exposure to the EU experienced significantly lower growth in TFP after the referendum. In both cases, the results imply that a firm with a mean EU exposure index of 0.1 experienced productivity growth of around 0.5 percentage points a year less after 2016 than a firm with no EU exposure. This translates into an overall within-firm Brexit impact of around 4% off the level of private sector TFP by 2024/25. The inclusion of the Covid control again makes little difference to the estimated Brexit impact.

Looking at the effects on TFP within firms by year (Figure 9), the impacts are estimated to have accumulated gradually over time. The effects of Brexit on TFP also appear to be more strongly associated with the DMP proxy for Brexit uncertainty rather than the first moment effects on sales (Table A7, columns (5) and (6)).

Although we find clear micro-level evidence that Brexit lowered within-firm TFP growth, the evidence on sales growth is more mixed. Columns (4), (5) and (6) of Table 3 show that we find a negative effect on sales growth for firms with higher EU exposure after 2016, but this is only statistically significant at the 10% level.[24] The effects of Brexit on nominal sales will also be

[24] For labor productivity, we do not find a significant relationship with Brexit exposure after the referendum, as shown in Table A7, although there is a significant correlation with Brexit uncertainty (Table A8). Conceptually, TFP should be the best metric to look at, as it accounts for differences in capital as well as labor input, and because it is normalized by industry in each year, that may help to better understand changes in productivity within and across industries.

affected by what happened to firms' prices as well as their sales volumes. If Brexit pushed up prices, for example by increasing costs, then the effects on sales volumes would be larger than the impacts on sales values. The estimated impacts on value-added are significant at the 5% level (Table A8).

There are a number of potential channels through which the vote for Brexit could have lowered productivity within firms. These include elevated uncertainty reducing investment in intangibles like training or software, reduced innovation, inferior inputs from diverted trade, increased stock levels and management time being lost to the Brexit process. Below, we consider the evidence for these different channels in more detail. We find that all of them may have played some role, although it is difficult to precisely quantify each of them. The composition of the channels may also have changed over time.

Elevated uncertainty could have lowered productivity by reducing spending on intangibles that can boost productivity. When respondents to the DMP survey were asked which types of investment they had reduced in response to Brexit, the most common response was spending less on machinery, equipment and building. But a number also reported investing less in research and development, software and training (Figure A17). If the coefficients on Brexit exposure are allowed to vary by industry in our main micro regressions, we find a positive correlation between the investment and TFP coefficients in each industry (Figure A18). That would also be consistent with some spillover from lower investment to lower TFP.

We also investigate whether firms that had a higher exposure to the EU became less likely to register patents after the vote for Brexit, using this as a proxy for innovation. We do this using data from the PATSTAT database, matched to our EU firm exposure measure. Firms with a higher level of exposure to the EU were much more likely to register patents prior to the referendum (Figure A19), being typically larger and more internationally exposed. The regression results reported in Table 4 find tentative evidence that firms more exposed to the EU became relatively less likely to apply for patents after 2016. This coefficient is only significant at the 10% level, but the data we use only go up to 2020, and given that the process of developing

new innovations takes time, it is plausible that these results could become stronger as more data become available.[25]

A second channel which may have led to lower productivity is the time spent by senior management on Brexit preparations. Firms in the DMP survey were asked about this repeatedly between 2017 and 2020, focusing on CFO and CEO time, which our respondents would be most aware of. On average, nearly 10% of CFOs were spending six hours or more per week on preparing for Brexit over this period, with a quarter spending between one and five hours a week (Figure A20). Around three-quarters reported spending at least some time planning for Brexit.

We find that time spent planning for Brexit by senior management is directly correlated with lower productivity growth in the post referendum period before the UK formally left the EU. Column (1) of Table 5 shows that average CFO hours spent on Brexit planning are, unsurprisingly, well correlated with firms' prior EU exposure. In column (2), we interact average CFO hours spent on Brexit with a post-referendum dummy in a regression with TFP growth as the dependent variable. This coefficient is not significant. But only estimating this equation covering the period before the UK formally left the EU (column 3), the coefficient is larger and more strongly significant in those earlier years when the preparations for Brexit would have been taking place. While this does not prove causality, it is at least consistent with the time and cost of preparing for Brexit being a factor that contributed to lower productivity growth.

Related to time spent on Brexit planning, many firms increased their stock levels in preparation for the UK leaving the EU (Figure A20). For some firms, this was expected to be a temporary measure, but others expected to hold more stock on a permanent basis to help mitigate the extra barriers to trading with the EU. This may also have lowered measured productivity by increasing firms' input costs while not raising their sales, at least temporarily. Column (4) of Table 6 shows in regression form that firms that were more exposed to the EU did increase their stocks-to-total-assets ratio after 2016. Column (5) helps to confirm that this build-up of stocks largely took place prior to the UK actually leaving the EU.

[25] We are in the process of obtaining updated patent data to 2023.

Over the longer term, the productivity implications of Brexit may be associated with lower trade and less specialization, rather than with the costs of transition and heightened uncertainty. Freeman et al. (2024), who analyze administrative data on trade in goods, find that exports and imports to the EU only fell once the new TCA came into effect in 2021, with no significant impact before that. Lower trade itself is therefore unlikely to have been a significant contributor to lower productivity before 2021.[26]

Although the largest effects of Brexit on productivity are estimated to have been within-firms, the vote to leave the EU also had an impact on aggregate productivity through reallocation *between* firms. Figure 10 shows that there was a positive correlation between pre-referendum EU exposure and labor productivity.[27] It also shows that more productive firms expected more of a reduction in sales from Brexit over the long term. If high productivity firms were more adversely affected by Brexit and therefore made up a relatively smaller share of the UK economy than was previously the case, that would also have lowered aggregate productivity. To quantify the effect among surviving firms, we compare the average level of actual labor productivity in each year, weighted by actual employment, to a counterfactual using alternative employment weights that are based on what employment in each firm might have been in the absence of Brexit. These alternative employment weights are constructed using the coefficients from the employment regressions in Table 2.

Our estimates imply that reallocation-type effects among surviving firms lowered aggregate productivity by 0.5% in 2024/25. These effects are estimated to have accumulated gradually over time, in line with the increasing impacts of Brexit on employment.[28]

[26] Broadbent (2024) notes that exporting firms may initially have benefited from the referendum, as sterling depreciated immediately and the new trading rules did not take effect until almost five years later.
[27] Here we use labor productivity rather than TFP because it is not possible to easily compare the level of TFP across industries given the way it is normalised.
[28] As well as between-firm effects among surviving firms, firm entry and exit can also have similar reallocation type implications for aggregate productivity. To assess this, we use two-digit industry data on firm birth and death rates from the ONS as dependent variables in a set of difference-in-differences regressions. These regressions include industry-level measures of pre-referendum exposure to the EU that are constructed from our firm-level data, again using the six-measure average. These regressions are reported in Table A9. The coefficients on EU exposure are not statistically significant, implying that changes in firm entry and exit associated with Brexit are unlikely to have had a large impact on aggregate productivity.

5 COMPARING MACRO AND MICRO ESTIMATES

Bringing together our macro and micro-based estimates of the impact of Brexit, both approaches indicate that the vote to leave the EU had a significant impact on the UK economy. However, the macro estimates are generally larger than the micro estimates. Table 6 summarizes the impacts. The macro estimates reported are for the year to 2025 Q4. The micro estimates are for financial year 2024/25. Using the macro approach, the level of GDP is estimated to have been 8% lower than it would otherwise have been, compared to 6% using the micro approach.[29] The macro impacts are estimated to be larger than the micro estimates for investment, employment and productivity.

Looking at the macro and micro-based impacts through time (Figure 9), they both have relatively similar profiles.[30] The effects on GDP and other variables are estimated to have grown gradually over time since the referendum, according to both approaches. The most notable differences are in business investment, where the macro estimates imply an earlier fall in investment. Differences for other variables are smaller.

One reason why the macro and micro estimates could differ is because of general equilibrium effects. The micro estimates assume that there was no Brexit impact on UK firms that had no direct exposure to the EU. But there could have been some effect on firms with no EU exposure if, for example, increased uncertainty and reduced consumer confidence also lowered demand for domestically produced goods and services. These general equilibrium effects need not necessarily be all negative for all firms. For example, lower demand for labor will reduce wages, and that may have benefited firms with no EU exposure. Similarly, the cut in interest rates that followed as part of the policy response to the referendum would have helped some firms.

[29] In order to generate a GDP impact from the micro-estimates, we combine our estimates of the impact of Brexit on investment and capital, employment and productivity. In our micro analysis, we estimate the effects on employment and TFP at the private sector level, but scale by their share in the whole economy to translate these into GDP space. We assume that there was no Brexit impact on the public sector. We also use labor productivity in our macro analysis for productivity even though TFP is a conceptually better measure to use, more comparable cross-country data are available for labor productivity. We use our micro-level TFP impacts when calculating the implied GDP impact from our micro-estimates.

[30] The macro impacts shown in Figure 9 smooth through the effects of the Covid pandemic for 2020, which otherwise adds significant volatility.

General equilibrium effects that impact all firms would only be picked up in the macro estimates, not the micro-estimates. As discussed earlier, the macro estimates could also capture factors driving cross-country differences in growth other than Brexit, such as the effects of the Covid pandemic or government policies.

5.1 A model of macro-micro divergence

In order to help reconcile our empirical macro and micro estimates of the impact of Brexit, we develop a general equilibrium model to highlight which types of general equilibrium channels could have been important. The model is not a comprehensive quantitative account of the Brexit shock. Rather, it illustrates how spillovers between firms can drive a wedge between micro and macro estimates, and how the *sign* of that wedge depends on which spillover channels dominate.

We build on the heterogeneous firm framework of Kahn and Thomas (2008) adding three features relevant to Brexit. First, a three-state Markov process for the aggregate regime: pre-referendum (*E*), post-referendum/pre-Brexit (*R*), and post-Brexit (*B*). The prolonged *R* state – from June 2016 to January 2020 – generates aggregate uncertainty that depresses investment through option-value effects, even before any Brexit costs materialise. Second, roundabout production, where firms use each other's output as intermediate inputs. Third, general equilibrium linkages through the goods market, input-output relationships, and the labor market.

Firms are heterogeneous in both transitory productivity (which follows an AR(1) process) and a permanent type that governs their exposure to Brexit. More productive firm types face higher probabilities of incurring a Brexit cost upon transition to state *B*, reflecting the empirical finding that more productive firms are more internationally exposed. Capital adjustment is subject to partial irreversibility, generating the real-options effects emphasised by Bernanke (1983), Dixit and Pindyck (1994) and Bloom (2009). Full model details are presented in the Appendix.

The model features three spillover channels:

1) **Aggregate demand spillovers** (negative): When Brexit reduces output at directly affected firms, aggregate demand falls, shifting the demand curve inward for all firms—including those

with no direct Brexit exposure. This channel operates when goods are imperfect substitutes (finite elasticity of substitution θ).

2) **Supply chain spillovers** (negative): When affected firms produce less, the aggregate intermediate good becomes scarcer and more expensive. All firms that use intermediates face higher costs, even if their own productivity is unchanged.
3) **Labor market spillovers** (positive): When Brexit reduces labor demand at affected firms, the equilibrium wage falls. Unaffected firms benefit from cheaper labor, partially offsetting the aggregate decline.

The net effect depends on which channels dominate. When negative spillovers (demand and supply chains) outweigh positive spillovers (wages), output at unexposed firms falls, compressing the treatment-control difference in micro regressions. The micro estimate then *understates* the true aggregate effect. Conversely, when positive spillovers dominate, the micro estimate overstates the aggregate effect.

To study the effects of Brexit we simulate the model to match the actual Brexit timeline. From simulated data, we construct both macro and micro-based estimates of the Brexit impact on aggregate output. The macro estimate compares aggregate output in the Brexit scenario to a counterfactual where the economy remains permanently in the pre-referendum state. The micro estimate involves running a difference-in-differences regression on simulated firm-level data, comparing high-exposure to low-exposure firms before and after the referendum, mirroring our empirical specification.

We compare four model variants that progressively activate these channels. Figure 11 shows the simulated macro and micro estimates under each specification. In each panel, the economy enters the post-referendum state in 2016 Q3 and transitions to post-Brexit in 2020 Q1.

In Model A, firms are effectively independent: there are no spillovers and there is no permanent productivity heterogeneity. The micro and macro estimates track each other closely, as expected. Both show output declining from 2016 Q3 onwards, reflecting how the post-referendum uncertainty alone depresses investment through option-value effects, before Brexit costs are

realised in 2020 Q1. Both the macro and micro estimates produce a long run Brexit impact on GDP of just under 7%.

Model B introduces heterogeneity in permanent productivity across firms, with more productive firms assumed to face higher Brexit exposure to the risk of having to pay a Brexit cost. The macro estimate now modestly exceeds the micro estimate, reflecting adverse reallocation: output shifts from high- to low-productivity firms, reducing aggregate productivity through a misallocation effect that the micro estimator does not capture. This is consistent with the empirical evidence presented in Section 4.6 of a relatively modest *between-firm* effect pushing down on aggregate productivity.

The key results are highlighted by the Model C and D variants. Model C activates negative spillover channels – imperfect substitution between varieties and roundabout production – and a large gap opens up: the macro impact substantially exceeds the micro estimate. The mechanism is that unexposed firms are dragged down by falling aggregate demand and rising intermediate input costs, even though they face no direct Brexit cost themselves. Because these firms serve as the control group in the micro regression, the treatment-control difference is compressed, and the micro estimate *understates* the true aggregate effect.

Model D illustrates the opposite case: when the only spillover operates through the labor market (upward-sloping labor supply), the micro estimate *exceeds* the macro estimate. Here, reduced labor demand from Brexit affected firms pushes down the equilibrium wage, benefiting the control group. This amplifies the treatment-control difference, and the micro estimate *overstates* the true aggregate impact.

This connects to what Wolf (2023) terms the “missing intercept” problem. The micro difference-in-differences estimator identifies the relative effect of Brexit on high- versus low-exposure firms – the *slope* – while absorbing any common effect on all firms through time fixed effects. But when general equilibrium spillovers shift outcomes for all firms, including controls, there is an additional level effect – the *intercept* – that the micro estimator cannot recover:

$$Y_i(0,G) - Y_i(0,0) \quad = \quad \text{Spillover effect on unexposed firms} \quad = \quad \text{Missing intercept} \qquad (2)$$

where G denotes the aggregate treatment intensity and $Y_i(0,G)$ is the outcome of an untreated firm in an economy where a fraction G of firms are treated.

When negative spillovers dominate – as in Model C – the missing intercept is negative: unexposed firms are worse off than they would be in the absence of Brexit. The micro estimate understates the aggregate effect, and the macro estimate is larger. When positive spillovers dominate – as in Model D – the missing intercept is positive: unexposed firms benefit from lower wages, and the micro estimate overstates the aggregate effect.

Our empirical finding that the macro estimate (8%) exceeds the micro estimate (6%) implies a negative missing intercept of approximately 2 percentage points. This is consistent with demand and supply chain linkages outweighing labor market spillovers as transmission mechanisms for the Brexit shock. The micro estimates could therefore be viewed as lower bounds on the true causal effect.

6 COMPARISONS OF BREXIT ESTIMATES TO EARLIER FORECASTS

Brexit is a novel example of an event where forecasts of its macroeconomic impact can be systematically evaluated after the event. Figure 12 compares ex-ante forecasts made by academic and professional economists to our ex-post estimates of the impact of Brexit on GDP from this paper (the average of our macro and micro estimates) at short-, medium- and long-term horizons.[31] Because of the importance of Brexit, we were able to find 36 forecasts from 25 institutions, noting that there are more forecasts than institutions as some institutions forecast over multiple time horizons.

In the short term (first two years after the referendum), the forecasts typically overestimated the negative impact that Brexit would have on the UK economy. The median forecast was for a GDP

[31] IMF (2016a) and Emmerson et al. (2016) also provide details of forecasts that were made around the time of the referendum for the impact of Brexit on GDP.

impact of around -2% in the short-term, compared to our estimate (taking the average of our macro and micro approaches) of around -1%. In the medium term, economists predicted a reduction in GDP of around 3%. That is close to the average of our estimates for years 3 to 5 after the referendum, but below our estimate of 5% if we take a wider medium-term definition of years 3 to 9 post-referendum. Overall, these prior forecasts were impressively accurate over the short to medium term, particularly given the nature of the uncertainties in making such forecasts.

However, over the longer term, forecasters underestimated the impact of Brexit on GDP. Their median forecast of a 4% reduction in GDP from Brexit is materially below our longer-run estimate of 6% to 8%. This could be due in part to the protracted nature of the Brexit process and the associated uncertainty, which was not necessarily expected when the initial predictions were made. This highlights the political challenges in leaving a large trading bloc, and the need to take them into account in forecasting.

We also consider the accuracy of forecasts made by different groups of forecasters.[32] Forecasters are grouped into academics, banks and consultancies, policymakers and political advocacy groups. Figure 13 tries to adjust for the fact that forecasts were made for different time horizons and compares them to our estimates of the impact of Brexit. Overall, academics, banks and consultancies, and policymakers all had relatively similar forecast accuracy, with academics having a marginally lower absolute forecast errors. In general terms all these groups had relatively

[32] Forecasters used a range of approaches in making their predictions for the impact of Brexit. Banks typically published short to medium term forecasts, underpinned by historical analogues and reduced-form empirical relationships linking uncertainty to output. Academic studies typically adopted either quantitative trade models or an econometric approach. Bertelsmann Stiftung (2015) use the IFO trade model (Aichele et al., 2014). Dhingra eta al. (2017) considered both static and dynamic effects in a quantitative trade model, building on Costinot and Rodriguez-Clare (2014). Econometric-based studies include Baker et al. (2016), who adopted a global econometric model, and Ebell and Warren (2016) who input Brexit shocks into the National Institute Global Econometric Model (NiGEM), developed by the NIESR. Policymakers used similar econometric methods. Both the HM Treasury and OECD used the NiGEM model, feeding in calibrated shocks to uncertainty and longer-term trade openness. The IMF combined analysis of historical episodes, econometric estimates from standard gravity models, and simulations from structural macroeconomic models. Consultancies include commercial forecasting and advisory firms and use simplified modelling methods. Oxford Economics adopt a gravity-based model, whilst PwC employ a computable general equilibrium model underpinned by the ONS data. Among political advocacy groups, Mansfield (2014) estimated the Brexit impact by reversing the CEPR (2013) predicted impact of the Trans-Atlantic Trade and Investment Partnership (TTIP) Agreement between the European Union and the United States. Minford (2016) considered a general equilibrium, open economy model where the EU Customs Union creates a wedge between world and UK consumer prices. Brexit removes distortions and lowers consumer prices by 8%.

good forecast performance, with a mean deviation of about 0.1% of GDP per year. In contrast, forecasts made by political advocacy groups were much less accurate, with a mean deviation ten-times larger at about 1% of GDP per year. One explanation for this difference is that academics, banks and consultants have relatively strong incentives for forecast accuracy, while advocacy organizations are perhaps seeking to demonstrate to voters the merits of a particular political position.

7 CONCLUSION

This paper presents a comprehensive economic analysis of the UK's decision to leave the European Union. We employ both macro and micro approaches to evaluate the implications for GDP, investment, employment, and productivity. Our macro analysis is based on comparing the UK's economic performance against a set of comparable countries, using a range of different weighting methods and comparator countries to estimate what the UK economy might have looked like without Brexit. Our micro approach employs a difference-in-differences estimation using firm-level data from the Decision Maker Panel survey, matched with firm accounts. We develop a general equilibrium model to help reconcile the macro and micro-based estimates and show that the larger macro impact is consistent with negative spillovers via demand and supply chain linkages outweighing more positive spillovers through the labor market.

We estimate that by the end of 2025, the UK economy was approximately 8% smaller than it would have been without Brexit, based on macro data, and 6% smaller using firm-level micro data. Investment is estimated to have been 12-13% lower, employment 3-4% lower and productivity also 3-4% lower than it would have been if the UK had not voted to leave the EU.

We show that Brexit generated a large, broad and long-lasting increase in uncertainty. This contributed to lower business investment, in particular, but it also may have reduced productivity too by restraining innovation and spending on potentially productivity enhancing forms of capital expenditure. We also show how the time and resources firms devoted to preparing for Brexit were strongly correlated with lower productivity. These channels have potentially been more important than the effects of reduced trade with the EU, at least initially.

The UK's experience of Brexit also has some parallels with the recent implementation of new tariffs on goods entering the United States in 2025. There are few other examples of increases in trade and immigration barriers between major developed countries, and like Brexit, announcements on tariffs have created uncertainty about what future trading arrangements could be and what the process towards a long-term solution might look like. In the case of Brexit, there was a substantial economic impact on the United Kingdom, but it arose gradually over the subsequent decade, suggesting the greatest impacts of trade and migration barriers can take years to arise.

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Table 1: EU exposure and Brexit uncertainty

Dependent variable: Brexit uncertainty (0-3 scale)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Share of sales to EU	0.840***						0.315***	
	(0.057)						(0.059)	
Share of costs from EU imports		0.870***					0.522***	
		(0.048)					(0.050)	
Share of EU migrants in workforce			0.789***				0.658***	
			(0.037)				(0.037)	
Share of sales covered by EU regulations				0.580***			0.399***	
				(0.026)			(0.028)	
Share of directors who are EU nationals					0.492***		0.141***	
					(0.042)		(0.045)	
Dummy for being EU owned						0.303***	0.017	
						(0.043)	(0.047)	
EU exposure (6 measure average)								2.139***
								(0.071)
Observations	7,144	7,144	7,144	7,144	7,144	7,144	7,144	7,144
R-squared	0.037	0.049	0.066	0.064	0.019	0.006	0.149	0.127

Notes: DMP data for all variables, except share of directors who are EU nationals and ownership which are from the Bureau Van Dijk FAME database. EU exposure measures are for 2016 Q1, just before the Brexit referendum, except for directors and ownership data which are for 2015. Dependent variable is average Brexit uncertainty per firm, as collected in DMP surveys between August 2016 and April 2024. Brexit uncertainty is based on responses to the question: 'How much has the result of the EU referendum affected the level of uncertainty affecting your business?' Brexit uncertainty is defined as 0 for those who answered, 'Not important', 1, for 'One of many drivers of uncertainty', 2, for 'One of the top two or three drivers of uncertainty', and 3, for 'The largest current source of uncertainty'. Missing values for uncertainty for an individual firm in a given period are imputed from a regression using time and firm fixed effects. All equations are estimated by OLS with robust standard errors. *** p<0.01, ** p<0.05, * p<0.1.

Table 2: EU exposure and outcomes for investment and employment

Dependent variable (all in growth rates):	Investment			Employment		
All equations estimated 2011-2024 (financial years)	(1)	(2)	(3)	(4)	(5)	(6)
EU exposure (6 measure average)*pre-referendum	8.902**			2.591**		
	(3.824)			(1.135)		
EU exposure (6 measure average)*post-referendum	-5.623**	-14.634***	-15.115***	-1.943**	-4.189***	-4.379***
	(2.491)	(5.115)	(5.108)	(0.765)	(1.369)	(1.368)
Covid-19 impact on investment growth			0.733***			
			(0.046)			
Covid-19 impact on employment growth						0.248***
						(0.022)
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	No	Yes	Yes	No	Yes	Yes
Observations	59,062	59,062	59,062	70,378	70,378	70,378
Test exposure coefficients are equal pre and post referendum (p-value):	0.0015			0.0006		
Implied impact of Brexit on levels in 2024 (%):						
- Private sector			-11.7			-3.4
- Whole economy						-2.8

Notes: EU exposure is the average of the following 6 exposure measures: share of sales to EU; share of costs from EU imports; share of EU migrants in workforce; share of sales covered by EU regulations; share of directors who are EU nationals; and a dummy for being EU owned. All are on a 0-1 scale. DMP data for all exposure variables, except share of directors who are EU nationals and ownership which are from the Bureau Van Dijk FAME database. EU exposure measures are for 2016 Q1, just before the Brexit referendum, except for directors and ownership data which are for 2015. Regressions use company accounts data from the Bureau Van Dijk FAME database for investment and employment where available and DMP data where accounts data are missing. Data used are from financial years 2011 to 2024, but 2016 is excluded (years are defined from Q3 to Q2 in next calendar year, so 2017 represents 2017/18 and would cover firms with a financial year end between 2017 Q3 and 2018 Q2). Covid-19 impact variables are from the DMP survey and are impacts on the firm estimated by survey respondents (see Appendix for more details on these). These Covid controls are interacted with separate year dummies where data are missing. Standard errors are clustered at the firm level. *** p<0.01, ** p<0.05, * p<0.1.

Memo: The mean of the Brexit exposure measure is 0.1.

Table 3: EU exposure and outcomes for TFP and sales

Dependent variable (all in growth rates):	TFP			Sales		
Equations estimated 2011-2024 (financial years)	(1)	(2)	(3)	(4)	(5)	(6)
EU exposure (6 measure average)*pre-referendum	2.930*			1.706		
	(1.503)			(1.686)		
EU exposure (6 measure average)*post-referendum	-1.350	-5.178**	-5.003**	-1.487	-3.620*	-4.013*
	(1.181)	(2.183)	(2.191)	(1.231)	(2.073)	(2.077)
Covid-19 impact on sales growth per employee			0.320***			
			(0.035)			
Covid-19 impact on sales growth						0.694***
						(0.030)
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	No	Yes	Yes	No	Yes	Yes
Observations	46,627	46,627	46,627	59,089	59,089	59,089
Test exposure coefficients are equal pre and post referendum (p-value):	0.0338			0.1109		
Implied impact of Brexit on levels in 2024, within firm only (%):						
- Private sector			-3.9			-3.1
- Whole economy			-3.2			-2.5

Notes: EU exposure is the average of the following 6 exposure measures: share of sales to EU; share of costs from EU imports; share of EU migrants in workforce; share of sales covered by EU regulations; share of directors who are EU nationals; and a dummy for being EU owned. All are on a 0-1 scale. DMP data for all exposure variables, except share of directors who are EU nationals and ownership which are from the Bureau Van Dijk FAME database. EU exposure measures are for 2016 Q1, just before the Brexit referendum, except for directors and ownership data which are for 2015. Regressions use company accounts data from the Bureau Van Dijk FAME database for sales and TFP growth where available and DMP data where accounts data are missing for sales. Data used are from financial years 2011 to 2024, but 2016 is excluded (years are defined from Q3 to Q2 in next calendar year, so 2017 represents 2017/18 and would cover firms with a financial year end between 2017 Q3 and 2018 Q2). TFP is calculated as the residual from a production function $\ln(Y_{it}) = 0.63\ln(L_{it})+0.37\ln(K_{it})$ where Y_{it} is real value-added of firm i in year t, L is labour input (total real labour costs) and K is capital (total real fixed assets), nominal values from accounting data are deflated using the GDP deflator. TFP data are normalised by 4-digit industry (using data for the full DMP sampling frame) within each year. Real value-added is defined as operating profits plus total labour costs divided by the aggregate GDP deflator. Covid-19 impact variables are from the DMP survey and are impacts on the firm estimated by survey respondents (see Appendix for more details on these). These Covid controls are interacted with separate year dummies where data are missing. Standard errors are clustered at the firm level. *** p<0.01, ** p<0.05, * p<0.1.

Memo: The mean of the Brexit exposure measure is 0.1.

Table 4: EU exposure and patent applications

Dependent variable: Probability of applying for at least one patent All equations estimated 2012-2020	All regions	UK	US	Top 5 non-Europe	EU	World Patent Office
	(1)	(2)	(3)	(4)	(5)	(6)
EU exposure (6 measure average)*post referendum	-2.011*	-1.223	-0.548	-1.389*	-0.429	-0.755
	(1.089)	(0.978)	(0.635)	(0.730)	(0.788)	(0.750)
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	52,244	52,244	52,244	52,244	52,244	52,244

Notes: EU exposure is the average of the following 6 exposure measures: share of sales to EU; share of costs from EU imports; share of EU migrants in workforce; share of sales covered by EU regulations; share of directors who are EU nationals; and a dummy for being EU owned. All are on a 0-1 scale. DMP data for all exposure variables, except share of directors who are EU nationals and ownership which are from the Bureau Van Dijk FAME database. EU exposure measures are for 2016 Q1, just before the Brexit referendum, except for directors and ownership data which are for 2015. Patents data are from World Patent Statistical Database and are for calendar years. We thank Ralf Martin (Imperial), Arjun Shah (King's College London), Anna Valero (LSE) and Dennis Verhoeven (KU Leuven) for their assistance with enabling the data on patents to be linked to the DMP.

Table 5: Impact of preparing for Brexit

Dependent variable:	CFO weekly hours Brexit planning	TFP growth		ΔStocks/total assets	
Time period (financial years)	2017-20 average	2011-24	2011-19	2011-24	2011-19
	(1)	(2)	(3)	(4)	(5)
EU exposure (6 measure average)	4.043***				
	(0.298)				
CFO weekly hours Brexit planning*post-referendum		-0.201	-0.408**		
		(0.154)	(0.197)		
EU exposure (6 measure average)*post-referendum				0.465*	1.072***
				(0.247)	(0.316)
Covid-19 impact on sales growth per employee		0.361***			
		(0.040)			
Time fixed effects	No	Yes	Yes	Yes	Yes
Firm fixed effects	No	Yes	Yes	Yes	Yes
Observations	2,897	39,766	25,412	46,508	29,156

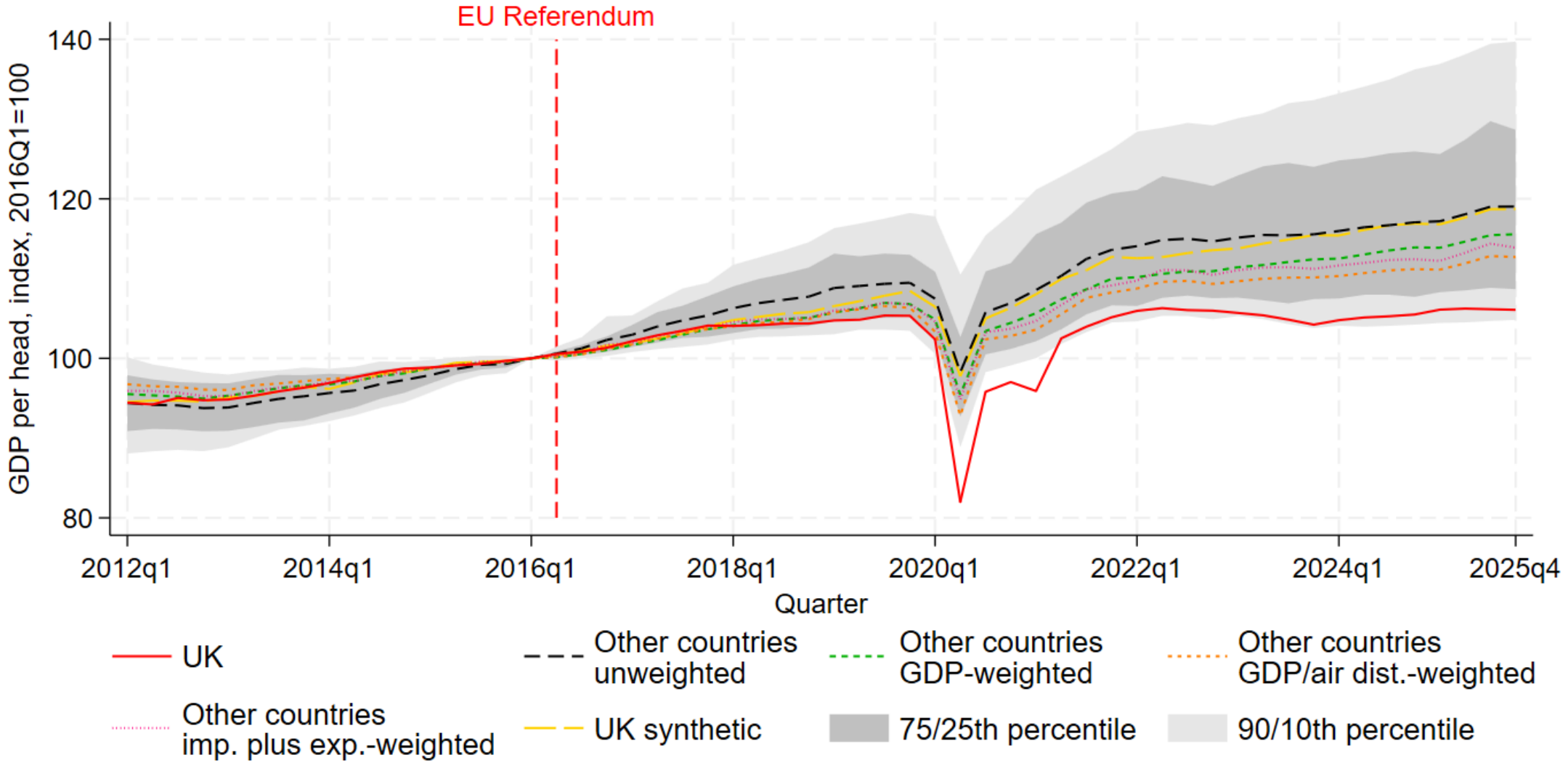
Notes: EU exposure is the average of the following 6 exposure measures: share of sales to EU; share of costs from EU imports; share of EU migrants in workforce; share of sales covered by EU regulations; share of directors who are EU nationals; and a dummy for being EU owned. All are on a 0-1 scale. DMP data for all exposure variables, except share of directors who are EU nationals and ownership which are from the Bureau Van Dijk FAME database. EU exposure measures are for 2016 Q1, just before the Brexit referendum, except for directors and ownership data which are for 2015. Data on CFO hours spent planning for Brexit are averages of data collected between November 2017 and March 2020. They are based on the question 'On average, how many hours a week are the CEO and CFO of your business spending on preparing for Brexit at the moment?' Please select one option for each for CEO and CFO: (i) None; (ii) Up to 1 hour; (iii) 1 to 5 hours; (iii) 6 to 10 hours; (iv) More than 10 hours; (v) Don't know'. Midpoints are assigned to responses in each category. TFP growth data are based on company accounts data from Bureau Van Dijk FAME and are calculated using the approach explained in the footnote to Table 3. Data from on stocks/total assets are company accounts data from Bureau Van Dijk FAME

Table 6: Summary of estimated Brexit impacts

	Macro estimates (year to 2025 Q4)	Micro estimates (financial year 2024/25)
Business investment	-13%	-12%
Whole economy employment	-4%	-3%
Whole economy productivity	-4%	-3%
GDP	-8%	-6%

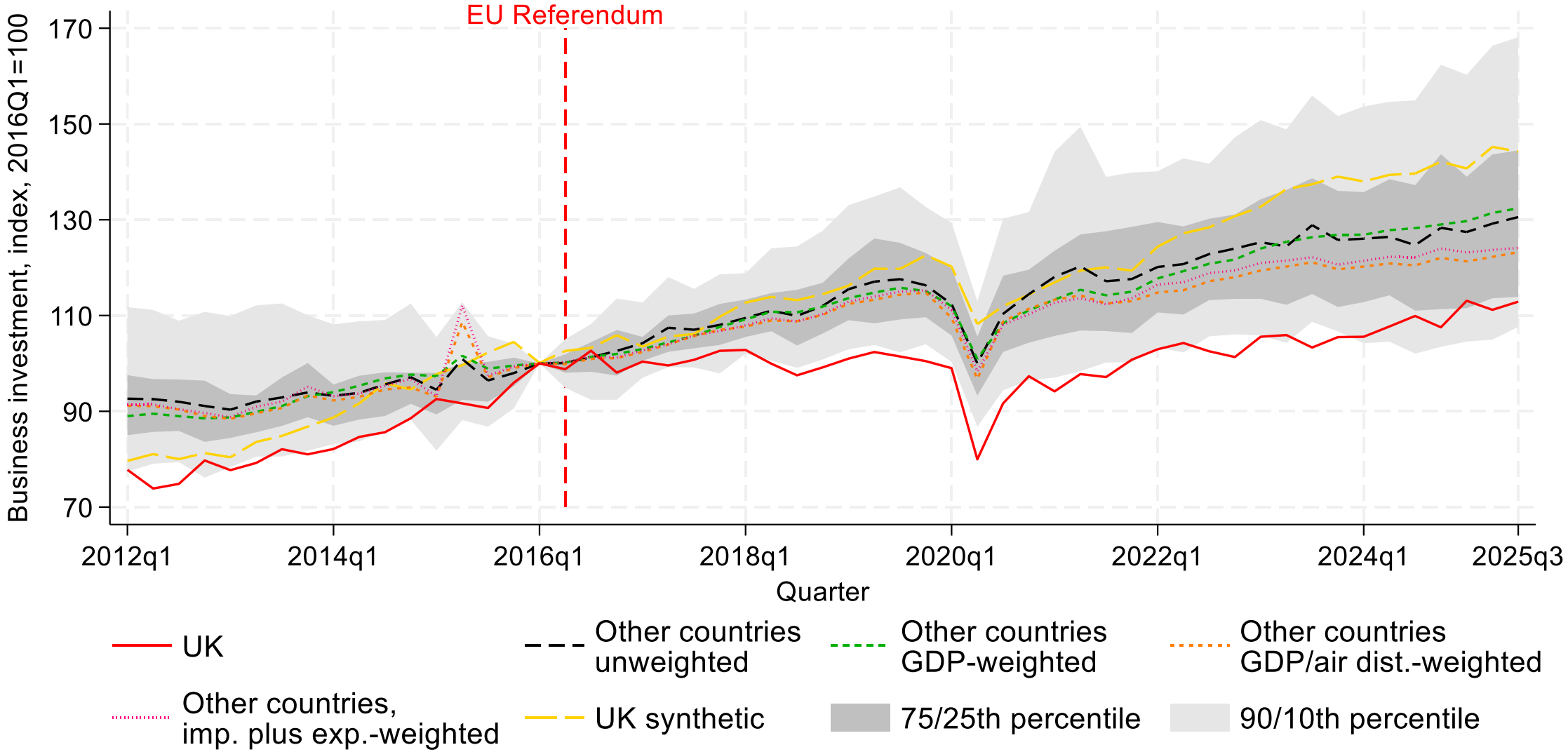
Notes: Estimates for employment, productivity and GDP are for the whole economy. Whole economy micro estimates for employment and productivity are constructed by scaling private sector estimates by their share in whole economy employment. Productivity impacts are based on TFP estimates for the micro estimates and labour productivity for the macro estimates. GDP micro-based estimates are constructed by combining TFP, employment and capital impact estimates. Capital impacts are estimated from investment impacts by assuming that annual investment is equivalent to 6% of the capital stock and a depreciation rate of 4%, in line with official data. The macro estimates represent the average of the UK relative to 5 different comparator country metrics: GDP weighted; GDP/air distance weighted; UK trade weighted; formal synthetic control; and simple unweighted. Investment macro impacts are for 2025 Q1 to 2025 Q3 rather than 2025 Q1 to 2025 Q4.

Figure 1: GDP per capita cross-country comparison



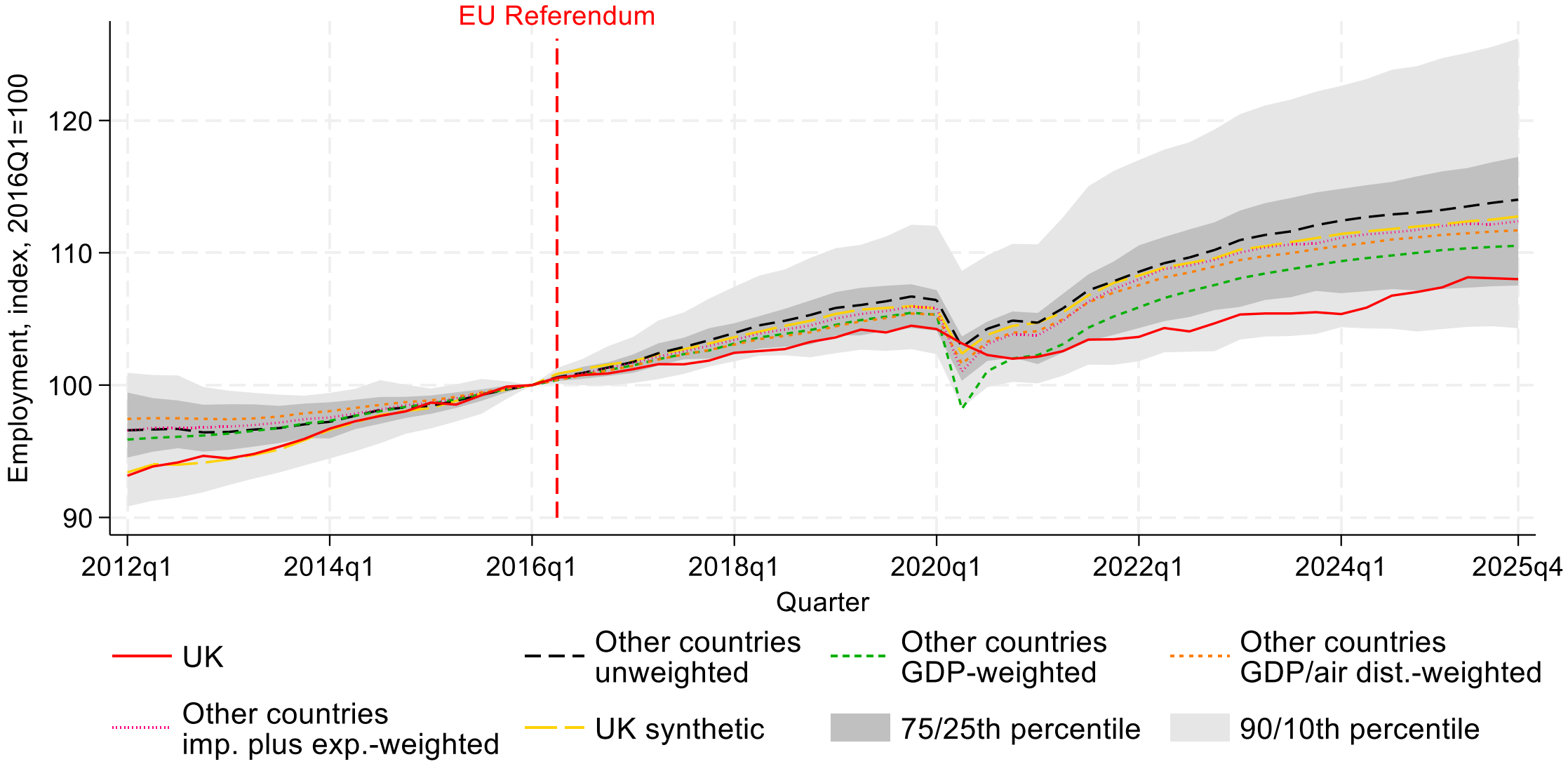
Notes: The figure uses data on real gross domestic product per person in the population. Comparator countries are US, Canada, EU-27 countries, Iceland, Norway, Switzerland, and Japan. All series used in the calculations have been seasonally adjusted. The synthetic control method estimates the effect of the EU referendum on the UK's economy by comparing the evolution of GDP per capita for the UK to the evolution of GDP per capita for a synthetic control group. We use data starting from 2006Q1 up to the EU referendum (2016Q2, 41 periods) to obtain optimal weights that minimize the prediction error in the pre-referendum period. To predict UK GDP per capita in the pre-referendum period we used GDP per capita, trade openess, investment ratio, educational attainment, and industry share in value added. Due to highly volatile time series we excluded Cyprus and Malta. For Ireland we use a measure of modified domestic demand rather than GDP because of distortons in the headline GDP data. The country weights are: US: 0.605, CAN: 0, AUS: 0, BEL: 0, BUL: 0, CRO: 0, CYP: 0, CZE: 0, DEN: 0, EST: 0.095, FIN: 0.016, FRA: 0, GER: 0, GRE: 0.111, HUN: 0, IRE: 0.041, ITA: 0.056, LAT: 0, LIT: 0.042, LUX: 0, MAL: 0, NET: 0, POL: 0, POR: 0, ROM: 0, SLK: 0, SLO: 0, SPA: 0, SWE: 0, ICE: 0.035, NOR: 0, CHE: 0, JAP: 0. Percentiles were estimated using the bootstrapping method. The minimum average *annual* growth in GDP per head post-2016 was -0.2%, the maximum was 4.2% and the standard deviation was 1.2%. Minimum average *quarterly* growth in GDP per head post-2016 was -0.1%, the maximum was 1%, and the standard deviation was 0.3%. Sources: OECD, Irish Central Statistics Office and World Bank.

Figure 2: Business investment cross-country comparison



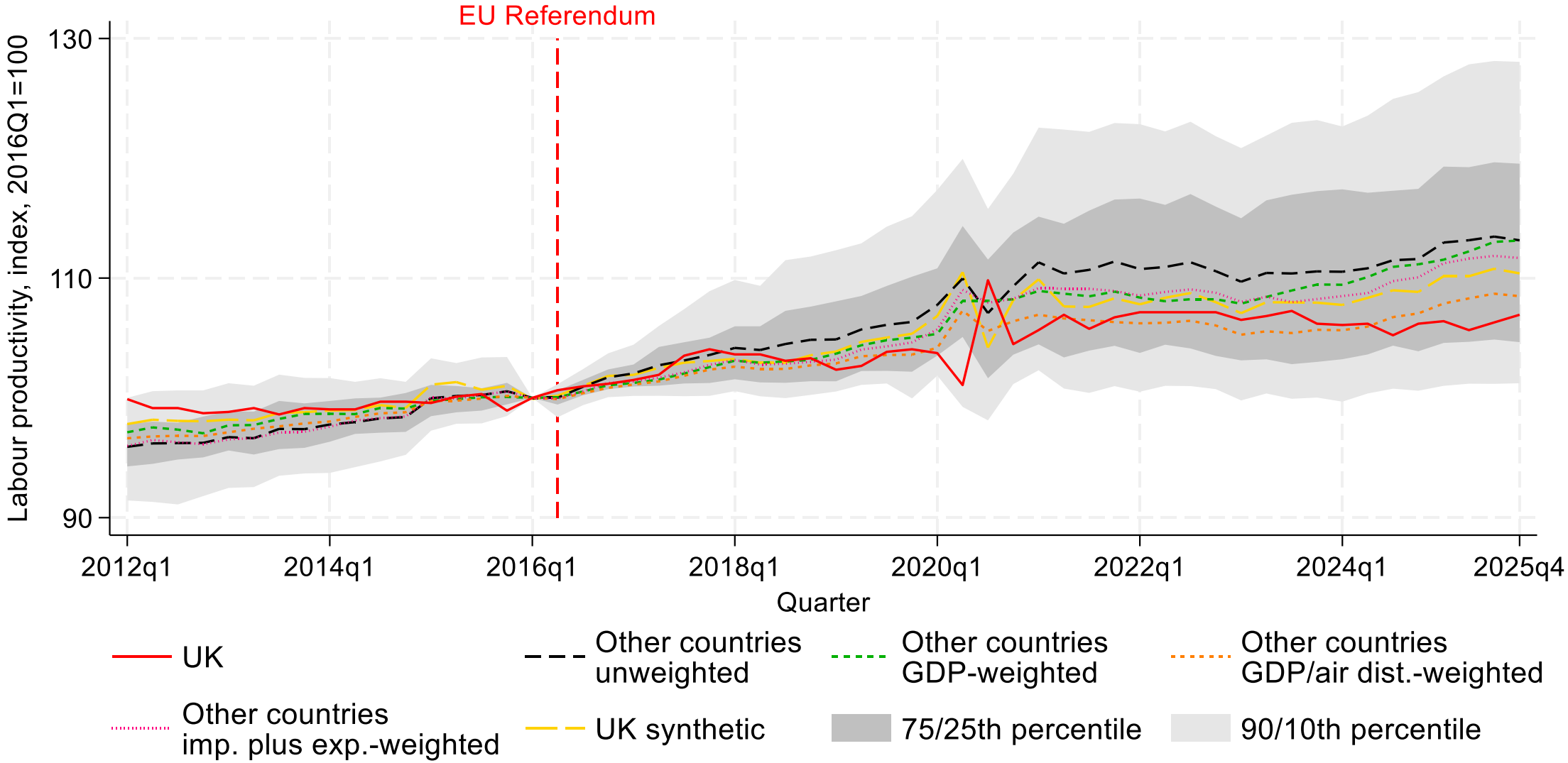
Notes: Investment is defined as business non-residential gross fixed capital formation. Comparator countries are US, Canada, EU-27 countries, Iceland, Norway, Switzerland, and Japan. All series used in the calculations have been seasonally adjusted. The synthetic control method estimates the effect of the EU referendum on the UK's economy by comparing the evolution of UK investment to the evolution of investment for a synthetic control group. We use data starting from 2006Q1 up to the EU referendum (2016Q2, 41 periods) to obtain optimal weights that minimize the prediction error in the pre-referendum period. To predict business investment in the UK in the pre-referendum period we used the values of business investment in other countries in that period. Not included in the estimation were Cyprus, Estonia, Ireland, and Malta due to highly volatile data. For Belgium the series used includes residential investment. The country weights are: US: 0.026, CAN: 0.026, AUS: 0.025, BEL: 0.028, BUL: 0.018, CRO: 0.022, CYP: 0.027, CZE: 0.024, DEN: 0.024, EST: 0.02, FIN: 0.028, FRA: 0.026, GER: 0.025, GRE: 0.193, HUN: 0.036, IRE: 0.01, ITA: 0.033, LAT: 0.014, LIT: 0.031, LUX: 0.03, MAL: 0.018, NET: 0.028, POL: 0.018, POR: 0.033, ROM: 0.014, SLK: 0.02, SLO: 0.026, SPA: 0.025, SWE: 0.026, ICE: 0.04, NOR: 0.025, CHE: 0.03, JAP: 0.03. Percentiles were estimated using the bootstrapping method. Sources: ONS, U.S. Bureau of Economic Analysis, Statistics Canada, Eurostat and OECD.

Figure 3: Employment cross-country comparison



Notes: Employment is the number of the employed people in the population aged 15 and over. Comparator countries are US, Canada, EU-27 countries, Iceland, Norway, Switzerland, and Japan. All series used in the calculations have been seasonally adjusted. The synthetic control method estimates the effect of the EU referendum on the UK's economy by comparing the evolution of UK employment to the evolution of employment for a synthetic control group. We use data starting from 2006Q1 up to the EU referendum (2016Q2, 41 periods) to obtain optimal weights that minimize the prediction error in the pre-referendum period. To predict employment in the UK in the pre-referendum period we used employment in other countries in that period. The country weights are: US: 0.009, CAN: 0.011, AUS: 0.009, BEL: 0.008, BUL: 0.008, CRO: 0.014, CYP: 0.004, CZE: 0.011, DEN: 0.007, EST: 0.012, FIN: 0.006, FRA: 0.009, GER: 0.011, GRE: 0.019, HUN: 0.403, IRE: 0.005, ITA: 0.006, LAT: 0.002, LIT: 0.002, LUX: 0.022, MAL: 0.04, NET: 0.007, POL: 0.019, POR: 0.006, ROM: 0.007, SLK: 0.01, SLO: 0.008, SPA: 0.005, SWE: 0.013, ICE: 0.006, NOR: 0.278, CHE: 0.017, JAP: 0.009. Percentiles were estimated using the bootstrapping method. Sources: U.S. Bureau of Labor Statistics, OECD, Eurostat and Swiss Federal Statistical Office. .

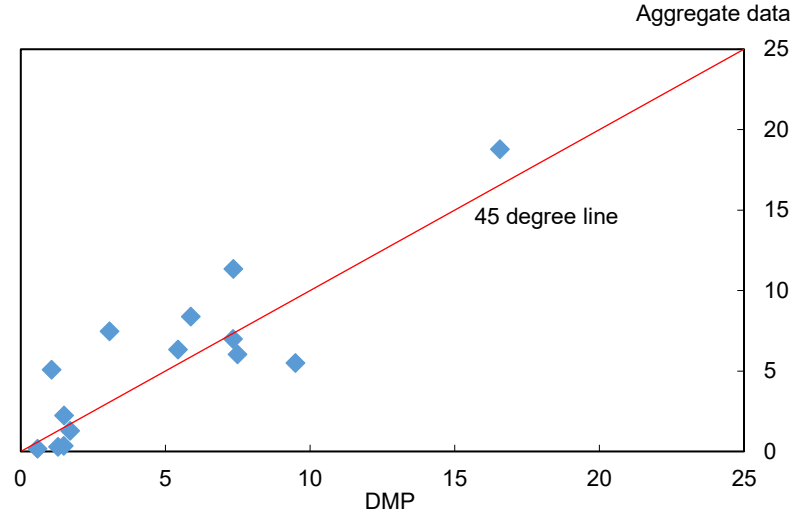
Figure 4: Labor productivity cross-country comparison



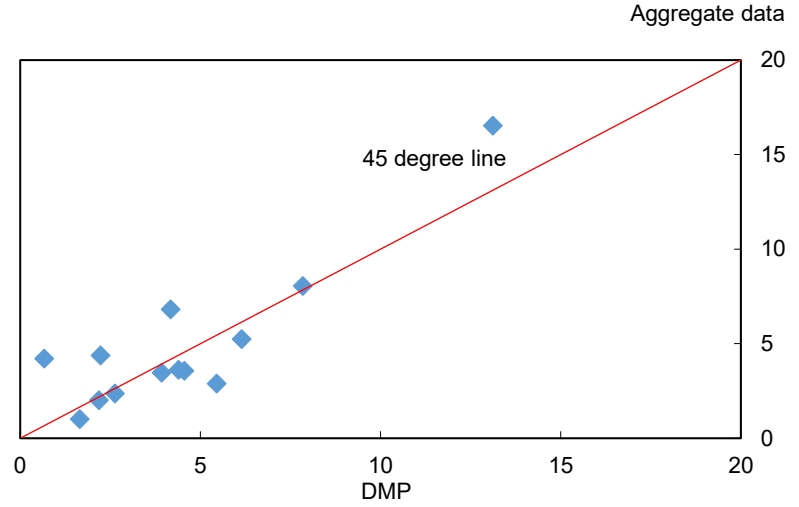
Notes: Labour productivity defined as real output per hour worked. Comparator countries are US, Canada, EU-27 countries, Iceland, Norway, Switzerland, and Japan. All series used in the calculations have been seasonally adjusted and some series have been calendar adjusted too. The series for Canada measures business sector labour productivity. The series for Japan was constructed using measures of productivity in services, manufacturing, construction and mining sectors weighted by the size of each sector in terms of their contributions to GDP. The synthetic control method estimates the effect of the EU referendum on the UK's economy by comparing the evolution of UK labor productivity to the evolution of labor productivity for a synthetic control group. We use data starting from 2006Q1 up to the EU referendum (2016Q2, 41 periods) to obtain optimal weights that minimize the prediction error in the pre-referendum period. To predict labor productivity in the UK in the pre-referendum period we used labor productivity in other countries in that period. The country weights are: US: 0.023, CAN: 0.028, AUS: 0.026, BEL: 0.03, BUL: 0.017, CRO: 0.025, CYP: 0.03, CZE: 0.025, DEN: 0.026, EST: 0.02, FIN: 0.031, FRA: 0.028, GER: 0.027, GRE: 0.191, HUN: 0.031, IRE: 0.012, ITA: 0.034, LAT: 0.014, LIT: 0.02, LUX: 0.035, MAL: 0.017, NET: 0.029, POL: 0.016, POR: 0.029, ROM: 0.012, SLK: 0.017, SLO: 0.028, SPA: 0.023, SWE: 0.029, ICE: 0.029, NOR: 0.033, CHE: 0.028, JAP: 0.036. Percentiles were estimated using the bootstrapping method. Sources: Eurostat, OECD, ONS, Statistics Canada, Japan Productivity Center.

Figure 5: Measures of pre-referendum exposure to the EU

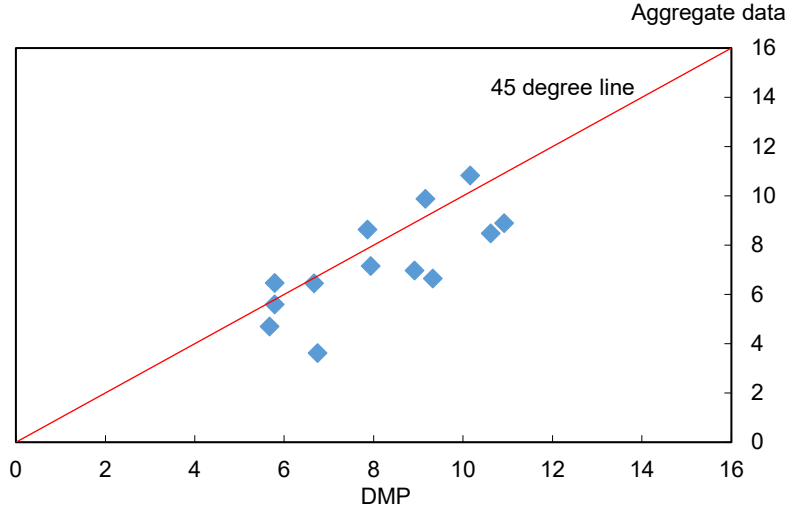
Percentage of sales that were exports to the EU, by industry



Percentage of costs that were imports from the EU, by industry



Percentage of EU migrants in workforce, by industry

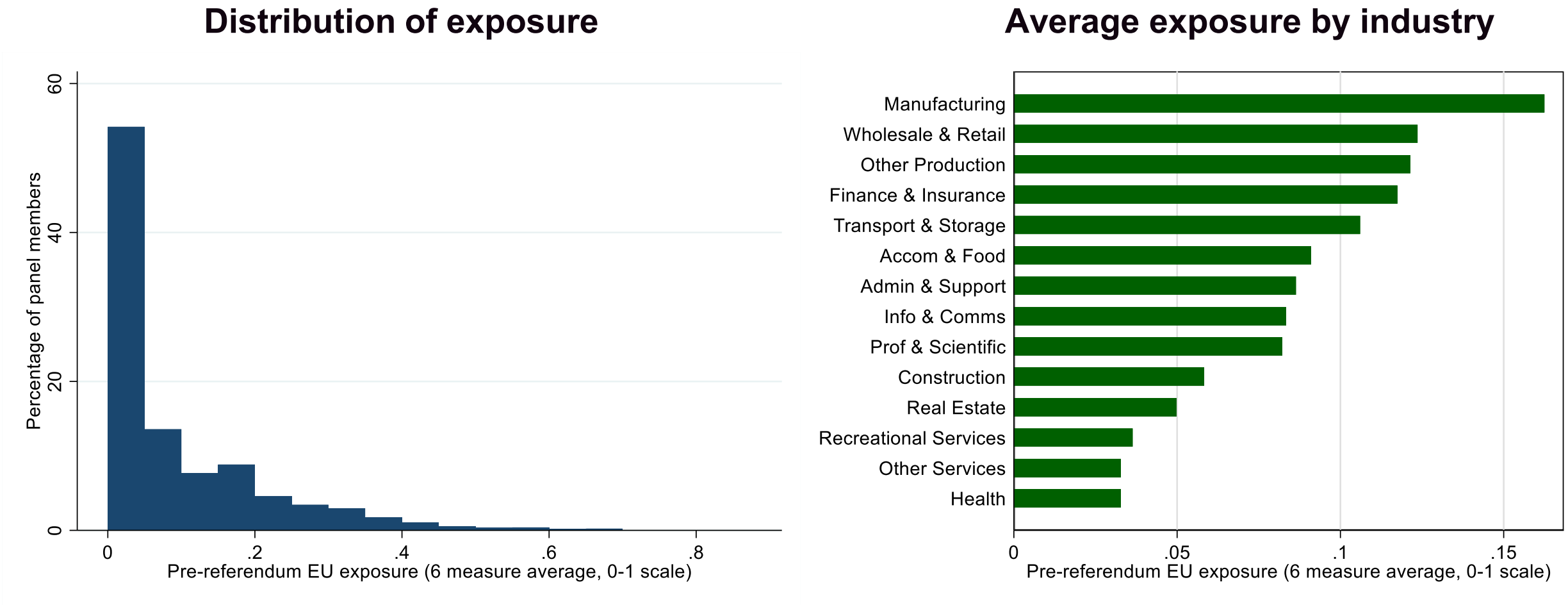


Aggregate statistics

	DMP	Aggregate data
Percentage of sales that were exports to EU	7.0%	7.4%
Percentage of costs that were imports from EU	8.9%	6.9%
- Excluding wholesale and retail	7.1%	7.4%
Percentage of EU migrants in workforce	9.1%	8.1%

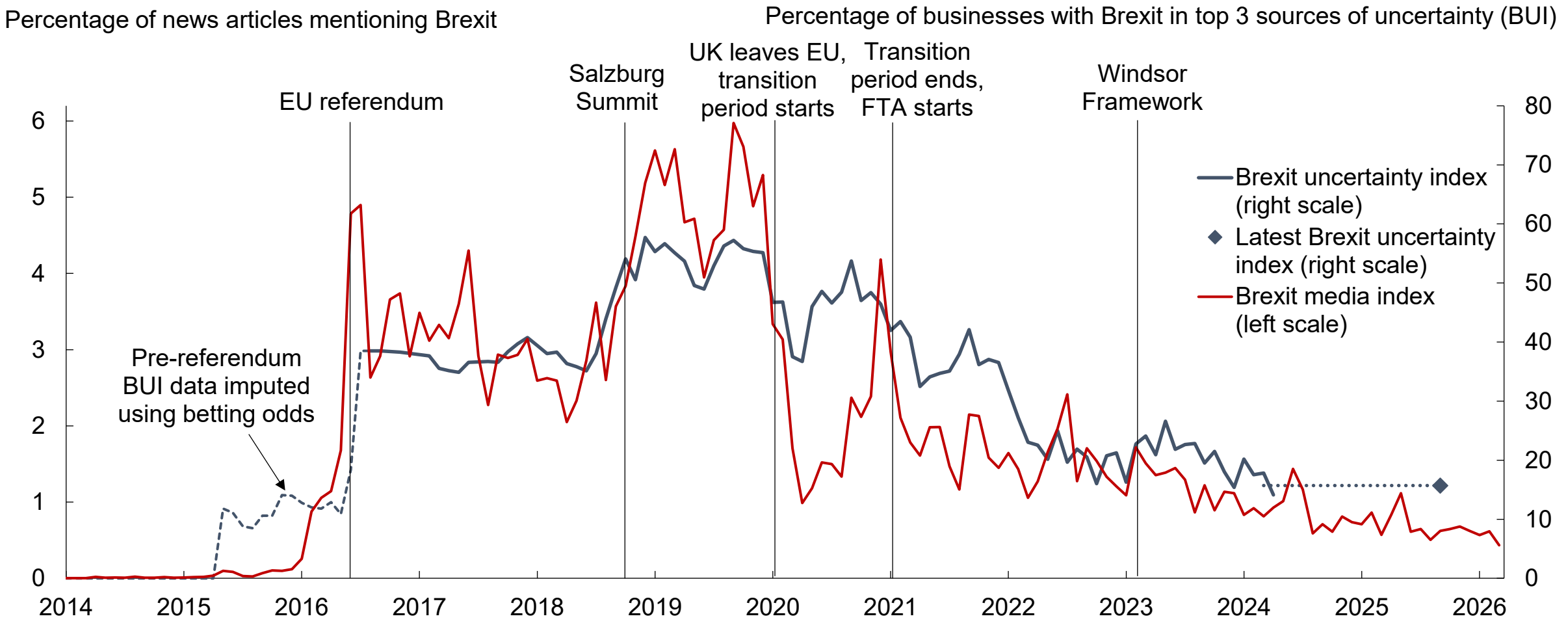
Notes: DMP data on the percentage of sales that were exports to the EU, percentage of costs that were imports from the EU and percentage of employees who were EU migrants are for 2016 Q1. Aggregate data on the percentage of sales that were exports to the EU and the percentage of costs that were imports from the EU are for 2015. They are calculated from the ONS 2015 Input-Output tables and are for the market sector. Imports as a percentage of costs are imports that are used for intermediate consumption. The share of imports used for intermediate consumption that are from the EU in each industry is assumed to be the same as the share of EU imports in total imports in that industry. The industry scatter plot for imports excludes wholesale and retail, where aggregate data only capture imports in the provision of wholesales and retail services, whereas the DMP data are also likely to be capturing the import content of good sold. Aggregate data on the percentage of employees who were EU migrants are for 2016 H1. They are calculated from the ONS Labour Force Survey and are the percentage of employees who report working in the private sector who were born in the EU. Sources: Decision Maker Panel and ONS.

Figure 6: Pre-referendum exposure to the EU



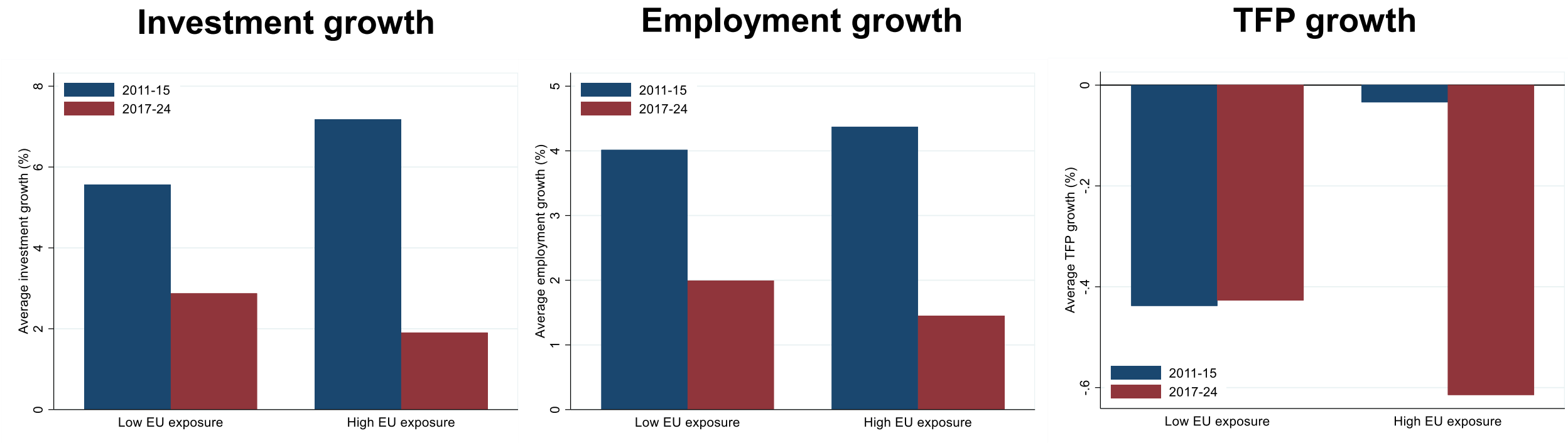
Notes: EU exposure is the average of the following 6 exposure measures: share of sales to EU; share of costs from EU imports; share of EU migrants in workforce; share of sales covered by EU regulations; share of directors who are EU nationals; and a dummy for being EU owned. All are on a 0-1 scale. DMP data for all exposure variables, except share of directors who are EU nationals and ownership which are from the Bureau Van Dijk FAME database. EU exposure measures are for 2016 Q1, just before the Brexit referendum, except for directors and ownership data which are for 2015.

Figure 7: Brexit uncertainty index and Brexit media index



Notes: Brexit uncertainty index shows the percentage of DMP survey respondents who view Brexit as their "top" or "one of their top three" sources of uncertainty in response to the question 'How much has the result of the EU referendum affected the level of uncertainty affecting your business?'. Values are interpolated for some months before August 2018 when the question was not asked. Final diamond is for August and September 2025. The Brexit uncertainty question was not asked between April 2024 and July 2025. Brexit media index is the percentage of articles in British newspapers which mention the term 'Brexit' in each month. Sources: Access World News' News-Bank and Decision Maker Panel.

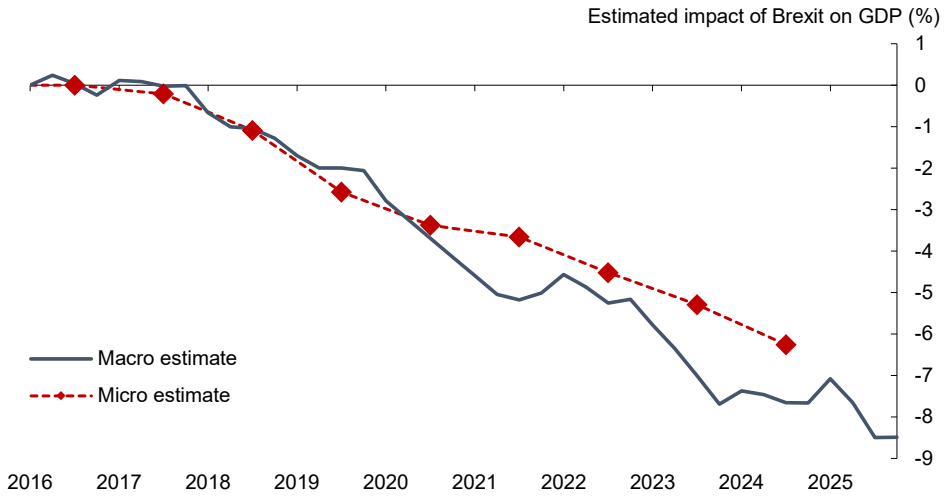
Figure 8: Investment, employment and productivity growth by EU exposure



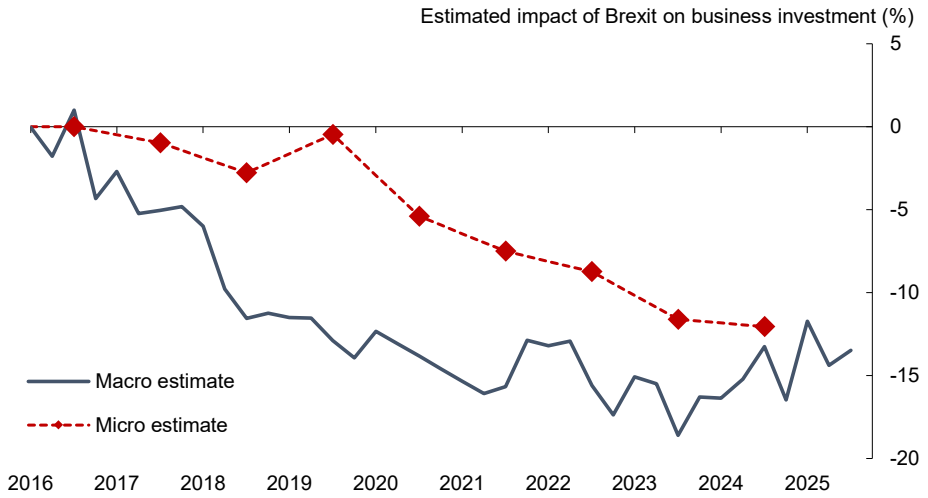
Notes: High EU exposure is defined as firms with above average pre-referendum exposure to the EU, based on the average of the following 6 exposure measures: share of sales to EU; share of costs from EU imports; share of EU migrants in workforce; share of sales covered by EU regulations; share of directors who are EU nationals; and a dummy for being EU owned. All are on a 0-1 scale. Low EU exposure is defined as having below average pre-referendum exposure on the same metric. Data are for financial years, which are defined from Q3 to Q2 in next calendar year, so 2017 represents 2017/18 and would cover firms with a financial year end between 2017 Q3 and 2018 Q2.

Figure 9: Estimated impact of Brexit

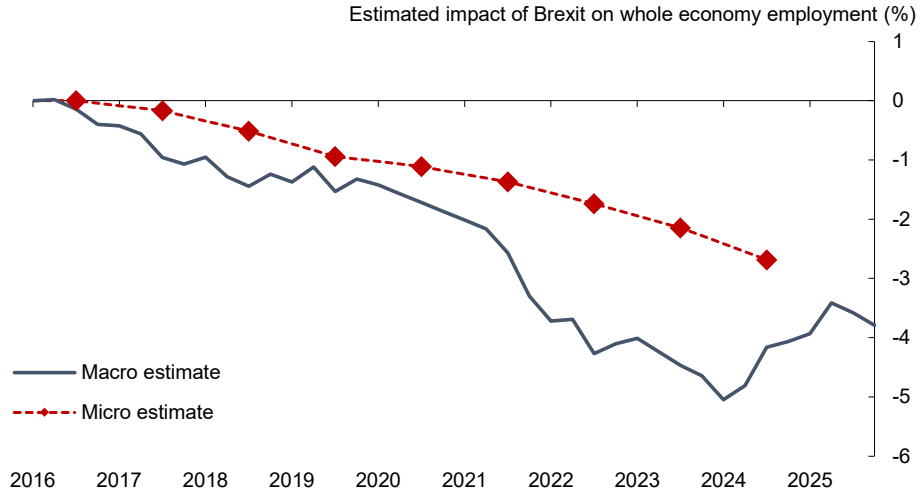
GDP



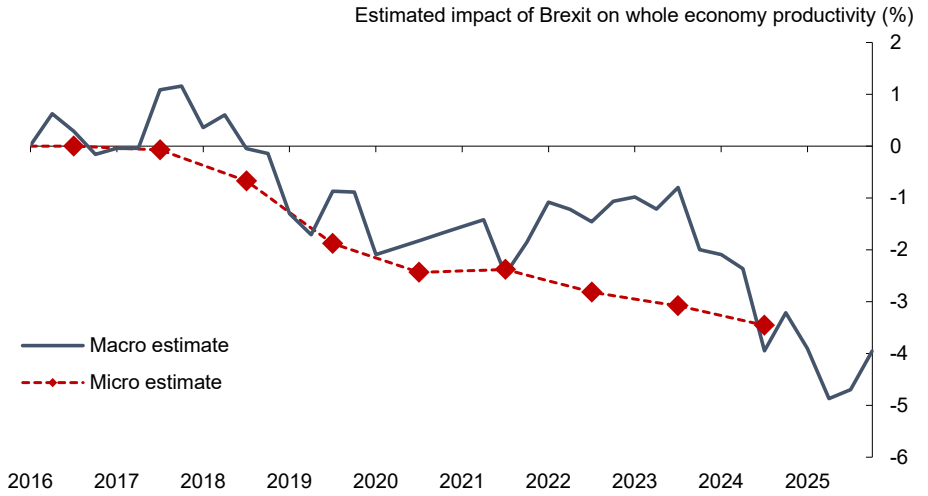
Business investment



Whole economy employment

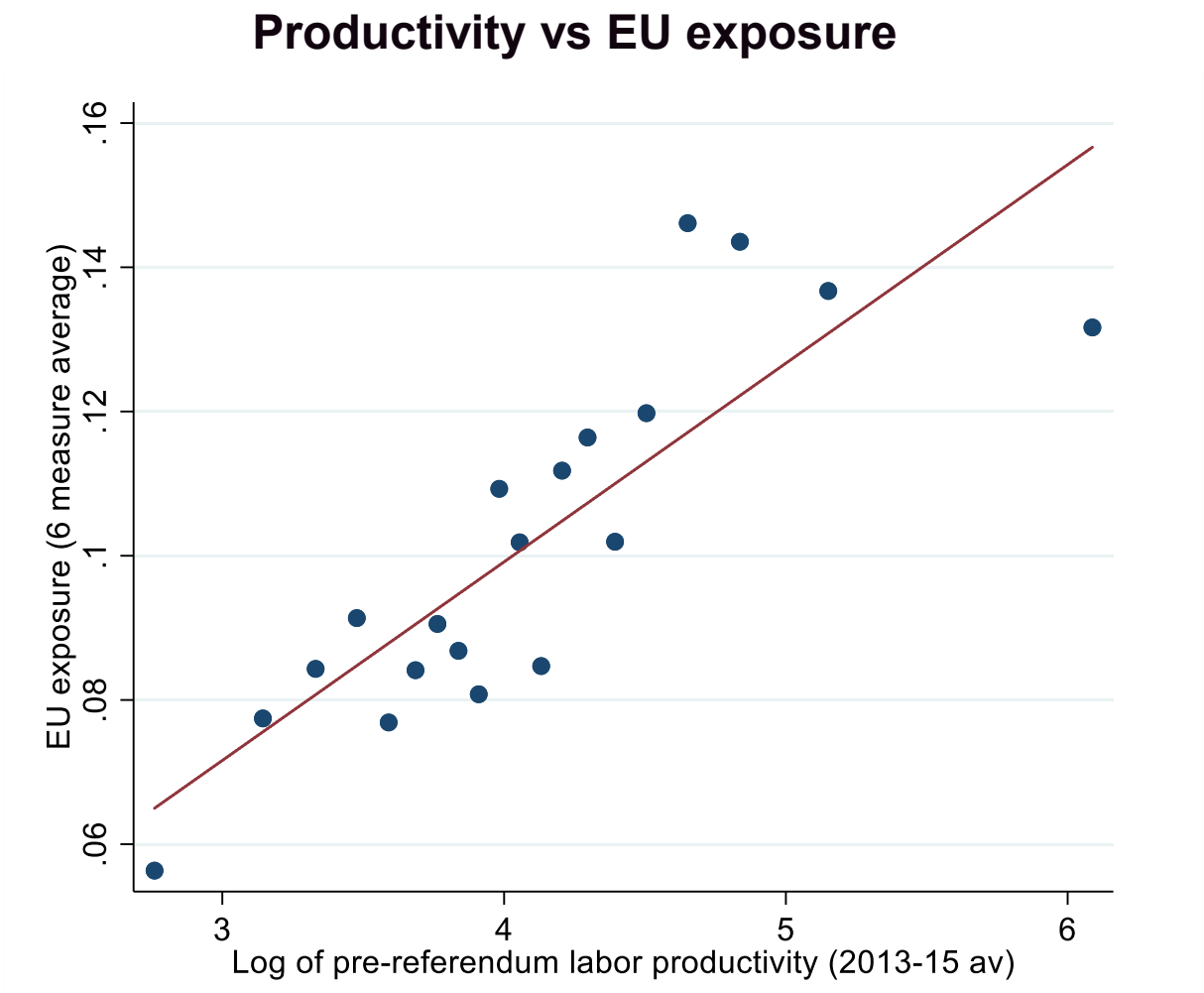


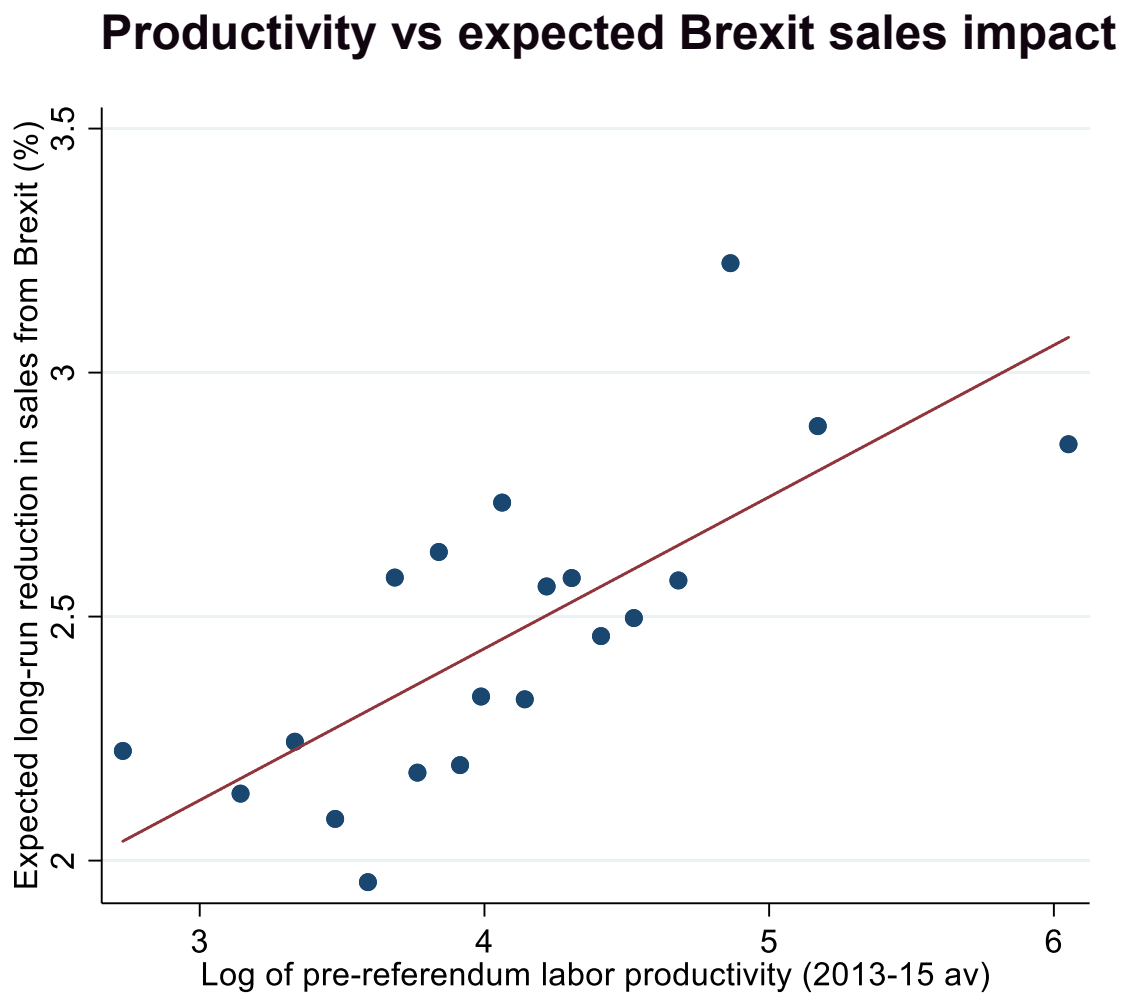
Whole economy productivity



Notes: Estimates for employment, productivity and GDP are for the whole economy. Whole economy micro estimates for employment and productivity are constructed by scaling private sector estimates by their share in whole economy employment. Productivity impacts are based on TFP estimates for the micro estimates and labor productivity for the macro estimates. GDP micro-based estimates are constructed by combining TFP, employment and capital impact estimates. Capital impacts are estimated from investment impacts by assuming that annual investment is equivalent to 6% of the capital stock and using a depreciation rate of 4%. Micro estimates are annual and are for financial years (shown as red diamonds which are plotted for Q3). Macro estimates are quarterly. The macro estimates represent the average of the UK relative to 5 different comparator country metrics: GDP weighted; GDP/air distance weighted; UK trade weighted; formal synthetic control; and simple unweighted. Macro estimates for 2020 Q2 to 2021 Q1 are calculated by interpolating between estimates for 2020 Q1 and 2021 Q2 to smooth through the impact of the Covid-19 pandemic.

Figure 10: Pre-referendum labor productivity and EU exposure

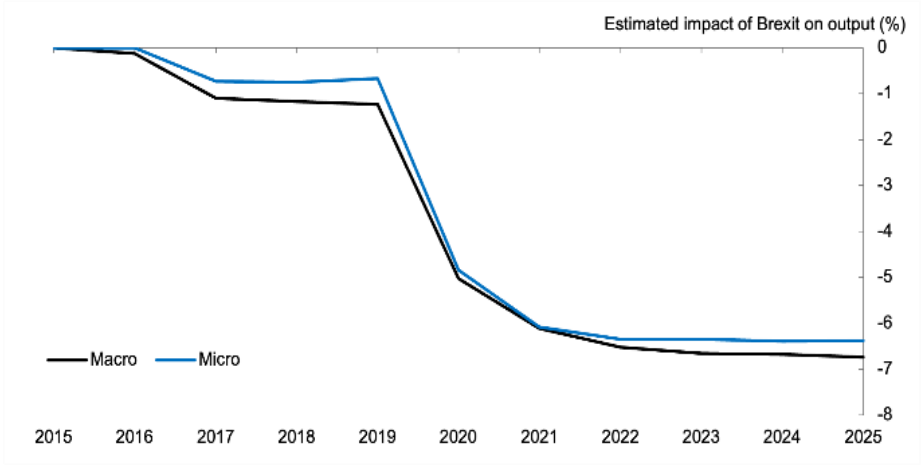




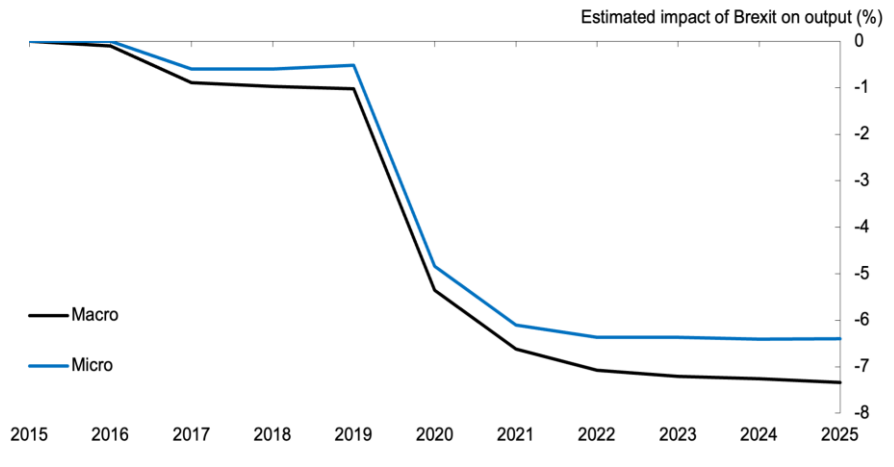
Notes: EU exposure is the average of the following 6 exposure measures: share of sales to EU; share of costs from EU imports; share of EU migrants in workforce; share of sales covered by EU regulations; share of directors who are EU nationals; and a dummy for being EU owned. All are on a 0-1 scale. DMP data for all exposure variables, except share of directors who are EU nationals and ownership which are from the Bureau Van Dijk FAME database. EU exposure measures are for 2016 Q1, just before the Brexit referendum, except for directors and ownership data which are for 2015. Brexit sales impact the is average expected long-run reduction in sales from Brexit, per firm, as collected in DMP surveys between February 2017 and April 2024. Missing values for Brexit sales impact in a given survey year are imputed from a regression using time and firm fixed effects. Pre-referendum labor productivity defined as the annual real value-added per employee in £ thousands (2013-2015 average) and is calculated using accounts data from the Bureau van Dijk FAME dataset. The figure shows binscatter plots which split responses into 25 groups according to average pre-referendum labor productivity. Sources: Bureau van Dijk FAME and Decision Maker Panel.

Figure 11: Simulated macro and micro estimates of the Brexit impact

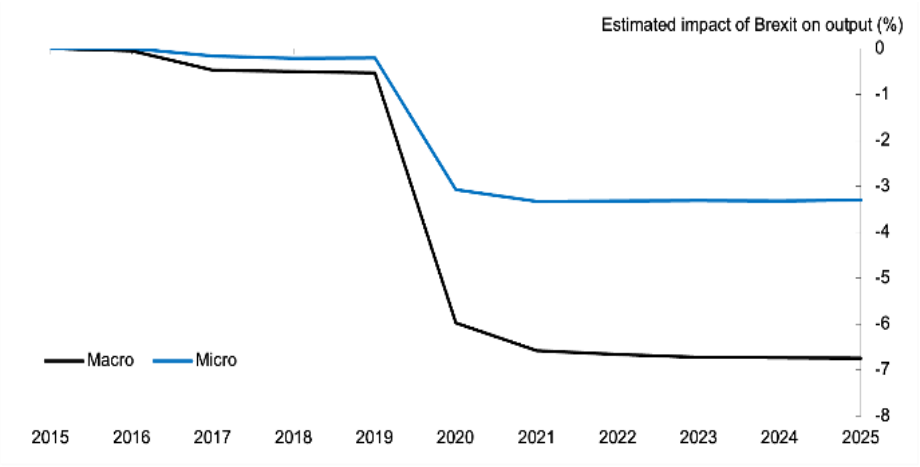
Model A: No spillovers, no reallocation



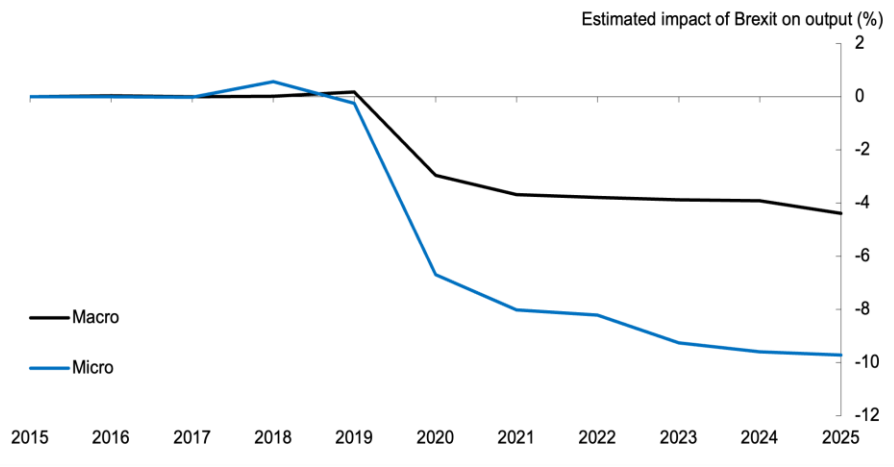
Model B: Reallocation only



Model C: Negative demand and supply chain spillovers

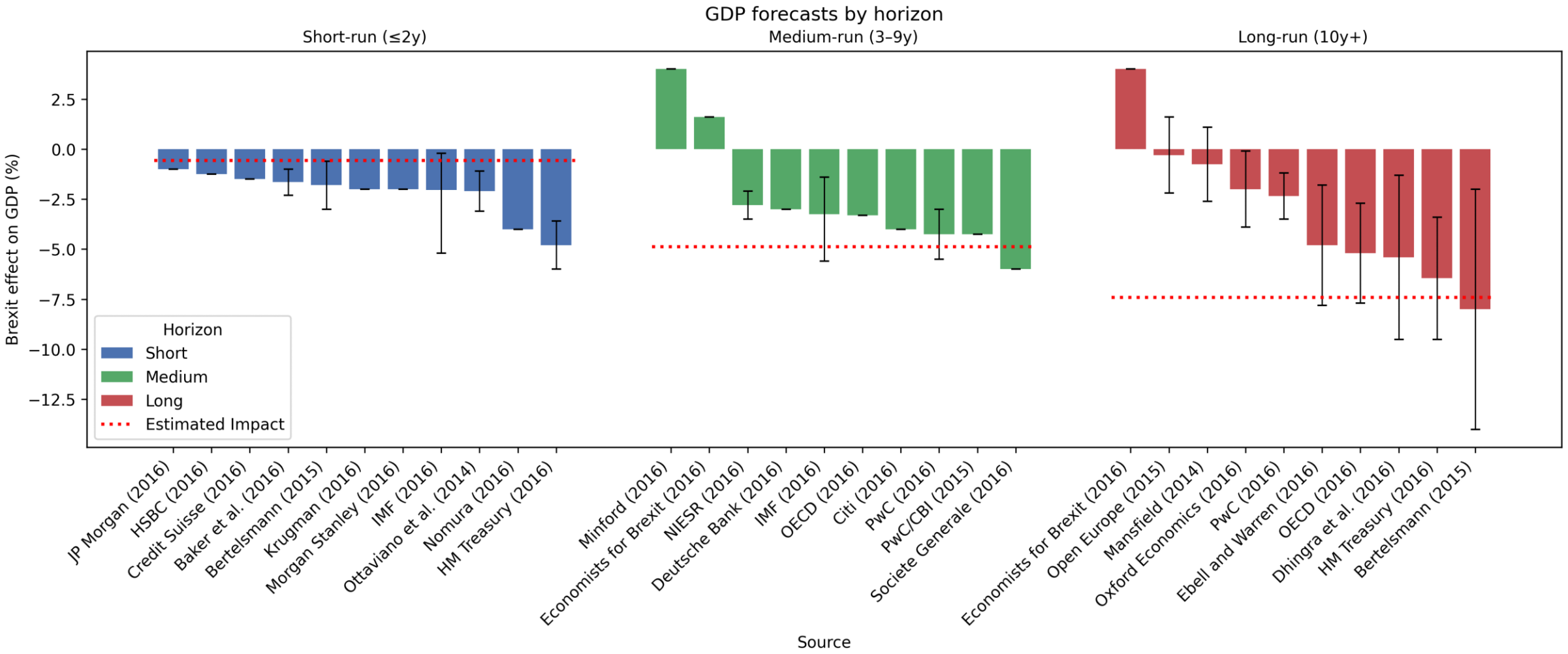


Model D: Positive labor market spillovers



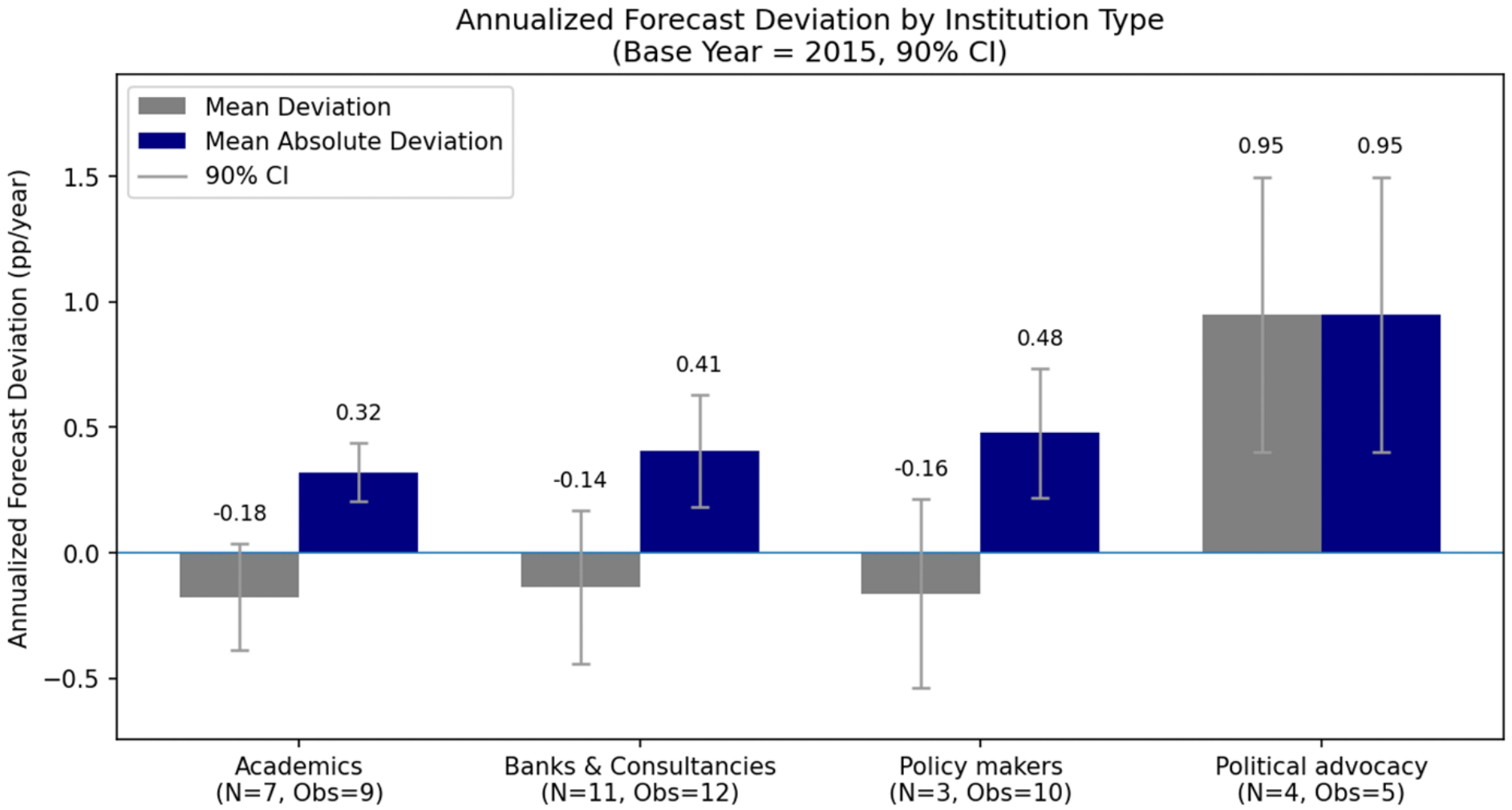
Notes: Simulated macro and micro estimates of the Brexit impact on output under four model specifications. Macro estimates show aggregate output in the Brexit scenario relative to a counterfactual of no Brexit. Micro estimates are based on simulated firm-level data and applying the same empirical specification as the main micro analysis in this paper that involves comparing the performance of firms according to their pre-referendum exposure to the EU. In Model A, firms are effectively independent and there are no spillovers. In Model B, there is reallocation from higher productivity Brexit exposed firms to lower productivity firms with lower exposure. In Model C, negative demand and supply chain spillovers are introduced (with no reallocation). In Model D, the only spillovers are positive ones through the labor market where labor demand from Brexit exposed firms pushes down the equilibrium wage, benefiting the less exposed firms (again with no reallocation).

Figure 12: Predictions of the impact of Brexit on UK GDP



Notes: Bars indicate institutions' forecast of the percentage impact of Brexit on UK GDP, taking the unweighted mean if multiple estimates are provided for different scenarios. Where an institution reports multiple forecasts for a given time horizon, we combine these and report the mean, min, and max of all observations in the time-horizon. The capped stalks denote the minimum and maximum forecast recorded in the specified time period by the institution. We source bank forecasts from Emmerson et al. (2016) (Société Générale, PWC/CBI, Nomura, Citi, Deutsche Bank, Morgan Stanley, Credit Suisse, HSBC, JP Morgan), and originally sourced from the JP Morgan research note, Machie (2016). Short-run forecast are estimates of the impact of Brexit on UK GDP 1-2 years after the referendum. Medium-run forecasts are estimates of the impact 3 to 9 years ahead, and long-run forecasts are for 10 years+. All forecasts shown were made around the time of the referendum. Red dotted lines show the estimated impacts from this paper, based on the average of the micro and macro estimates: long-term estimates uses latest available estimate, micro (financial year 2024/25) and macro (year to 2025 Q4).

Figure 13: Deviations of estimated Brexit GDP impacts from forecasters' earlier predictions



Notes: Forecast deviation is defined as each institution's original prediction less the unweighted mean of our micro- and macro-based predictions for the corresponding time horizon. This is normalised to give the annualized forecast deviation by dividing the total deviation by forecast horizon relative to the year of publication. For each institution group, we take an unweighted average over forecast observations. Where an institution reports multiple forecasts for a given time horizon, we combine these and report the mean, min, and max of all observations in the time-horizon. Error bars represent 90% confidence intervals computed across forecasts within each group. Institutions are grouped as follows. Banks (Citi, Deutsche Bank, Morgan Stanley, Credit Suisse, HSBC, JP Morgan, Nomura, Societe Generale). Consultancies (PwC, PwC/CBI, Oxford Economics). Policy makers (HM Treasury (2016), IMF (2016), OECD (2016)). Academics include university-based researchers and research institutes (Krugman (2016), Baker et al. (2016), Ottaviano et al. (2014), Dhingra et al. (2016), Ebell and Warren (2016), NIESR, Bertelsmann (2015)). Political advocacy (Economists for Brexit, Open Europe, Minford (2015), Mansfield (2014)). Number of institutions (N), observations (Obvs). Note that where N < Obvs, the institution has produced separate forecasts for multiple years.

Appendix

APPENDIX: MODEL DETAILS

This appendix provides the full specification of the general equilibrium model summarised in Section 5.1 of the main text.

The Goods Market

Consumption, investment, and intermediate goods are all CES aggregates of differentiated varieties $z \in [0,1]$:

$$X_t = \left[\int_0^1 x_t(z)^{\frac{\theta-1}{\theta}} dz \right]^{\frac{\theta}{\theta-1}} \tag{1}$$

where $x \in \{c,m,i,y\}$ denotes consumption, intermediates, investment, and output respectively, and capital letters denote aggregates. The parameter $\theta > 1$ is the elasticity of substitution between varieties.

Standard results imply that firms face an isoelastic demand curve for their output:

$$y_t(z) = Y_t p_t(z)^{-\theta} \tag{2}$$

where $y_t(z) = c_t(z)+i_t(z)+m_t(z)$ is total demand for variety z, and $p_t(z)$ is its relative price. The aggregate price index is normalised to unity.

Firms

Technology

There is a continuum of firms of measure one, indexed by z. Time t is discrete (quarters). Each firm employs capital k, labor n, and intermediates m to produce its own variety of output:

$$y_t(z) = A_t(z)k_t(z)^{\alpha}n_t(z)^{\nu}m_t(z)^{\mu}, \qquad \text{where} \quad \alpha + \nu + \mu < 1 \tag{3}$$

The assumption of decreasing returns to scale is standard in the literature on heterogeneous firms with monopolistic competition, reflecting the presence of fixed factors such as managerial talent or organisational capital. Total factor productivity $A_t(z)$ is a composite of three components:

$$A_t(z) = (1 - \tau_t(z))\Lambda(z)\tilde{A}_t(z) \tag{4}$$

where $\tau_t(z) \in [0,1)$ is a firm-specific Brexit cost (described below), $\Lambda(z)$ is a time-invariant productivity type, and $\tilde{A}_t(z)$ is an idiosyncratic productivity shock. The latter follows an AR(1) process in logs:

$$\ln\tilde{A}_t(z) = \rho\ln\tilde{A}_{t-1}(z) + \sigma_Z\varepsilon_t(z), \qquad \varepsilon_t(z) \sim N(0,1) \tag{5}$$

We allow for heterogeneity in the time-invariant component $\Lambda(z)$, with some firms being persistently more productive than others. This captures the empirical regularity that more productive firms tend to be more internationally exposed and hence more likely to be affected by Brexit.

Capital Adjustment Costs

Each firm's capital stock evolves according to the standard law of motion:

$$k_{t+1}(z) = (1 - \delta_k)k_t(z) + i_t(z) \tag{6}$$

where δ_k is the depreciation rate and $i_t(z)$ denotes gross investment. Capital adjustment is subject to partial irreversibility: if installed capital is sold, this occurs at a discount $S \in (0,1)$ to the purchase price. The adjustment cost function is:

$$AC_t^k(z) = S|i_t(z)| \cdot \mathrm{I}[i_t(z) < 0] \tag{7}$$

This asymmetric adjustment cost generates the option-value effects that are central to the investment uncertainty relationship emphasised by Bernanke (1983) and Bloom (2009).

The Firm's Problem

Firms choose investment, intermediates, and labor to maximise the present discounted value of profits. Let $V(k,A,\tau,\tilde{}\ \Lambda;M,\Omega)$ denote the value function, where the state variables are: (i) the firm's capital stock k; (ii) idiosyncratic productivity $A\tilde{}$; (iii) the Brexit cost τ; (iv) the firm's permanent type Λ; (v) the aggregate Brexit state M; and (vi) the joint distribution of firm-level states Ω. The Bellman equation is:

$$\begin{aligned} V(k, \tilde{A}, \tau, \Lambda; M, \Omega) = \max_{i,n,m} \Big\{ & p(z)y(z) - W(\Omega)n - m - i - AC^k(i) \\ & + \beta \mathbb{E}\left[V(k', \tilde{A}', \tau', \Lambda; M', \Omega') \right] \Big\} \end{aligned} \tag{8}$$

subject to the production function (**3**), the demand curve (**2**), the capital law of motion (**6**), and the adjustment cost (**7**). The distribution evolves according to $\Omega' = \Gamma(M,\Omega)$.

Given that capital is predetermined within the period, firms effectively solve two separable problems: a static problem choosing output (and hence labor and intermediates) given capital, and a dynamic problem choosing investment. The static problem yields factor demands as

functions of capital, productivity, and aggregate variables, which we substitute into the dynamic problem.

Households

The economy is populated by a unit measure of identical households who choose consumption C, labor supply N, and firm ownership shares ψ' to maximise lifetime utility:

$$W(M,\Omega) = \max_{C,N,\psi'} \left\{ U(C,N) + \beta \mathbb{E}\left[W(M',\Omega') \right] \right\} \tag{9}$$

subject to the budget constraint:

$$C + \int q(k',\tilde{A},\tau;M,\Omega)\, d\psi'(k',\tilde{A},\tau) \leq W(M,\Omega)N + \int \left[\pi(z) + p(z) \right] d\psi(z) \tag{10}$$

where $q(\cdot)$ is the price of firm shares, $\pi(z)$ denotes dividends, and $p(z)$ is the ex-dividend share price.

We specify period utility as quasi-linear in consumption:

$$U(C_t,N_t) = C_t - \theta_L N_t^{\eta}, \qquad \eta \geq 1 \tag{11}$$

where θ_L governs the disutility of labor and η is the inverse Frisch elasticity. This specification yields a constant discount factor β and, when $\eta = 1$, a time-invariant wage $W_t = \theta_L$. When $\eta > 1$, labor supply is upward-sloping in the wage, allowing for equilibrium wage adjustment in response to aggregate shocks.

The Brexit Process

Brexit is modelled as a three-state Markov process. The economy can be in one of three regimes: $M_t \in \{E,R,B\}$, denoting pre-referendum, post-referendum but pre-Brexit, and post-Brexit respectively. Transitions follow:

$$P = \begin{bmatrix} 1-\pi_{ER}-\pi_{EB} & \pi_{ER} & \pi_{EB} \\ \pi_{RE} & 1-\pi_{RE}-\pi_{RB} & \pi_{RB} \\ \pi_{BE} & \pi_{BR} & 1-\pi_{BE}-\pi_{BR} \end{bmatrix} \tag{12}$$

The post-referendum, pre-Brexit state R features two sources of aggregate uncertainty: whether the UK will ultimately leave the EU or reverse the referendum result, and the timing of either transition. This captures the prolonged period of policy uncertainty between June 2016 and January 2020.

At the point of transition from state R to state B, a fraction of firms are revealed to face a permanent productivity cost $\tau > 0$ for as long as the economy remains in state B. This represents increased costs of trade and sourcing inputs. The probability of incurring this cost varies with firm type:

$$\Pr(\tau_t(z) = \tau \mid M_t = B) = f(\Lambda(z), \tilde{A}_t(z)) \tag{13}$$

where $f(\cdot)$ is increasing in both arguments. This captures the empirical finding that more productive firms were more exposed to Brexit, reflecting their greater engagement in international trade, higher rates of EU ownership, and deeper integration with European supply chains.

Market Clearing

The economy is closed to international trade in goods and assets. Markets clear for each variety z and for labor:

$$y_t(z) = c_t(z) + i_t(z) + m_t(z) \quad \forall z \tag{14}$$

$$N_t^S = \int n_t(z)\, dz \tag{15}$$

where N_t^S is aggregate labor supply from households.

The closed economy assumption is a simplification that allows us to focus on domestic spillover mechanisms without tracking the real exchange rate. The firm-level Brexit cost τ can be interpreted as a reduced-form stand-in for the productivity losses associated with increased trade barriers, without explicitly modelling bilateral trade.

Spillover Mechanisms

The model features three channels through which Brexit can generate spillovers between firms.

Aggregate Demand Spillovers. The CES demand system implies that optimal firm-level output is increasing in aggregate output Y_t. When aggregate demand falls, each firm's residual demand curve shifts inward, reducing its profit-maximising output even if its own productivity is unchanged. When $\theta < \infty$, goods are imperfect substitutes and this demand externality is operative. As $\theta \to \infty$, goods become perfect substitutes, firm-level prices become independent of aggregate output, and demand spillovers vanish.

Supply Chain Spillovers. When $\mu > 0$, firms use the aggregate intermediate good as an input. A negative productivity shock to some firms raises the price of intermediates faced by all firms, reducing output even among those not directly affected. As $\mu \to 0$, the intermediate input share vanishes and supply chain spillovers disappear.

Labor Market Spillovers. When $\eta > 1$, labor supply is upward-sloping. If Brexit reduces labor demand by directly affected firms, the equilibrium wage falls, benefiting unaffected firms through lower input costs. This generates *positive* spillovers that partially offset the aggregate impact. When $\eta = 1$, labor supply is perfectly elastic at $W = \theta_L$, the wage is constant, and labor market spillovers are absent.

Nesting Special Cases. By taking parameters to their limits, we can isolate each spillover channel:

No spillovers: $\theta \to \infty$, $\mu = 0$, $\eta = 1$. Firms are independent; micro and macro estimates coincide.

Demand spillovers only: $\theta < \infty$, $\mu = 0$, $\eta = 1$. Negative spillovers through aggregate demand.

Supply chain spillovers only: $\theta \to \infty$, $\mu > 0$, $\eta = 1$. Negative spillovers through intermediates.

Wage spillovers only: $\theta \to \infty$, $\mu = 0$, $\eta > 1$. Positive spillovers through labor market adjustment.

Calibration

We calibrate the model at quarterly frequency. The table below reports baseline parameter values and sources.

Preferences and Technology. The discount factor $\beta = 0.95^{1/4}$ implies an annual real interest rate of approximately 5%. The capital share $\alpha = 0.25$ and labor share $\nu = 0.5$ are standard. The intermediate input share $\mu = 0.375$ matches aggregate input-output tables. Capital depreciates at 10% annually ($\delta_k = 0.026$ quarterly). The resale discount $S = 0.339$ follows Bloom (2009). The persistence and volatility of idiosyncratic productivity ($\rho = 0.95$, $\sigma_Z = 0.051$) are taken from Khan and Thomas (2008).

Brexit Parameters. The Brexit cost $\tau = 0.1$ represents a 10% productivity penalty for affected firms. We allow for four firm types varying in permanent productivity Λ and Brexit exposure probability. Types 1 and 2 have $\Lambda = 1$; types 3 and 4 have $\Lambda = 1.1$ (10% more productive). The probability of incurring the Brexit cost ranges from 0.2 for type 1 to 0.8 for type 4. This captures the positive correlation between productivity and EU exposure documented in our microdata.

Brexit Transition Probabilities. The transition matrix (12) is calibrated as follows. The probability of moving from pre-referendum to post-referendum is low ($\pi_{ER} = 0.01$), reflecting 43 years of EU membership. Direct transition from E to B is impossible ($\pi_{EB} = 0$). Once in the post-referendum state, the probability of Brexit occurring is moderate ($\pi_{RB} = 0.1$), while reversal is possible but unlikely ($\pi_{RE} = 0.05$). From the post-Brexit state, re-entry is highly improbable ($\pi_{BE} = 0.01$), and direct return to R is impossible ($\pi_{BR} = 0$).

Parameter	Definition	Value	Source
Preferences and Technology			
β	Quarterly discount factor	$0.95^{1/4}$	Standard
θ_L	Disutility of labor	2	Bloom et al. (2018)
η	Inverse Frisch elasticity	2	Bloom et al. (2018)
α	Capital share	0.25	Bloom et al. (2018)
v	Labor share	0.5	Chetty et al. (2011)
μ	Intermediate input share	0.375	Input-output tables
ρ	Productivity persistence	0.95	Khan and Thomas (2008)
σ_Z	Productivity shock std. dev.	0.051	Khan and Thomas (2008)
δ_k	Quarterly depreciation rate	0.026	King and Rebelo (1993)
S	Resale discount	0.339	Bloom (2009)
θ	Elasticity of substitution	2	Baseline
Brexit Parameters			
τ	Brexit productivity cost	0.1	—
Λ	Type 1–2 permanent productivity	1.0	—
	Type 3–4 permanent productivity	1.1	—
$\Pr(\tau)$	Type 1 exposure probability	0.2	—
	Type 2 exposure probability	0.4	—
	Type 3 exposure probability	0.6	—
	Type 4 exposure probability	0.8	—

Model Solution and Policy Experiment

We solve the model numerically using standard methods for heterogeneous agent economies with aggregate shocks. The firm's problem is solved by value function iteration over a discretised state space for capital and productivity. Aggregate output is determined by iterating on the goods market clearing condition until convergence.

Policy Experiment. We simulate the model to match the empirical Brexit timeline. The economy operates in the pre-referendum state E from 2010 to 2016 Q2. In 2016 Q3, coinciding with the June 23 referendum, the economy transitions to state R. It remains in this post-referendum, pre-Brexit state until 2020 Q1, when the UK formally leaves the EU and the economy transitions to state B. Firm-level Brexit costs are revealed at this point.

Constructing Micro and Macro Estimates. From the simulated panel, we construct two estimates of the Brexit impact on aggregate output:

The **macro estimate** compares aggregate output in the Brexit scenario to a counterfactual where the economy remains permanently in state E.

The **micro estimate** runs a difference-in-differences regression on simulated firm-level data, comparing high-exposure to low-exposure firms before and after the referendum, mirroring our empirical specification.

Model Variants

We compare four model variants that isolate different spillover mechanisms:

	Model A (Benchmark)	**Model B** (Reallocation)	**Model C** (Negative spillovers)	**Model D** (Positive spillovers)
θ (substitution)	∞	∞	2	∞
μ (intermediates)	0	0	0.375	0
η (labor supply)	1	1	1	2
Λ heterogeneity	No	Yes	No	No
Spillover sign	None	None	Negative	Positive

Detailed Results

Model A: No Spillovers, No Reallocation. In the benchmark specification with no spillover channels and homogeneous permanent productivity, the micro and macro estimates track each other closely, as expected when firms are effectively independent. Output begins to decline upon transition to state R in 2016 Q3, even before Brexit formally occurs. This reflects the forward-looking nature of investment: once in state R, firms face a positive probability of transitioning to state B and incurring the Brexit cost. This elevated uncertainty reduces the expected return to

investment, causing firms to postpone capital expenditure. The decline accelerates after 2020 Q1 when Brexit costs are realised. Figure A21 confirms that output declines are monotonically increasing in Brexit exposure probability.

Model B: Reallocation Effects. Introducing heterogeneity in permanent productivity Λ, with high-productivity firms (types 3 and 4) facing greater Brexit exposure, causes the macro estimate to modestly exceed the micro estimate. This reflects adverse reallocation: output shifts from high productivity to low-productivity firms, reducing aggregate productivity through a composition effect. The micro estimate, which identifies the average treatment effect on treated firms relative to control firms, does not capture this between-firm reallocation. The gap between estimates is modest, consistent with our empirical finding that within-firm effects dominate between-firm reallocation.

Model C: Negative Spillovers. Activating negative spillover channels by setting $\theta = 2$ (finite substitution elasticity) and $\mu = 0.375$ (positive intermediate input share), while maintaining $\eta = 1$ (constant wage), produces a substantial gap between macro and micro estimates. The mechanism operates through two reinforcing channels. First, when Brexit reduces output at directly affected firms, aggregate demand Y_t falls, shifting the demand curve inward for all firms including those not directly exposed. Second, reduced output at affected firms raises the price of intermediates, increasing costs for unaffected firms.

Both channels cause output at unaffected firms to decline, even though they face no direct Brexit cost. In the micro regression, these firms serve as the control group. Because the control group is also negatively affected—albeit less so than the treatment group—the treatment-control difference understates the true aggregate effect. This is the empirical manifestation of SUTVA violation through negative spillovers. Figure A21 shows that even the lowest-exposure group experiences meaningful output declines.

Model D: Positive Spillovers. Isolating positive spillovers through the labor market by setting $\eta = 2$ while shutting down demand and supply chain channels ($\theta \to \infty$, $\mu = 0$) produces the opposite pattern: the micro estimate now exceeds the macro estimate in absolute value. When Brexit

reduces labor demand at directly affected firms, the equilibrium wage falls to clear the labor market. Unaffected firms benefit from lower labor costs, partially offsetting the aggregate output decline. In the micro regression, these positive spillovers to the control group amplify the treatment-control difference, causing the micro estimate to overstate the aggregate effect.

SUTVA, the Micro Estimator, and the Missing Intercept

The micro difference-in-differences estimator identifies the average treatment effect under the stable unit treatment value assumption (SUTVA), which requires that potential outcomes for any firm do not depend on the treatment status of other firms:

$$Y_i(d, D_{-i}) = Y_i(d) \quad \forall D_{-i} \tag{16}$$

where $Y_i(d)$ is firm i's potential outcome under own treatment d, and D_{-i} denotes the treatment vector of all other firms. Under SUTVA, the micro estimator recovers:

$$\hat{\beta}_{\text{micro}} = \text{E}[Y_i(1) - Y_i(0)] = \text{ATE} \tag{17}$$

When spillovers are present, SUTVA fails. Let G denote the aggregate treatment intensity (e.g., the fraction of firms directly affected by Brexit). Observed outcomes depend on both own treatment and aggregate exposure: $Y_i^{\text{obs}} = Y_i(D_i, G)$. The micro estimator then identifies:

$$\hat{\beta}_{\text{micro}} = \text{E}[Y_i(1, G) \mid D_i = 1] - \text{E}[Y_i(0, G) \mid D_i = 0] \tag{18}$$

With negative spillovers, untreated firms have lower output than they would absent any treatment in the economy: $Y_i(0, G) < Y_i(0, 0)$. The treatment-control difference therefore understates the full effect of Brexit, and $|\hat{\beta}_{\text{micro}}| < |\text{ATE}|$. The macro estimator, by comparing the UK to untreated countries, captures the full aggregate effect including spillovers.

This connects to what Wolf (2023) terms the "missing intercept" problem in applied work that uses cross-sectional or difference-in-differences variation to estimate aggregate effects. The micro estimator identifies only the *slope* − the differential effect of Brexit on high- versus low-exposure firms − while the *intercept* − the level effect on the control group − is absorbed by time fixed effects. When general equilibrium spillovers shift outcomes for all firms, including controls, this intercept is "missing" from the micro estimate. In our setting, the missing intercept is precisely the spillover effect on unexposed firms:

$$\text{Missing Intercept} = Y_i(0, G) - Y_i(0,0) \tag{19}$$

The gap between our macro and micro estimates of approximately 2 percentage points provides a direct estimate of this missing intercept. The fact that the macro estimate exceeds the micro estimate implies that the missing intercept is negative: unexposed firms were dragged down by general equilibrium forces, consistent with negative demand and supply chain spillovers dominating any positive wage spillovers.

Table A1: Descriptive statistics

	Mean (weighted)	Mean (unweighted)	Standard deviation	10th percentile	25th percentile	Median	75th percentile	90th percentile
Accounts data (2015)								
Employment	918	394	4849	13	27	67	157	408
Sales (£, 000)	175813	86320	1026065	1938	5490	12278	28097	83099
Investment (£,000)	8003	3588	91672	0	10	82	466	2259
Percentage of publically listed firms	4%	2%	-	-	-	-	-	-
First and second moment Brexit impacts								
Expected long-run impact on sales from Brexit (%)	-2.5	-2.7	4.1	-9.6	-5.0	-1.0	0.0	0.4
Average Brexit uncertainty (0-3 scale)	1.3	1.2	0.8	0.0	0.8	1.1	1.8	2.2
Pre-referendum EU exposure								
Share of sales to EU	0.07	0.07	0.17	0	0	0	0.05	0.25
Share of costs from EU imports	0.09	0.09	0.19	0	0	0	0.07	0.30
Share of EU migrants in workforce	0.14	0.14	0.24	0	0	0.03	0.12	0.58
Share of sales covered by EU regulations	0.17	0.15	0.32	0	0	0	0.07	1
Share of directors who are EU nationals	0.07	0.07	0.20	0	0	0	0	0.33
Dummy for being EU owned	0.04	0.04	0.19	0	0	0	0	0
EU exposure (6 measure average)	0.10	0.09	0.12	0	0.01	0.04	0.14	0.26

Notes: Data for the 7144 firms who have data on all six pre-referendum EU exposure measures. Accounts data are from the Bureau van Djik FAME database. DMP data for all EU exposure variables, except share of directors who are EU nationals and ownership which are from the Bureau Van Dijk. First and second moment impacts of Brexit are from DMP survey. Standard deviations and percentiles reported are from unweighted data. Weighted data are weighted together using pre-referendum employment with weights capped at 250 employees for larger firms.

Table A2: Linear probability models for propensity to respond to DMP survey

Dependent variable: Ever responded to a survey if in sampling frame	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Leave vote share	-0.000	0.010	-0.009	-0.008	-0.004	-0.007	-0.006
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
Log of employment			0.027***	0.010***	0.009***	0.008***	0.012***
			(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Log of sales				0.010***	0.007***	0.008***	0.002
				(0.002)	(0.002)	(0.002)	(0.002)
Log of assets					0.006***	0.003***	0.003***
					(0.001)	(0.001)	(0.001)
Log of firm age						0.020***	0.019***
						(0.002)	(0.002)
Log of labour productivity							0.012***
							(0.004)
1 digit industry dummies	No	Yes	Yes	Yes	Yes	Yes	Yes
Observations	62,403	62,403	62,403	62,403	62,403	62,403	62,403
R-squared	0.000	0.006	0.030	0.035	0.035	0.037	0.037
F-test for joint significance of industry dummies (p-value)	-	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Notes: Linear probability model for whether a firm is in the DMP sampling frame and has ever responded to a DMP survey between September 2016 and May 2026 (1=responded to DMP, 0=Not responded). Only includes firms that were incorporated and had a set of published accounts for 2015 or earlier, and who were part of the sampling frame by the start of 2024. Firm characteristics are pre-referendum accounts data from the Bureau Van Dijk FAME database (2015 data for most firms, earlier data if 2015 data were not available). Regressions also include dummy variables (coefficients not reported) for missing employment, sales or labour productivity data. 'Leave vote share' is Electoral Commission data on the share of the vote for leaving the EU in the local authority that a firm is headquartered in. Robust standard errors are used. *** p<0.01, ** p<0.05, * p<0.1.

Table A3: EU exposure and expected long-run impact of Brexit on sales

Dependent variable: Expected long-run reduction in sales from Brexit (%)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Share of sales to EU	4.968***						2.997***	
	(0.366)						(0.378)	
Share of costs from EU imports		3.225***					1.470***	
		(0.298)					(0.320)	
Share of EU migrants in workforce			3.219***				2.553***	
			(0.242)				(0.240)	
Share of sales covered by EU regulations				2.660***			1.786***	
				(0.172)			(0.181)	
Share of directors who are EU nationals					1.852***		0.466*	
					(0.261)		(0.274)	
Dummy for being EU owned						0.907***	-0.193	
						(0.266)	(0.283)	
EU exposure (6 measure average)								9.217***
								(0.442)
Observations	7,144	7,144	7,144	7,144	7,144	7,144	7,144	7,144
R-squared	0.040	0.021	0.034	0.042	0.008	0.002	0.091	0.073

Notes: DMP data for all variables, except share of directors who are EU nationals and ownership which are from the Bureau Van Dijk FAME database. EU exposure measures are for 2016 Q1, just before the Brexit referendum, except for directors and ownership data which are for 2015. Dependent variable is average expected long-run reduction in sales from Brexit, per firm, as collected in DMP surveys between February 2017 and April 2024. Missing values for Brexit sales impact in a given survey year are imputed from a regression using time and firm fixed effects. All equations are estimated by OLS with robust standard errors. *** p<0.01, ** p<0.05, * p<0.1.

Table A4: EU exposure and firm outcomes, by year

Dependent variable (all in growth rates):	Investment	Employment	TFP	Sales
All equations estimated 2011-2024 (financial years)	(1)	(2)	(3)	(4)
EU exposure (6 measure average)*2017	-9.945	-2.338	-0.603	9.568***
	(12.002)	(1.947)	(4.283)	(3.362)
EU expoure (6 measure average)*2018	-18.822	-4.374**	-6.962	-4.420
	(11.634)	(2.040)	(4.430)	(3.526)
EU exposure (6 measure average)*2019	23.954*	-5.469***	-14.419***	-2.463
	(12.256)	(2.110)	(4.666)	(3.543)
EU exposure (6 measure average)*2020	-50.941***	-2.613	-6.644	-12.632***
	(12.191)	(2.018)	(5.368)	(4.456)
EU exposure (6 measure average)*2021	-21.803*	-3.522	1.136	-3.167
	(12.729)	(2.251)	(5.410)	(4.675)
EU exposure (6 measure average)*2022	-12.767	-4.870**	-4.925	-1.351
	(11.884)	(2.159)	(5.355)	(3.836)
EU exposure (6 measure average)*2023	-29.636**	-5.517***	-2.564	-3.029
	(12.955)	(2.095)	(5.101)	(3.709)
EU exposure (6 measure average)*2024	-4.616	-7.022***	-3.714	-17.789***
	(13.021)	(2.148)	(5.449)	(3.756)
Covid controls	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Observations	59,062	70,378	47,630	60,325

Notes: EU exposure is the average of the following 6 exposure measures: share of sales to EU; share of costs from EU imports; share of EU migrants in workforce; share of sales covered by EU regulations; share of directors who are EU nationals; and a dummy for being EU owned. All are on a 0-1 scale. DMP data for all exposure variables, except share of directors who are EU nationals and ownership which are from the Bureau Van Dijk FAME database. EU exposure measures are for 2016 Q1, just before the Brexit referendum, except for directors and ownership data which are for 2015. Regressions in this table use company accounts data from the Bureau Van Dijk FAME database for investment, employment, sales and TFP growth where available and DMP data where accounts data are missing for investment, employment and sales. Data used are from financial years 2011 to 2024, but 2016 is excluded (years are defined from Q3 to Q2 in next calendar year, so 2017 represents 2017/18 and would cover firms with a financial year end between 2017 Q3 and 2018 Q2). Covid-19 impact variables are from the DMP survey and are impacts on the firm estimated by survey respondents (see Appendix for more details on these). These Covid controls are interacted with separate year dummies where data are missing. Standard errors are clustered at the firm level. *** p<0.01, ** p<0.05, * p<0.1.

Table A5: Investment robustness

Dependent variable: Investment growth	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
All equations estimated 2011-2024 (financial years)		(Accounts data only)							
EU exposure (6 measure average)*post-referendum	-15.115***	-10.598**							
	(5.108)	(5.282)							
Principal component EU exposure (6 measure average)*post-referendum			-1.066**						
			(0.435)						
EU exposure (5 measure average, excluding share of sales to EU)*post-referendum				-14.402***					
				(4.611)					
EU exposure (5 measure average, excluding share of costs from EU imports)*post-referendum					-12.309**				
					(4.955)				
EU exposure (5 measure average, excluding EU migrant worker share)*post-referendum						-10.719**			
						(4.576)			
EU exposure (5 measure average, excluding importance of EU regulations)*post-referendum							-12.217**		
							(5.394)		
EU exposure (5 measure average, excluding EU directors share)*post-referendum								-16.040***	
								(4.943)	
EU exposure (5 measure average, excluding Dummy for EU owned)*post-referendum									-17.228***
									(4.944)
Covid-19 impact on investment growth	0.733***	0.738***	0.733***	0.733***	0.733***	0.733***	0.733***	0.733***	0.733***
	(0.046)	(0.055)	(0.046)	(0.046)	(0.046)	(0.046)	(0.046)	(0.046)	(0.046)
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	59,062	53,877	59,062	59,062	59,062	59,062	59,062	59,062	59,062

Notes: EU exposure is the average of the following 6 exposure measures: share of sales to EU; share of costs from EU imports; share of EU migrants in workforce; share of sales covered by EU regulations; share of directors who are EU nationals; and a dummy for being EU owned. All are on a 0-1 scale. DMP data for all exposure variables, except share of directors who are EU nationals and ownership which are from the Bureau Van Dijk FAME database. EU exposure measures are for 2016 Q1, just before the Brexit referendum, except for directors and ownership data which are for 2015. Regressions in this table use company accounts data from the Bureau Van Dijk FAME database for investment, where available and DMP data where accounts data are missing. Data used are from financial years 2011 to 2024, but 2016 is excluded (years are defined from Q3 to Q2 in next calendar year, so 2017 represents 2017/18 and would cover firms with a financial year end between 2017 Q3 and 2018 Q2). Covid-19 impact variables are from the DMP survey and are impacts on the firm estimated by survey respondents (see Appendix for more details on these). These Covid controls are interacted with separate year dummies where data are missing. Standard errors are clustered at the firm level. *** p<0.01, ** p<0.05, * p<0.1.

Table A6: Investment robustness

Dependent variable: Investment growth	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
All equations estimated 2011-2024 (financial years)	All firms	Below average profit margin in 2013-15	Above average profit margin in 2013-15	Smaller firms (<100 employees in 2013-15)	Larger firms (100+ employees in 2013-15)	Younger firms (born 2000+)	Older firms (born pre-2000)	Manufacturing, retail & finance	Other industries
EU exposure (6 measure average)*post-referendum	-15.115***	-16.935**	-6.057	-10.472	-17.713**	-24.804***	-9.760	-21.683***	-9.738
	(5.108)	(8.350)	(7.303)	(7.150)	(7.273)	(9.455)	(5.938)	(6.751)	(8.984)
Covid-19 impact on investment growth	0.733***	0.748***	0.770***	0.746***	0.673***	0.710***	0.749***	0.830***	0.666***
	(0.046)	(0.074)	(0.070)	(0.064)	(0.071)	(0.070)	(0.062)	(0.069)	(0.061)
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	57,962	19,500	20,059	30,045	20,079	27,114	30,848	22,789	35,173
Test that exposure coefficients are equal:			(2) vs (3)		(4) vs (5)		(6) vs (7)		(8) vs (9)
- p value			0.33		0.48		0.18		0.29

Notes: EU exposure is the average of the following 6 exposure measures: share of sales to EU; share of costs from EU imports; share of EU migrants in workforce; share of sales covered by EU regulations; share of directors who are EU nationals; and a dummy for being EU owned. All are on a 0-1 scale. DMP data for all exposure variables, except share of directors who are EU nationals and ownership which are from the Bureau Van Dijk FAME database. EU exposure measures are for 2016 Q1, just before the Brexit referendum, except for directors and ownership data which are for 2015. Regressions in this table use company accounts data from the Bureau Van Dijk FAME database for investment, where available and DMP data where accounts data are missing. Data used are from financial years 2011 to 2024, but 2016 is excluded (years are defined from Q3 to Q2 in next calendar year, so 2017 represents 2017/18 and would cover firms with a financial year end between 2017 Q3 and 2018 Q2). Covid-19 impact variables are from the DMP survey and are impacts on the firm estimated by survey respondents (see Appendix for more details on these). These Covid controls are interacted with separate year dummies where data are missing. Standard errors are clustered at the firm level. *** p<0.01, ** p<0.05, * p<0.1.

Table A7: First and second moment impact of Brexit

Dependent variable (all in growth rates):	Investment		Employment		TFP		Sales	
All equations estimated 2011-2024 (financial years)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Brexit uncertainty*post-referendum	-1.725*	-1.973***	-0.221		-0.597*	-0.772**	0.075	
	(0.888)	(0.752)	(0.222)		(0.350)	(0.305)	(0.335)	
Expected long-run reduction in sales from Brexit*post-referendum	-0.080		-0.118***	-0.139***	-0.059		-0.252***	-0.245***
	(0.155)		(0.040)	(0.034)	(0.062)		(0.060)	(0.052)
Covid controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	94,560	94,560	113,689	113,689	80,012	80,012	99,181	99,181
Implied impact of Brexit on levels in 2024 (%):								
- Private sector		-19.8		-2.8		-7.8		-5.0
- Whole economy				-2.3		-6.4		

Notes: Brexit uncertainty is based on responses to a DMP question on the importance of Brexit as a source of uncertainty and is measured on a scale of 0 to 3. Expected long-run reduction in sales from Brexit is also based on a DMP question and is in percentage terms. Uncertainty data were collected in surveys between August 2016 and April 2024. Sales impact data were collected between February 2017 and April 2024. Missing values for both variables in a given survey year are imputed from a regression using time and firm fixed effects. Regressions in this table use company accounts data from the Bureau Van Dijk FAME database for investment, employment, sales and TFP growth where available and DMP data where accounts data are missing for investment, employment and sales. Data used are from financial years 2011 to 2024, but 2016 is excluded (years are defined from Q3 to Q2 in next calendar year, so 2017 represents 2017/18 and would cover firms with a financial year end between 2017 Q3 and 2018 Q2). TFP is calculated as the residual from a production function $\ln(Yit) = 0.63\ln(L_{it})+0.37\ln(K_{it})$ where Y_{it} is real value-added of firm i in year t, L is labour input (total real labour costs) and K is capital (total real fixed assets), nominal values from accounting data are deflated using the GDP deflator. TFP data are normalised by 4-digit industry (using data for the full DMP sampling frame) within each year. Real value-added is defined as operating profits plus total labour costs divided by the aggregate GDP deflator. Covid controls are variables for the impact of Covid-19 on investment growth for the investment equations, Covid-19 impact on employment growth in the employment equations, Covid-19 impact on sales growth in the sales equations and Covid-19 impact on sales per employee growth in the TFP equations. Covid-19 impact variables are from the DMP survey and are impacts on the firm estimated by survey respondents (see Appendix for more details on these). These Covid controls are interacted with separate year dummies where data are missing. Standard errors are clustered at the firm level. *** p<0.01, ** p<0.05, * p<0.1.

Memo: The mean of Brexit uncertainty is 1.25 and the expected long-run reduction in sales is 2.5%.

Table A8: EU exposure and GVA/labor productivity growth

Dependent variable (all in growth rates):	Value-added			Labor productivity		
All equations estimated 2011-2024 (financial years)	(1)	(2)	(3)	(4)	(5)	(6)
EU exposure (6 measure average)*post-referendum	-5.754**			-1.662		
	(2.506)			(2.010)		
Brexit uncertainty*post-referendum		-0.957**			-0.727**	-0.834***
		(0.392)			(0.331)	(0.284)
Expected long-run reduction in sales from Brexit*post-referendum		-0.145**	-0.236***		-0.036	
		(0.070)	(0.061)		(0.059)	
Covid-19 impact on sales growth	0.597***	0.599***	0.599***			
	(0.042)	(0.036)	(0.036)			
Covid-19 impact on sales growth per employee				0.423***	0.424***	0.424***
				(0.038)	(0.033)	(0.033)
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	48,435	81,321	81,321	48,089	80,786	80,786
Implied impact of Brexit on levels in 2024 (%):						
- Private sector	-4.5		-4.8	-1.3		-8.4
- Whole economy	-3.7		-3.9	-1.1		-6.9

Notes: EU exposure is the average of the following 6 exposure measures: share of sales to EU; share of costs from EU imports; share of EU migrants in workforce; share of sales covered by EU regulations; share of directors who are EU nationals; and a dummy for being EU owned. All are on a 0-1 scale. DMP data for all exposure variables, except share of directors who are EU nationals and ownership which are from the Bureau Van Dijk FAME database. EU exposure measures are for 2016 Q1, just before the Brexit referendum, except for directors and ownership data which are for 2015. Regressions in this table use company accounts data from the Bureau Van Dijk FAME database. Real value-added is defined as operating profits plus total labour costs divided by the aggregate GDP deflator. Labor productivity is defined as annual real value-added per employee. Data used are from financial years 2011 to 2024, but 2016 is excluded (years are defined from Q3 to Q2 in next calendar year, so 2017 represents 2017/18 and would cover firms with a financial year end between 2017 Q3 and 2018 Q2). Covid-19 impact variables are from the DMP survey and are impacts on the firm estimated by survey respondents (see Appendix for more details on these). These Covid controls are interacted with separate year dummies where data are missing. Standard errors are clustered at the firm level. *** p<0.01, ** p<0.05, * p<0.1.

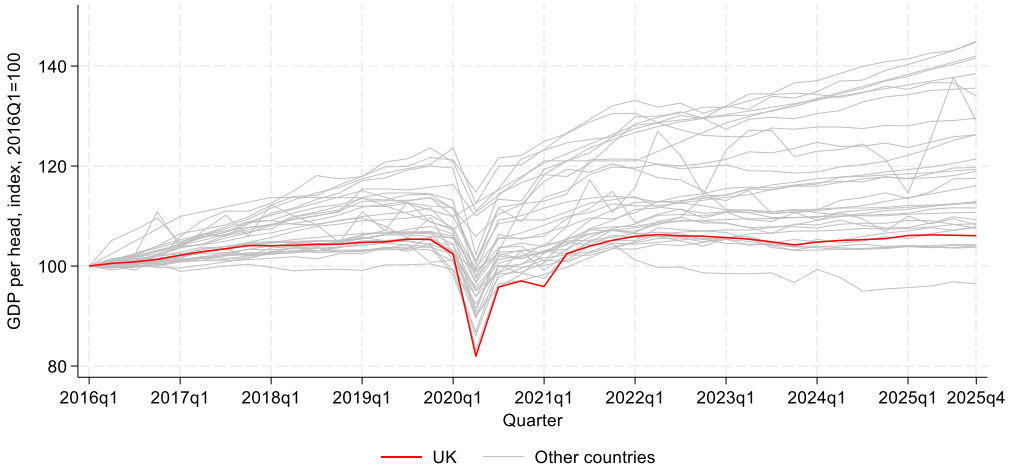
Table A9: Firm entry and exit regressions

Dependent variable:	2 digit industry level data (2011-2024)			
	Net entry rate	Net entry rate	Entry rate	Exit rate
	(1)	(2)	(3)	(4)
EU exposure (6 measure average)*post-referendum	-1.476	-4.691	-3.094	1.368
	(3.490)	(6.791)	(7.541)	(2.951)
2 digit industry dummies	No	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Observations	1,019	1,019	1,019	1,019
R-squared	0.113	0.377	0.588	0.723

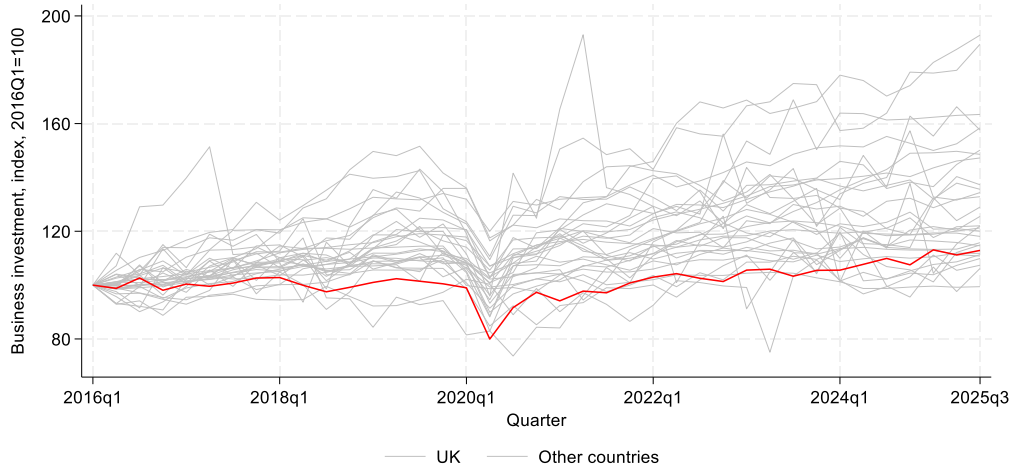
Notes: EU exposure is the average of the following 6 exposure measures: share of sales to EU; share of costs from EU imports; share of EU migrants in workforce; share of sales covered by EU regulations; share of directors who are EU nationals; and a dummy for being EU owned. All are on a 0-1 scale. DMP data for all exposure variables, except share of directors who are EU nationals and ownership which are from the Bureau Van Dijk FAME database. EU exposure measures are for 2016 Q1, just before the Brexit referendum, except for directors and ownership data which are for 2015. Two-digit industry data on firm birth and rates by year are from the Office for National Statistics. Two-digit industry data on exposure to the EU are constructed by collapsing the firm level data down to industry level. *** p<0.01, ** p<0.05, * p<0.1.

Figure A1: Comparison of UK versus other individual countries

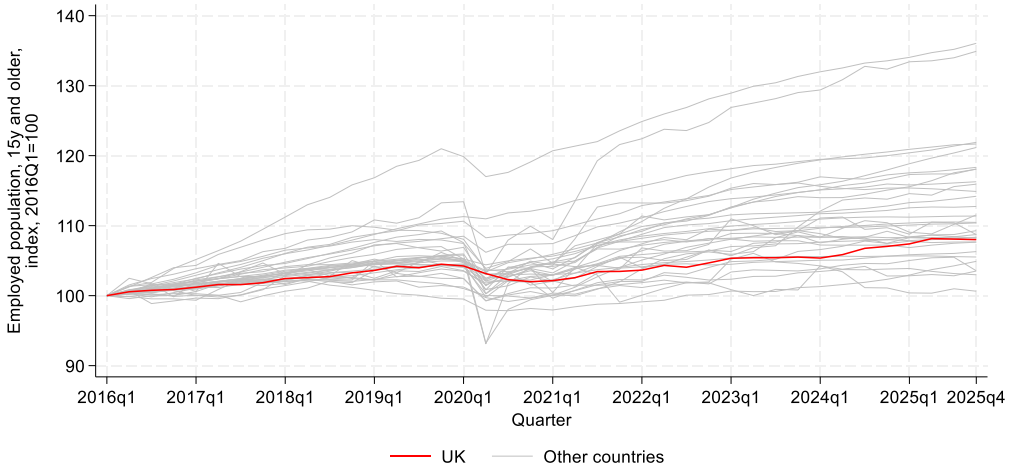
GDP per capita



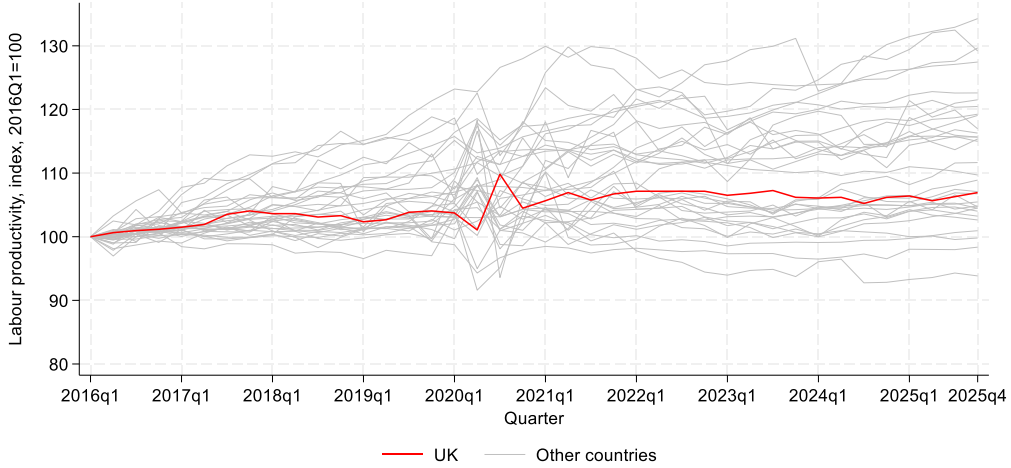
Business investment



Employment



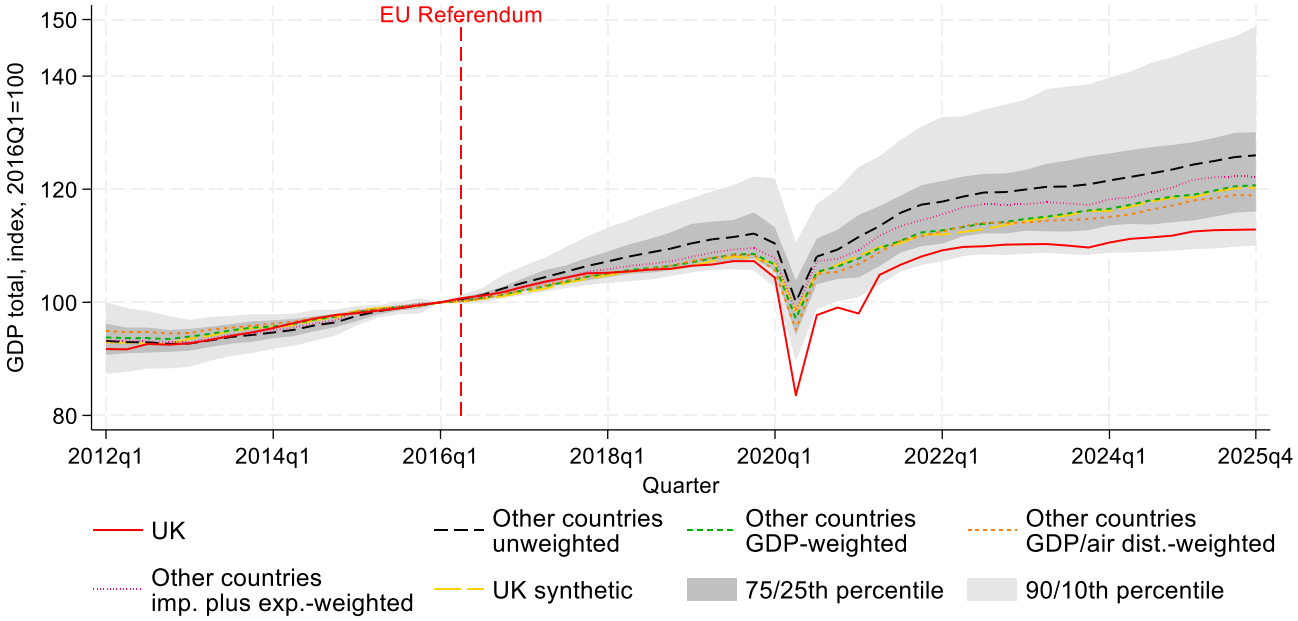
Labor productivity



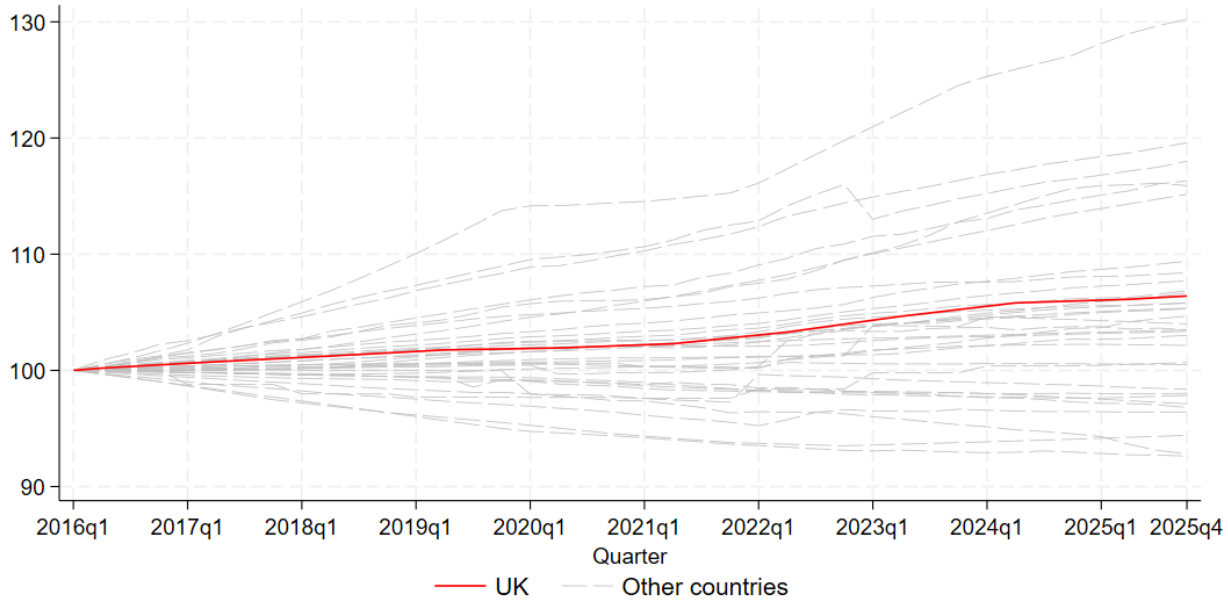
Notes: Other countries include US, Canada, EU-27 countries, Iceland, Norway, Switzerland, and Japan. Sources: ONS, U.S. Bureau of Economic Analysis, Statistics Canada, Eurostat, OECD.

Figure A2: Headline GDP and population cross-country comparisons

Headline GDP



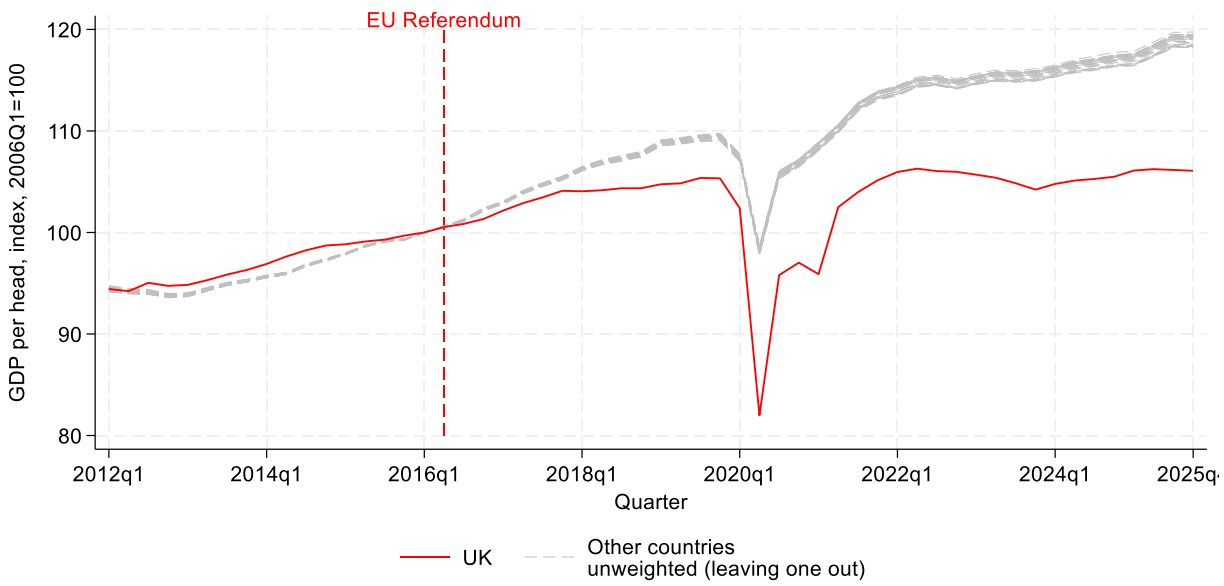
Population



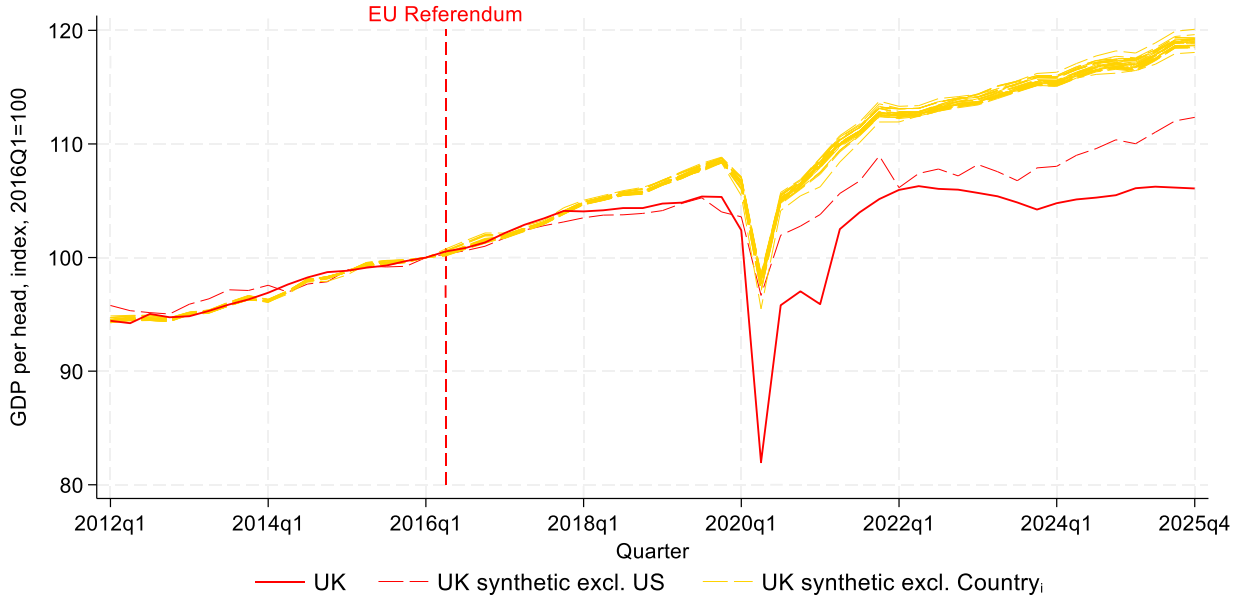
Notes: Caluclations for the headline GDP chart are similar to those described in the footnote to Figure 1, other than that total real GDP is used rather than real GDP per capita. The country weights for the syntheitic control are: US: 0.102, CAN: 0, AUS: 0, BEL: 0, BUL: 0, CRO: 0, CYP: 0, CZE: 0, DEN: 0, EST: 0, FIN: 0, FRA: 0, GER: 0, GRE: 0.359, HUN: 0, IRE: 0.087, ITA: 0, LAT: 0, LIT: 0, LUX: 0, MAL: 0, NET: 0, POL: 0, POR: 0, ROM: 0.271, SLK: 0, SLO: 0, SPA: 0, SWE: 0, ICE: 0, NOR: 0, CHE: 0, JAP: 0.181. Percentiles were estimated using the bootstrapping method. Sources: OECD, Irish Central Statistics Office and World Bank.

Figure A3: Impact of leaving one country out of GDP per head macro comparisons

Unweighted average



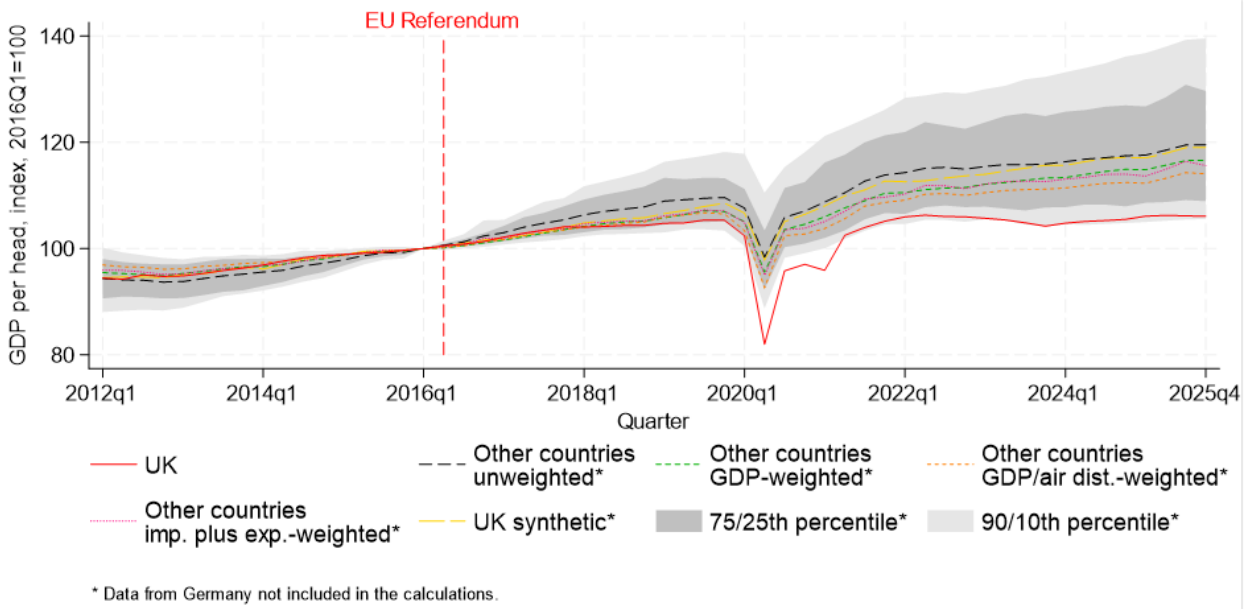
Synthetic control



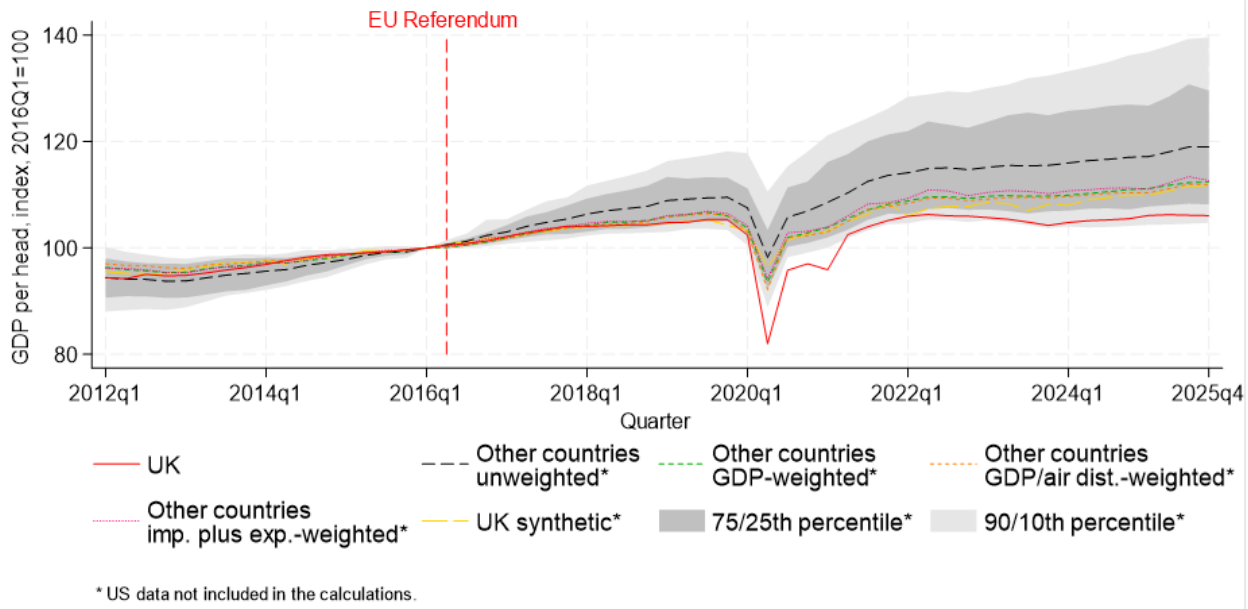
Notes: For the unweighted average chart, the grey lines represent the unweighted average of GDP per head for all countries except the UK, each calculated by dropping one country at a time. For the synthetic control chart the yellow lines represent the UK synthetic control by dropping one country at a time, apart from the dashed red line which represents the UK synthetic control excluding the US. Calculations are otherwise as explained in the footnote to Figure 1. The root mean squared percentage error in the pre-referendum after excluding each country from the donor pool is as follows: US: 0.75, CAN: 0.42, AUS: 0.43, BEL: 0.41, BUL: 0.42, CRO: 0.41, CYP: 0.42, CZE: 0.44, DEN: 0.41, EST: 0.44, FIN: 0.44, FRA: 0.45, GER: 0.44, GRE: 0.48, HUN: 0.41, IRE: 0.42, ITA: 0.41, LAT: 0.43, LIT: 0.46, LUX: 0.43, MAL: 0.43, NET: 0.41, POL: 0.42, POR: 0.42, ROM: 0.41, SLK: 0.41, SLO: 0.42, SPA: 0.44, SWE: 0.44, ICE: 0.44, NOR: 0.41, CHE: 0.42, JAP: 0.42.

Figure A4: Impact of dropping Germany and the US from GDP per head macro comparisons

Excluding Germany

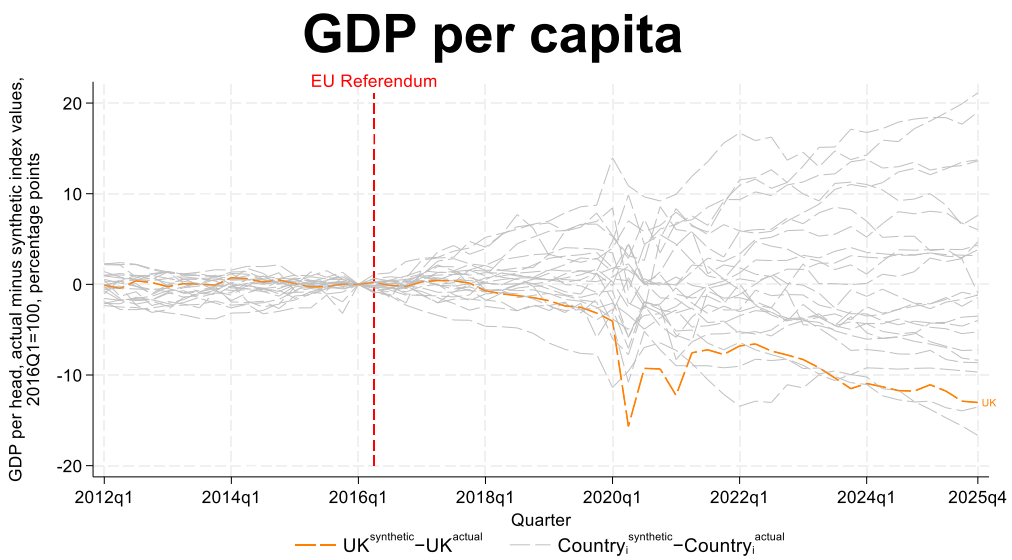


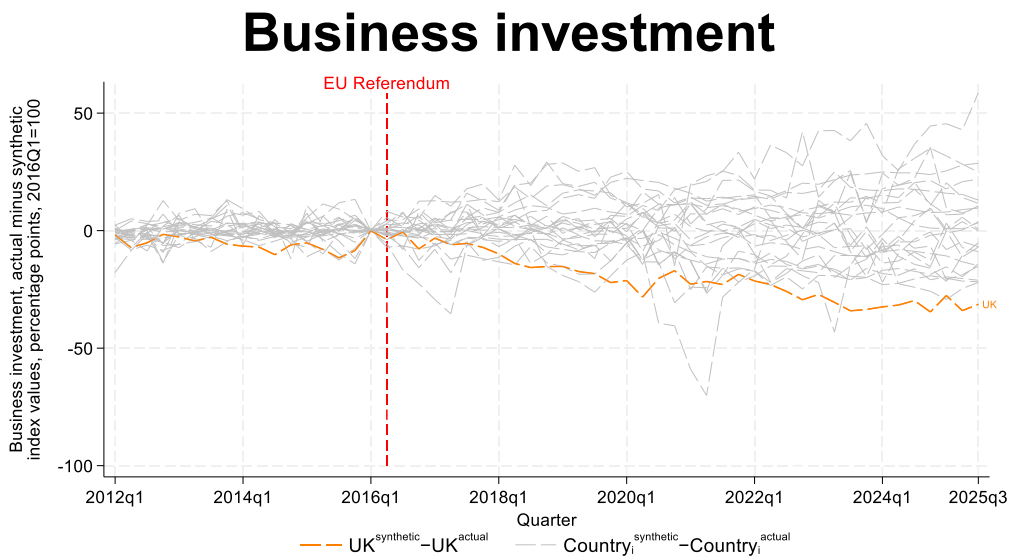
Excluding the US

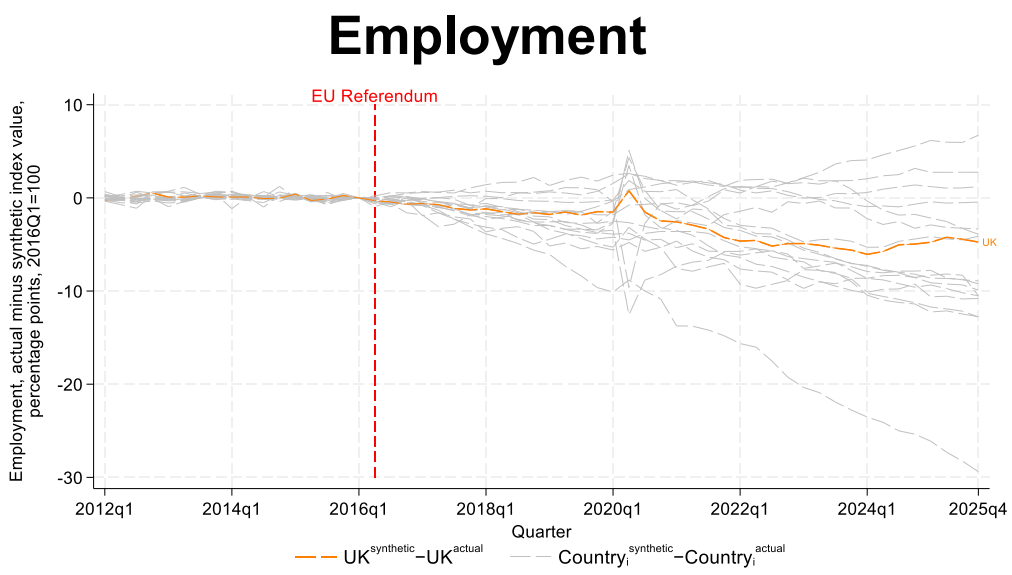


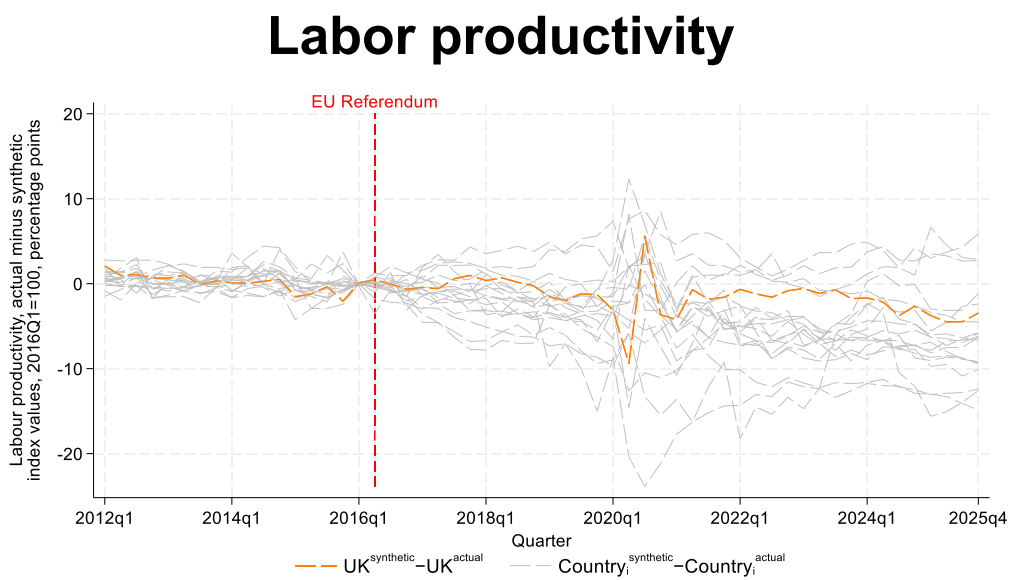
Notes: Notes are as for Figure 1, other than that Germany is excluded from the calculations in the left panel and the US is excluded on the right panel.

Figure A5: Permutation tests for synthetic control analysis



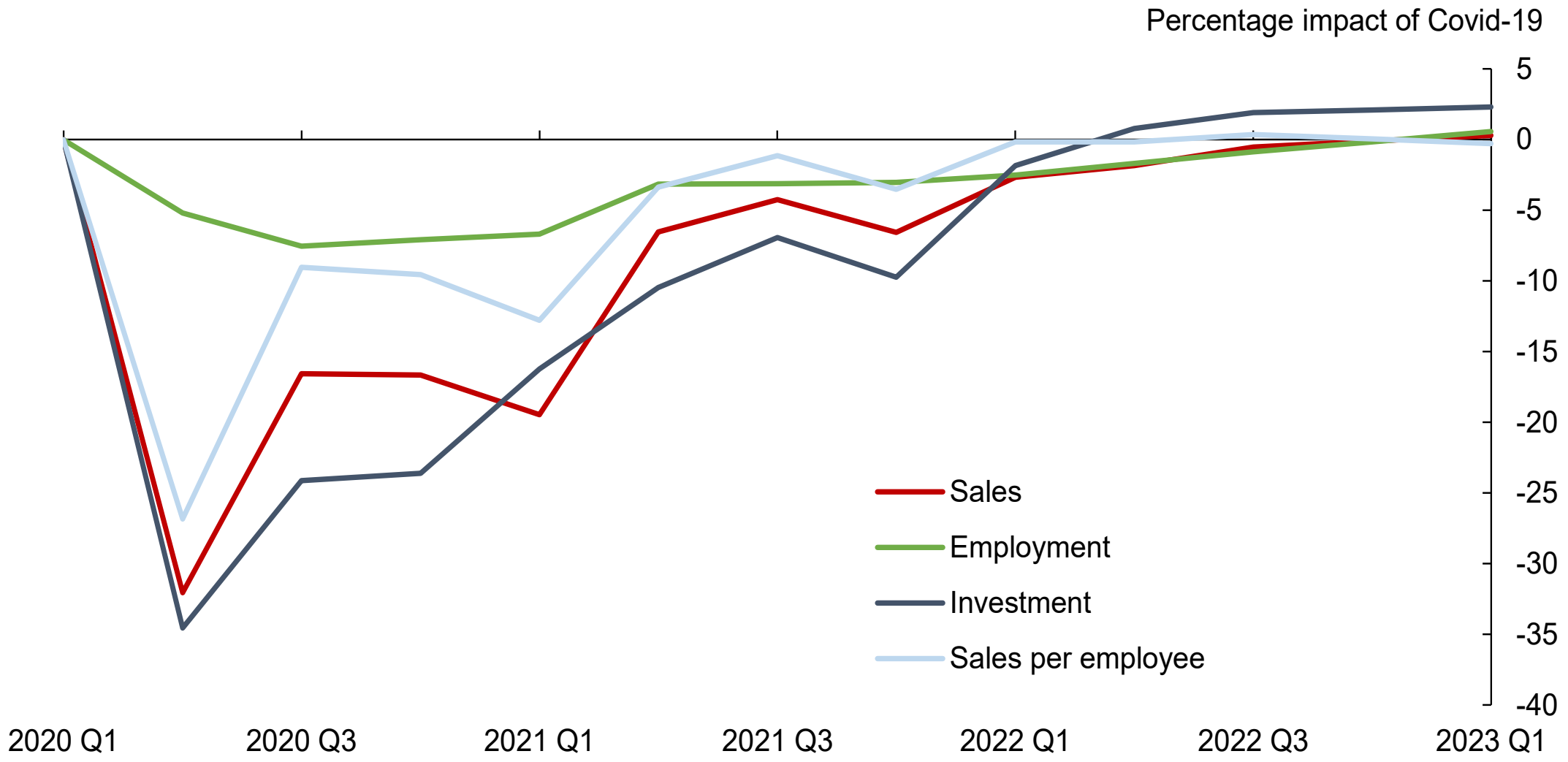






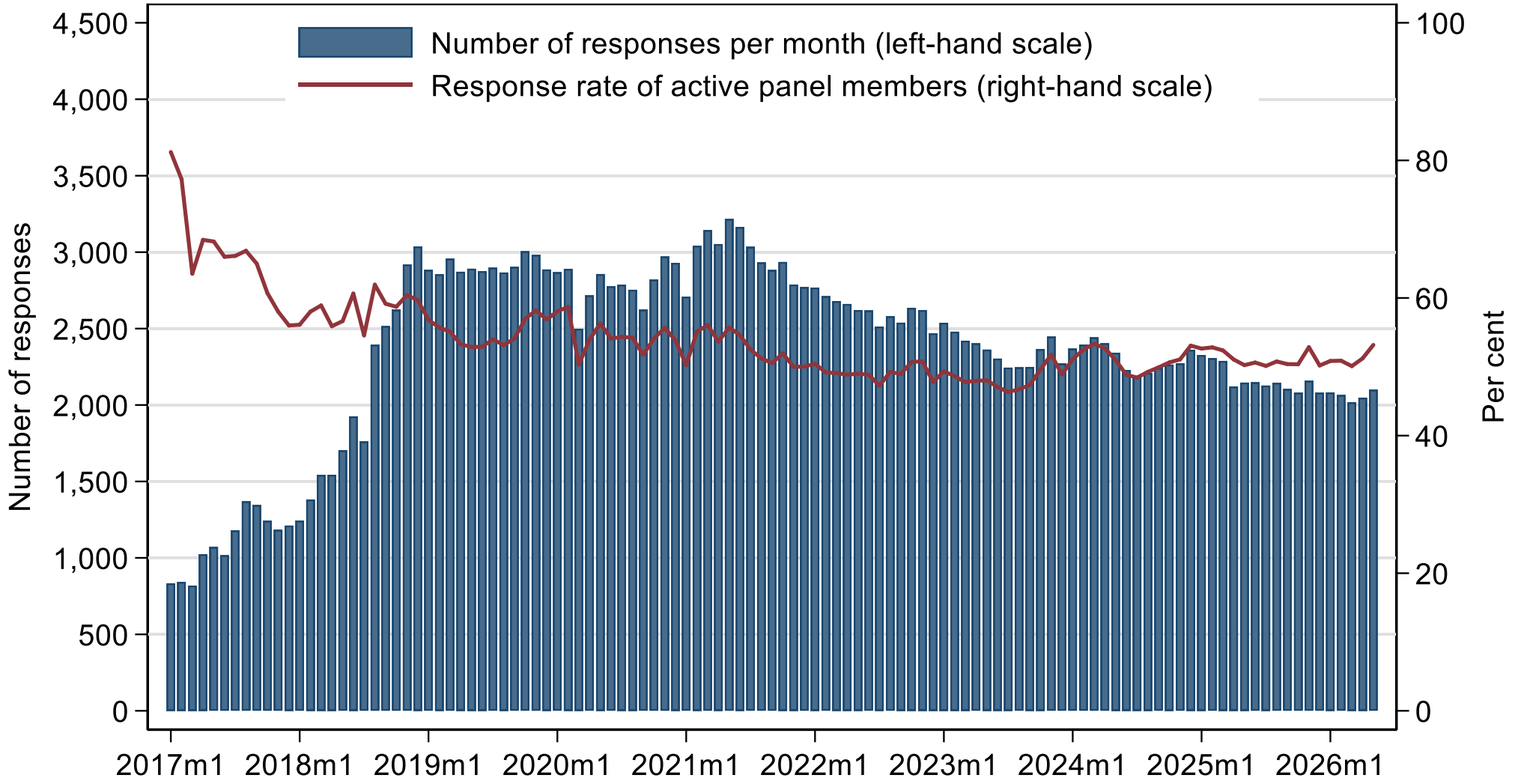
Notes: These charts show the difference between the synthetic values and the actual values calculated separately for every single country in the sample. Each line in this chart corresponds to a different country. Other countries include US, Canada, EU-27 countries, Iceland, Norway, Switzerland, and Japan. Sources: ONS, U.S. Bureau of Economic Analysis, Statistics Canada, Eurostat, OECD.

Figure A6: Impact of Covid-19 on businesses



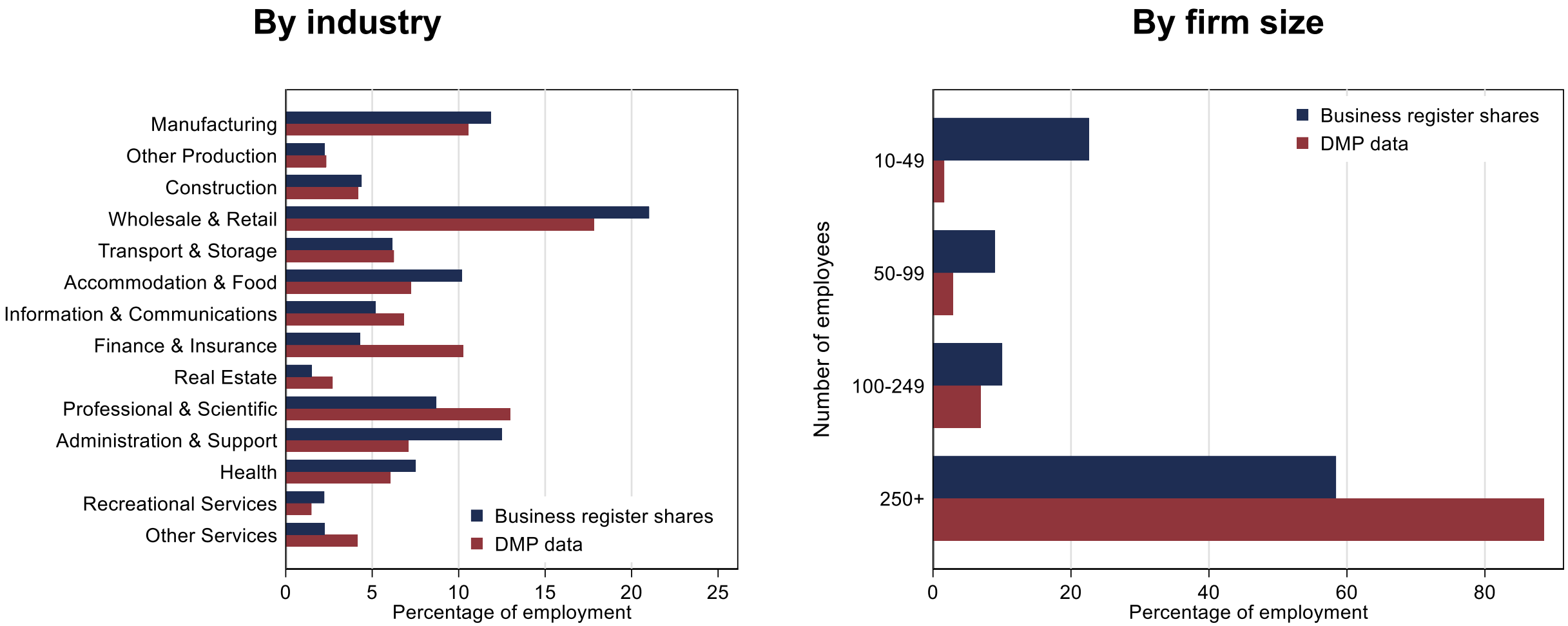
Notes: The results are based on the questions: 'Relative to what would otherwise have happened, what is your best estimate for the impact of the spread of Covid-19 on the sales/employment/capital expenditure of your business in each of the following periods?' Impact on sales per employee is a calculated using responses to the questions on sales and employment questions. Data shown for 2023 Q1 are for 2023+. Source: Decision Maker Panel.

Figure A7: DMP sample size and response rate



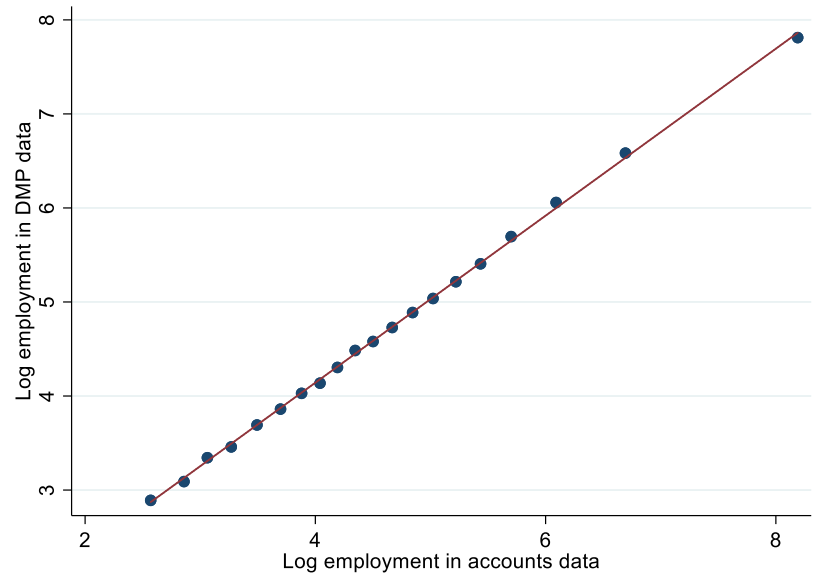
Notes: The response rate of active panel members is calculated as the response rate of panel members who had completed at least one survey over the last twelve months.

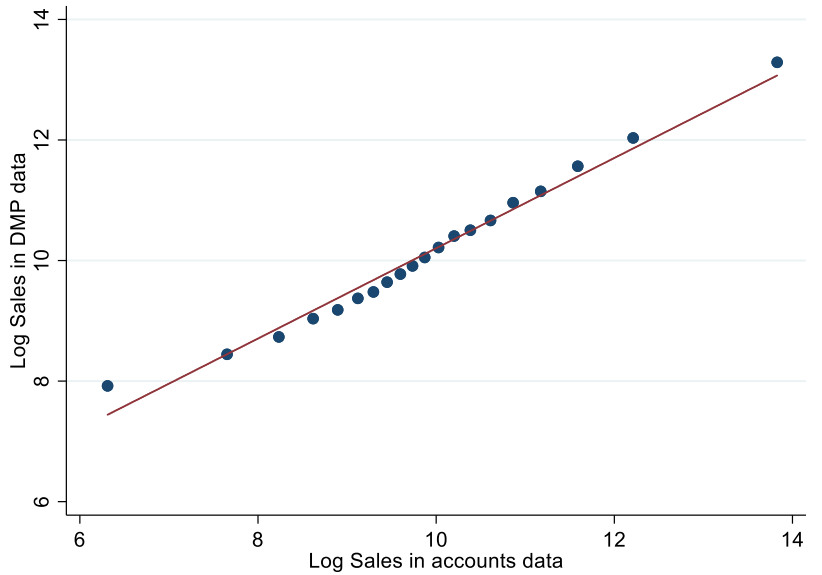
Figure A8: DMP sample versus Business Register

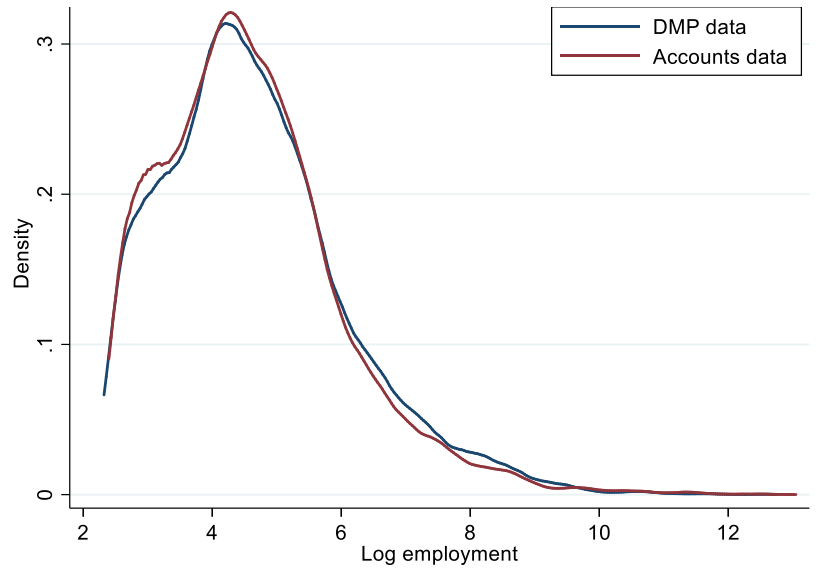


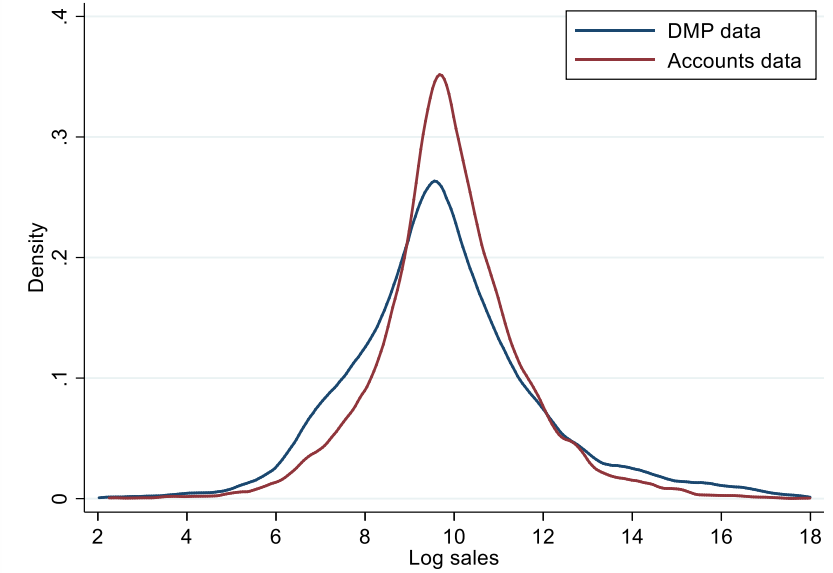
Notes: The results presented here are averages for 2017 to 2025. Sources: Department for Business, Energy and Industrial Strategy (BEIS) and Decision Maker Panel.

Figure A9: DMP data versus company accounts data



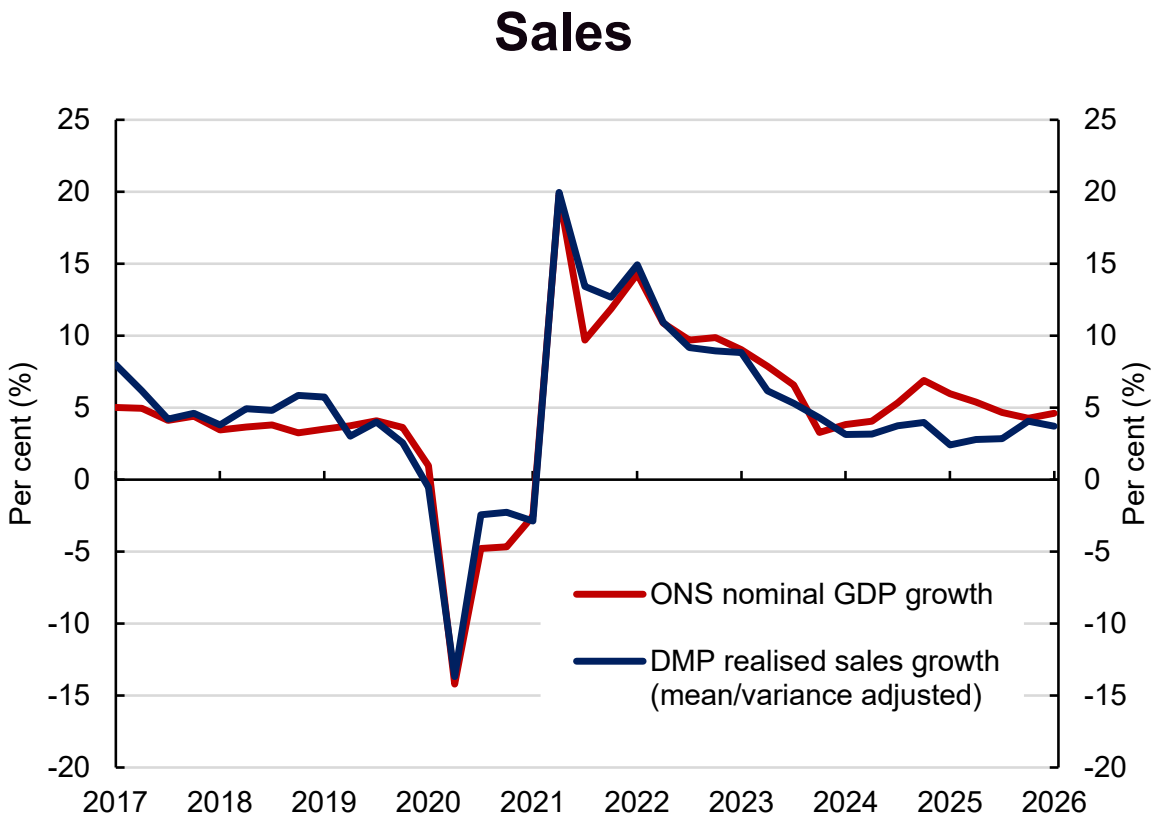


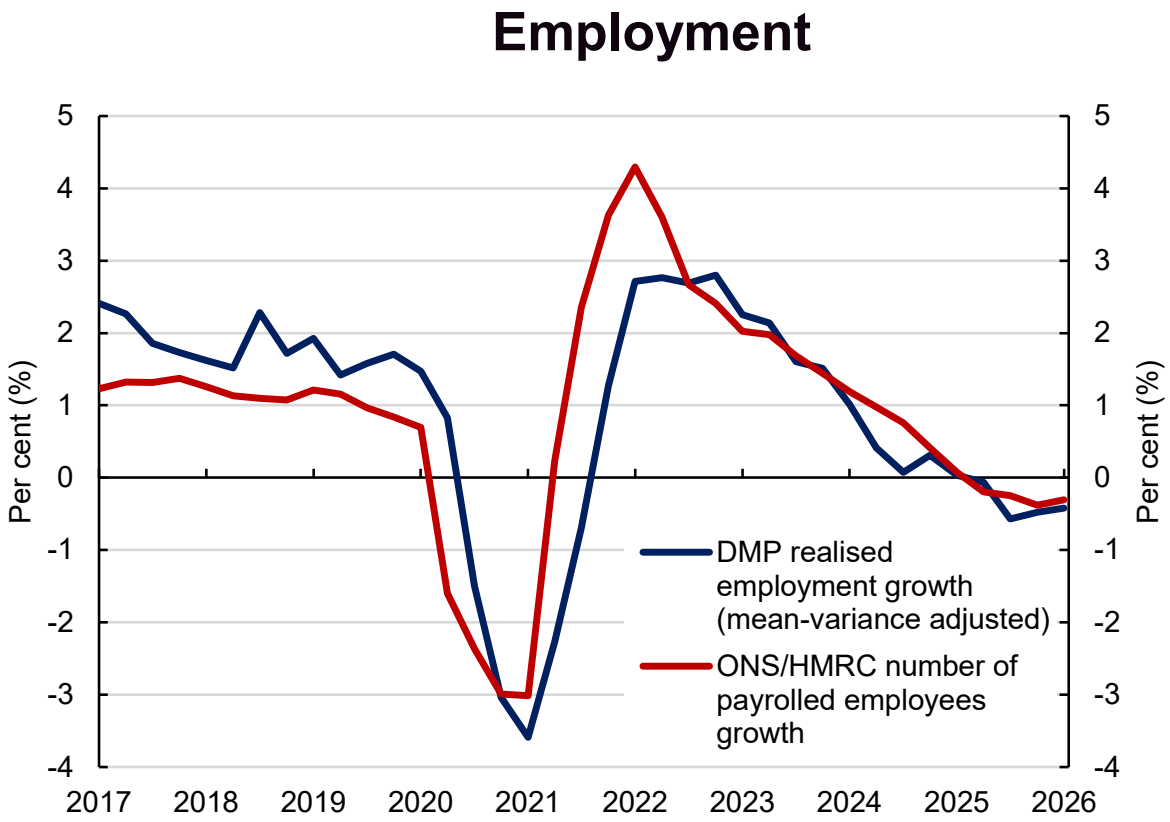




Notes: Sales values from the DMP survey are annualised average quarterly sales reported by businesses across the year. DMP employment data are averages across the year. DMP data are plotted against annual company accounts data from Bureau Van Dijk for the corresponding financial year. The dots on the top charts each represent 5% of observations, grouped by log employment/sales from accounts data. Charts are based on annual data between 2017 and 2024.

Figure A10: DMP data versus official aggregate statistics

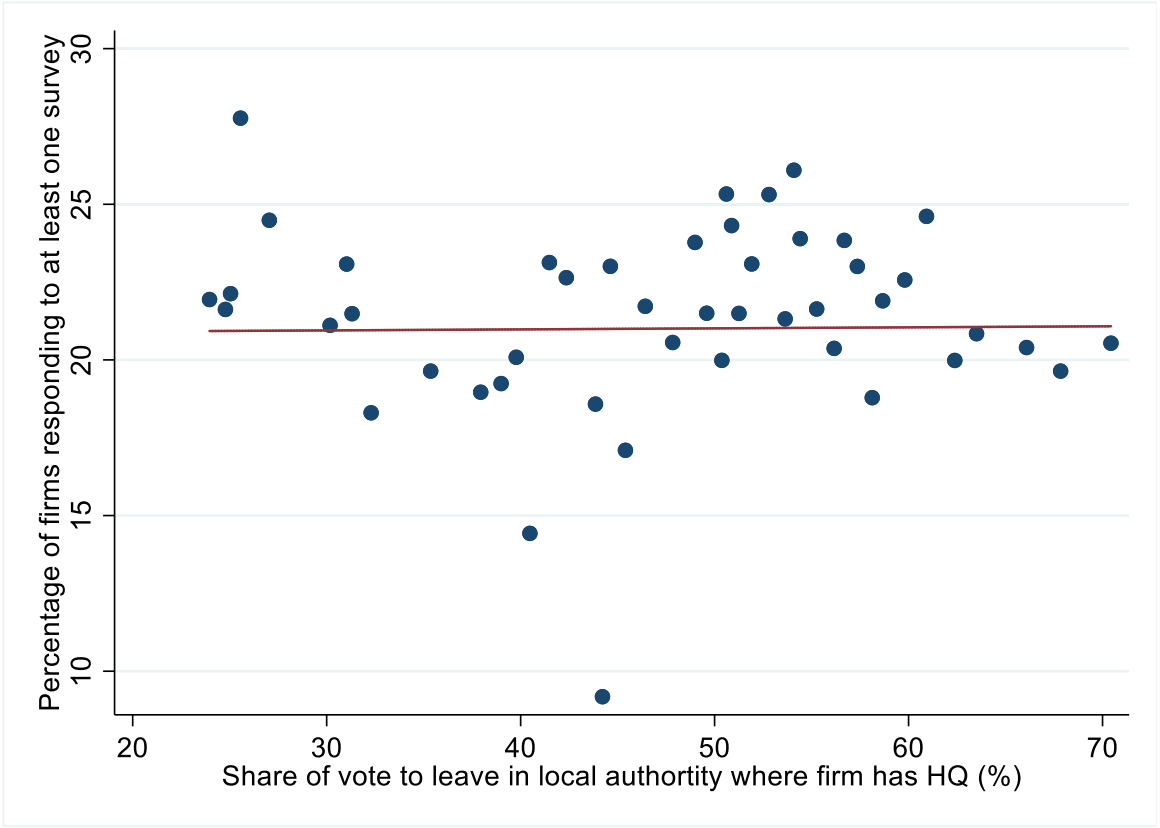




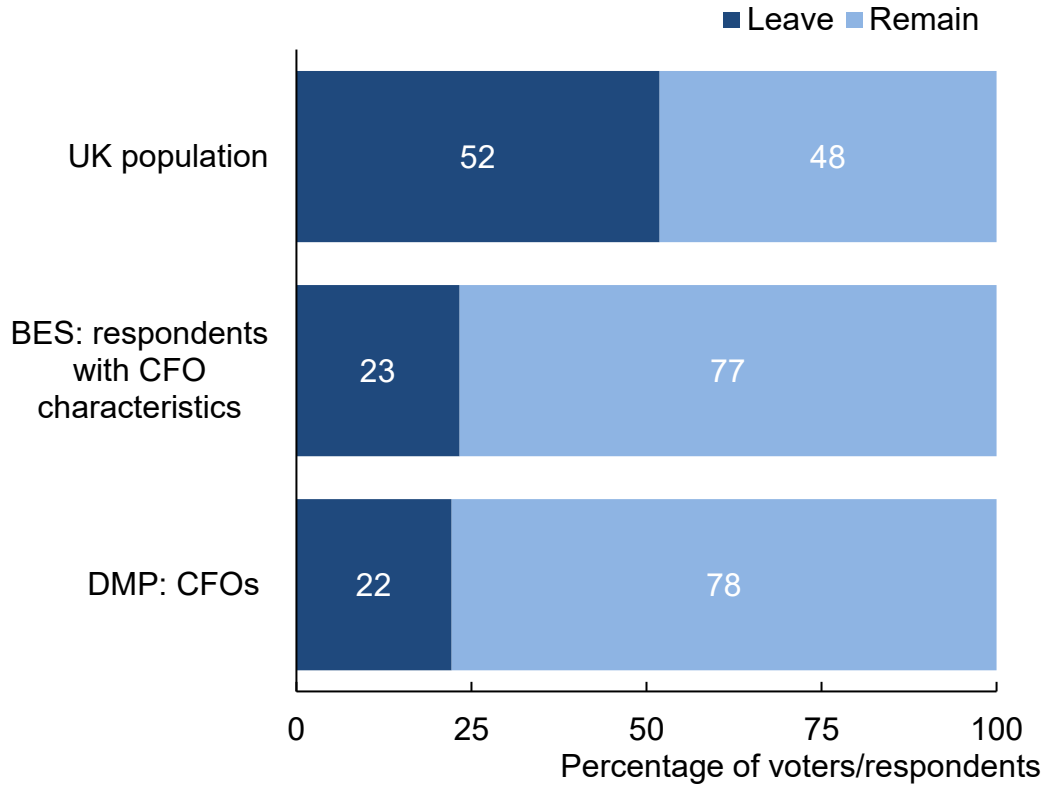
Notes: DMP sales data are compared to whole economy nominal GDP growth at current market prices. DMP employment (for the private sector) is compared to ONS/HMRC data on the number of payrolled employees. DMP data are adjusted to match the mean and variance of growth in the corresponding aggregate series over the time period shown on each chart. Sources: DMP; ONS; HMRC and authors' calculations.

Figure A11: Characteristics of DMP survey respondents

Response rates and local Brexit vote shares



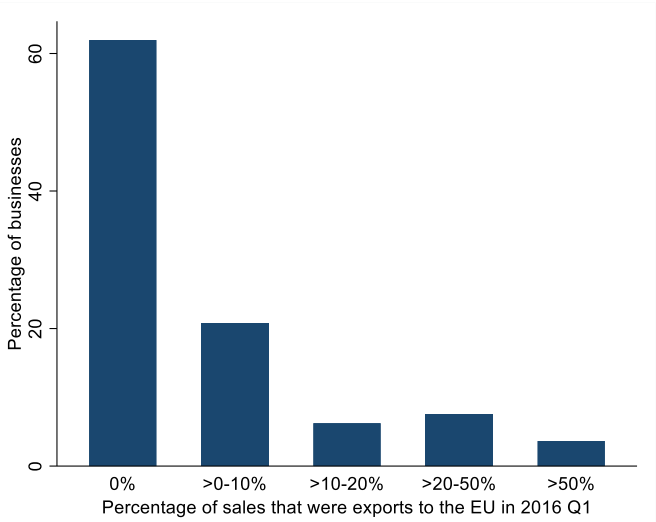
Personal views on Brexit



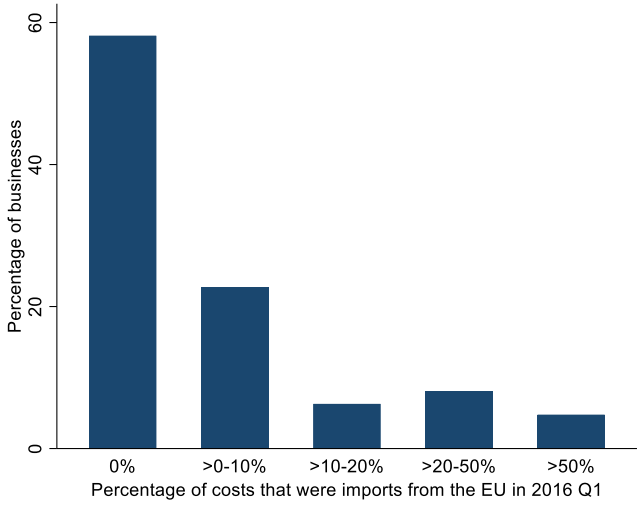
Notes: The left panel shows a binscatter plot which splits firms into 50 groups according to the share of the vote to leave the EU in the local authority where the firms has its headquarters. Personal views of DMP members on Brexit in the right panel are at the time of the June 2016 referendum and are taken from questions asked in the February to April 2018 surveys. Respondents who did not have a strong view either way or who preferred not to state (7 per cent) were excluded. The question asked respondents 'Taking everything into account, how do you personally view the UK voting to leave the European Union at the time of referendum? (i) Very positive; (ii) Somewhat positive; (iii) Neither positive nor negative; (iv) Somewhat negative; (v) Very negative; (vi) Prefer not to state; (vii) Don't know'. British Election Study data are self-reported referendum votes. Respondents with CFO characteristics are defined as managers/professionals by work type with a degree and annual income of over £50,000. Sources: Electoral Commission, British Election Study and Decision Maker Panel.

Figure A12: Pre-referendum exposure of DMP firms to the EU

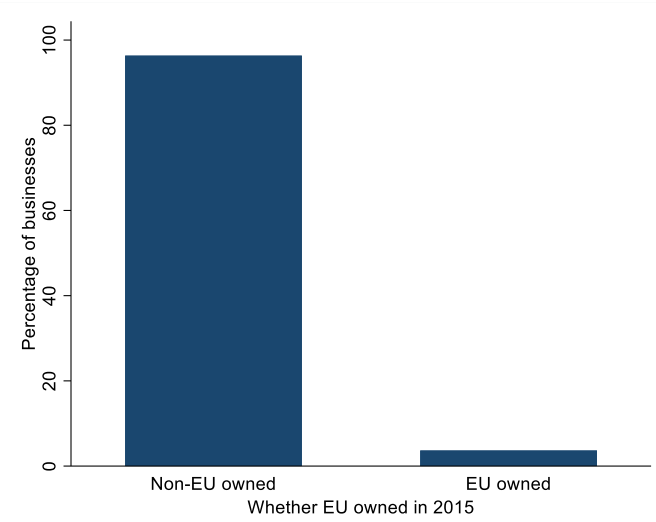
Percentage of sales that were exports to the EU



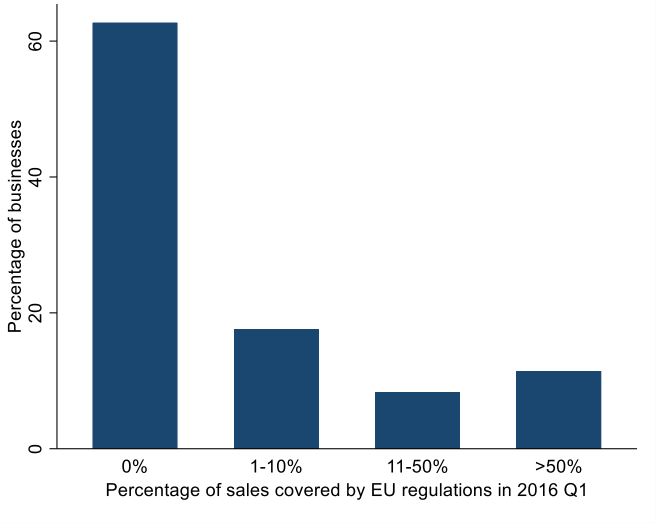
Percentage of costs that were imports from the EU



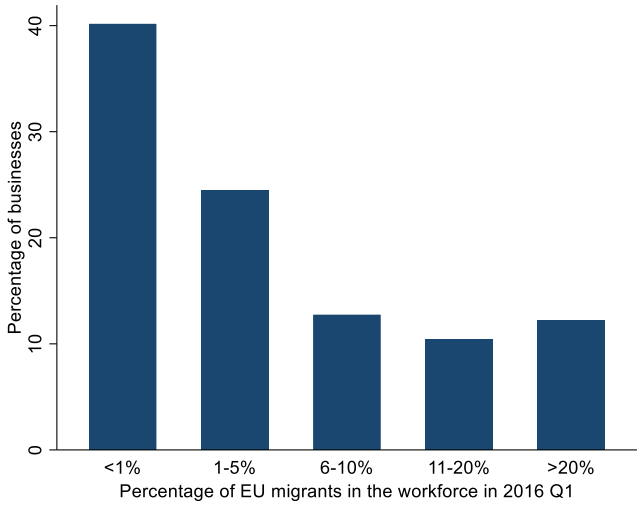
Whether EU owned



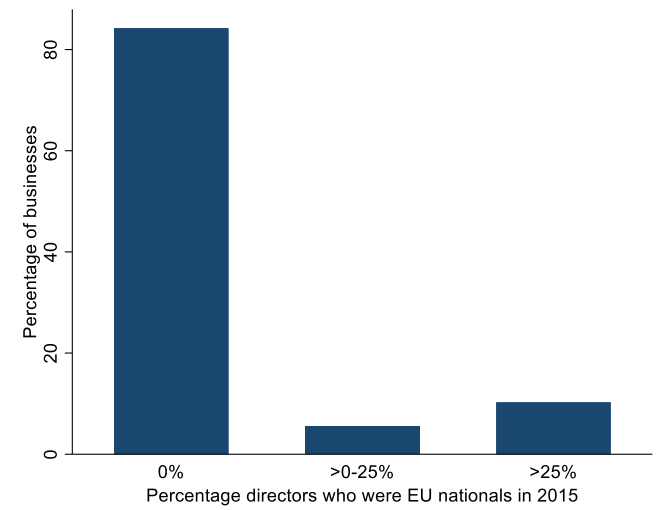
Percentage of sales covered by EU regulations



Percentage of workforce who were EU migrants



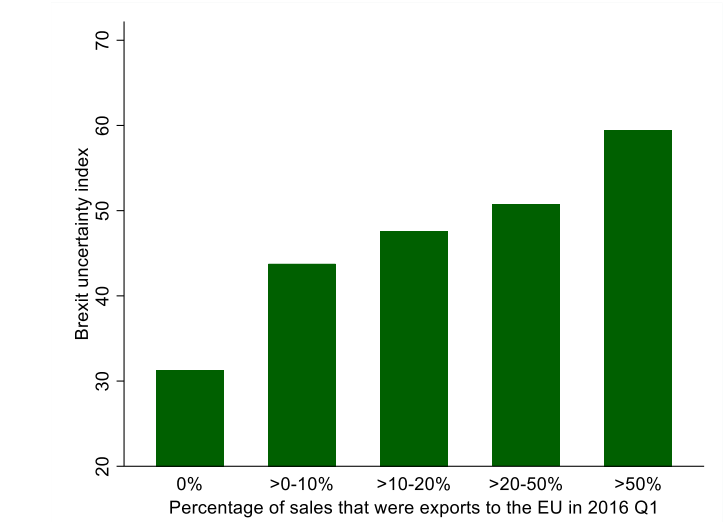
Percentage of directors who were EU nationals



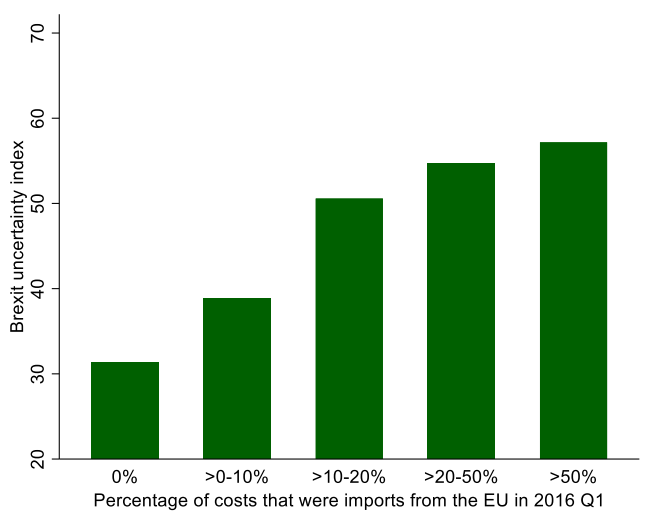
Notes: EU exports, EU imports, sales covered by EU regulations and EU migrant workers data are from the Decision Maker Panel. EU directors and ownership data are from Bureau Van Dijk FAME.

Figure A13: Brexit uncertainty and prior EU exposure

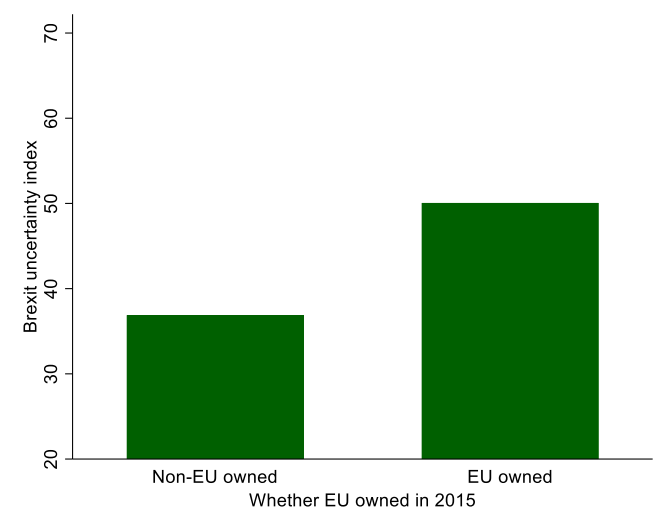
Percentage of sales that were exports to the EU



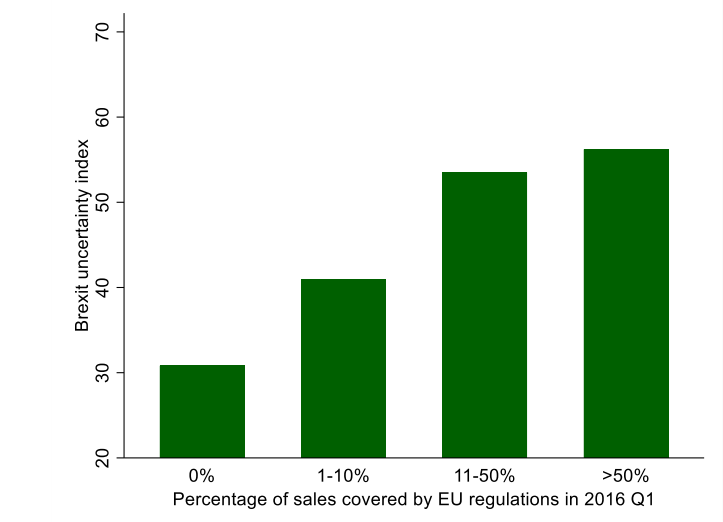
Percentage of costs that were imports from the EU



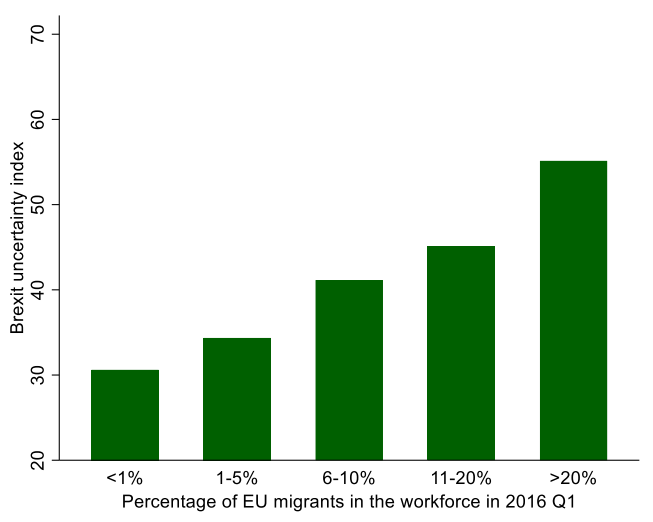
Whether EU owned



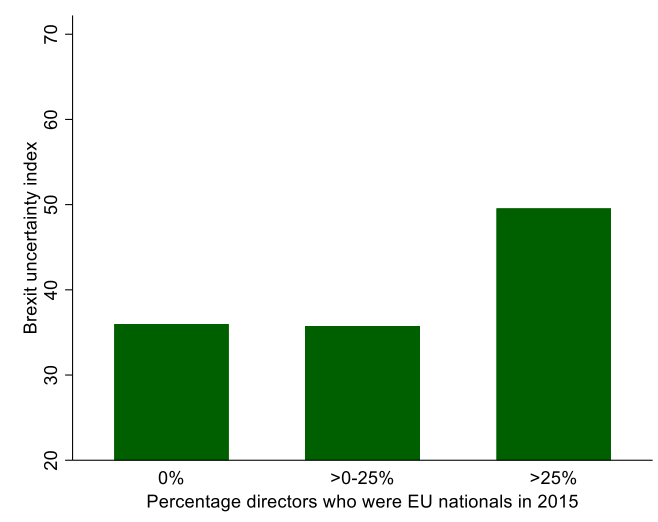
Percentage of sales covered by EU regulations



Percentage of workforce who were EU migrants

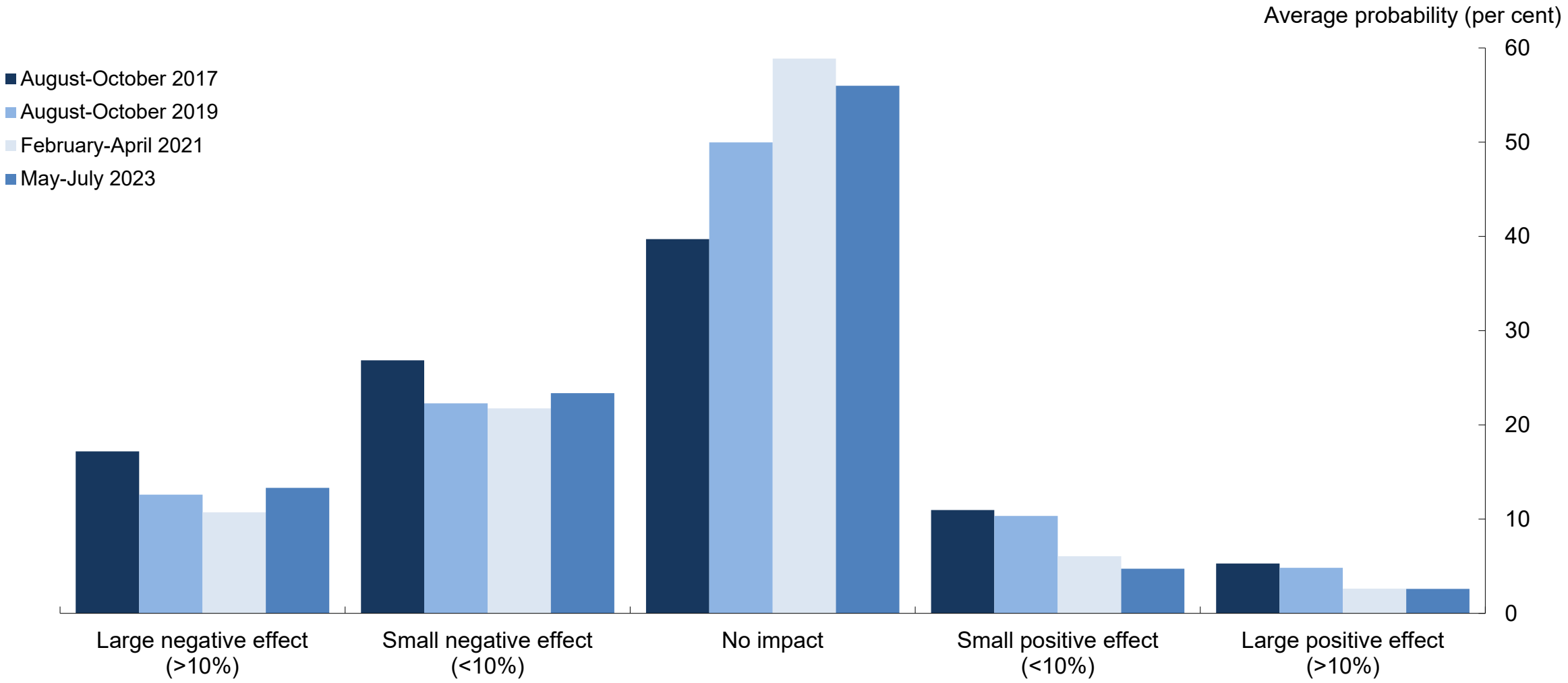


Percentage of directors who were EU nationals



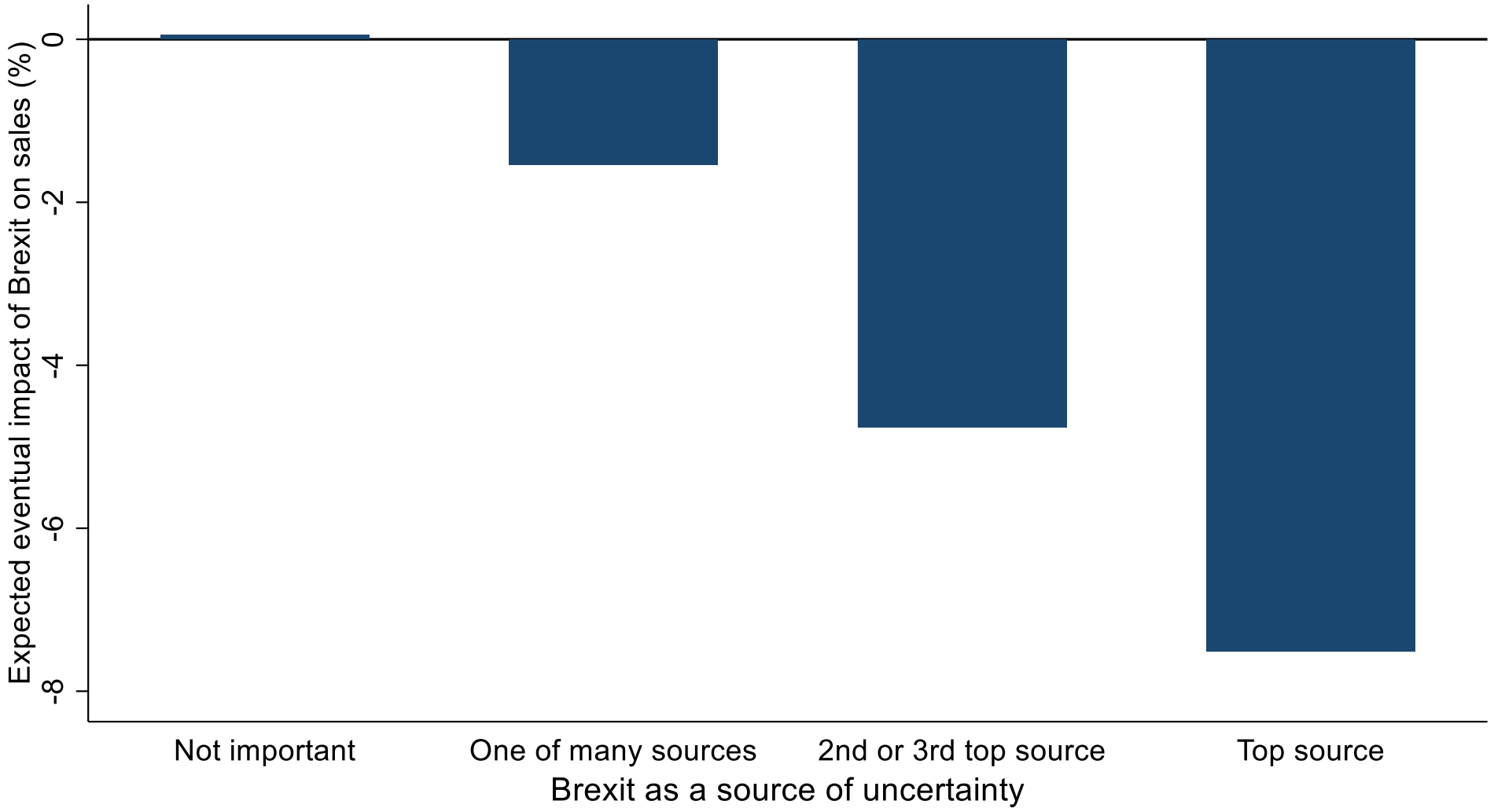
Notes: EU exports, EU imports, sales covered by EU regulations and EU migrant workers data are from the Decision Maker Panel. EU directors and ownership data are from Bureau Van Dijk FAME. Brexit uncertainty index shows the percentage of DMP survey respondents who view Brexit as their "top" or "one of their top three" sources of uncertainty in response to the question 'How much has the result of the EU referendum affected the level of uncertainty affecting your business?'. Brexit uncertainty data are averages for August 2016 to April 2024.

Figure A14: Expected eventual impact of Brexit on sales



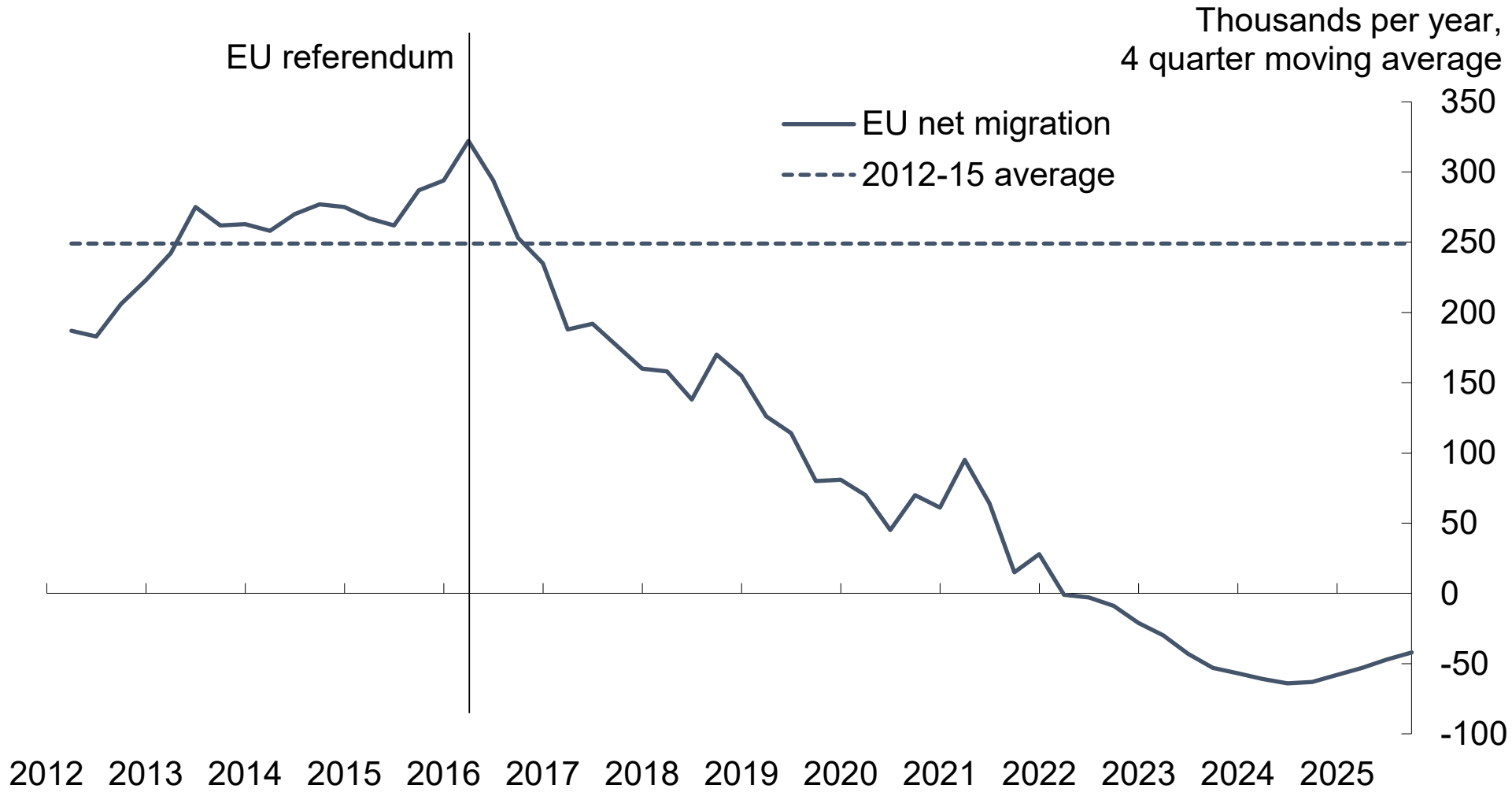
Notes: Question: 'How do you expect the eventual Brexit agreement to affect your sales once the UK has left the EU, compared to what would have been the case had the UK remained a member of the EU? What is the percentage likelihood (probability) that it will: (i) Have a large positive effect on sales at home and abroad, adding 10% or more to sales; (ii) Have a modest positive effect on sales at home and abroad, adding less than 10% to sales; (iii) Make little difference; (iv) Have a modest negative effect on sales at home and abroad, subtracting less than 10% from sales; (v) Have a large negative effect on sales at home and abroad, subtracting more than 10% from sales'. Source: Decision Maker Panel.

Figure A15: Correlation between first moment and second moment impact of Brexit



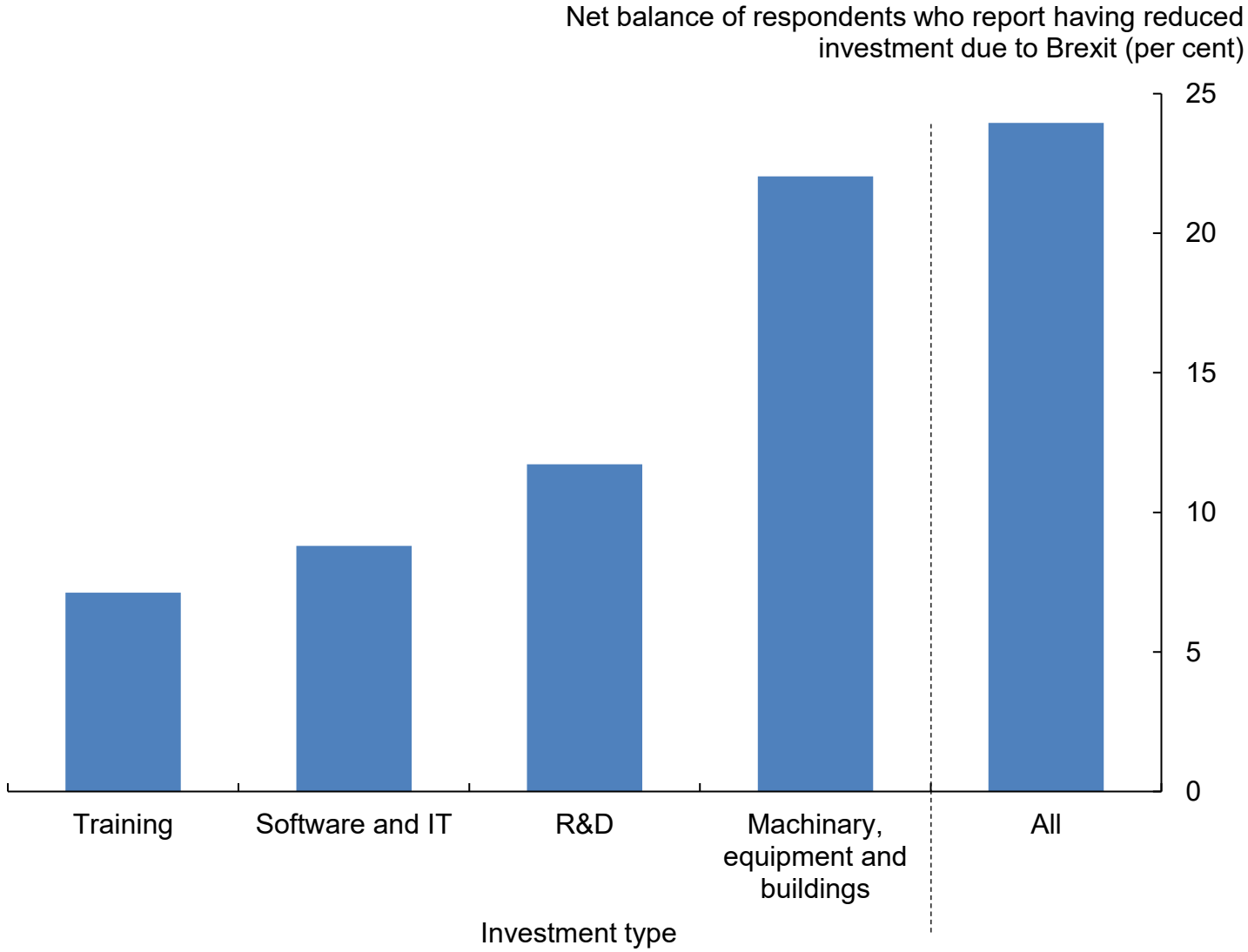
Notes: Based on DMP questions reported in the footnotes to Figure 7 and Figure A14. Figure is based on averages of data collected in DMP surveys between August 2016 and April 2024. Source: Decision Maker Panel.

Figure A16: Net migration from the EU to the UK



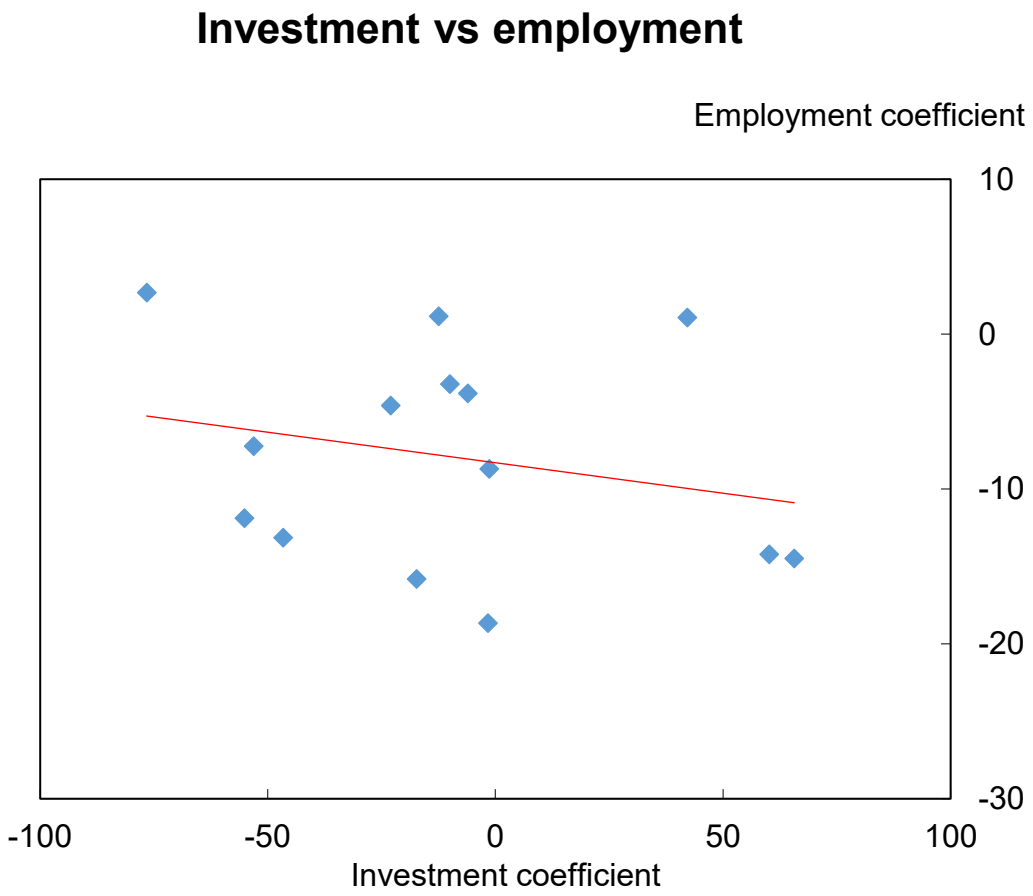
Source: ONS.

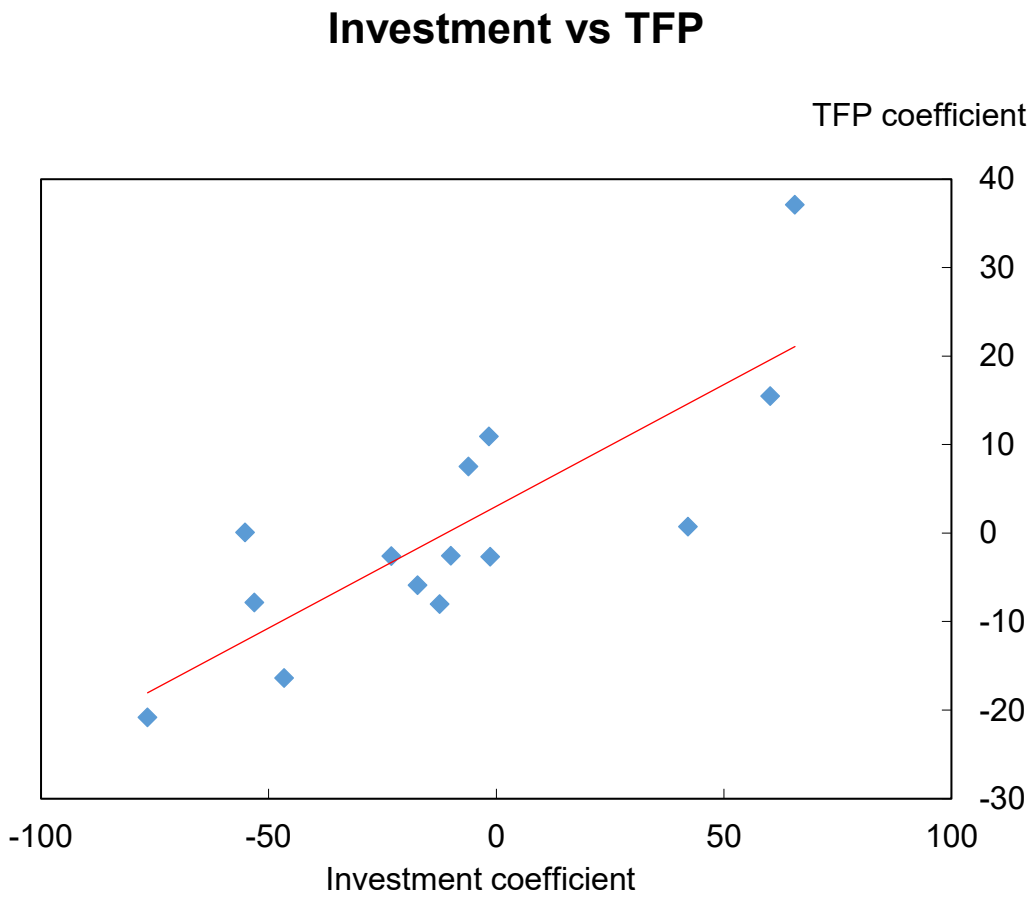
Figure A17: Impact of Brexit on different types of investment



Notes: The results are based on the question 'Could you say how the UK's decision to vote 'Leave' in the EU referendum has affected your capital expenditure since the referendum? Please select one option for each type of investment [Training of employees; Software, data, IT, website; Research and development; Machinery, equipment and buildings]: a large positive influence, adding 5% or more; a minor positive influence, adding less than 5%; no material impact; a minor negative influence, subtracting less than 5%; a large negative influence, subtracting 5% or more.' 'Net balance' is defined as the share who say that Brexit has reduced investment less the share saying it has increased investment. Data were collected between February and April 2019. Source: Decision Maker Panel.

Figure A18: Correlations between 1 digit industry level coefficients on EU exposure in firm outcome regressions

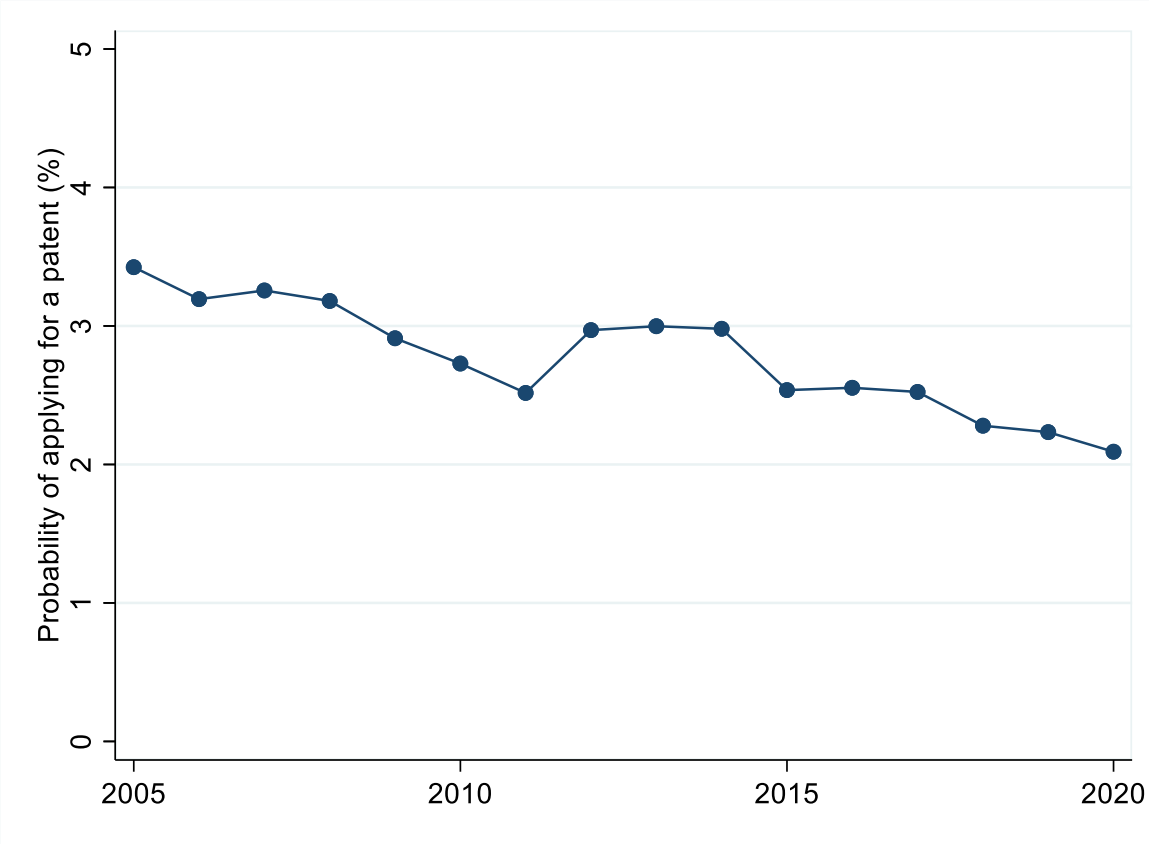




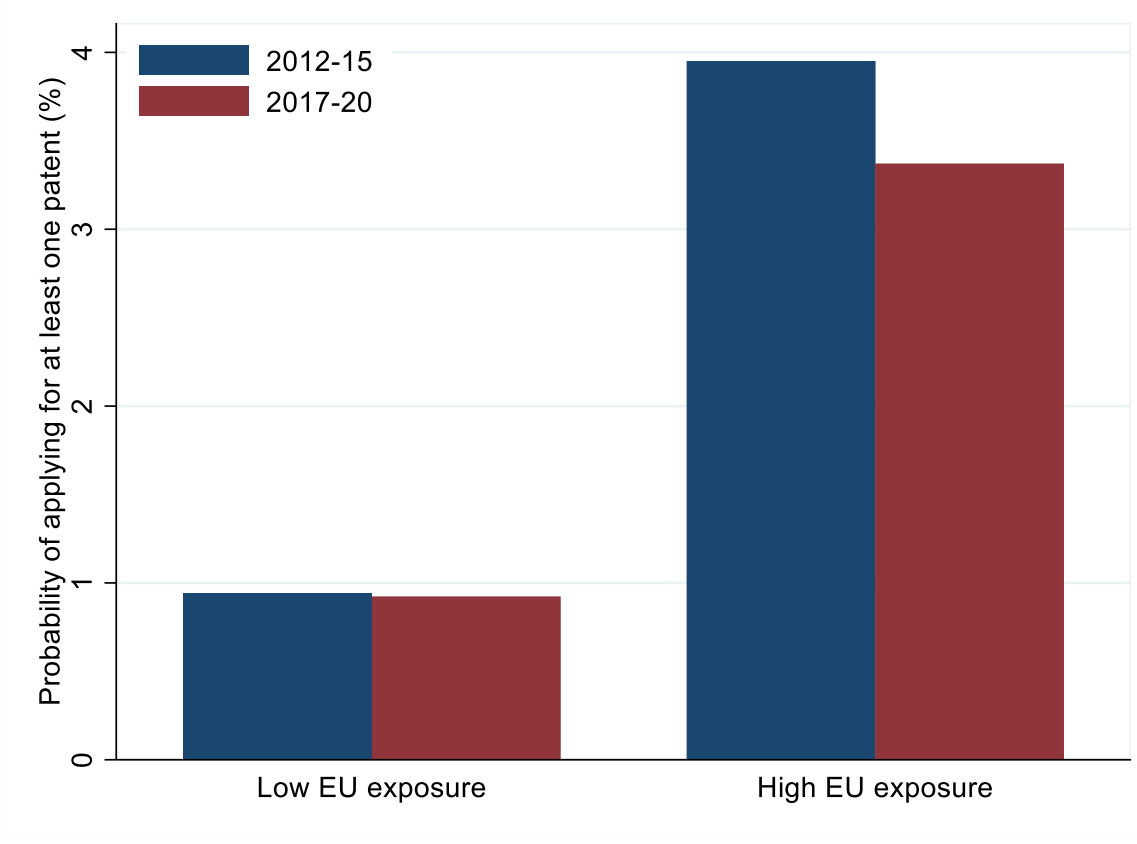
Notes: The figures show the correlation between the industry level coefficients on EU exposure*post referendum in regressions for investment growth vs regressions for employment/TFP growth where the coefficients on EU exposure*post referendum are allowed to vary by industry. These regressions are identical to those shown in Tables 2 and 3, other than that coefficients are allowed to vary by industry

Figure A19: Patents analysis

Probability of DMP firms applying for a patent



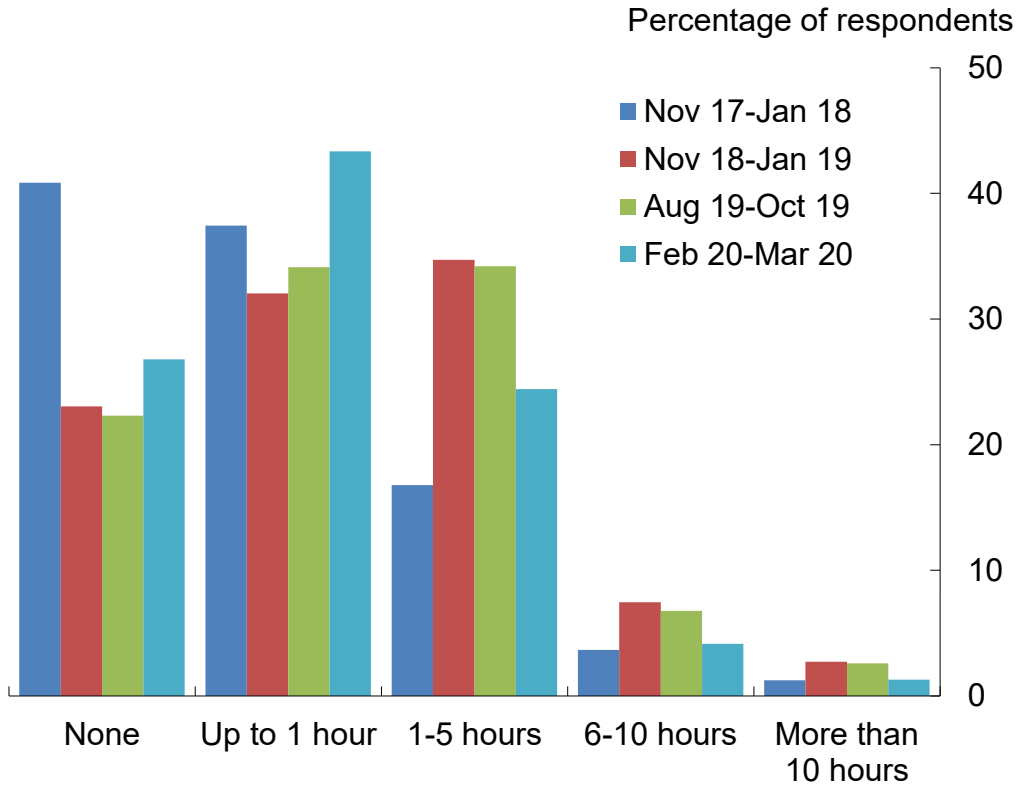
Split by EU exposure



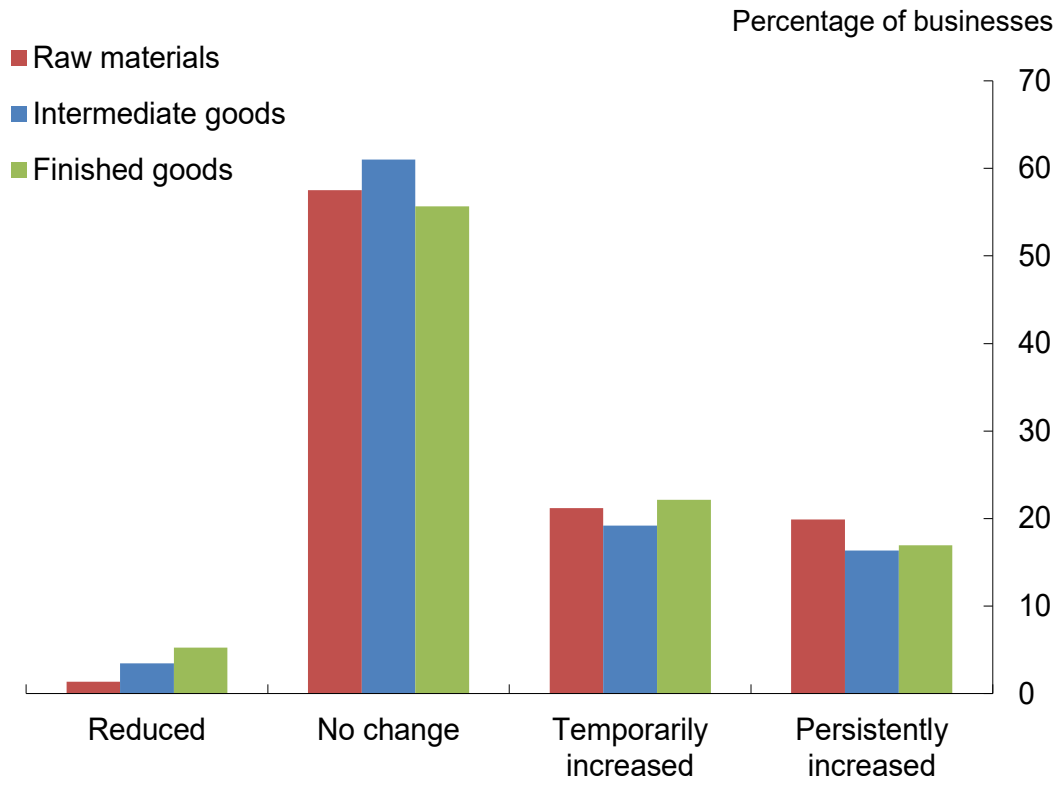
Notes: High EU exposure is defined as firms with above average pre-referendum exposure to the EU, based on the average of the following 6 exposure measures: share of sales to EU; share of costs from EU imports; share of EU migrants in workforce; share of sales covered by EU regulations; share of directors who are EU nationals; and a dummy for being EU owned. All are on a 0-1 scale. Low EU exposure is defined as firms with below average pre-referendum exposure on the same metric. Patents data are from World Patent Statistical Database. We thank Ralf Martin (Imperial), Arjun Shah (King's College London), Anna Valero (LSE) and Dennis Verhoeven (KU Leuven) for their assistance with enabling the data on patents to be linked to the DMP.

Figure A20: Time spent planning for Brexit and impact on stocks

Weekly CFO hours spent on Brexit planning



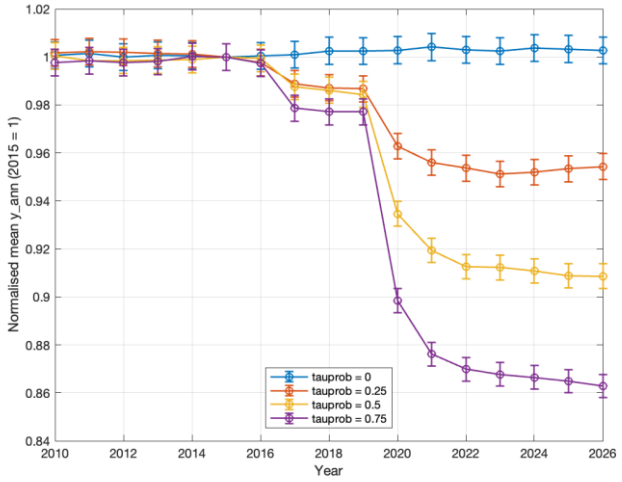
Impact of Brexit on stocks in 2019



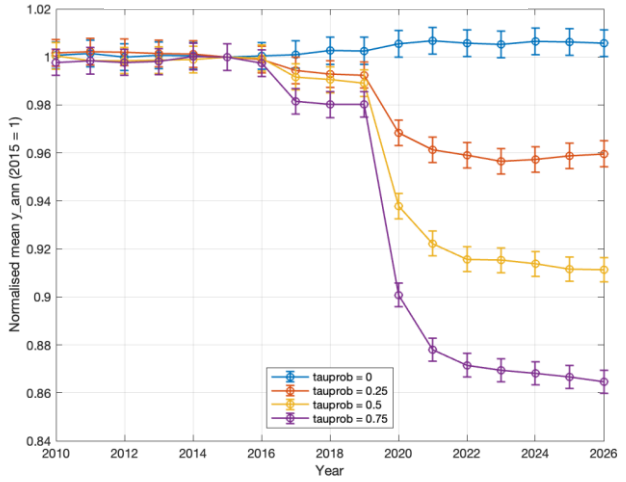
***Notes**:* Charts are based on the questions 'On average, how many hours a week are the CEO and CFO of your business spending on preparing for Brexit at the moment?' and 'Which of the following statements best describes how the UK's decision to leave the EU has affected your stockbuilding decisions? (i) Stock levels have been increased, and expect to increase further; (ii) Stock levels have increased, expect to maintain higher level over medium term; (iii) Stock levels have been increased, expect to run down after 31 October 2019; (iv) Stock levels have been increased, expect to run down over next few months; (v) Stock levels had been increased, but have already been reduced to normal levels; (vi) Stock levels have been unchanged; vii) Stock levels have been reduced; viii) Not applicable, do not hold stocks ". The stocks question was asked between May and July 2019, and the figure excludes firms who do not hold stocks. Source: Decision Maker Panel.

Figure A21: Output by Brexit exposure under different model variants

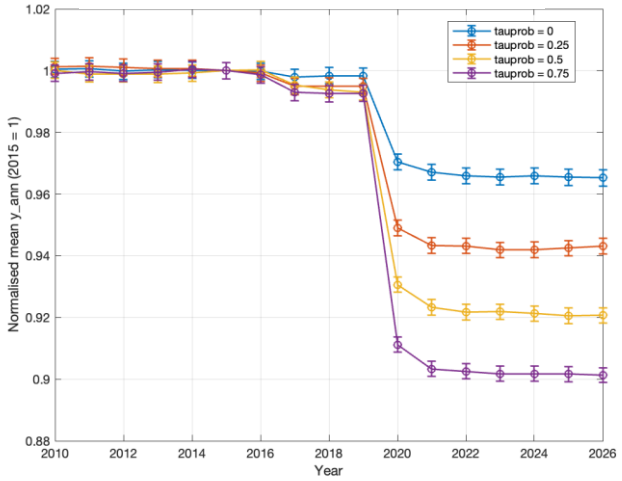
Model A: No spillovers, no reallocation



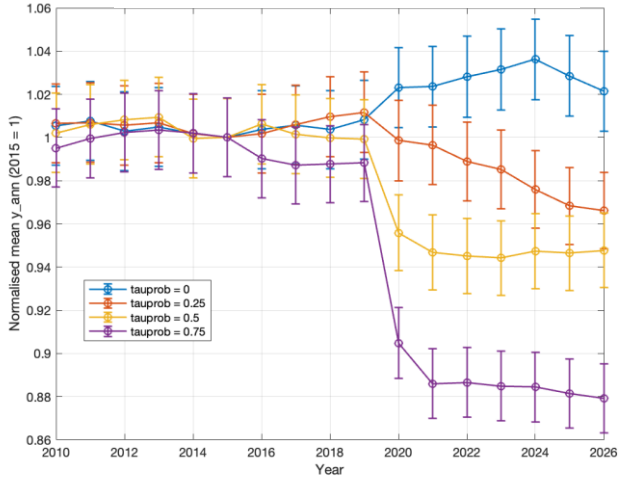
Model B: Reallocation only



Model C: Negative demand and supply chain spillovers



Model D: Positive labor market spillovers



Notes: Charts show simulated output (normalised to 2015) for firms grouped according to their probability of incurring the Brexit cost τ (tauprob), with 95% confidence intervals. In Model A, firms are effectively independent and there are no spillovers. In Model B, there is reallocation from higher productivity Brexit exposed firms to lower productivity firms with lower exposure. In Model C, negative demand and supply chain spillovers are introduced (with no reallocation). In Model D, the only spillovers are positive ones through the labor market where labor demand from Brexit exposed firms pushes down the equilibrium wage, benefiting the less exposed firms (again with no reallocation).