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Abstract: We use a major new survey of UK firms, the Decision Maker Panel, to assess the impact of the June 2016 Brexit referendum. We identify three key results. First, the UK's decision to leave the EU has generated a large, broad and long-lasting increase in uncertainty. Second, anticipation of Brexit is estimated to have gradually reduced investment by about 11% over the three years following the June 2016 vote. This fall in investment took longer to occur than predicted at the time of the referendum, suggesting that the size and persistence of this uncertainty may have delayed firms' response to the Brexit vote. Finally, the Brexit process is estimated to have reduced UK productivity by between 2% and 5% over the three years after the referendum. Much of this drop is from negative *within*-firm effects, in part because firms are committing several hours per week of top-management time to Brexit planning. We also find evidence for smaller negative *between*-firm effects as more productive, internationally exposed, firms have been more negatively impacted than less productive domestic firms.

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1. INTRODUCTION

This paper uses a major new survey of UK firms, the Decision Maker Panel (DMP), to study the impact of the UK's decision to leave the European Union in the 23 June 2016 referendum (Brexit). The DMP was created by a Bank of England-Nottingham-Stanford research collaboration, collecting data on several thousand firms each month. As such, this paper studies the impact of an unexpected, large and persistent uncertainty shock – the Brexit process. The vast majority of "uncertainty shocks" throughout history – the 1973 OPEC oil price shock, Gulf Wars I or II, the 9/11 attacks, the collapse of Lehman Brothers, etc. – generate a surge in uncertainty that subsides reasonably quickly as markets participants' initial fears are allayed by further information becoming available. Brexit is unusual in that it generated *persistent* uncertainty – three years after the original vote, the UK had not left the EU, there was still no clarity on the eventual outcome and our survey results show that there was substantial unresolved uncertainty.

The vote for Brexit was a largely unexpected event and we observe that it has had a heterogeneous impact on firms according to their pre-referendum exposure to Europe. The betting markets put the odds on Brexit at around 30% in the months before the vote.[1] Combining firm-level data from the DMP with a population accounting dataset we can estimate the causal impact of the Brexit process so far using a classic difference-in-difference estimation. Overall, this paper finds three important new results.

First, the UK's decision to leave the EU has generated a high, broad and persistent increase in uncertainty. Figure 1 plots our Brexit Uncertainty Index (BUI), which shows the share of firms reporting that Brexit was in their top three drivers of uncertainty. This demonstrates that even three years after the June 2016 vote firms reported extremely high levels of Brexit uncertainty – more than half of firms reported Brexit being one of their top three sources of uncertainty. The uncertainties surrounding Brexit are also complex – for example, around what the UK's eventual relationship with the EU will look like and how this will affect market access, the supply of migrant

[1] For example, see Bell (2016). Financial markets similarly did not seem to expect Brexit. Indeed, 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.

labour and the UKs product regulations. There is also uncertainty around how the UK will transition to that new post-Brexit position, how the relationship will look at different points in time and what each of these will mean for the prospects of individual businesses.

Second, anticipation of Brexit has substantially reduced UK investment, cutting this by around 11%, relative to what would have otherwise happened. Interestingly, this fall in investment took three years to fully materialize, with these investment effects building gradually. In contrast, forecasts made in the aftermath of the referendum predicted that investment growth would fall sharply within the first year after the Brexit vote and then recover. This delay suggests firms may not respond as rapidly to large shocks that cause persistent uncertainty rather than short-term uncertainty, possibly because uncertainty leads firms to act cautiously, as discussed, for example, in Guiso and Parigi (1999) and Bloom, Bond and Van Reenen (2007).

Finally, we estimate that the Brexit process has reduced the level of UK productivity by between 2% and 5% over the three years since the referendum. Much of this drop is from a negative *within*-firm effect, in part because firms are committing several hours per week of top-management time to Brexit planning. But we also find evidence of a smaller negative *between*-firm effect – more productive internationally exposed firms are estimated to have shrunk relative to less productive domestically focused firms.

This paper links to three major strands of literature. First is the literature on uncertainty, for example, Bernanke (1983), Dixit and Pindyck (1994), Fernandez-Villaverde et al. (2011), Arellano et al. (2018) and Basu and Bundick (2017). Brexit offers an almost ideal uncertainty shock to evaluate – it was large, mostly unexpected, accompanied by little other change (at least initially), and should be expected to have had heterogeneous impacts on different types of UK firms depending on their prior exposure to the EU.

Second, there is a large literature on trade reforms, including for example 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) and Crowley et al (2018).

These generally show positive growth impacts from freer trade – 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. Within the scope of this literature the withdrawal of the UK from the EU single market and customs union can be seen as a "reverse" trade reform – reducing free-trade and increasing uncertainty.

Finally, there is the nascent Brexit literature, including papers like Van Reenen (2016), Sampson (2017), Breinlich et al. (2018), Davies and Studnicka (2018), Dhingra, et al. (2018), Graziano et al. (2018), Born et al. (2019) and Costa et al. (2019) predicting negative effects on UK investment, trade, employment, wages and firm entry. McGrattan and Waddle (2017) and Steinberg (2019) argue that Brexit is likely to reduce overall UK welfare, while Crowley et al. (2019) and Vandenbussche et al. (2019) argue that Brexit will cause economic damage to many firms outside the UK. However, there also some who argue that Brexit will have a more positive effect on the UK economy, for example Booth et al. (2015), Whyman and Petresku (2017) and Minford (2019).

The structure of the article is as follows. Section 2 provides an overview of the Decision Maker Panel, survey design and validation of the data; section 3 presents results around Brexit uncertainty; section 4 presents the impact of the Brexit process so far on UK firms; section 5 concludes.

2. THE DECISION MAKER PANEL (DMP)

2.1 The Survey Process and Sampling Frame

The Decision Maker Panel was launched in August 2016 by the Bank of England, University of Nottingham and Stanford University, supported by funding from the Economic and Social Research Council. The survey is closely based on the Survey of Business Uncertainty run in the US by the Atlanta Fed, which is described in Altig et al. (2019). The sampling frame for the DMP is the population of all 42,000 active UK businesses with 10+ employees in the Bureau van Dijk FAME database.[2] Firms are selected randomly from this sampling frame and are invited by

[2] FAME is provided by Bureau Van Dijk (BVD) using data on the population of UK firms from the UK Companies House. FAME itself is part of the global AMADEUS database.

telephone to join the panel by a team of trained analysts from the Decision Maker Panel Unit based at the University of Nottingham. Once firms are part of the panel they receive monthly emails linking to a 5-minute online survey. Firms that do not respond for three consecutive months are re-contacted on whether they received the emails or have any issues with the survey. When the recruitment team first contact firms they ask to speak to the CFO, and failing that the CEO. 85% of respondents are in these two positions (70% are CFOs and 15% are CEOs).

The survey panel has grown rapidly – in less than one year (by April 2017) there were more than 1,000 monthly respondents and within two years almost 3,000 monthly respondents (See Figure A1). Taking all of the surveys up to June 2019 together, 7,200 firms have responded to at least one DMP survey. This represents a response rate of around 25% out of the 28,000 firms who had been contacted and invited to join the DMP by June 2019.[3] The sample that we use in this paper are the 5,900 firms who have ever responded to the DMP and answered a question about the importance of Brexit as a source of uncertainty. This provides a large and representative sample for our analysis: these firms account for around 3.7 million employees, which is approximately 14% of UK private sector jobs.

The DMP provides good coverage of different industries and firm sizes (see Figures A2 and A3). It also has broadly equal coverage of both "Remain" and "Leave" voting areas. The linear response regressions in Table A1 show that the survey response rate is independent of local Brexit vote share in the local authority in which a firm is headquartered, although somewhat larger firms and older firms were slightly more likely to respond.[4] We also verify that panel respondents in "Leave" voting local authorities were more likely to be personally in favour of Brexit and that those in more "Remain" areas were more likely to have a negative personal view on Brexit (Table A2). Overall, only 24% of panel members had a positive personal view of Brexit at the time of the referendum. That contrasts with the country as a whole which had a 52% vote share for Brexit. However, this difference appears to simply reflect the demographic of CFOs. Using data from the British Election Survey, we show that 23% of those with "CFO like characteristics" (managers with a degree and

[3] We define contacted as a telephone call being answered or an email being responded to.
[4] The p-value on the Brexit vote share coefficient is typically between 0.3 and 0.5 in the regressions reported in Table A1.

income over £50,000 a year) supported Brexit at the time of referendum (Figure A4), which is almost identical to our DMP figure. Further details on the survey methodology can be found in Bloom et al. (2017).[5]

In summary, the DMP has several advantages relative to other surveys of UK firms. It is now one of the largest regular business surveys, with a panel of 8,000 firms and around 3,000 responding in any given month.[6] The DMP is representative of UK firms given its construction from a random sample of the population of all 10+ employee firms. Finally, it provides rapid feedback (responses are available within one week of the close of the survey) due to its electronic collection of information directly from key decision makers (CFOs and CEOs).

2.2 Content of the DMP survey

The DMP had four types of questions:

A) Regular Brexit Questions: respondents are asked on a regular basis about the level of Brexit uncertainty facing their business and how they expect Brexit to affect the sales of the firm that they represent.

B) Regular questions on subjective expectations: respondents are asked on a rotating basis about their past, current, and one year ahead expectations of sales, employment, investment and prices. The expectations questions follow Altig et al. (2019) by asking firms for their lowest, low, medium, high and highest expectations and the probabilities associated with them. As a result subjective expectations and uncertainty can be generated for each of these variables.

C) Special topics: a set of special questions are asked on a rotating basis, primarily in relation to Brexit. These have included questions on the amount of managerial time spent on Brexit preparations, their expectations over the time horizon of Brexit, their main sources of Brexit uncertainty, how different types of investment have been affected by the Brexit process and how Brexit has influenced stock-building decisions.

[5] Further information and aggregated data are available on the survey website: www.decisionmakerpanel.co.uk.
[6] By way of comparison, the BCC survey has 6,000 quarterly responses, the CIPS survey 1,400, CBI suite of surveys 650 and the Deloitte CFO survey around 130.

D) Pre-referendum measures of exposure to the EU: we also collected data for every firm upon entry to the panel about their 2016 first-half export and import share to or from the EU, share of EU migrants in their labour force, and share of sales covered by EU regulations.[7]

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 rotate through all questions. This allows us to spread about 15 minutes of survey questions over three 5-minute modules. Moreover, since the sample engages 3,000 firms, we have around 1,000 firms responding to each question per month, yielding a regular monthly flow of data.[8]

2.3 Validating the survey responses

There are three ways in which we validate the quality of the DMP data. First, we compare the DMP data to accounting data for the same firm in the same year. This shows a tight match (see Figure A5). Survey values for sales, employment and investment align very closely with audited accounting values for the same period. Second, we compare aggregated DMP values with aggregated accounting population data or ONS national accounts for variables such as sales, investment and employment. Again, these align relatively well in levels and broad trends (see Figure A6).[9] And we also benchmark the DMP data on Brexit exposure to external sources of

[7] Prior to the introduction of a separate introductory questionnaire for new joiners, all panel members were asked to provide these data once in 2017 and again in 2018. We also use data from the BVD FAME database on whether a firm is ultimately owned in the EU as an additional EU exposure measure. These data were downloaded at the start of 2018, but given lags in the data should broadly represent ownership status around the time of the referendum. 8% of firms in our sample are EU owned.

[8] Aggregated survey results are weighted using employment data, although the regressions in this paper are run on an unweighted basis. To construct the weights, respondents are divided into 52 groups based on 13 industries and 4 size categories. The weight of each company is calculated as the total employment share accounted for by that group within the business population divided by the number of DMP respondents within that group. So, for example, all manufacturers with at least 250 employees (the largest size group) are given the same weight. Finance & insurance and other production industries were initially excluded from the survey but have been part of the DMP since early 2018. These industries are given zero weight in that earlier period, with the weights of other sectors being proportionally scaled up.

[9] Sales and employment growth rates in the accounting data tend to be higher than in official aggregate data. This may partly reflect a survivor bias in the accounting data where output and jobs lost from firms that go out of business are not captured because these firms never report accounts after they die. There is a similar issue in the DMP data where these failed firms stop responding to the survey.

aggregate data.[10] Table A3 shows that these match up well.[11] Finally, we compare predicted values with realizations one year later. As shown in Figure A8, there is a good correlation in growth rates of actual and predicted sales, employment, investment and prices, but as is also shown in Figure A9 a close association between firms' subjective uncertainty and subsequent forecast errors. This suggests that panel members both know their businesses well and think carefully about the answers that they provide to the DMP survey.

3. EVALUATING BREXIT UNCERTAINTY

A key question we ask our panelists is "*How much has the result of the EU referendum affected the level of uncertainty affecting your business*" with four possible responses: (1) 'Not important', (2) 'One of many drivers of uncertainty', (3) 'One of the top two or three drivers of uncertainty', and (4) 'The largest current source of uncertainty'. We use this to generate our key Brexit Uncertainty Index (BUI), which is defined as the share of firms which choose options (3) or (4) – that is rating Brexit as, at the least, one of the three highest drivers of uncertainty for their business.

This BUI is plotted in Figure 1. It shows that Brexit uncertainty was high after the June 2016 vote – just under 40% of firms rated Brexit as one of the three main drivers of uncertainty. 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. The EU and UK did subsequently come to a withdrawal agreement in November 2018, but this was rejected by the UK Parliament and the BUI remained at an elevated level in the run-up to 29 March 2019 when the UK was originally due to leave the EU. After Brexit was postponed until 31 October 2019 uncertainty started declining, although it still remained at very high levels as of July 2019, and higher than it was in the first two years after the referendum.

[10] The distributions of these exposure measures are shown in Figure A7.

[11] The only exception to this is the import content of costs in wholesale and retail where imports appear more important in the DMP than in aggregate data. That is likely to reflect some double counting where retailers define goods imported via wholesalers as imports. Technically they were not imported by the retailer and are not measured as such in official data, but for our purpose the ultimate import content is likely to be more relevant. Aside from this, the DMP data on Brexit exposure also correspond well to official data at an industry level. For 2 digit industries with at least 20 DMP observations, the correlation coefficients between DMP and ONS industry level data are all between 0.6 and 0.8 for export, import and migrant share data.

One driver of Brexit uncertainty is likely to be the lack of clarity over the timing of the Brexit process. Figure 2 contains responses to a question about the timing of Brexit from the DMP, showing a broad range of views over the possible end date, with respondents thinking there was around a 10% chance that Brexit would never happen. There are also many different aspects to this uncertainty across firms. Figure A10 shows that firms have reported uncertainty around the impact of Brexit on labour, regulations, demand, customs and supply chains to all be important.[12]

Consistent with the importance of Brexit in governing overall uncertainty, we see in Figure 3 that Brexit uncertainty is well correlated with the subjective uncertainty that firms expressed in the sales, employment, investment and price growth questions.[13] This supports the claim that Brexit uncertainty has been a key determinant of overall uncertainty for UK firms.

Interestingly, while our key Brexit Uncertainty Index in Figure 1 has been rising since the Brexit vote, other standard measures of uncertainty have not. Stock-market volatility, which is a key measure of uncertainty in the literature (e.g. Leahy and Whited 1996 or Bloom 2009), rose after the Brexit vote but dropped back down within weeks (Figure 4). This suggests that the lack of information revealed after the June 2016 vote resulted in subdued stock-market volatility, since for many months after the vote very little progress was made in the Brexit process.

Thus, while classic "stochastic volatility" uncertainty shocks generate increased stock-market volatility, the "Bayesian" Brexit uncertainty shock does not. "Stochastic volatility" uncertainty shocks are described as a jump in σ_t in equation (1) below, where jumps in uncertainty lead to both an increase in the variance in the distribution of future outcomes for the driving process A_t but also an increased variance of realizations. This is the type of uncertainty process commonly modelled in the finance literature (e.g. Hull and White 1987) or the macro uncertainty shock literature (e.g. Hassler (1996) or Bloom (2009)) where uncertainty and volatility move closely together.[14]

$$A_t = A_{t-1} + \sigma_t \varepsilon_t \qquad \varepsilon_t \sim N(0,1) \tag{1}$$

[12] Bloom et al (2018) reports additional analysis of the DMP uncertainty measure.
[13] To generate subjective uncertainty for each variable we used the 5-point estimated values and probabilities, using the same process as Altig et al. (2019).
[14] For example, the correlation between the VIX (1 month implied volatility on the S&P500 index) and the monthly standard-deviation of daily returns on the S&P500 index is around 0.9.

Brexit appears to have been different, following a process more like equation (2) below

$$A_t = A_{t-1} + \sigma_{t-s}\varepsilon_t \qquad \varepsilon_t \sim N(0,1) \tag{2}$$

where the critical difference is that the impact of uncertainty on the driving process is lagged by s periods (which, in the case of Brexit, could be several years). That is, after a jump up in uncertainty (σ_t) in period t it is not until period t+s that realizations become more volatile. This is a "Bayesian" uncertainty shock in that the prior of outcomes in period t+s (and beyond) becomes more dispersed, but the variance of realizations does not increase before then. Given that stock markets react to news, and that the Brexit process made little progress after the initial vote, Brexit uncertainty appears to be better defined as a "Bayesian" uncertainty shock, similar in spirit to Bernanke (1983).

Another measure of uncertainty is forecast disagreement, which again appears to spike around the Brexit vote and then subside as Figure 4 shows. This highlights one of the downsides of forecaster disagreement as a measure of uncertainty - each forecaster was probably more uncertain after Brexit, but if they all provide a central forecast of, say, 1% GDP growth, then disagreement will be low.

Finally on Figure 4, we plot the UK Economic Policy Uncertainty (EPU) Index from Baker et al. (2016) based on stories in newspapers relating to uncertainty, which shows a six standard-deviation increase in June 2016 followed by a drift downwards. While the EPU index remained elevated after the June 2016 vote, averaging about two standard-deviations above its long-run average, the level, three years later, was still below the June 2016 value. This decline could be explained by Brexit news fatigue whereby the UK media has become saturated with Brexit news and the number of stories in UK newspapers has fallen off despite uncertainty apparently rising according to the BUI. Indeed, the UK component of the World Uncertainty Index from Ahir et al. (2019), which is based on Economic Intelligence Unit quarterly reports (which are less likely to display Brexit fatigue) show a flat level of post-Brexit UK uncertainty.

In summary, this highlights that for protracted Bayesian uncertainty shocks – events that unravel over extended periods of months or years like economic reforms or political reforms – traditional measures of uncertainty based on stock-market, news or disagreement measures may imperfectly measure uncertainty over time.

4. THE IMPACT OF THE BREXIT VOTE

To estimate the causal impact of the Brexit vote on UK firms we exploit two things. First, that the vote for Brexit was a surprise, with betting odds giving Brexit about a 30% chance of success over the 6 months preceding the June 2016 vote. With little pre-referendum anticipation effect, the changes between more and less EU exposed firms post 2016 should primarily reflect the impact of the Brexit vote and subsequent process. Second, Brexit should have a heterogeneous impact on UK firms. In particular, firms with high trade volumes with the EU, large shares of EU migrant workers and a higher coverage of EU regulations were most exposed. This provides the between-firm variation to enable us to identify the impact that the Brexit process has had.

To demonstrate how Brexit uncertainty was associated with prior exposure to the EU, Table 1 shows regressions of our firm-level Brexit uncertainty measure (on a 1 to 4 scale) against what firms report as their pre-Brexit (first-half of 2016) share of sales exported to the EU in column (1), share of costs that were imports from the EU in column (2), share of workforce that were EU migrant workers in column (3), share of sales covered by EU regulations in column (4) and whether a firm was ultimately EU owned in column (5). We see, not surprisingly, that firms with higher levels of trade, employment, regulatory and ownership links with the EU have reported significantly higher levels of Brexit uncertainty. In column (6) we add all the measures together and include industry dummies, finding similar results. We focus here and for the rest of the paper on Brexit uncertainty measured on a 1 to 4 scale rather than just focusing on whether Brexit is in a firm's top 3 sources of uncertainty. The 1 to 4 scale data are richer, and perhaps as a consequence, have a slightly stronger relationship with prior exposure to the EU.[15]

Before examining the impact of the Brexit vote we also need to discuss what our Brexit uncertainty measure is capturing. The referendum result both increased uncertainty for firms (in the language

[15] This can be seen, for example, by the R^2 in column 6 of Table 1 (which use the 1-4 scale) being higher than in column 7 (which uses a 0-1 scale for whether Brexit is a top 3 source of uncertainty or not), although in general our results are robust to whichever measure we use. Our regressions use a measure of average uncertainty for each firm over the three years since the Brexit referendum. This is allows us to adjust for when a firm joined the panel and is derived as the fitted values from a regression using actual uncertainty responses as the dependent variable with time and firm fixed effects as explanatory variables. In aggregate, Brexit uncertainty data look very similar whether measured on a 1-4 or a 0-1 scale, as can be seen from Figure A11.

of equation (2) it was a positive shock to σ_t) and likely reduced the first moment (in the language of equation (1) it was a negative shock to ε_t). Whilst the DMP does ask firms about both uncertainty and how they expect Brexit to affect their sales, these two measures are well correlated (as shown by Figure A12) and both are related to prior exposure to the EU, making it hard to disentangle the first and second moment effects.[16] We therefore use just the DMP Brexit uncertainty data in our analysis, which has a stronger relationship with EU exposure[17], but we refer to it as a measure of overall Brexit exposure in our results tables and interpret our estimated impacts of the Brexit process so far as the *reduced form* impact that combines both the first and second moment effects.

In an attempt to evaluate how much the survey uncertainty measure is picking up first vs second moment exposure of firms to Brexit, Table 2 shows regressions of the change in stock price returns and volatility against our Brexit uncertainty survey question. In summary, we see that for firms reporting higher Brexit uncertainty, stock-price returns were lower 30 days after the vote vs 30 days before the vote (column 1) and stock price volatility was higher (column 2). Hence, our Brexit uncertainty measure does indeed appear to be capturing firms' exposure to both higher uncertainty but also some element of bad news (since stock returns were significantly negative).[18]

Finally, in columns (3) to (5) of Table 2 we regress, in reverse, our Brexit uncertainty measure on the change in firm stock returns and/or volatility in the 30-day window around the Brexit vote. We find (column 5) that the change in stock volatility measure has the highest explanatory power for our Brexit uncertainty measure. This suggests that our Brexit uncertainty survey question is potentially most correlated with the second moment (uncertainty) impact of Brexit, but also contains some substantial first moment impact. Given we only have one shock – the Brexit process – we ultimately cannot separate these two channels, and, from this point on, will interpret the results as the overall impact of the Brexit process on firms, noting this likely includes a major uncertainty element.

[16] The first moment effect is estimated by asking firms to attach probabilities to Brexit eventually having a positive/negative effect of more than 10%/less than 10% on sales, or having no impact. Chart A13 shows responses to this question. Point estimates are constructed by attaching midpoints of 5% and 20% to the response categories for a less than 10% and more than 10% impact respectively.

[17] This point is shown by the R^2 in column 1 of Table 6 being higher than that in column 3.

[18] In the previous section we discussed how stock market measures may imperfectly measure the uncertainty relating to Brexit. However, this was a point about the persistence of Brexit uncertainty and focussing on stock market developments over a short window close to the referendum should still be meaningful.

4.1 Investment and Employment

In Table 3 we examine the impact of Brexit exposure on firms' investment and employment. We estimate this using difference-in-difference equations of the type shown in equation (3) below:

$$Y_{it} = \beta\, U_i \, x \, Post_t + f_i + m_t + e_{it} \quad (3)$$

where Y_{it} is investment or employment growth of firm i in year t, U_i is average uncertainty of firm i over the three years since the referendum, $Post_t$ is a dummy variable that equals 1 after the EU referendum (July 2016 onwards), and f_i and m_t are firm and year fixed effects.[19]

These equations use investment and employment data collected from the DMP after the referendum where available, and data from company accounts where not (including obviously the pre-referendum period before the DMP was launched).[20] We use the DMP data when available rather than accounting data, because the DMP data are both more timely and have advantages in terms of measurement.[21] However, we also show (in Table A4) that our results are robust to using accounting data for the period when accounting data are available. Equations are estimated from 2011-2018 where years are defined from Q3 to Q2 in the following calendar year - for example, 2018 corresponds to 2018 Q3 to 2019 Q2.[22] We define years in this way so that the EU referendum, which took place on 23 June 2016, falls neatly just before the year that we define as 2016. Our equations cover five years before the referendum and three years after it.

Column (1) of Table 3 shows that businesses with higher levels of Brexit uncertainty have experienced significantly lower growth in investment since the referendum, relative to the period before the referendum. The coefficient on the Brexit uncertainty variable is significant at the 1% level. The interpretation of the coefficient is that a firm with one unit higher uncertainty (on the 1-

[19] U_i is a constant across for each firm across the estimation period, including before the referendum.

[20] We estimate the investment equation in growth rates rather than using a more commonly used level specification because the DMP does not contain capital data to scale the level of investment and attempting to impute capital into the DMP adds measurement error which appears to distort the results. In the accounting data, investment is defined as change in tangible fixed assets plus depreciation. In the DMP, respondents are asked to report 'Capital expenditure'.

[21] Employment data refer to the number of UK employees in the DMP, rather total employment, which may include overseas operations. For investment, the DMP asks directly about capital expenditure rather than having to estimate it from accounting data on tangible fixed assets and depreciation. DMP data are reported quarterly but for our regression analysis we convert this to annual data by aggregating the quarterly responses and annualising where data are missing.

[22] We assign annual accounts data to the year in which the accounting period ends.

4 scale) has had average investment growth that is 2.8pp a year lower since the referendum (so would be just over 8pp lower after three years in levels terms).

Column (2) of Table 3 allows the effect of Brexit uncertainty to vary in each year after the referendum rather than reporting an average effect. It shows that investment growth was significantly lower for firms more affected by Brexit uncertainty in the first year after the referendum (2016, defined as 2016 Q3 to 2017 Q2), but less so in the second year. However, the effect intensified again in the third year as the point at which the UK was due to leave the EU approached. Interestingly, this impact was spread across the three years, so that investment growth was slowed in each of year 1, 2 and 3 after the Brexit vote, suggesting a gradual response of firms to Brexit uncertainty. This contrasts clearly with the macro forecasts that were made in Autumn 2016 following the Brexit vote. As Figure 5 shows, these typically predicted that investment growth would fall sharply in calendar years 2016 and 2017 but then recover to pre-Brexit rates from 2018 onwards.[23] In the event, there was a material fall in investment growth after the referendum, but it was smaller than initially expected. However, investment growth has subsequently not picked up as had been expected and has remained close to zero.

One possible explanation for this more gradual response of firms to the Brexit vote is that the huge uncertainty surrounding the process and its persistent nature may have led firms to act cautiously and not cut investment as quickly as might have been expected based on evidence from previous more modest and short-lived uncertainty shocks. As discussed in Guiso and Parigi (1999) and Bloom, Bond and Van Reenen (2007) there is a "cautionary effect" of uncertainty, in that higher uncertainty reduces the response of firms to external shocks. As such, the persistently high Brexit uncertainty may have actually slowed the negative response of firms to the Brexit shock itself, leading to a gradual multi-year drop in activity rather than one large drop and recovery.

In column (3) of Table 3 we show that our results are robust to using an instrumental variables approach where the IVs are firms' EU exposure prior to the referendum (the first stage is

[23] Based on the median of real business investment forecasts from the Bank of England, Office for Budget Responsibility and National Institute of Economic and Social Research. Other forecasters often only produce projections for economy wide investment rather than business investment, which also includes both housing and government investment, although broadly similar trends are evident there too.

essentially the same specification as in column (6) of Table 1). Indeed, the coefficient is now substantially larger, although it also has a much greater standard error, so we cannot reject the hypothesis that column (3) and column (1) have the same point-estimate.[24]

Turning to employment, we see in columns (4) to (6) that the results are all negative but none are statistically significant. Therefore, whilst there is some tentative evidence that the Brexit process has led to lower employment, the finding is less robust than for investment.

The estimates in Table 3 can be used to quantify the magnitudes of the reductions in investment and employment that have occurred in anticipation of Brexit by working out how different average investment and employment would have been if all firms had the lowest level of Brexit uncertainty rather than their actual reported values. Here the choice of counterfactual for the uncertainty series is important. The most extreme counterfactual is that all firms would have had an uncertainty score of 1 (i.e. at the very bottom of the 1-4 scale - Brexit not an important source of uncertainty at all), which compares to the actual average of 2.38 over the period since the referendum. Using the equation reported in column (1) of Table 1 would imply that investment growth has been around 3.8 percentage points (pp) a year (3.8=2.749*(2.38-1)) lower than it otherwise would have been since the referendum, a reduction of approximately 11% in the level of investment over three years.[25] On employment, the corresponding figures would be 0.3pp (0.3=0.23*(2.38-1)) a year off employment growth or 0.9% off the level over three years, although as seen above, these employment effects are not statistically significant.

[24] Table A4 shows how the investment results are also robust to using uncertainty on a 0-1 that than 1-4 scale and to only estimating using accounts data for investment. Using accounts data means that the equations can only be estimated for the first two years after the referendum rather than the first three, given the additional lags in the accounting data, but it can be used to show how the investment results are robust to estimating in levels terms as well as in growth space. As an additional robustness check we also allowed the coefficient on Brexit exposure in the investment equation to be different for firms with their headquarters in "Leave" voting local authorities to those based in "Remain" areas, but there was little difference between the two (see Table A5).

[25] These estimates are likely to be upper bounds of the direct responses of firms to the anticipation of Brexit and could be lower if firms are assumed to have faced some degree of uncertainty about Brexit in the period before the referendum. For example, if average uncertainty (on the 1-4 scale) was 1.5 rather than 1 in the pre-referendum period, the total investment impact would be around 7% rather than 11%. However, these estimates do not capture more second-round general equilibrium effects or the fact the price of investment good has increased for all firms. These factors might be likely to increase the size of the overall Brexit effect on investment.

Our estimates of the impact of the Brexit process on investment and employment are broadly consistent with the slow-down of investment and employment growth observed in official aggregate data since the Brexit referendum. Annual growth in real investment in the official data has slowed from an average of almost 5% a year between 2011 and 2015 to around 0.5% a year since the referendum (Figure A14), a reduction of just over 4pp a year and very close to our estimated impact from the Brexit process.[26] Similarly employment growth has slowed by a similar amount to our estimate (albeit insignificant) Brexit effect of 0.3pp a year. Our estimates therefore suggest that the Brexit process can account for most of the slow-down in investment and employment growth in the UK since the referendum.

4.2 Brexit and Productivity

In Table 4 we turn to productivity. Column (1) shows that value-added growth is estimated to have fallen by about 1pp per year after 2016 for firms with 1 unit higher Brexit uncertainty (on the 1-4 scale). Since employment did not fall much in relation to Brexit uncertainty this translates into a negative impact on labour productivity and TFP in columns (2) and (3). In column (4) we report the IV estimates for the impact of the Brexit process on firm level productivity. In all cases we see a negative impact, which is significant in the OLS estimates, but not in the IV estimate. The magnitude of this coefficient implies that a firm with one unit higher Brexit uncertainty would have had 1pp a year lower growth in labour productivity and TFP.[27]

In Figure 6 we show one potential reason for the negative impact of the Brexit process on firm productivity, which is the use of senior management time on Brexit preparation. We asked 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?*", finding that, between November 2018 and January 2019, 10% of CFOs and 6% of CEOs were spending 6 hours or more a week on Brexit preparations, while over 70% of both CFOs and CEOs reported spending some time each week on Brexit

[26] Figure A12 shows the change in real business investment growth since the referendum, which is usually the measure that commentators and forecasters concentrate on. Our regressions use nominal investment data and the equivalent slowing in official data is slightly smaller in nominal terms (3.9pp rather than 4.4pp), but this does not alter our conclusion that the Brexit process can account for most of the slowing in investment growth since the EU referendum.
[27] As with investment, there was little difference in the results if the coefficient on Brexit uncertainty was allowed to be different for firms with their headquarters in "Leave" voting local authorities to those based in "Remain" areas (see Table A5). Also, if the coefficient on Brexit uncertainty is allowed to change by year in these regressions it is similar in the first and second year after the referendum (these results are not reported).

preparations. In Table 5 we formally regress CEO+CFO time use (in hours per week) on Brexit exposure and find large OLS and IV coefficients.[28] We also examine expenditures on Brexit preparations (excluding staff costs). On average firms reported that they had spent the equivalent of around 0.4% of a year of sales revenue by the spring of 2019.[29] In columns (3) and (4) of Table 5 we confirm that this measure has a strong relationship with Brexit exposure.[30]

Of course there are other reasons for the negative impact of the Brexit process on productivity – including reduced spending on intangibles like R&D, software and training (the DMP also provides some evidence of this, see Figure A15), lower levels of multinational investment and lower supplies of skilled foreign workers. All these mechanisms could potentially generate the (significant) negative impact on firm-level TFP that we demonstrate in our results.

Finally, in Table 6, we examine the impact of the Brexit process on productivity through the between-firm reallocation channel (or the Brexit misallocation channel). Figure 7 summarizes the results. We see in the top left panel that more productive firms (defined in terms of pre-referendum productivity from 2013-2015) experienced greater levels of Brexit uncertainty. As a result more productive firms are predicted to have experienced greater reductions in size as a consequence of the Brexit process (top right panel). One obvious explanation is that more productive firms have a higher propensity to trade, as confirmed by the bottom two panels in Figure 7. Thus, the UK's decision to leave the EU is likely to have already led to a reallocation of activity away from more productive internationally exposed firms towards less productive local firms.

[28] Respondents were given 6 options to select from for both CEOs and CFOs: none; up to 1 hour; 1 to 5 hours; 6 to 10 hours; more than 10 hours; and don't know. We use midpoints for each of these bins (assuming a value of 15 for more than 10 hours) to produce a continuous variable and exclude don't knows. This question has been asked twice in the DMP, November 2017-January 2018 and November 2018-January 2019. We use the average of the two responses for each firm in our regression, imputing any missing data using time and firm fixed effects to take account of the fact that CFOs and CEOs reported spending more time on Brexit planning the second time this was asked.

[29] This question was asked between February and April 2019.

[30] If these of time and resources spent on Brexit planning measures are added directly into equations for TFP growth, the coefficients are not statistically significant, although that may also be related to the fact that they are only available for smaller sub-sample of firms (the time variables are available for around half of firms and amount spent for around a quarter).

Table 6 confirms these results in a regression specification. In column (1) we see that our key Brexit uncertainty exposure measure is positively correlated with firms' exposure to the EU in exports, imports, labour use, regulation and ownership (indeed this is our first stage in the earlier IV regressions). In column (2) we confirm the direct correlations between productivity and Brexit uncertainty. In columns (3) and (4) we see that more EU exposed firms and more productive firms also expect a greater reduction in sales due to the effects of Brexit. Finally, in column (5) we see that firms with higher pre-referendum productivity reported higher trade with Europe and a higher share of sales covered by regulations (although no significant link with migrant worker share).

To try to quantify the impact of these between-firm effects on productivity we compare measures of aggregate productivity calculated with and without an adjustment for more productive firms being more adversely affected by the Brexit process. The baseline is simply pre-referendum labour productivity weighted by value-added in the corresponding period. To construct our counterfactual we first estimate Brexit uncertainty for each firm based purely on their pre-referendum productivity, these are simply the fitted values from the equation shown in column (2) of Table 6. We then estimate value-added for each firm had the UK voted to remain in the EU using column (1) in Table 4 on the relationship between uncertainty and value-added since the referendum. As inputs into this calculation we take pre-referendum productivity as the starting point and make the assumption that uncertainty for each firm was at the bottom of the 1-4 scale rather than taking the value predicted in the previous step. We then reweight pre-referendum aggregate productivity using these alternative value-added estimates and compare to our baseline. This exercise suggests that between-firm effects may have lowered aggregate productivity growth by around 0.1pp a year since the Brexit referendum, or 0.3% in total over 3 years.

Our magnitude calculations suggest that this misallocation effect has been smaller than the within-firm effect on productivity. Taking our within-firm coefficients at face value and using a counterfactual assumption that uncertainty would have otherwise been 1 on the 1-4 scale implies that productivity growth has been around 1.5pp a year lower than it otherwise would have been, or 4.5pp in total over three years.[31] As before, this would be an upper bound and estimates using

[31] For labour productivity, the calculation uses the coefficient from column (2) of Table 4: 1.056*(2.38-1)=1.5pp a year. For TFP, the coefficient in column (3) is only marginally larger (1.114 versus 1.056) and the Brexit effect still

a more conservative counterfactual assumption would be smaller. But unlike for investment, there is also some evidence of these productivity effects being significantly smaller for large companies who account for the majority of output growth (Table A6), and using these alternative estimates that allow the effects to vary by firm size would reduce the size of the within-firm effect to around 0.6pp a year or 1.8pp in total over three years.[32] Overall, the combined productivity impact of the Brexit process appears large enough to have reduced UK productivity by between 2% and 5% in total over the three years since the referendum.

A slowing in productivity that is related to the Brexit process is consistent with official data. Average labour productivity growth in the official data has slowed by around 0.2pp a year relative to the five years before the referendum (Figure A14). However, this pre-referendum period was also a time of historically weak productivity growth, and had the UK decided to stay in the EU it may have been expected to increase (and that was predicted by many forecasters prior to the referendum).

5. CONCLUSION

We use a major new survey of UK firms, the Decision Maker Panel, which generates information across a representative sample of firms each month, to identify three key results on the effects of the June 2016 Brexit referendum. First, the UK's decision to leave the EU has generated a large, broad and long-lasting increase in uncertainty. Compared to previous uncertainty shocks Brexit is notable for its persistently high level of uncertainty, which sets it apart from other measures of uncertainty which capture immediate responses to shocks that quickly die away. Second, anticipation of Brexit has gradually reduced investment by about 11% over the three years following the June 2016 vote. This fall in investment took longer to arise than predicted at the time

rounds to 1.5pp a year to one decimal place. The valued added and productivity equations are only estimated over two years since the referendum given that they rely on more lagged data from company accounts. We assume that the relationships estimated over the first two years also hold in the third year to provide comparable estimates to our investment impacts which are estimated over 3 years.

[32] The effects on labour productivity for firms with over 1000 employees are not significantly different from zero but are significantly smaller than the effects for firms with under 100 employees (Table A6 column 4). These differences in TFP space are more modest (column 5). Table A6 also reports the investment regressions allowing the effects of Brexit exposure to vary by firm size. The point estimates of the coefficients on Brexit exposure are slightly larger for larger firms but these differences are not close to being statistically significant.

of the Brexit vote, suggesting that heightened and persistent uncertainty may have slowed firms' response to the Brexit vote. Finally, the Brexit process is estimated to have reduced the level of UK productivity by between 2% to 5% over the three years since the referendum. Much of this drop is from a negative *within*-firm effect, in part because firms are committing several hours per week of top-management time to Brexit planning. But we also find evidence for a smaller negative *between*-firm effect too as more productive internationally exposed firms have shrunk relative to less productive domestic firms.

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Table 1: Characteristics of firms who are uncertain about Brexit

Dependent variable:	Brexit uncertainty (1-4 scale)						(0-1 scale)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Share of sales to EU	0.820***					0.334***	0.161***
	(0.079)					(0.084)	(0.041)
Share of costs from EU imports		0.999***				0.474***	0.196***
		(0.068)				(0.073)	(0.036)
Share of EU migrants in workforce			1.791***			1.293***	0.629***
			(0.143)			(0.150)	(0.077)
Share of sales covered by EU regulations				0.835***		0.522***	0.248***
				(0.053)		(0.055)	(0.028)
EU owned (dummy variable)					0.351***	0.153***	0.068***
					(0.042)	(0.044)	(0.023)
3 digit industry dummies	No	No	No	No	No	Yes	Yes
Observations	5,870	5,870	5,870	5,870	5,870	5,870	5,870
R-squared	0.020	0.040	0.026	0.041	0.011	0.175	0.157

***Notes**:* DMP data for all variables, except ownership which is from the Bureau Van Dijk FAME database. EU exposure measures are for 2016 H1, just before the Brexit referendum. Dependent variable is average uncertainty per firm in the three years after the referendum. Missing values for uncertainty in a given year are imputed from a regression using time and firm fixed effects. Dummy variables are included for any firms with missing EU exposure data (coefficients not reported). All equations are estimated by OLS with robust standard errors. *** p<0.01, ** p<0.05, * p<0.1.

Table 2: Brexit uncertainty and stock price response to the referendum result

Dependent variable:	Change in stock returns around referendum	Change in stock volatility around referendum	Brexit uncertainty		
	(1)	(2)	(3)	(4)	(5)
Brexit uncertainty	-0.614*	0.457***			
	(0.326)	(0.139)			
Change in stock returns around referendum			-0.022*		-0.020
			(0.012)		(0.013)
Change in stock volatility around referendum				0.075***	0.073***
				(0.024)	(0.025)
Observations	238	228	238	228	228
R-squared	0.014	0.034	0.014	0.034	0.045

Notes: Stock price data are from Compustat. DMP data for all other variables, except ownership which is from the Bureau Van Dijk FAME database. Sample is all public firms in the DMP who have responded to the Brexit uncertainty question and were actively trading in the 30 days before and after Brexit vote. Changes in stock returns around the referednum are calculated as the difference in the returns from the average price in the 30 days after the vote to the 30 days before the vote. Changes in stock volatility are calculated as the difference between the average standard deviation of daily stock returns in the 30 days after and the 30 days before the referendum. Instruments for Brexit exposure are “Share of sales exported to EU”, “Share of costs imported from EU”, “Share of migrant workers”, “Coverage of EU regulations” and "EU ownership" just before the referendum. Dummy variables are included for any firms with missing EU exposure data (coefficients not reported). All equations are estimated by OLS with robust standard errors. *** p<0.01, ** p<0.05, * p<0.1.

Table 3: Impact of the Brexit process on investment and employment

Dependent variable:	Investment growth			Employment growth		
All equations estimated 2011-2018	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	IV	OLS	OLS	IV
Brexit exposure*all years post referendum	-2.749***		-6.245**	-0.230		-0.856
	(0.896)		(2.937)	(0.207)		(0.678)
Brexit exposure*2016 dummy		-2.993**			-0.166	
		(1.356)			(0.292)	
Brexit exposure*2017 dummy		-2.081*			-0.296	
		(1.194)			(0.267)	
Brexit exposure*2018 dummy		-3.215**			-0.226	
		(1.272)			(0.244)	
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	21,537	21,537	21,537	35,499	35,499	35,499
IV regression first stage:						
Share of sales to EU			0.179**			0.222**
			(0.088)			(0.086)
Share of costs from EU imports			0.694***			0.683***
			(0.079)			(0.075)
Share of EU migrants in workforce			1.382***			1.457***
			(0.172)			(0.153)
Share of sales covered by EU regulations			0.646***			0.604***
			(0.065)			(0.060)
EU owned (dummy variable)			0.170***			0.205***
			(0.051)			(0.046)
F-test of excluded instruments (p-value)			0.000			0.000
Overidentification test (p-value)			0.658			0.160

***Notes*:** Sample uses DMP data where available (all post August 2016) and company accounts from Bureau Van Dijk FAME otherwise. Only observations with investment/employment growth rates between -100% and 100% (measured using DHS growth rates) are used. All regressions include a data source dummy. Data from 2011-2018 (years are defined from Q3 to Q2 in next calendar year, post Brexit defined as 2016 Q3 onwards). Brexit exposure is based on responses to a DMP question on the importance of Brexit as a source of uncertainty (average per firm on a 1-4 scale for three years after the referendum with missing firm/year observations imputed from a regression using time and firm fixed effects) – for magnitudes note that this is around 1.4 higher than assuming all firms had the lowest possible level of Brexit uncertainty, i.e. not important at all. Instruments for Brexit exposure are “Share of sales exported to EU”, “Share of costs imported from EU”, “Share of migrant workers”, “Coverage of EU regulations” and "EU ownership" just before the referendum. Dummy variables are included for any firms with missing EU exposure data (coefficients not reported). Standard errors are clustered at the firm level. *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Impact of the Brexit process on within-firm productivity

Dependent variable (all in growth terms):	Value-added	Labour productivity	TFP	TFP
All equations estimated 2011-2017	(1)	(2)	(3)	(4)
	OLS	OLS	OLS	IV
Brexit exposure*all years post referendum	-1.054**	-1.056**	-1.114***	-1.689
	(0.429)	(0.421)	(0.427)	(1.497)
Time fixed effects	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Observations	23,308	23,308	23,308	23,308
IV regression first stage:				
Share of sales to EU				0.206**
				(0.093)
Share of costs from EU imports				0.637***
				(0.081)
Share of EU migrants in workforce				1.184***
				(0.175)
Share of sales covered by EU regulations				0.553***
				(0.067)
EU owned (dummy variable)				0.152***
				(0.049)
F-test of excluded instruments (p-value)				0.000
Overidentification test (p-value)				0.161

***Notes*:** Sample uses company accounts data from the Bureau Van Dijk FAME database for value-added, labour productivity and TFP. Only observations with value-added, labour productivity, TFP and employment growth rates between -100% and 100% (measured using DHS growth rates) are used. Data from 2011-2017 (years are defined from Q3 to Q2 in next calendar year, post Brexit defined as 2016 Q3 onwards). Labour productivity is defined as real value-added (operating profits plus total labour costs divided by the aggregate GDP deflator) per employee using accounting data. TFP is calculated as the residual from a production function $\ln(Y_{it}) = 0.7\ln(L_{it})+0.3\ln(K_{it})$ 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. Brexit exposure is based on responses to a DMP question on the importance of Brexit as a source of uncertainty (average per firm on a 1-4 scale for three years after the referendum with missing firm/year observations imputed from a regression using time and firm fixed effects) – for magnitudes note that this is around 1.4 higher than assuming all firms had the lowest possible level of Brexit uncertainty, i.e. not important at all. Instruments for Brexit exposure are “Share of sales exported to EU”, “Share of costs imported from EU”, “Share of migrant workers”, “Coverage of EU regulations” and "EU ownership" just before the referendum. Dummy variables are included for any firms with missing EU exposure data (coefficients not reported). Standard errors are clustered at the firm level. *** p<0.01, ** p<0.05, * p<0.1.

Table 5: Time/resources spent planning for Brexit and Brexit uncertainty/exposure

Dependent variable:	CEO & CFO weekly hours Brexit planning		Brexit spending as % of annual sales	
	(1)	(2)	(3)	(4)
	OLS	IV	OLS	IV
Brexit exposure	1.953***	3.323***	0.383***	0.927***
	(0.089)	(0.307)	(0.035)	(0.116)
Observations	3,215	3,215	1,625	1,625
R-squared	0.130		0.069	
IV regression first stage:				
Share of sales to EU		0.380***		0.298**
		(0.097)		(0.125)
Share of costs from EU imports		0.774***		0.826***
		(0.087)		(0.109)
Share of EU migrants in workforce		1.300***		1.252***
		(0.173)		(0.234)
Share of sales covered by EU regulations		0.560***		0.582***
		(0.068)		(0.081)
EU owned (dummy variable)		0.188***		0.167**
		(0.057)		(0.076)
F-test of excluded instruments (p-value)		0.000		0.000
Overidentification test (p-value)		0.067		0.182

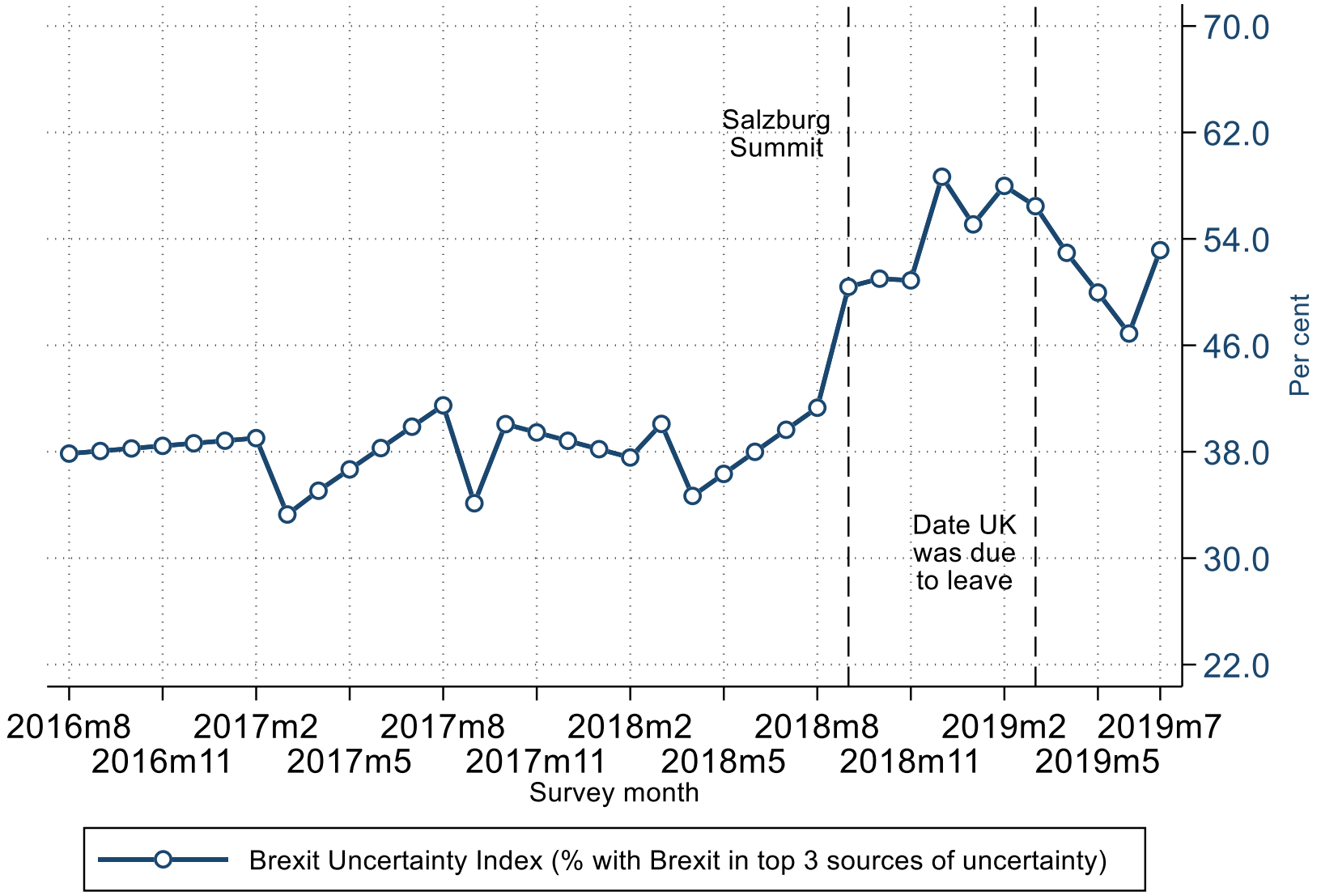
***Notes*:** DMP data for all variables, except ownership which is from the Bureau Van Dijk FAME database. Data on CEO/CFO hours spent planning were collected between November 2017-January 2018 and November 2018-January 2019. Dependent variable is average CEO+CFO hours per firm over the two time periods. Missing values for a given period are imputed from a regression using time and firm fixed effects. Data on spending on Brexit preparations were collected between February and May 2019. Brexit exposure is based on responses to a DMP question on the importance of Brexit as a source of uncertainty (average per firm on a 1-4 scale for three years after the referendum with missing firm/year observations imputed from a regression using time and firm fixed effects). Instruments for Brexit Uncertainty are “Share of sales exported to EU”, “Share of costs imported from EU”, “Share of migrant workers”, “Coverage of EU regulations” and EU ownership just before the referendum. Dummy variables are included for any firms with missing EU exposure data (coefficients not reported). Robust standard errors are used. *** p<0.01, ** p<0.05, * p<0.1.

Table 6: Impact of the Brexit process on between-firm productivity

Dependent variable:	Brexit exposure (uncertainty, 1-4 scale)		Expected eventual impact of Brexit on sales (%)		Log of pre-referendum labour productivity
	(1)	(2)	(3)	(4)	(5)
Share of sales to EU	0.335***		-2.777***		0.374***
	(0.089)		(0.667)		(0.084)
Share of costs from EU imports	0.504***		-1.636***		0.185***
	(0.078)		(0.475)		(0.057)
Share of EU migrants in workforce	1.183***		-4.690***		-0.159
	(0.168)		(1.126)		(0.146)
Share of sales covered by EU regulations	0.499***		-2.174***		0.095*
	(0.059)		(0.393)		(0.051)
EU owned (dummy variable)	0.144***		-0.187		0.116***
	(0.046)		(0.287)		(0.039)
Log of pre-referendum labour productivity		0.069***		-0.289**	
		(0.020)		(0.123)	
3 digit industry dummies	Yes	Yes	Yes	Yes	Yes
Observations	4,349	4,349	4,349	4,349	4,349
R-squared	0.166	0.110	0.098	0.066	0.298

***Notes**:* DMP data for all variables, except ownership and pre-referendum labour productivity which are from the Bureau Van Dijk FAME database. Pre-referendum labour productivity data are averages of 2013-15 data. Sample for all columns is restricted to firms for who uncertainty, sales impact and pre-referendum labour productivity data are all available. EU exposure measures are for 2016 H1, just before the Brexit referendum. Average uncertainty and expected sales impacts are averages per firm in the three years after the referendum. Missing values for a given year are imputed from a regression using time and firm fixed effects. Dummy variables are included for any firms with missing EU exposure data (coefficients not reported). All equations are estimated by OLS with robust standard errors. *** p<0.01, ** p<0.05, * p<0.1.

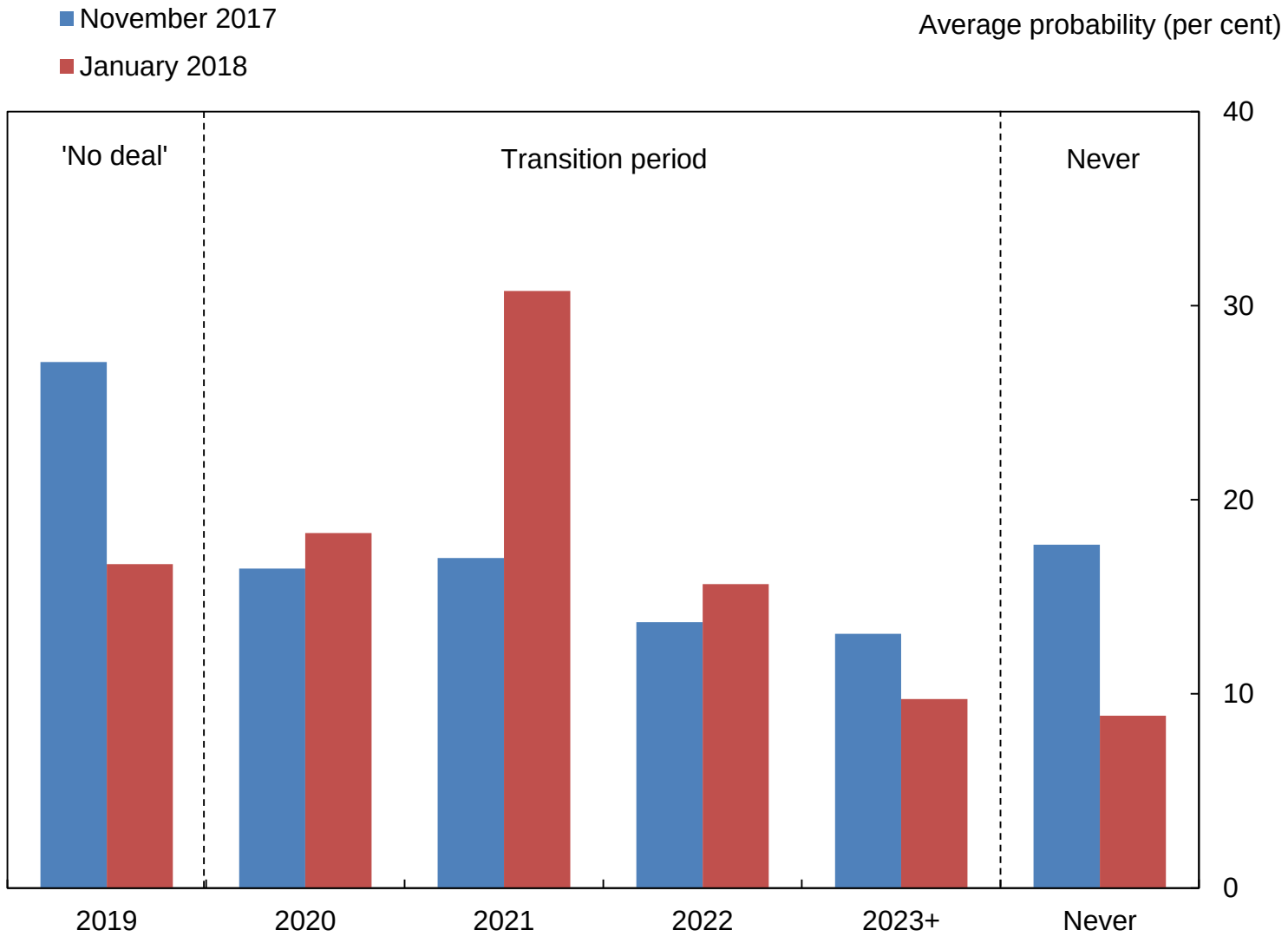
Figure 1: Brexit Uncertainty index



***Source*:** Decision Maker Panel and authors' calculations.

Notes: The results are based on the question '*How much has the result of the EU referendum affected the level of uncertainty affecting your business?*'. The line shows the percentage of respondents who view Brexit as "their top" or "one of their top three" sources of uncertainty. The remaining businesses reported Brexit to be "one of many" or "not an important" source of uncertainty for their business. Values are interpolated for months before August 2018 when the question about uncertainty was not asked *. All values are weighted.

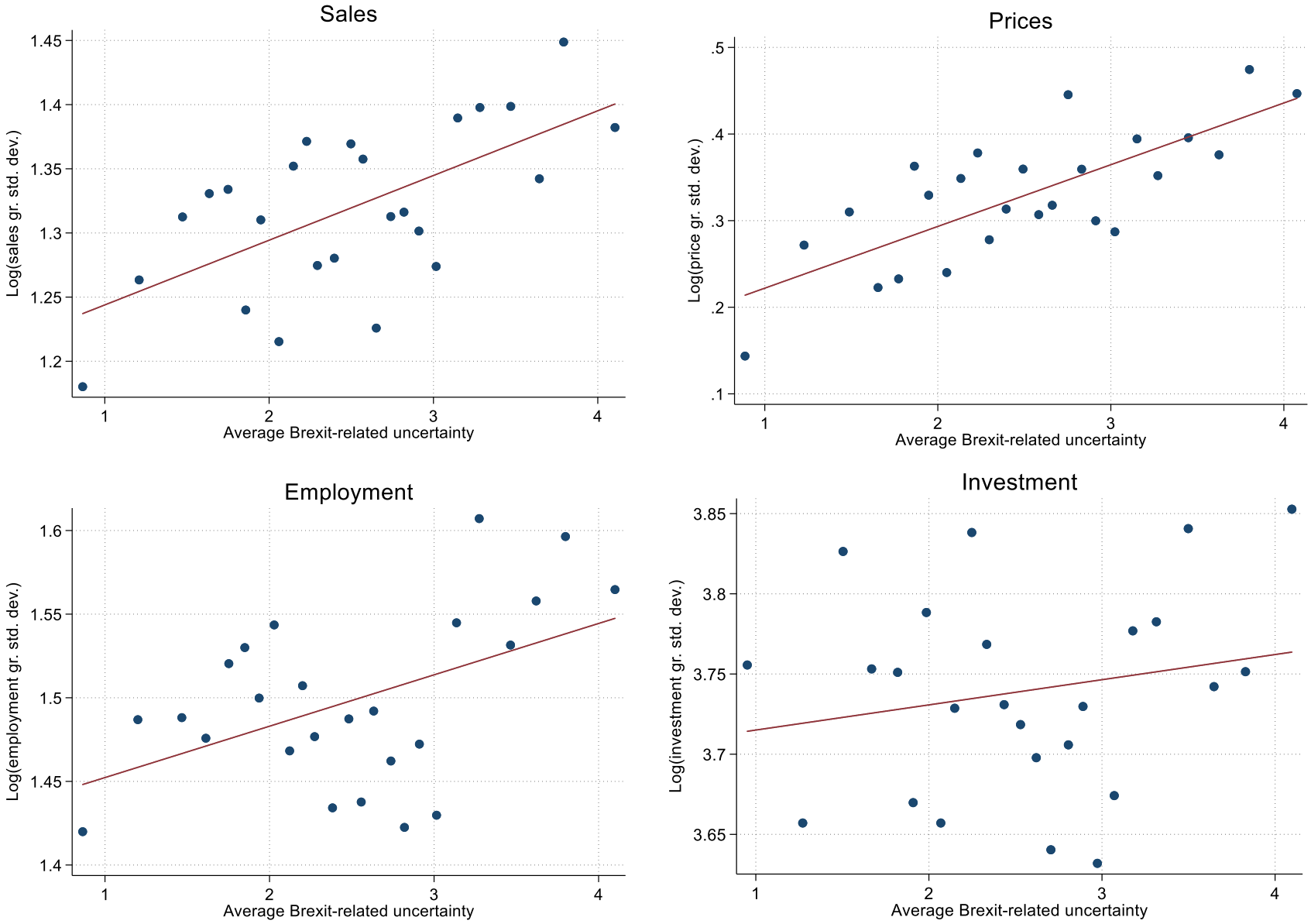
Figure 2: Uncertainty over when/if Brexit will happen



***Source*:** Decision Maker Panel and authors' calculations.

Notes: The results are based on the question '*What do you think is the percentage likelihood (probability) of the UK leaving the EU (after the end of any transitional arrangements) in each of the following years: 2019*; 2020; *2021*; *2022*; *2023 or later*; *Never*'. All values are weighted.

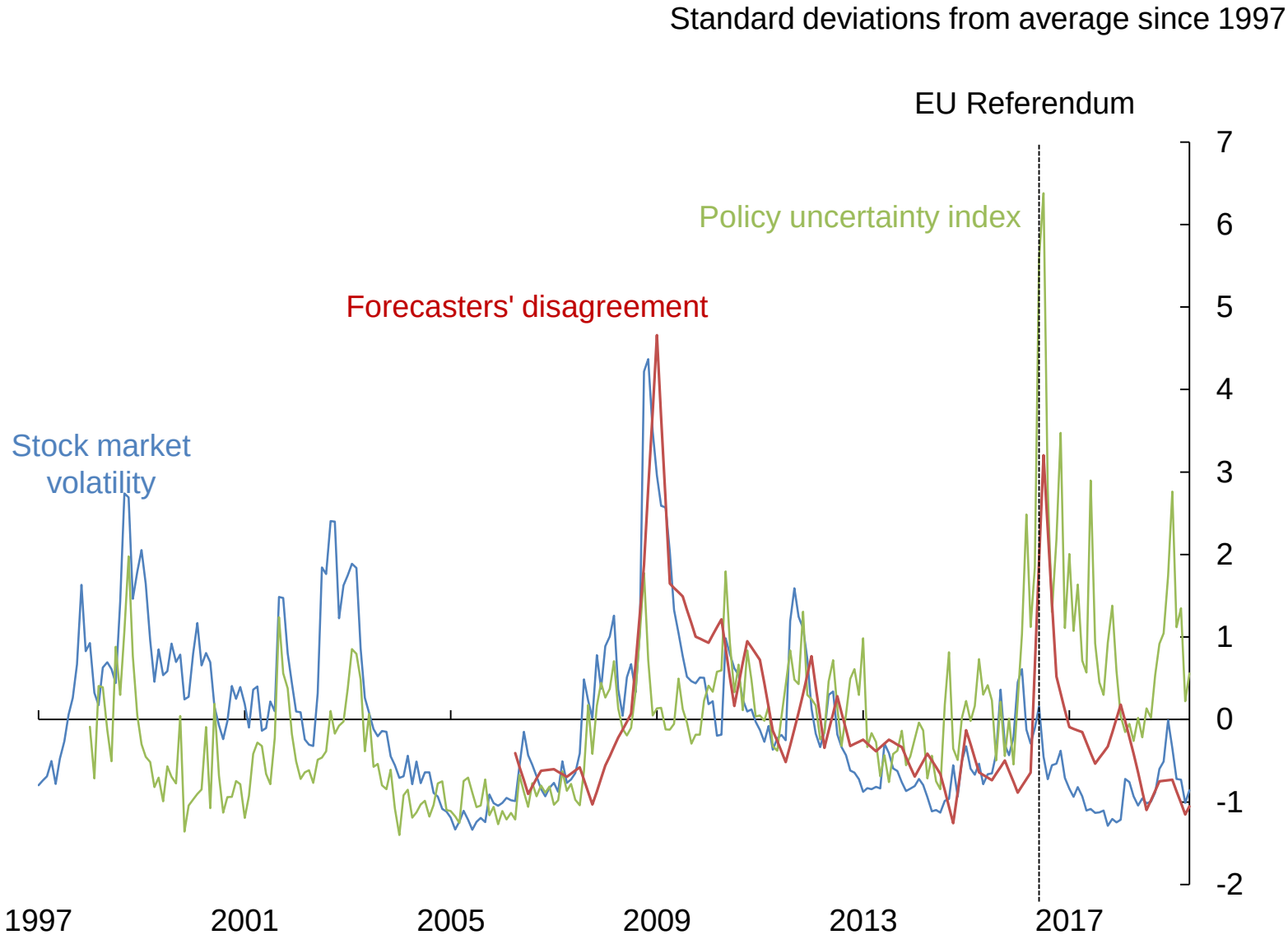
Figure 3: Brexit uncertainty and subjective uncertainty



Source: Decision Maker Panel and authors' calculations.

Notes: X-axes show average Brexit uncertainty on the 1 (not important) to 4 (largest source of uncertainty) scale based on responses to the question reported in the footnote to Figure 1. Y-axes show subjective uncertainty around the year-ahead growth rates calculated from the 5-bin outcomes and probabilities for each variable. Binscatter plots which split responses into 25 groups according to average Brexit uncertainty. Charts are based on data collected between September 2016 and June 2019.

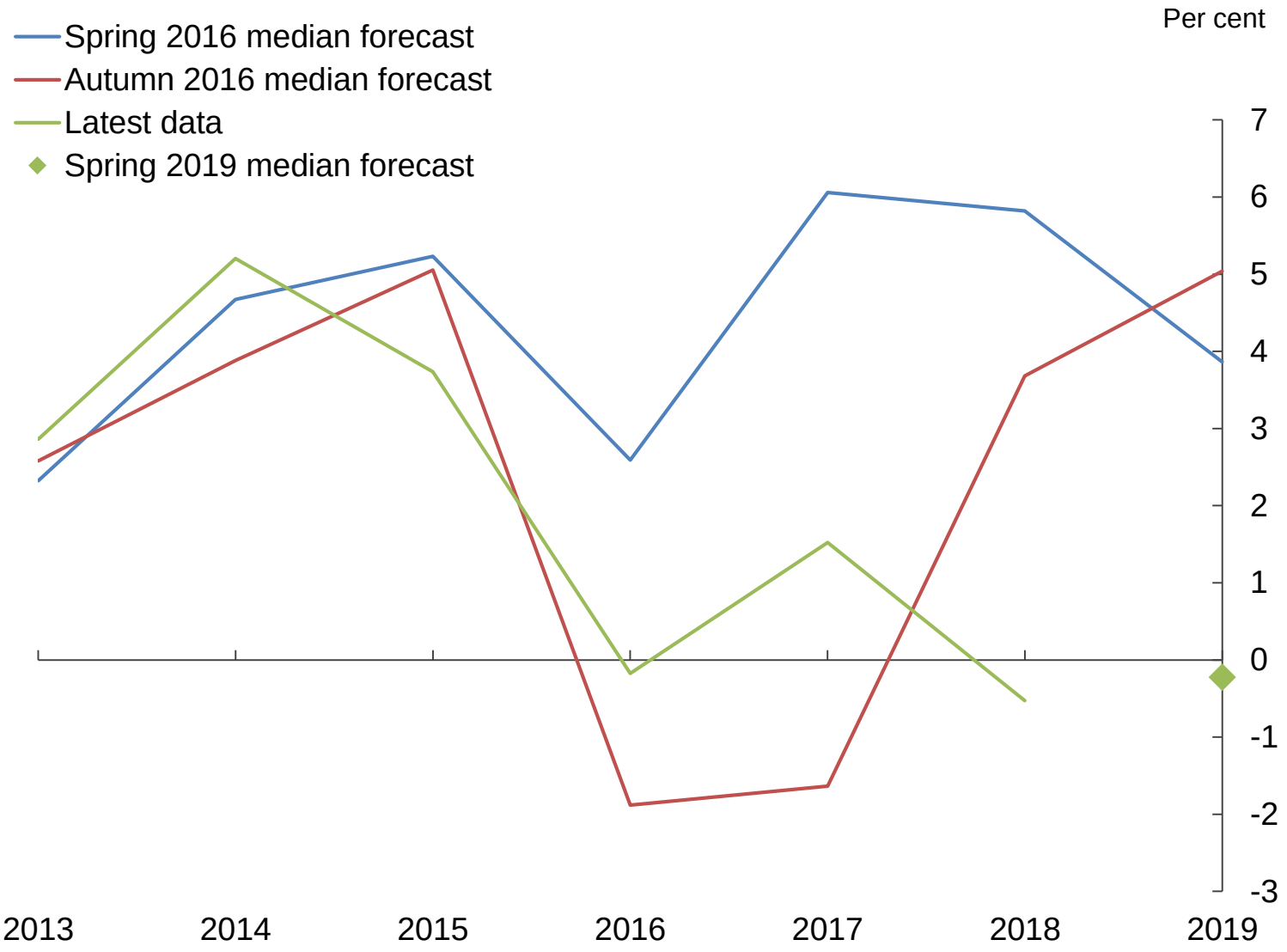
Figure 4: Measures of uncertainty



Source: Bank of England Survey of External Forecasters, Bloomberg, Baker, Bloom and Davis (2016) and authors' calculations.

Notes: All indices normalized to mean 0 and standard deviation 1 since 1997 to fit on the same scale. Forecasters' disagreement defined as the standard deviation of point forecasts of one-year-ahead GDP growth predictions provided to the Bank of England by professional forecasters. Stock market volatility defined as three-month option implied volatility of the FTSE-All Share Index. Policy uncertainty index defined as in Baker, Bloom and Davis (2016) and is based on newspaper reports.

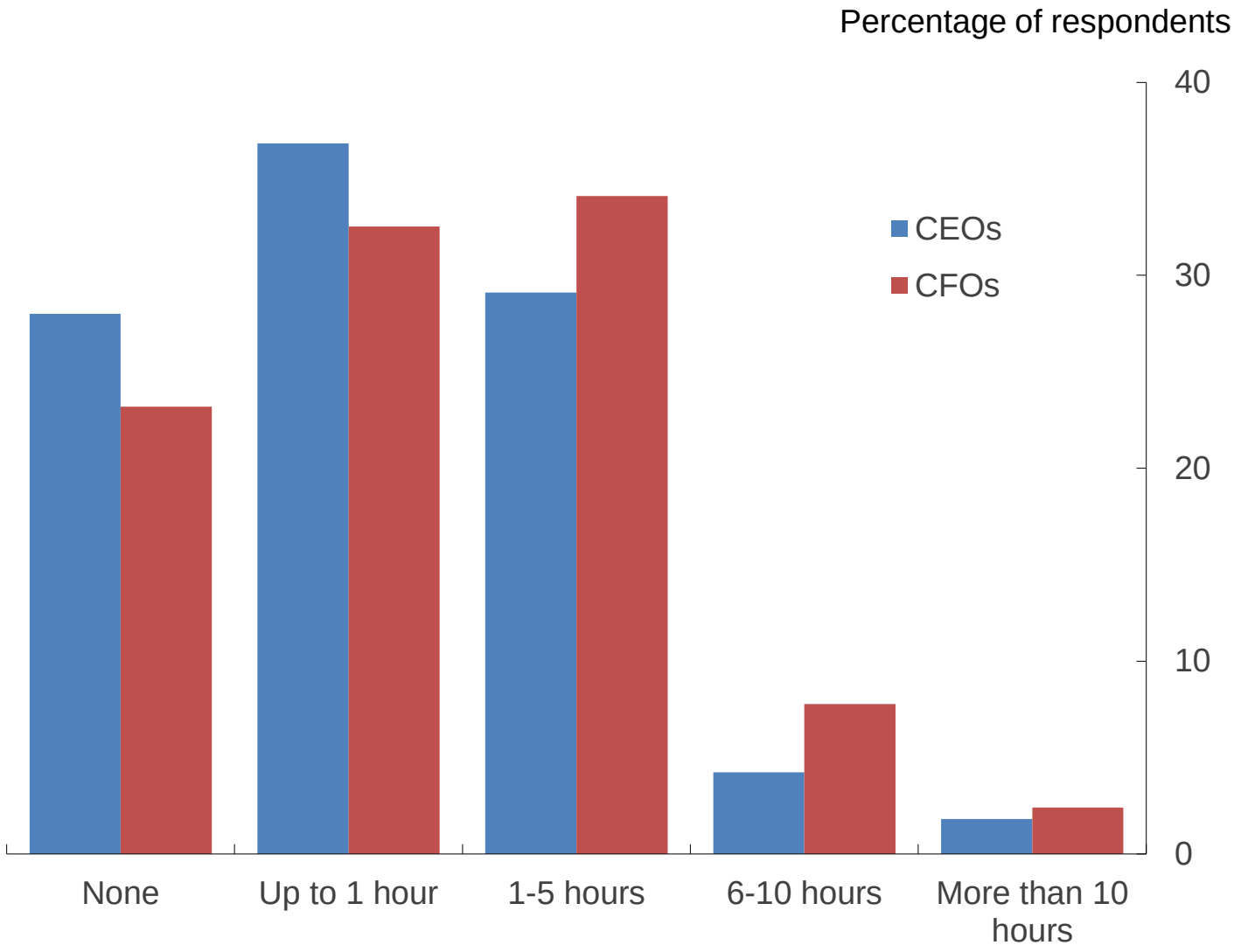
Figure 5: Forecasts of business investment growth



***Source*:** Bank of England, Office for Budget Responsibility (OBR), ONS, National Institute of Social and Economic Research (NIESR) and authors' calculations.

Notes: The forecast lines show the median forecast for calendar year growth in real business investment from the Bank of England, OBR and NIESR.

Figure 6: Number of hours a week spent on preparing for Brexit



***Source*:** Decision Maker Panel and authors' calculations.

Notes: The results 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: None; Up to 1 hour; 1 to 5 hours; 6 to 10 hours; More than 10 hours; Don't know*'. Results from November 2018 and January 2019 are shown (this was question was also asked between November 2017 and January 2018). Don't knows are excluded. All values are weighted.

Figure 7: Impact of Brexit on between-firm productivity

***Source*:** Bureau van Dijk FAME dataset, Decision Maker Panel and authors' calculations.

Notes: Average Brexit-related uncertainty is on the 1 (not important) to 4 (largest source of uncertainty) scale based on responses to the question reported in the footnote to Figure 1. Expected eventual impact on sales is based on responses to the 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: Have a large positive effect on sales at home and abroad, adding 10% or more to sales; Have a modest positive effect on sales at home and abroad, adding less than 10% to sales; Make little difference; Have a modest negative effect on sales at home and abroad, subtracting less than 10% from sales; Have a large negative effect on sales at home and abroad, subtracting more than 10% from sales'*. Point estimates are constructed by attaching midpoints of 5% and 20% to the response categories for a less than 10% and more than 10% impact respectively. Pre-referendum labour 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. Binscatter plots which split responses into 25 groups according to average pre-referendum labour productivity.

Appendix

Table A1: Linear probability models for propensity to respond to the DMP

Dependent variable: Ever responded to a survey if in sampling frame	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Leave vote share	-0.019	0.010	0.007	0.012	0.014	0.014	0.016
	(0.014)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
Log of employment			0.015***	0.010***	0.010***	0.010***	0.012***
			(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Log of sales				0.006***	0.003	0.004*	0.003
				(0.002)	(0.002)	(0.002)	(0.002)
Log of assets					0.003*	0.002	0.002
					(0.002)	(0.002)	(0.002)
Log of firm age						0.008***	0.008***
						(0.002)	(0.003)
Log of labour productivity							0.004
							(0.003)
3 digit industry dummies	No	Yes	Yes	Yes	Yes	Yes	Yes
Observations	42,129	42,129	42,129	42,129	42,129	42,129	42,129
R-squared	0.042	0.054	0.057	0.057	0.057	0.058	0.058

Notes: Linear probability model for whether a firm is in the sampling frame and has ever responded to a DMP survey between September 2016 and June 2019 (1=responded to DMP, 0=Not responded). Firm characteristics are latest accounts data from Bureau Van Dijk FAME database. '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 A2: Personal views on Brexit and Brexit vote share in local authority where firm is headquartered

Dependent variable: Leave vote share in local authority where firm is headquartered	(1)	(2)	(3)
Personal view on Brexit at time of referendnum:			
Very positive	0.051***	0.024*	
	(0.008)	(0.012)	
Somewhat positive	0.040***	0.013	
	(0.007)	(0.012)	
Neither positive nor negative	0.028**	-	-
	(0.011)		
Somewhat negative	0.011*	-0.016	
	(0.006)	(0.012)	
Very negative	-	-0.028**	
		(0.011)	
Positive			0.018
			(0.011)
Negative			-0.025**
			(0.011)
Observations	2,892	2,892	2,892
R-squared	0.021	0.021	0.020

Notes: '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. Personal views on Brexit at time of referendum from the DMP were collected in February-May 2018 and August-October 2018. For respondents who have answered more than once, their first response is used. Robust standard errors are used. *** p<0.01, ** p<0.05, * p<0.1.

Table A3: Aggregate exposure of DMP panel members to the EU vs other data sources

	DMP	Aggregate data
Percentage of sales to EU	6.8%	7.0%
Percentage of sales to non-EU	7.1%	8.0%
Percentage of costs that were imports	20.1%	13.4%
- *Excluding wholesale and retail*	*15.1%*	*14.0%*
Percentage of EU migrants in workforce	8.0%	6.9%

***Notes*:** DMP data are for 2016 H1. Aggregate export and import data are from the 2014 UK Input-Output tables. Aggregate migrant data are from the Labour Force Survey (2015-16 average).

Table A4: Robustness of investment and employment results

Data:	Accounts & DMP			Accounts only		
Estimation period:	2011-2018		2011-2017	2011-2017		
	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	Investment growth	Investment growth	Investment growth	Investment growth	Investment level	Employment growth
Brexit exposure (1-4 scale)*all years post referendum	-2.749***		-2.608**	-2.187*	-1.106**	-0.034
	(0.896)		(1.037)	(1.193)	(0.438)	-0.256
Brexit exposure (0-1 scale)*all years post referendum		-4.350**				
		-1.711				
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	21,537	21,537	18,149	15,454	15,454	30,040

***Notes*:** Sample uses DMP data where available (all post August 2016) and company accounts from Bureau Van Dijk FAME otherwise in columns 1 to 3 and just accounts data in 4 to 6. Only observations with investment/employment growth rates between -100% and 100% (measured using DHS growth rates) are used. In the levels equation in column 5 investment is scaled by tangible fixed assets in the previous year. All regressions include a data source dummy. Data from 2011 onwards (years are defined from Q3 to Q2 in next calendar year, post Brexit defined as 2016 Q3 onwards). Brexit exposure is based on responses to a DMP question on the importance of Brexit as a source of uncertainty (average per firm on a 1-4 scale for three years after the referendum with missing firm/year observations imputed from a regression using time and firm fixed effects) – for magnitudes note that this is around 1.4 higher than assuming all firms had the lowest possible level of Brexit uncertainty, i.e. not important at all. All equations are estimated by OLS. Standard errors are clustered at the firm level. *** p<0.01, ** p<0.05, * p<0.1.

Table A5: Allowing Brexit effects to vary by Leave/Remain area

Data:	Accounts and DMP		Accounts only		
Estimation period:	(2011-2018)		(2011-2017)		
Dependent variable (all in growth terms):	Investment	Employment	Value-added	Labour productivity	TFP
	(1)	(2)	(3)	(4)	(5)
Brexit exposure*all years post referendum interacted with whether firm is headquartered in a Leave or Remain local authority:					
Leave local authorities	-2.830***	-0.119	-1.030**	-1.034**	-1.009**
	(0.941)	(0.213)	(0.449)	(0.435)	(0.440)
Remain local authorities	-2.608***	-0.271	-1.102**	-1.203***	-1.347***
	(0.956)	(0.226)	(0.458)	(0.455)	(0.461)
Time fixed effects	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	21,243	35,036	23,017	23,017	23,017

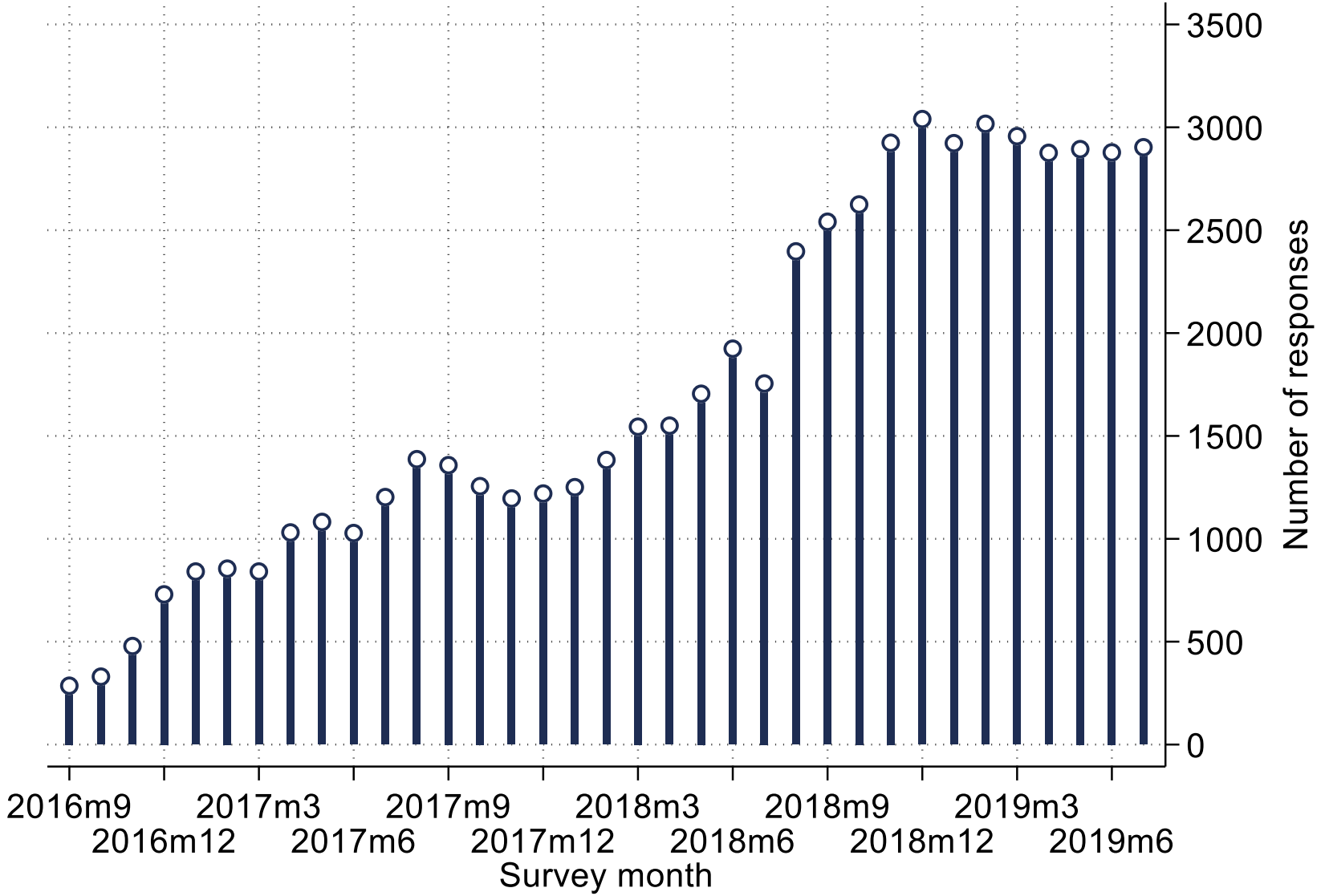
Notes : Sample uses DMP data where available (all post August 2016) and company accounts from Bureau Van Dijk FAME otherwise in columns 1 and 2 and just accounts data in columns 3 to 5. Only observations where the dependent variable has a growth rate between -100% and 100% (measured using DHS growth rates) are used. All regressions include a data source dummy. Data from 2011 onwards (years are defined from Q3 to Q2 in next calendar year, post Brexit defined as 2016 Q3 onwards). Brexit exposure is based on responses to a DMP question on the importance of Brexit as a source of uncertainty (average per firm on a 1-4 scale for three years after the referendum with missing firm/year observations imputed from a regression using time and firm fixed effects) – for magnitudes note that this is around 1.4 higher than assuming all firms had the lowest possible level of Brexit uncertainty, i.e. not important at all. Local authorities are divided into 'Leave' and 'Remain' areas using Electoral Commission Data according to which group received the most votes in that area in the referendum. All equations are estimated by OLS. Standard errors are clustered at the firm level. *** p<0.01, ** p<0.05, * p<0.1.

Table A6: Allowing Brexit effects to vary by firm size

Data:	Accounts and DMP		Accounts only		
Estimation period:	(2011-2018)		(2011-2017)		
Dependent variable (all in growth terms):	Investment	Employment	Value-added	Labour productivity	TFP
	(1)	(2)	(3)	(4)	(5)
Brexit exposure*all years post referendum interacted with firm size dummy:					
10-49 employees	-2.361**	-0.252	-1.740***	-1.492***	-1.503***
	(1.077)	(0.255)	(0.563)	(0.536)	(0.558)
50-99 employees	-3.136***	0.145	-1.323***	-1.657***	-1.202**
	(1.060)	(0.233)	(0.498)	(0.494)	(0.491)
100-249 employees	-2.239**	-0.359	-0.706	-0.493	-0.837*
	(1.021)	(0.231)	(0.465)	(0.458)	(0.457)
250-999 employees	-3.243***	-0.338	-0.859*	-1.092**	-0.895*
	(1.067)	(0.252)	(0.496)	(0.476)	(0.489)
1000+ employees	-3.242***	-0.553*	-0.208	-0.277	-1.202**
	(1.143)	(0.301)	(0.548)	(0.555)	(0.562)
Time fixed effects	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes
Observations	21,537	35,499	23,308	23,308	23,308

Notes: Sample uses DMP data where available (all post August 2016) and company accounts from Bureau Van Dijk FAME otherwise in columns 1 and 2 and just accounts data in columns 3 to 5. Only observations where the dependent variable has a growth rate between -100% and 100% (measured using DHS growth rates) are used. All regressions include a data source dummy. Data from 2011 onwards (years are defined from Q3 to Q2 in next calendar year, post Brexit defined as 2016 Q3 onwards). Brexit exposure is based on responses to a DMP question on the importance of Brexit as a source of uncertainty (average per firm on a 1-4 scale for three years after the referendum with missing firm/year observations imputed from a regression using time and firm fixed effects) – for magnitudes note that this is around 1.4 higher than assuming all firms had the lowest possible level of Brexit uncertainty, i.e. not important at all. All equations are estimated by OLS. Standard errors are clustered at the firm level. *** p<0.01, ** p<0.05, * p<0.1.

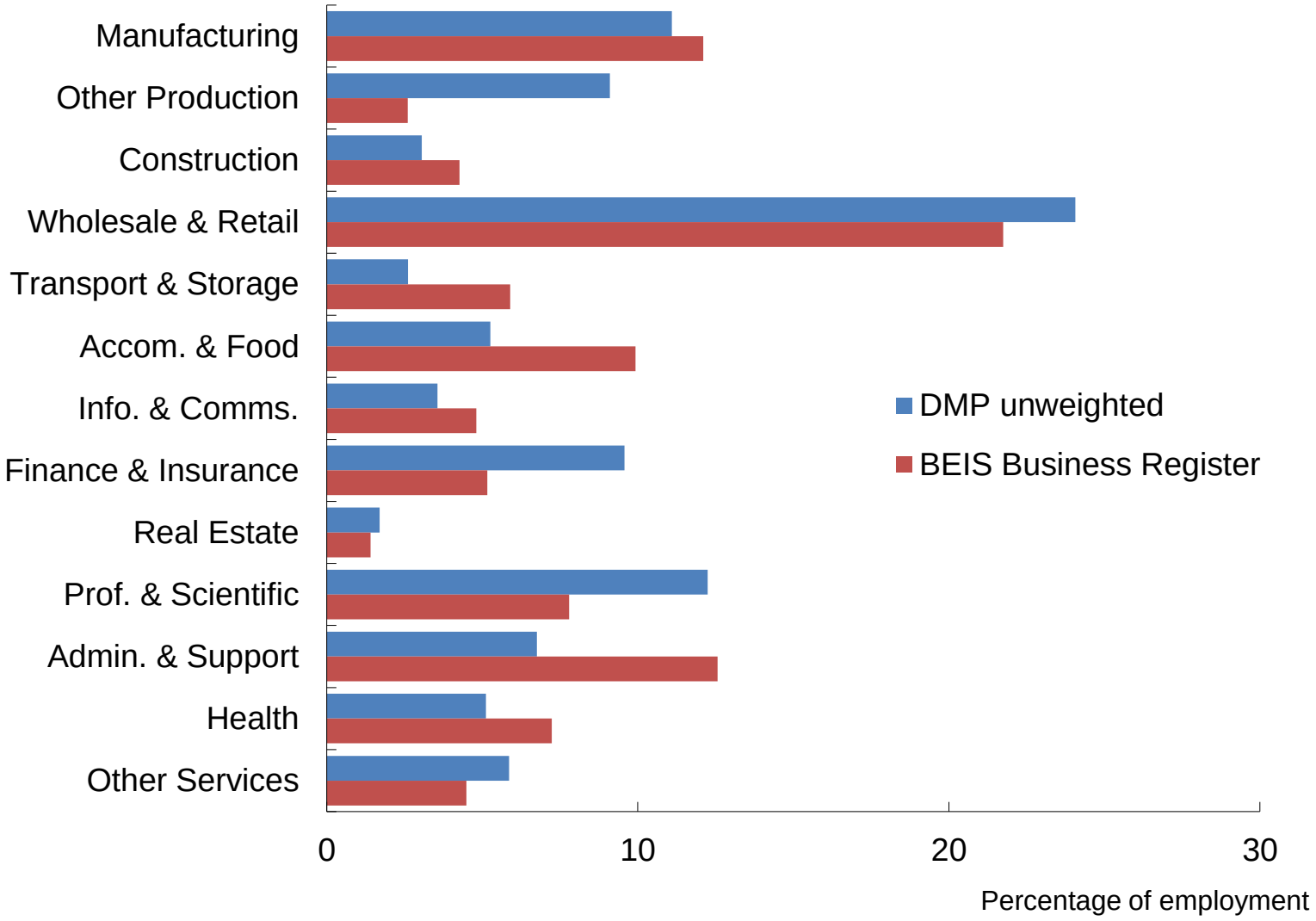
Figure A1: DMP sample size



Source: Decision Maker Panel and authors' calculations.

Notes: The dots show the number of responses to the Decision Maker Panel survey in each month since September 2016.

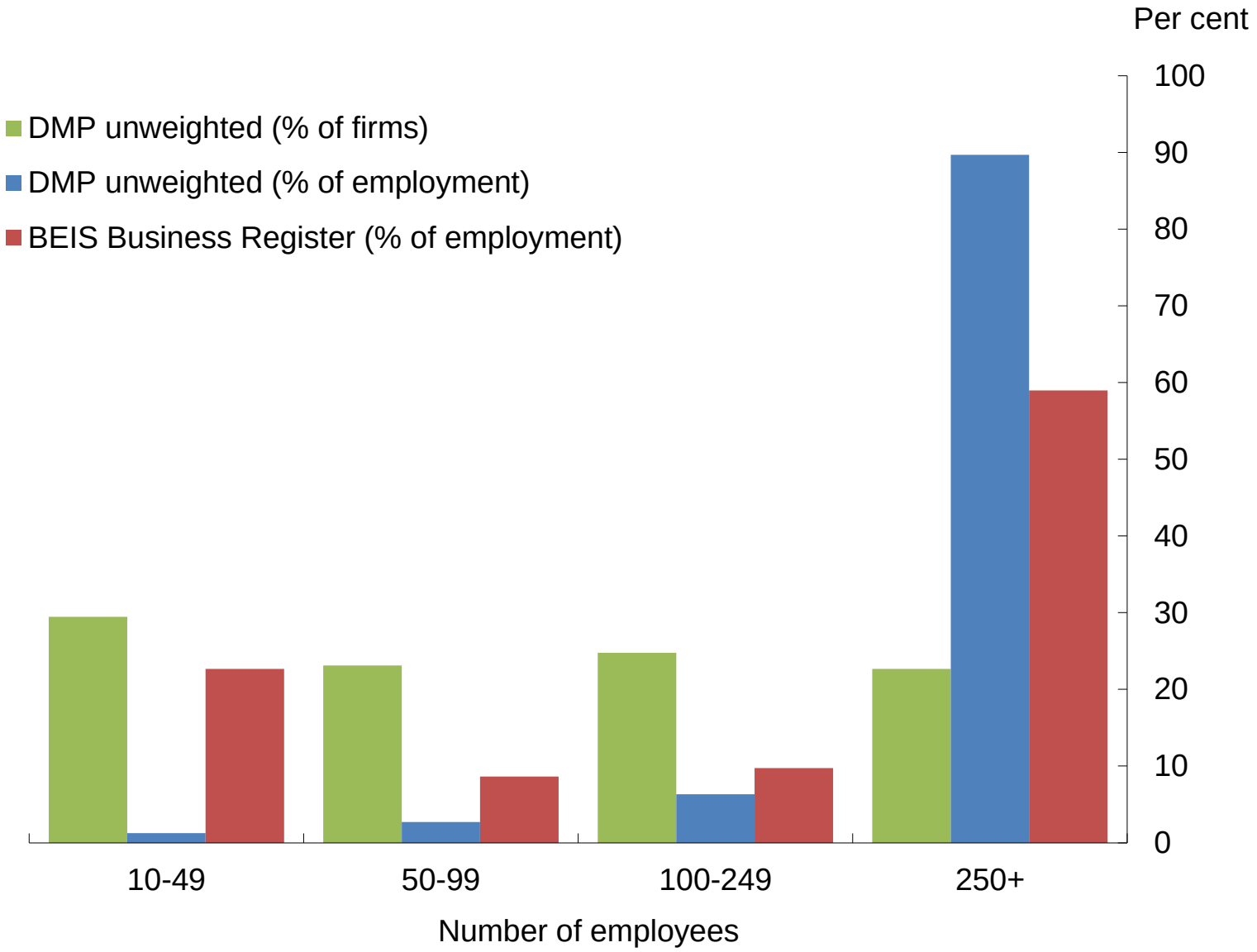
Figure A2: DMP members by industry



Source: Department for Business, Energy and Industrial Strategy (BEIS), Decision Maker Panel and authors' calculations.

Notes: The results presented here are for all DMP members who were sent the June 2019 survey.

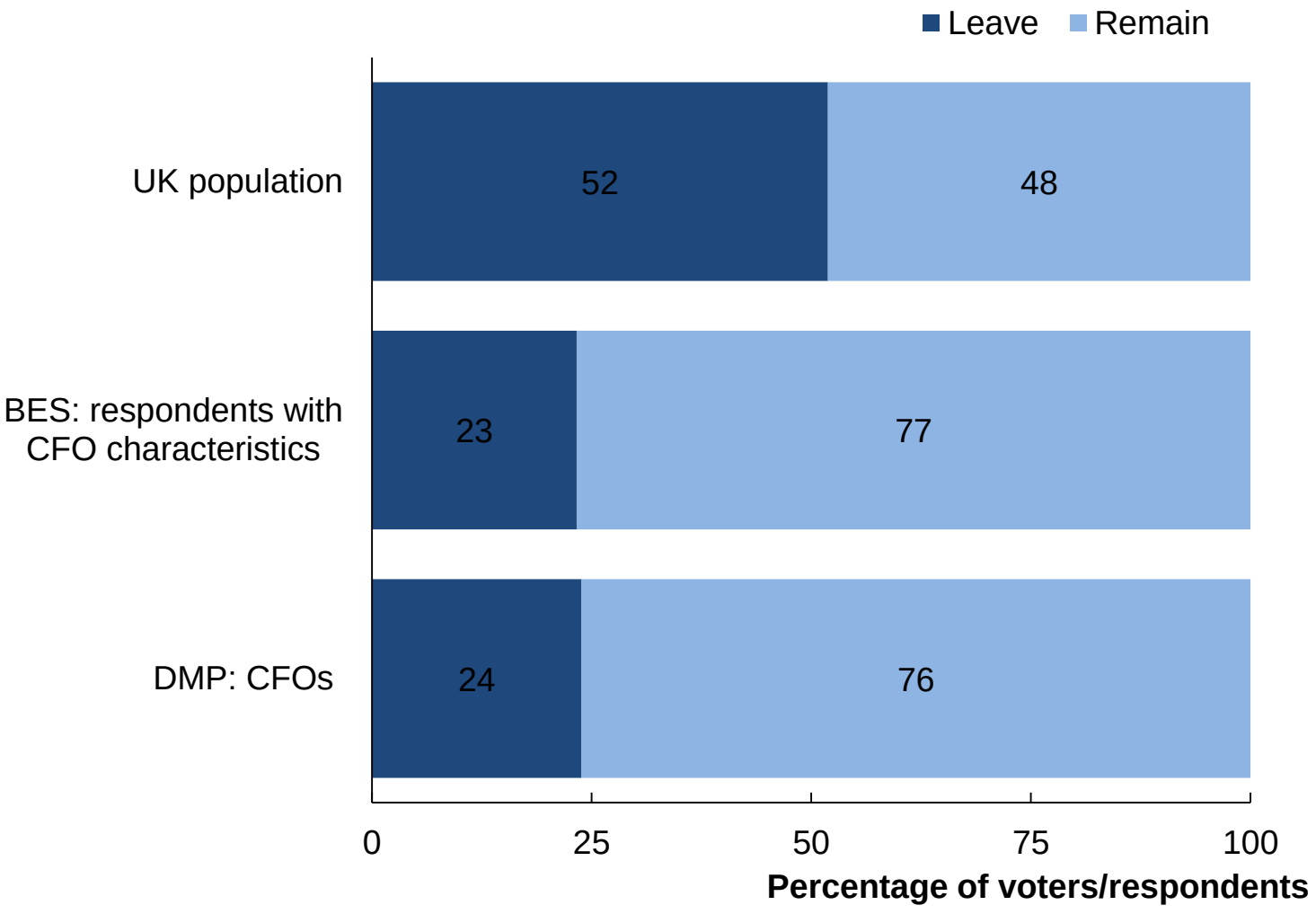
Figure A3: DMP members by firm size



Source: Department for Business, Energy and Industrial Strategy (BEIS), Decision Maker Panel and authors' calculations.

Notes: The results presented here are for all DMP members who were sent the June 2019 survey.

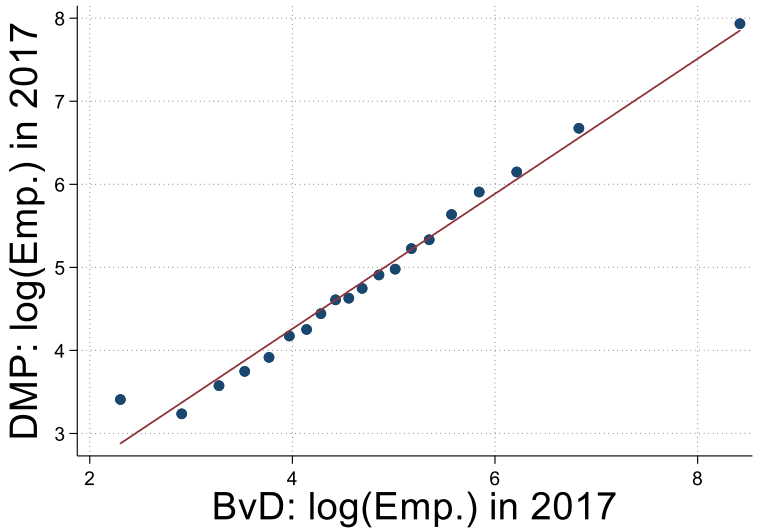
Figure A4: Personal views on Brexit

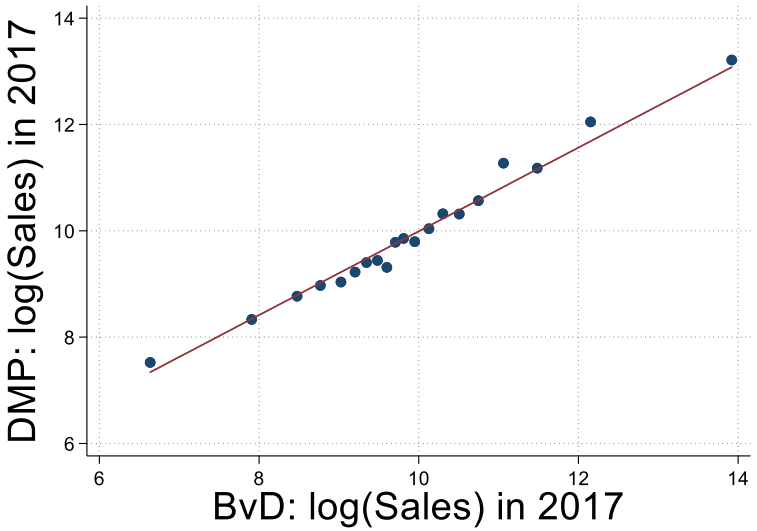


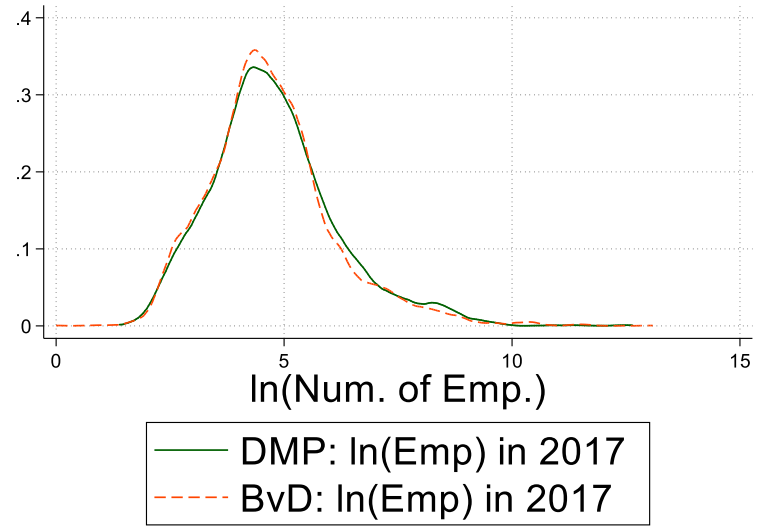
Source: Electoral Commission, British Election Study, Decision Maker Panel and authors' calculations.

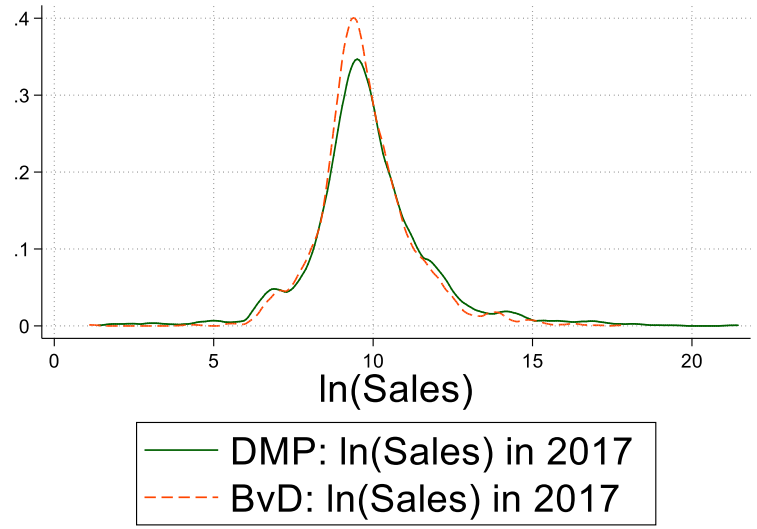
Notes: Personal views of DMP members at the time of the June 2016 referendum are taken from February to April 2018 surveys. Respondents who did not have a strong view either way (4 per cent) were excluded. The question asked respondents '*Taking everything into account, how do you personally view the UK voting to leave the European Union at the time of referendum? Very positive; Somewhat positive; Neither positive nor negative; Somewhat negative; Very negative; Prefer not to state; 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.

Figure A5: Comparison of DMP data to company accounts data





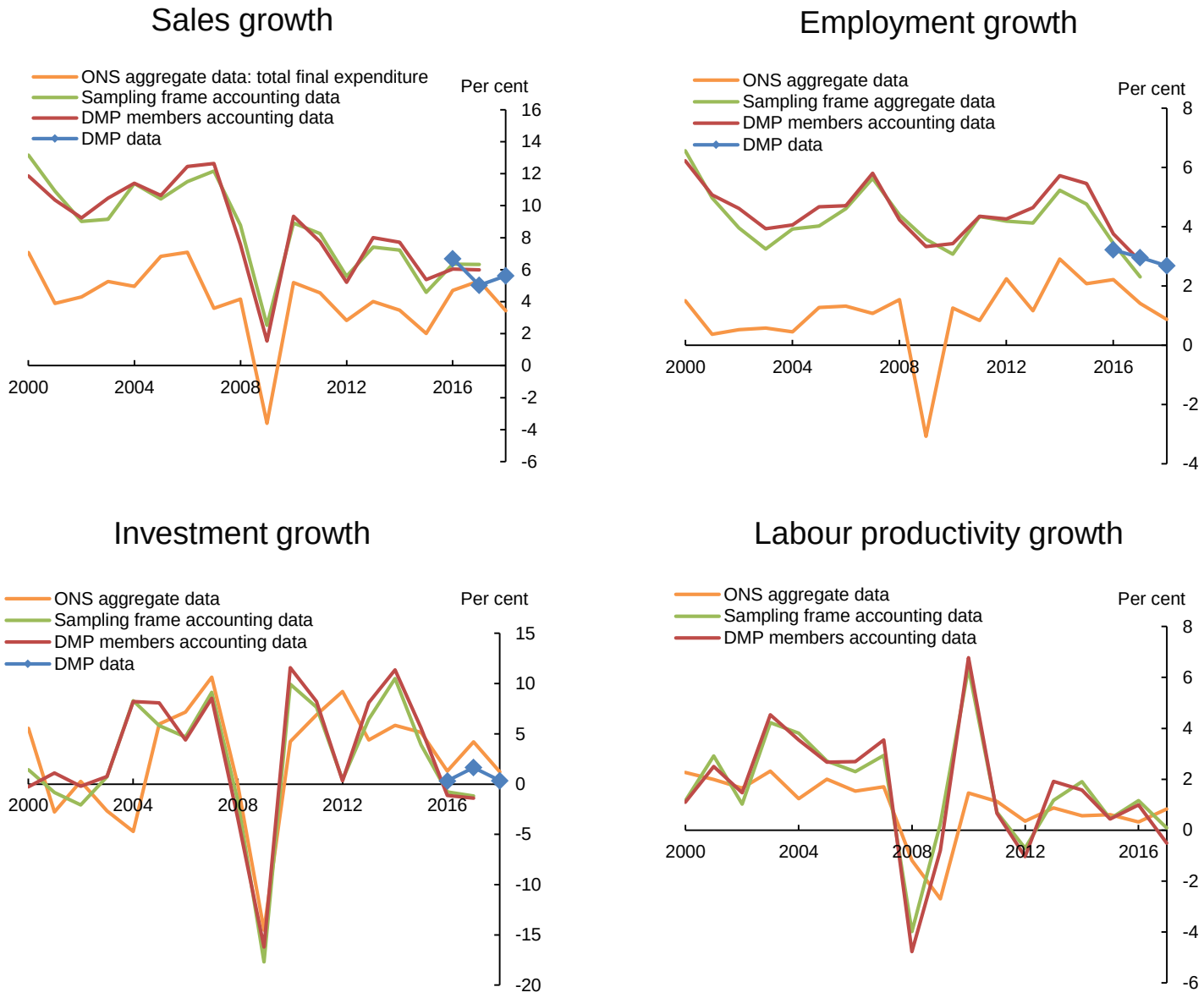




Source: Bureau van Dijk FAME dataset, Decision Maker Panel and authors' calculations.

Notes: Sales values from the DMP survey are based on annualised quarterly sales reported by businesses.

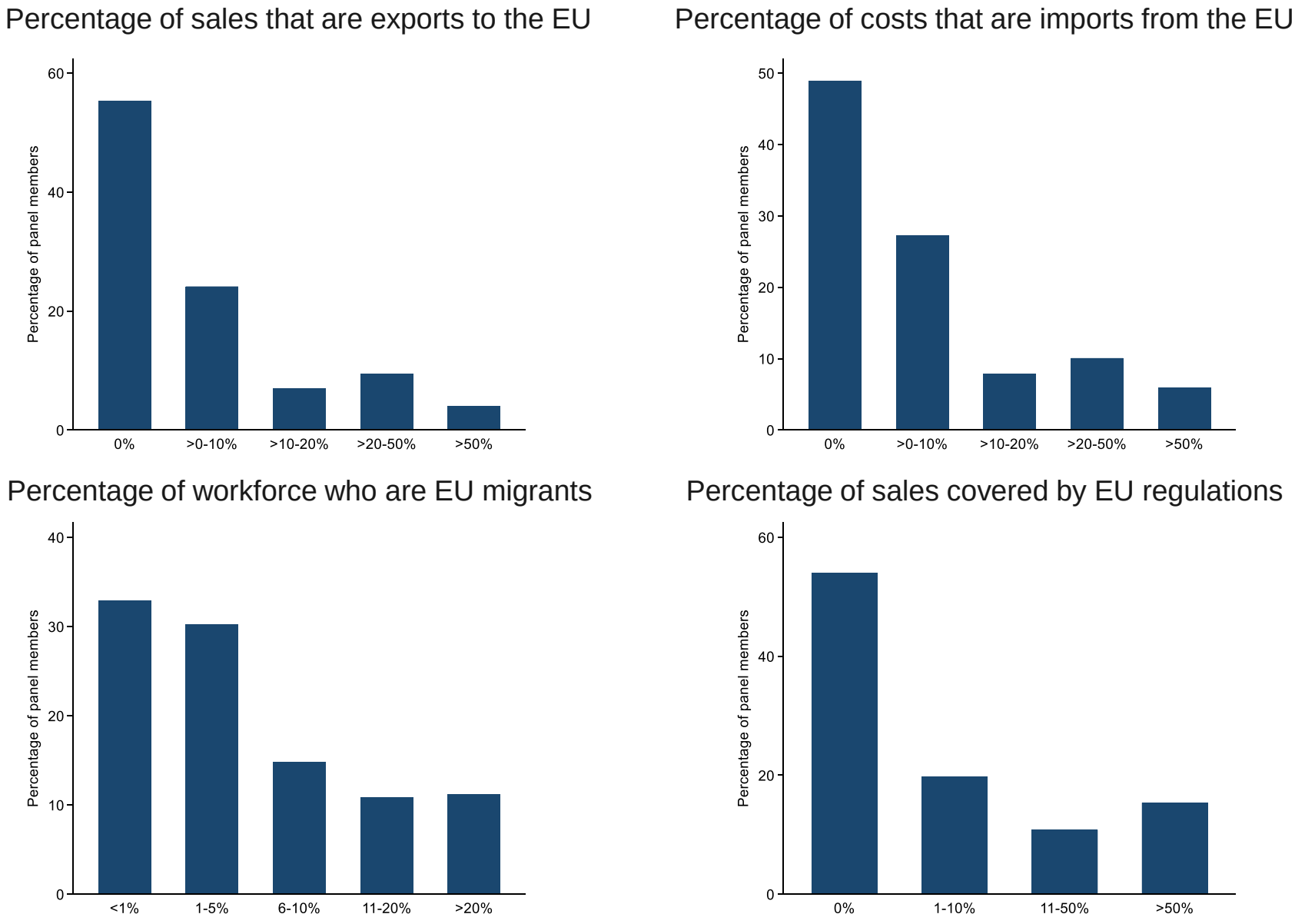
Figure A6: Comparison of DMP to other aggregate data



Source: Bureau van Dijk FAME dataset, Decision Maker Panel, ONS and authors' calculations.

Notes: Accounting data and DMP data are mean annual growth rates and are shown unweighted.

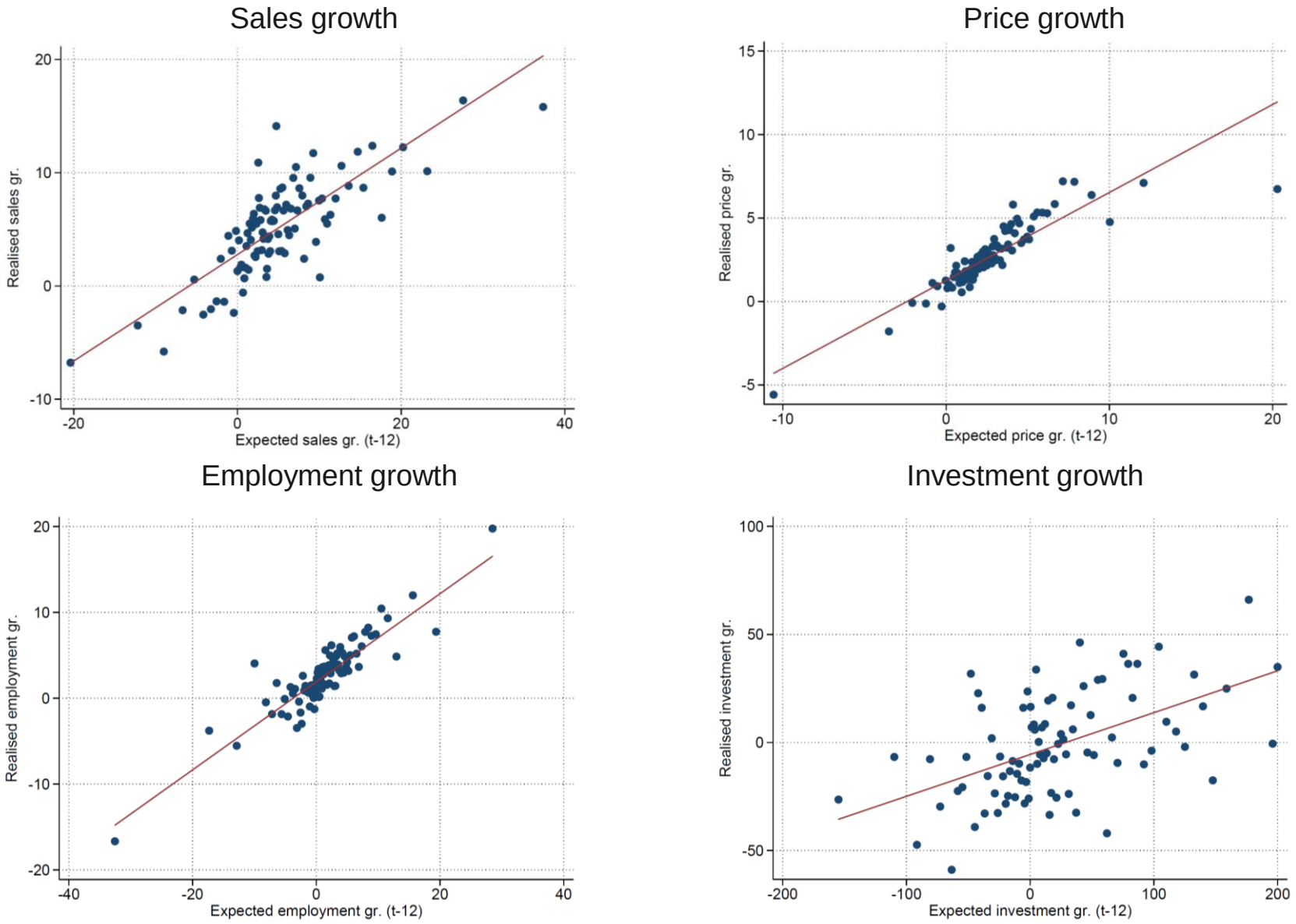
Figure A7: Exposure of DMP panel members to the EU



Source: Decision Maker Panel and authors' calculations.

Notes: EU exposure measures are for 2016 H1, just before the Brexit referendum.

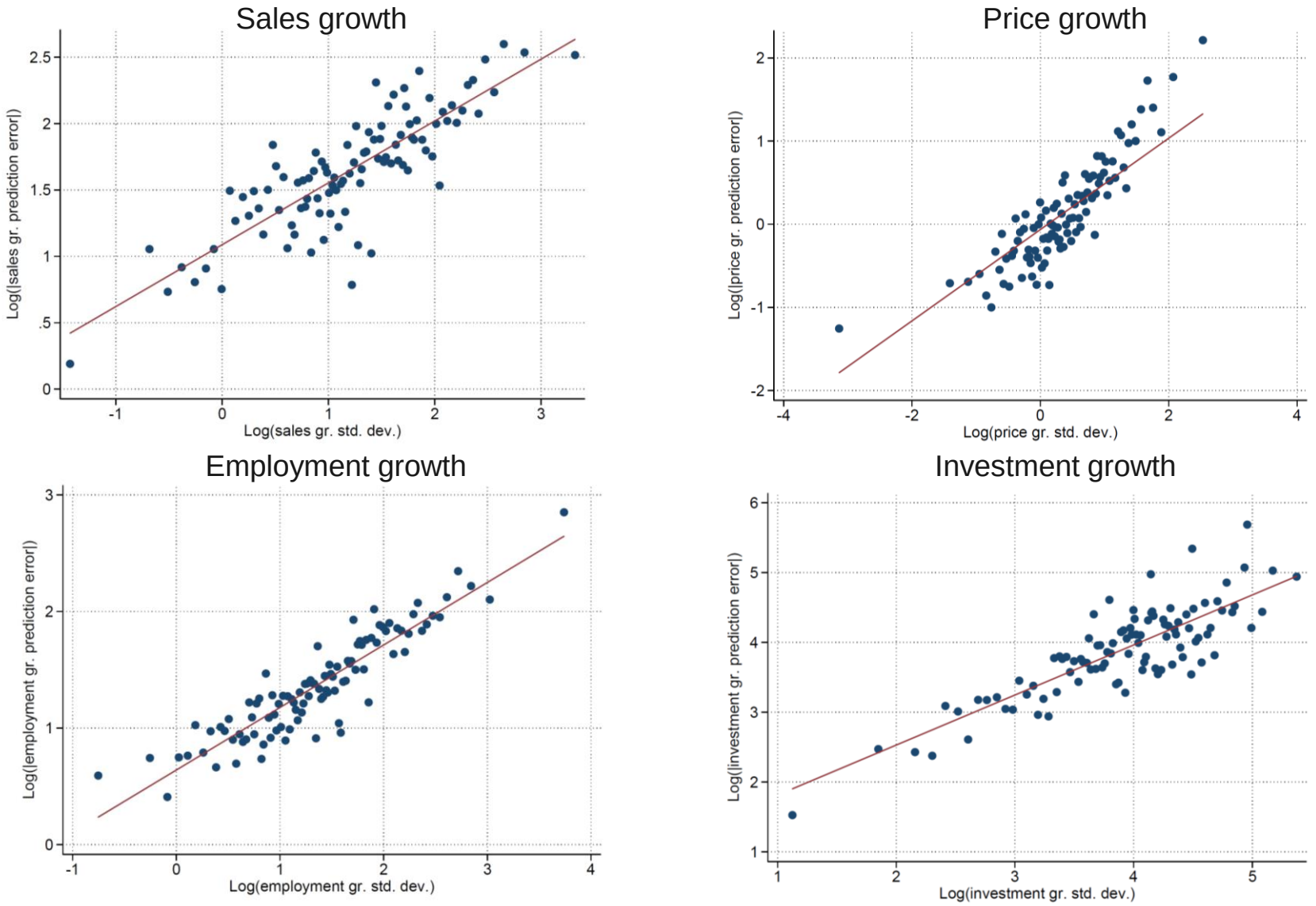
Figure A8: Forecasts versus realizations



Source: Decision Maker Panel and authors' calculations.

Notes: Y-axes show realised growth in sales, prices, employment and investment. X-axes show expectations for year-ahead growth rates calculated from the 5-bin outcomes and probabilities. Forecasts made between September 2016 and June 2018. Binscatter plots which split responses into 100 groups according to expected sales/price/employment/investment growth.

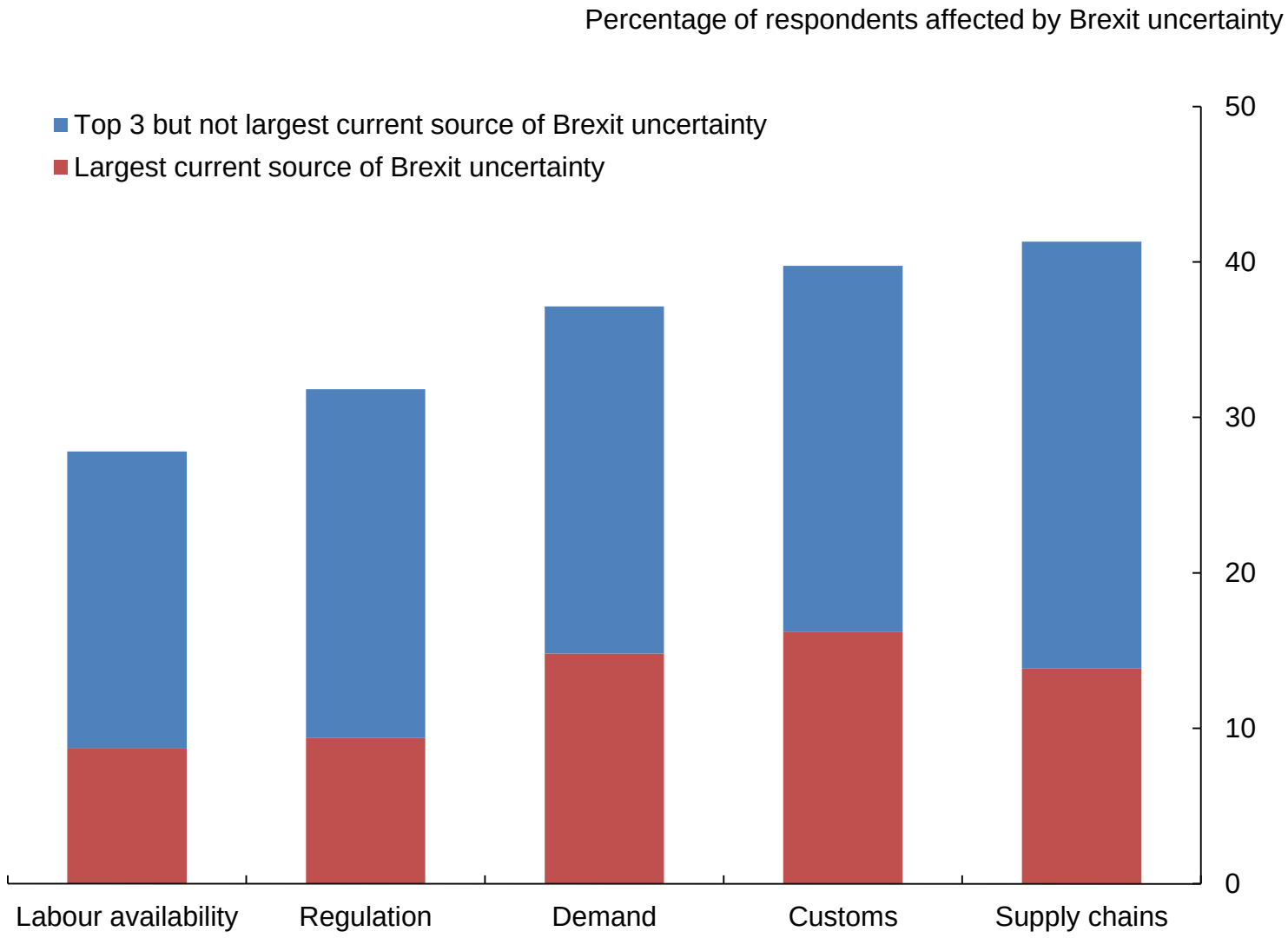
Figure A9: Subjective uncertainty versus forecast errors



Source: Decision Maker Panel and authors' calculations.

Notes: Y-axes show forecast errors defined as the absolute value of a forecast less realised growth over the following 12-month period. X-axes show subjective uncertainty around the year-ahead growth rates calculated from the 5-bin outcomes and probabilities. Forecasts made between September 2016 and June 2018. Binscatter plots which split responses into 100 groups according to the standard deviation of expected sales/price/employment/investment growth.

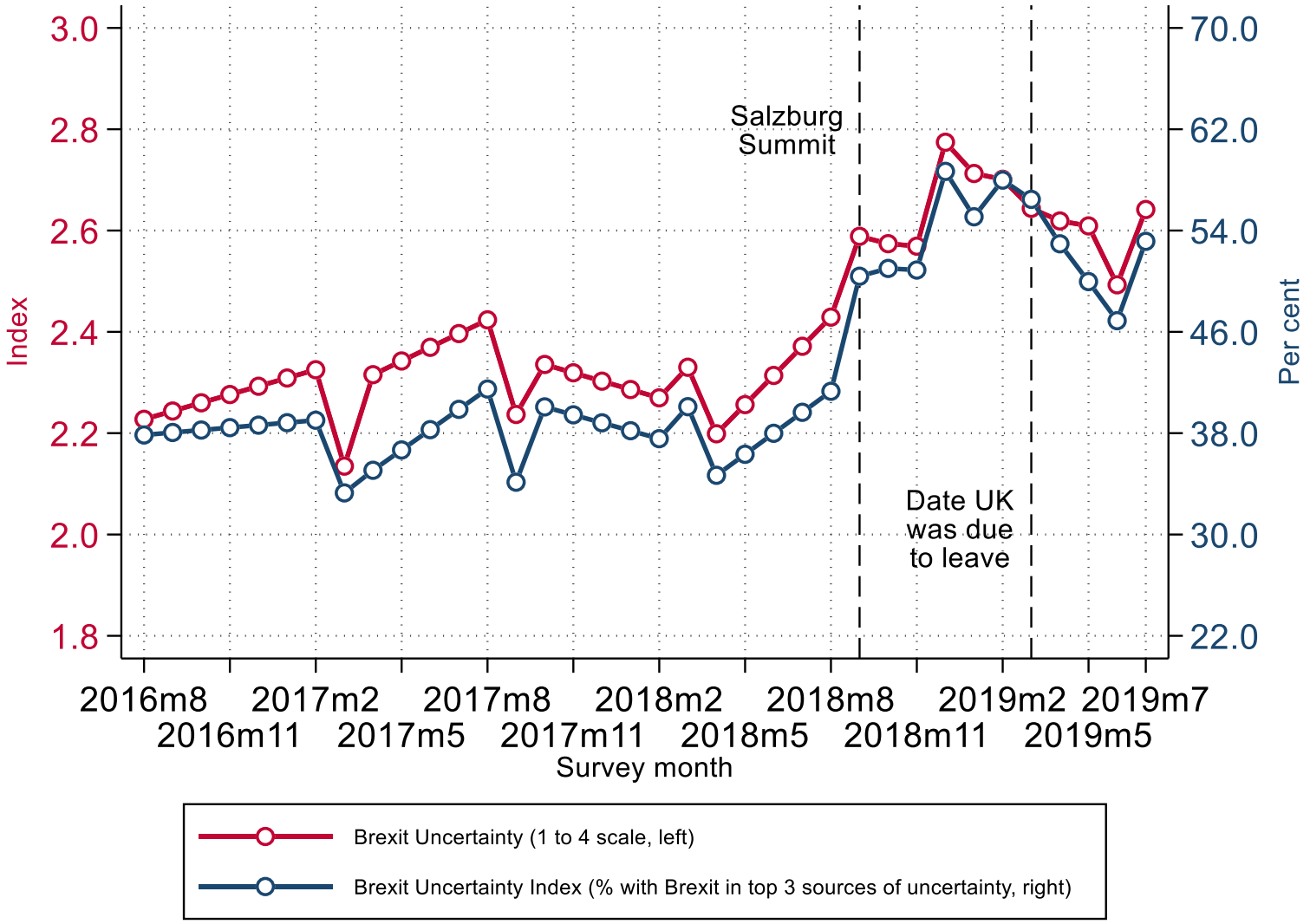
Figure A10: Sources of Brexit uncertainty



Source: Decision Maker Panel and authors' calculations.

Notes: The results are based on the question '*How important are the following factors as sources of Brexit-related uncertainty for your business at present? Please select one option for each [from Not important/One of many/One of top 2 or 3 but not largest source/Largest current source]: Uncertainty about demand for your goods/services; Uncertainty about the availability of labour; Uncertainty about supply chains/availability of inputs other than labour; Uncertainty about regulation; Uncertainty about customs arrangements/tariffs'.* Data were collected between February and April 2019. All values are weighted.

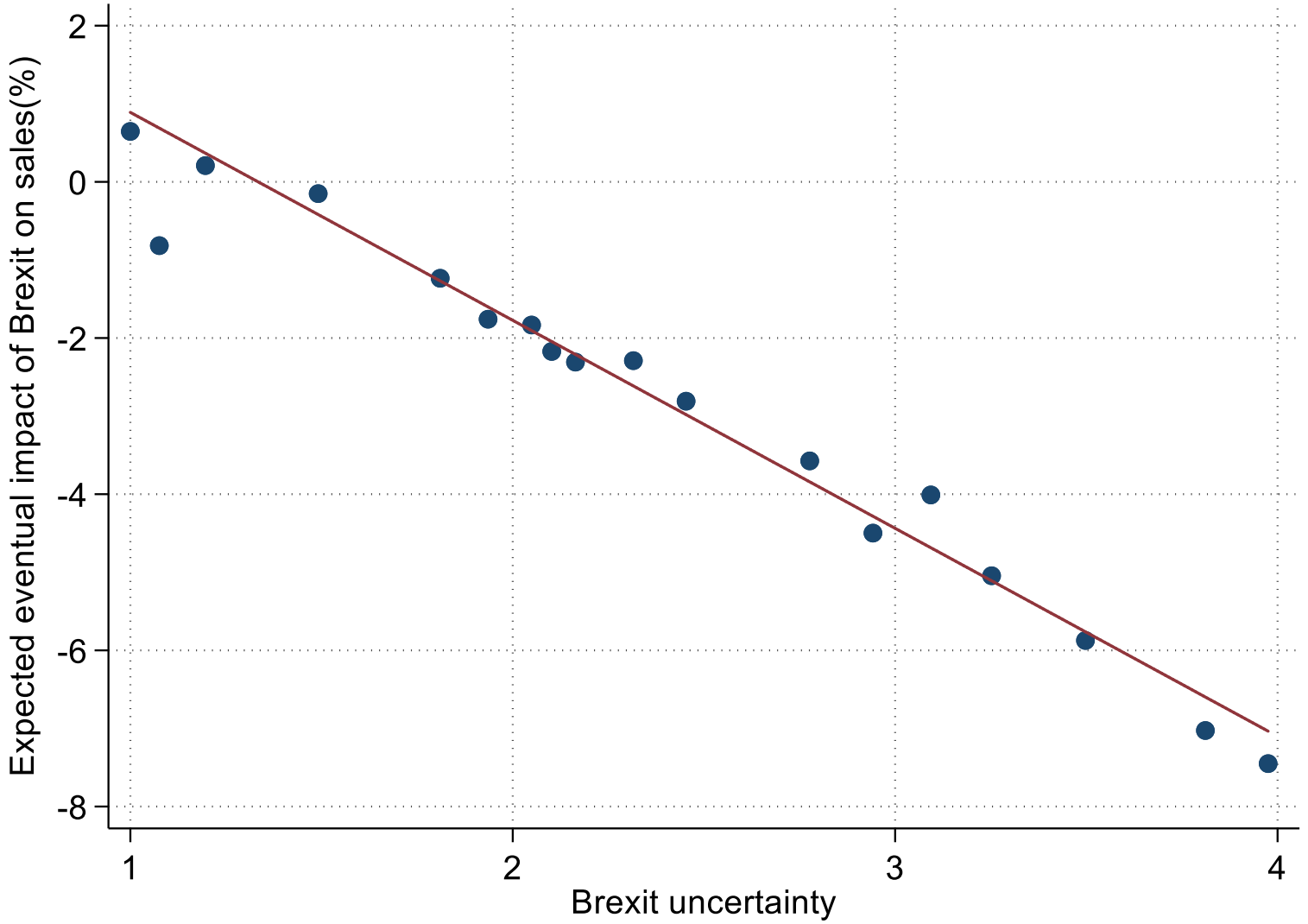
Figure A11: Brexit Uncertainty index



Source: Decision Maker Panel and authors' calculations.

Notes: The results are based on the question '*How much has the result of the EU referendum affected the level of uncertainty affecting your business?*'. The first index shows average responses to the uncertainty question, ranging from 1 to 4. The second index shows the percentage of respondents that view Brexit as one of the top 3 sources of uncertainty. Values are interpolated for months before August 2018 when the question about uncertainty was not asked. All values are weighted.

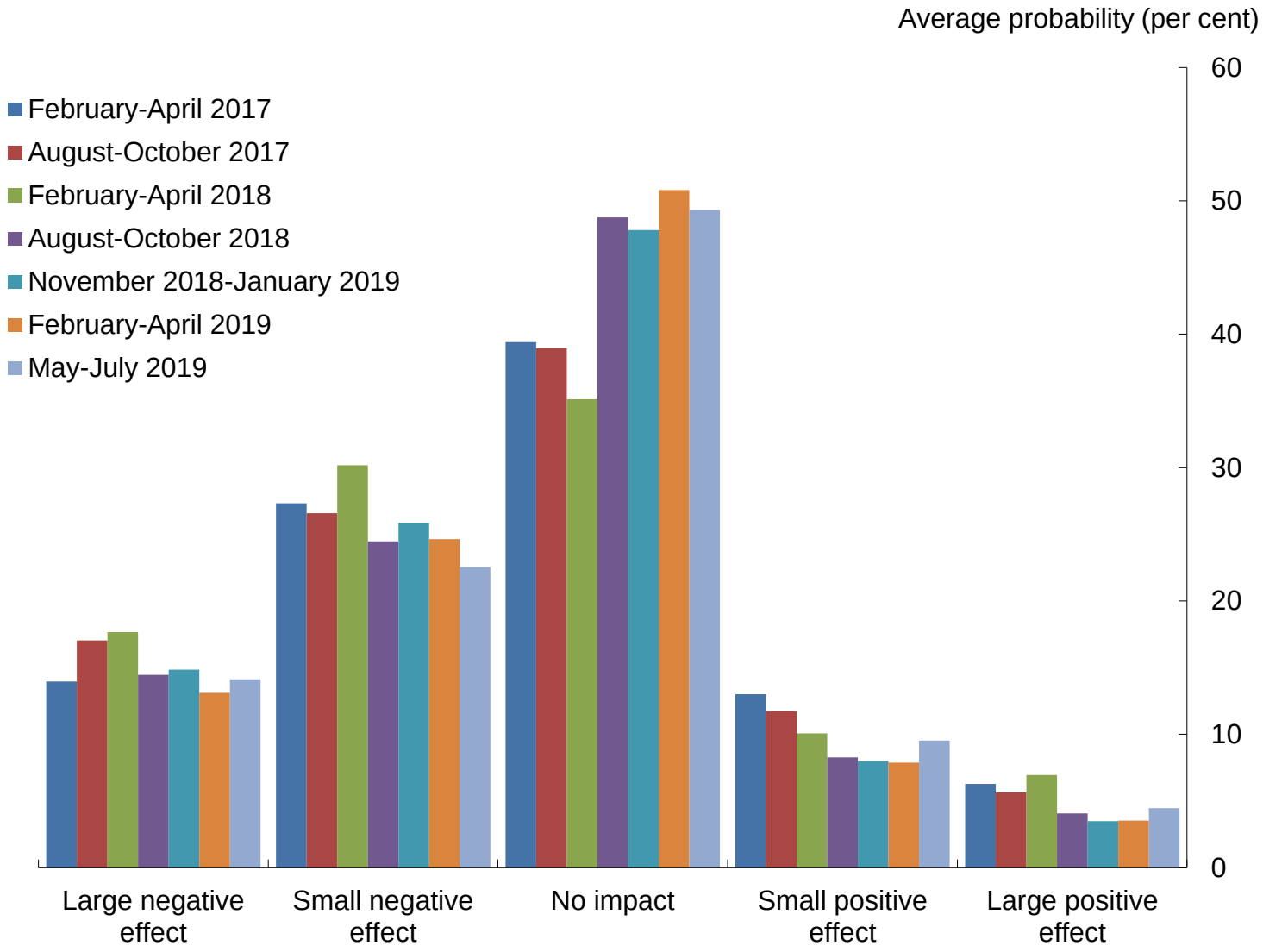
Figure A12: Brexit uncertainty and expected eventual sales impact



Source: Decision Maker Panel and authors' calculations.

Notes: For details about survey questions used for this chart, see footnotes under Figure 1 and Figure 7. Binscatter plots which split responses into 25 groups according to Brexit uncertainty.

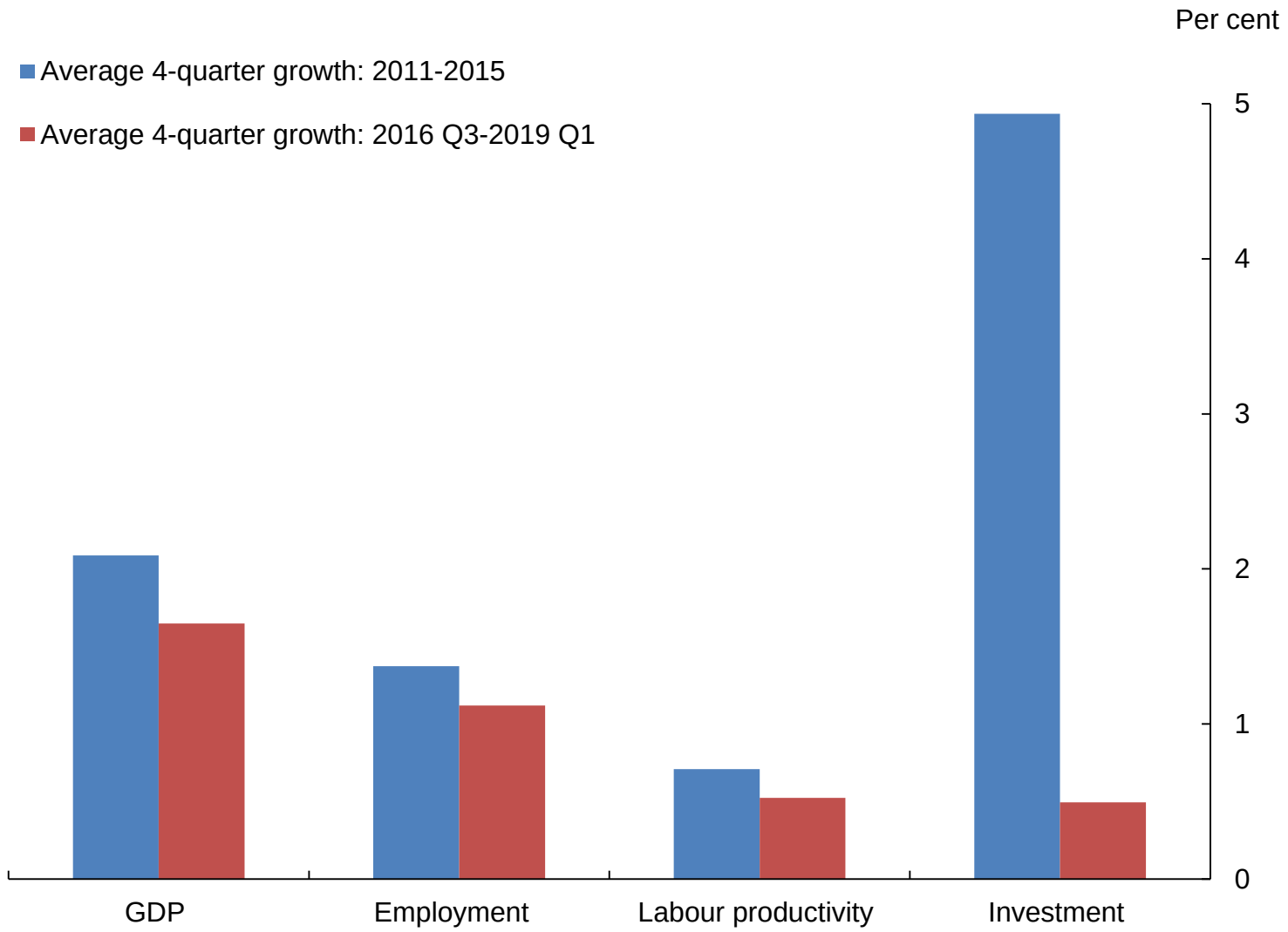
Figure A13: Expected eventual impact of Brexit on sales



Source: Decision Maker Panel and authors' calculations.

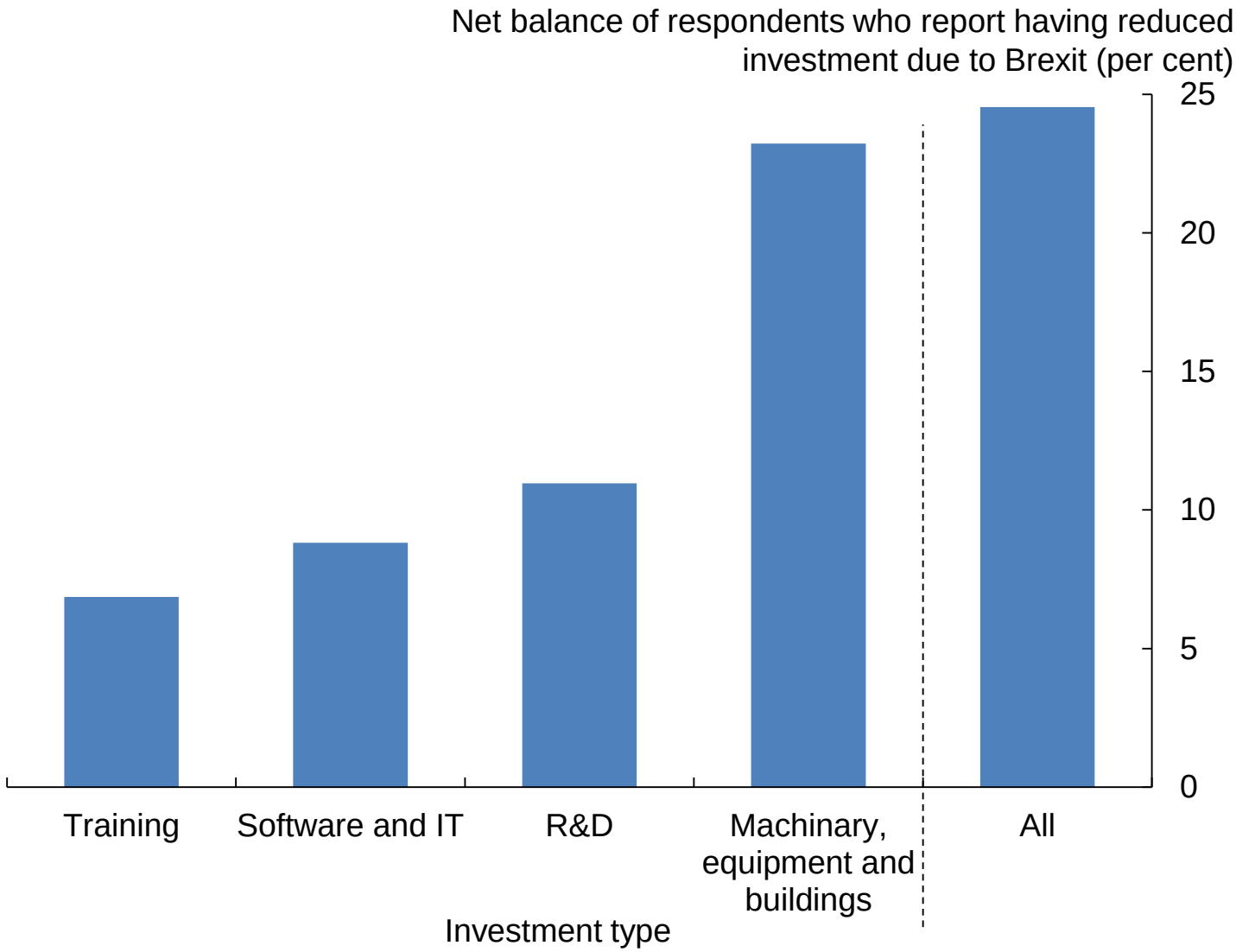
Notes: For details about survey question for this chart, see footnote under the Figure 7.

Figure A14: Macroeconomic aggregates before and after the referendum



Source: Office for National Statistics and authors' calculations. All variables are in real terms.

Figure A15: Brexit and intangible investment



Source: Decision Maker Panel and authors' calculations.

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. All values are weighted.