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Abstract

We use data from a large panel survey of UK firms to analyze the economic drivers of price setting since the start of the Covid pandemic. Inflation responded asymmetrically to movements in demand. This helps to explain why inflation did not fall much during the negative initial pandemic demand shock. Energy prices and shortages of labor and materials account for most of the rise during the rebound. Inflation rates across firms have become more dispersed and skewed since the start of the pandemic. We find that average price inflation is positively correlated with the dispersion and skewness of the distribution. Finally, we also introduce a novel measure of subjective inflation uncertainty within firms and show how this has increased during the pandemic, continuing to rise in 2022 even as sales uncertainty dropped back.

Key words: Inflation, Covid-19, uncertainty.

JEL classification: C83, D22, D84, E31.

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Introduction

Inflation in the US and UK is now at levels not seen for 40 years, reaching around 9% in 2022 Q2. Understanding what explains the recent strength in inflation is crucial for monetary policymakers dedicated towards bringing inflation back to their inflation targets. But analyzing the current period from a more timeless perspective is also important – providing identifying variation to improve understanding of how firms set prices, and therefore how best to model inflation dynamics.

In this paper, we use data from a large and representative survey of firms in the UK to study the behavior of inflation since the start of the Covid-19 pandemic. We also introduce a novel measure of inflation uncertainty within firms, showing how that uncertainty has evolved and studying its determinants and consequences. We focus on the UK but our findings are relevant to all countries experiencing similar inflationary episodes, for example, Figure 1 shows the strong co-movement between UK and US inflation during the pandemic.

We have five key empirical findings. First, the impact of the Covid pandemic on inflation was asymmetric: positive demand shocks from Covid boosted inflation at the firm level by more than negative Covid demand shocks reduced it. Second, this demand asymmetry can explain why inflation did not fall by more during the pandemic, but it does not explain much of the acceleration in inflation in late 2021-2022. Energy prices and shortages of labor and materials account for most of the rise in inflation, although these may also be linked, in part, to the impact of Covid elsewhere. Third, the distribution of inflation rates across firms has become more dispersed and positively skewed since the start of the pandemic. Uncertainty about future inflation within firms has increased too. Fourth, we find that average inflation at the industry level is positively correlated with realized dispersion and skewness across firms while, at the firm level, expected inflation is increasing in dispersion and skewness of their subjective expected inflation distribution. Fifth, we find that larger forecast errors and ex-ante uncertainty are negatively correlated with profit margins and TFP.

We use firm-level data from the Decision Maker Panel (DMP) survey. The DMP is a large and representative survey of CFOs in UK businesses. It was established in 2016 and is run by the Bank of England in partnership with the University of Nottingham and Stanford University. The survey is carried out online and receives close to 3,000 responses each month. In the survey, firms are asked about how the average price that they charge has changed over the last year. Although the survey data cover economy-wide prices, the DMP inflation data closely track the official UK Consumer Price Index. Firms are also asked how they expect their own prices to change over the next year. The expectations question asks about the distribution of expectations, allowing both a point estimate and a novel measure of uncertainty around expected own-price inflation to be calculated.

There are three parts to our empirical analysis of the recent behavior of inflation. The first analyses the economic drivers of inflation. To do this we estimate a firm-level Phillips curve using data from the DMP. Although Phillips curves are typically estimated using aggregate data, we establish that similar relationships hold at the firm level. In this framework, inflation depends on a measure of the business cycle, supply shocks and expected inflation. The DMP survey contains detailed questions on each of these that we include as explanatory variables in our regression estimates. In the second part, we study the recent relationship between the different moments of inflation in more detail, following the approach of Ball and Mankiw (1995), but also extending it by looking at similar relationships for expected inflation in addition to realized inflation. In the third part, we examine inflation uncertainty and forecast errors in more detail and study their consequences for profits and TFP.

We find evidence that inflation responded asymmetrically to movements in demand during the pandemic. To assess this we use businesses' own estimates of how Covid-19 has affected their sales, which we interpret as (exogenous) shocks to firm demand. The effect of demand shocks on inflation is estimated to have been stronger when demand was growing than when it was falling. When Covid was reducing sales, demand is only estimated to have had a small impact on inflation. But that effect is estimated to have been significantly larger when Covid was increasing sales.

The non-linearity that we identify in the effect of changes in demand on inflation helps to explain why inflation only fell modestly in the first year of the pandemic. However, it cannot explain much of the subsequent pickup in inflation because Covid still represented a negative demand shock for the majority of firms in that period. Instead, it is supply side factors that can explain most of the rise in inflation since 2021, as relative prices shifted. Some of these factors, such as supply and labor shortages, are also likely to be linked to Covid, while others, such as energy prices and additional costs related to Brexit, are less so.

The Covid pandemic has led to large changes in the distribution of inflation, both realized and expected, across firms and industries. Dispersion of inflation rates across firms increased in the early part of the pandemic and rose further from 2021. Skewness initially fell, but picked up during 2021 as aggregate inflation rose. That increase in skewness is likely to be explained, at least in part, by rises in energy prices and by supply and labor shortages affecting some firms by much more than others. At the same time that dispersion and skewness of realized inflation was rising, it was increasing for expected year-ahead inflation as well.

The structure of the DMP questions means that it is possible to study both dispersion and skewness of expected mean inflation forecasts *between* firms and to study uncertainty and skewness of the expected inflation distribution *within* firms. Since the DMP asks panel members to provide five scenarios for year-ahead own-price inflation and associated probabilities, this enables us to calculate the standard deviation and skewness of expectations within each firm. We describe these novel measures as subjective uncertainty and skewness. Subjective uncertainty around inflation rose at the start of the pandemic, but by less than a comparable measure for sales. Since 2021, as uncertainty about sales has declined, uncertainty about inflation has risen further to a new peak.

We find that realized inflation is positively correlated with the dispersion and skewness of the distribution. We estimate this using an industry-level panel constructed from the firm-level DMP data. Similarly, *within firms* we show that within-firm dispersion and skewness measures also have a positive correlation with expected inflation.

Our empirical results are potentially consistent with a model of menu costs in the presence of trend inflation of the type proposed by Ball and Mankiw (1994, 1995). This may be able to explain both the asymmetric response of inflation to demand shocks and the positive relationship between inflation and skewness. It would imply that the distribution of shocks can affect the aggregate inflation rate. We plan to explore this further in a subsequent version of this paper.

Looking in more detail at uncertainty within firms, we show how this also matters because it is typically associated with making bigger forecast errors in the future. It makes it harder for firms to plan ahead, which could lead to an inefficient allocation of resources. Tanaka et al. (2020) show that firms making larger errors in forecasting aggregate GDP predicts lower profitability and productivity. We find a similar result at the firm level in relation to prices; that is, when firms make larger errors in forecasting their own future prices, this is typically associated with lower profits and productivity too. Recent increases in inflation uncertainty have been largest among firms where uncertainty about sales is higher, firms more affected by supply and labor shortages and firms who are in industries that are energy intensive.

Our work relates to four different strands of literature: (i) analysis of the economic impacts of Covid-19 pandemic; (ii) how firms set prices and the reasons behind their pricing decisions; (iii) the asymmetric response of inflation to shocks; and (iv) using firm surveys to evaluate the impact of major shocks.

There is now a large, and still rapidly growing, literature on the economic impact of Covid-19, which are already too numerous to cite and many of which are surveyed in Brodeur et al. (2020) and Criscuolo (2021). Many different aspects of this shocks have been studied. Some examples include Bartik et al. (2020a and 2020b), Bloom et al. (2022), Brynjolfsson et al. (2020), Gourinchas et al. (2020), and Papanikolaou and Schmidt (2020) who show pervasive impacts on firms. Chetty et al. (2020), Forsythe et al. (2020) and Cajner et al. (2020) show large and heterogeneous labor market impacts of Covid-19; Guerrieri et al. (2022) show that supply shocks can cause demand shortages; and Jorda et al. (2022) examine the longer-run consequences of past pandemics.

Relatively less attention has been paid to the effects of the Covid pandemic on inflation than the other aspects. Bonam and Smădu (2021) and Daly and Chankova (2021) both look at how inflation has responded in the aftermath of past pandemics and find that it typically remained weak. Baqaee and Farhi (2022) show that negative sectoral supply shocks can be stagflationary and can be amplified by complementarities in production causing the effects to cascade from one sector to another. Davies (2021) studies the properties of the UK CPI microdata during the pandemic and finds that has been significant and sustained price volatility. We add to this evidence.

There is a long literature on how firms set prices reaching back to the 1970s. The more recent New-Keynesian literature typically uses a time-dependent approach to modelling how prices change, as in the model of Calvo (1983) where a subset of firms chosen randomly change prices at fixed intervals. The alternative state-dependent approach assumes that the decision to change prices depends on the state of the economy and the market faced by the firm; here costs of changing prices (as in the menu cost model of Mankiw, 1985) create sticky prices or the cost of acquiring information about prices (as in Mankiw and Reis, 2002) prevent prices changing continuously. Several studies have sought to test these models using microdata, including Bils and Klenow (2004), Klenow and Kryvtsov (2008) and Nakamura and Steinsson (2008). Trying to better fit the empirical facts has led to these models being adapted, e.g. Golosov and Lucas (2007) and Midrigan (2011). Our work contributes by providing a test of how well the different models fit the data during the Covid pandemic.

Some models, such as the menu cost models of Ball and Mankiw (1994) imply that inflation will respond asymmetrically to inflation in the presence of trend inflation. As noted above, this would be consistent with our empirical results showing a non-linearity of the Phillips curve. Forbes et al. (2021) find empirical evidence to support this in a cross-country panel. Our non-linear results at the firm level add support to this.

Finally, we also contribute to the growing literature on business surveys to evaluate the impact of major shocks we build on a recent growth literature, for example Altig et al. (2020b), Bhandari et al. (2020) and Candia et al. (2022). The use of these large, high-frequency forward-looking firm surveys is valuable in this context because of the timely nature of the survey data, and in our case also because the survey has both forward and backward looking aspects.

The structure of this paper is as follows. In the next section we provide more information on the Decision Maker Panel Survey that we use. Section 3 presents our results on the economic drivers of realized inflation. In Section 4 we present an analysis of the distribution of recent inflation and the relationship between the different moments. In section 5 we study price uncertainty and forecast errors in more detail. Section 6 concludes.

Section 2: The Decision Maker Panel (DMP)

The DMP is a large and representative online survey of Chief Financial Officers in UK businesses. It is similar in style to the Survey of Business Uncertainty run in the United States by the Federal Reserve Bank of Atlanta (Altig et al. (2020a)). The survey asks about recent developments and expectations for the year ahead in sales, prices, employment and investment. An important advantage of the DMP survey relative to many other business surveys is the quantitative nature of the data that it collects.

The sampling frame for the DMP is the population of UK businesses with 10 or more employees in the Bureau van Dijk FAME database.[1] It covers small, medium and large private sector businesses across all industries. Firms are selected randomly from this sampling frame and are 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. Once firms are part of the panel they receive monthly emails with links to a 5 to 10-minute online survey. Firms that do not respond to the survey for three consecutive months are re-contacted by telephone to check whether they received the emails or have other reasons for not completing the survey. When the DMP firm recruitment team first contact firms they ask to speak to the CFO, and failing that the CEO. As a result 85% of respondents are in these two positions (70% are CFOs and 15% are CEOs) with the remainder mostly senior finance managers. Given that the typical firm in the survey has about 100 employees these CFOs and CEOs have a very good sense of the overall direction and performance of the business.

The DMP grew quickly after its launch and has averaged just under 3,000 responses a month since 2019, covering around 5% of UK private sector employment. That makes it one of the largest monthly business surveys in Europe. 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 helps to keep the survey short for respondents whilst yielding a regular monthly flow of data. The response rate for active respondents in the region of 50-55% and has only fallen back modestly since 2019 despite the Covid pandemic (Figure A1 in the Appendix shows the response rate and number of responses per month).

An important advantage of the DMP survey relative to other business surveys is the quantitative nature of the data that it collects. This makes the data particularly valuable for research, especially for analyzing the impact of major economic events such as the Covid pandemic where the scale of changes is large. Many other business surveys tend to focus on questions that ask businesses to indicate whether they expect the conditions that they face to get better or worse, rather than by how much they expect them to get better or worse. The reason that the

[1] 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.

DMP targets the CFOs (or CEOs) at these firms is because they are likely to be sufficiently numerate to respond to somewhat complex quantitative questions.

Since its inception, the DMP has asked firms about how the average price that they charge has changed over the last year. The survey includes firms from across the economy, and therefore the pricing data are a mix of prices from consumer and producer facing businesses. However, the DMP inflation data closely tracks the UK aggregate Consumer Prices Index (Figure 1), and if the data is just restricted to consumer-facing firms, average inflation looks similar to that for all firms (Figure A2 in the Appendix). In this paper we use the full sample to take advantage of the extra observations that offers.

The survey also asks firms about their expectations for year-ahead inflation in their own average price. But rather than ask for a point estimate, respondents are asked about the distribution of expected possible outcomes. They are asked to provide their lowest, low, medium, high and highest expectations for year-ahead inflation, and then for the probabilities associated with each scenario, where those probabilities must sum to 100% (see Figure A3 in the Appendix for screenshots of how this works in the survey). From this, it is possible to calculate a mean expected outcome, a standard deviation and a skew. This is how we define our measures of subjective uncertainty and skewness around inflation. The survey also contains similar questions for sales, employment and investment, allowing comparable metrics to be calculated for these variables. Although other related surveys such as the Atlanta Fed's Survey of Business Uncertainty have similar questions which allow measures of subjective uncertainty to be calculated for sales and employment, the DMP survey is the only one that has regularly asked this type of question about prices.

As well the regular questions on sales, prices, employment and investment, the DMP survey also includes more ad-hoc special questions about topical policy issues. In particular, these special questions have focused on how Brexit and Covid have affected businesses.[2] Some of these questions have also asked about things that are potentially highly relevant for explaining movements in inflation. The questions we make use of this paper as explanatory variables are ones that ask about the effects of Covid on both sales and unit costs, supply and labor shortages, the effects of Brexit on unit costs and import intensity (to pick up the effects of import prices). See Figures A4 and A5 for more details on these data and the question wording used. One influence on inflation that the survey has not asked about at the firm level is the importance of energy use. Instead we merge in data on the percentage of costs that are accounted for by energy at the two-digit industry level in 2019 from the ONS Supply and Use tables to help us assess how energy input prices have affected inflation.[3]

[2] Bloom et al. (2019) use data from the DMP to analyze the impact of Brexit on UK firms. Bloom et al. (2022) study the effects of Covid-19 on productivity using DMP data.

[3] We also split out the share of costs that are accounted for by coal/petrol and those that are due to utilities and include them separately in our regressions.

Section 3: The economic drivers of inflation

In line with aggregate data, inflation within the DMP fell modestly during the first year of the Covid pandemic before picking up sharply thereafter (Figure 1). The DMP measure fell from an average of 2.3% in 2019 to 1.6% in 2020. But from 2021 Q1, inflation rose rapidly, exceeding 7% by 2022 Q2, and closely following the profile of aggregate CPI inflation data (Figure 1). The increase in inflation has been particularly pronounced for goods prices (Figure A2). This section focusses on the economic factors that can explain these movements in inflation. The next section discusses developments in the distribution in more detail.

To examine the dynamics of realized inflation we estimate a set of firm-level regressions. Our specifications involve estimation of a 'Phillips curve' relationship at the firm level. These include own price inflation ($\pi_{i,t}$) as the dependent variable and firm-level measures of demand ($Y_{i,t}$), supply side factors ($S_{i,t}$) and expected inflation ($E_t(\pi_{i,t+12})$) as explanatory variables, as represented in equation 1. Unlike typical Phillips curve estimation this relies more on variation across firms rather than over time, although there is still a time dimension to the panel that we use. It will also exclude more general equilibrium channels that would be captured by an aggregate Phillips curve because it is estimated at the firm level but includes time effects. The equations also include firm fixed effects. The equations are estimated on a quarterly basis between 2017 Q1 and 2022 Q2 and are based on almost 35,000 individual data points for around 5,500 unique firms. We then use the coefficients from these regressions to quantify the contributions from different factors to changes in inflation since the end of 2019.

$$\pi_{i,t} = \alpha_i + \beta_t + \sigma Y_{i,t} + \omega S_{i,t} + \gamma E_t[\pi_{i,t+12}] + \epsilon_{i,t} \quad (1)$$

The first influence on inflation that we examine is the effects of demand. The Covid pandemic is a good example of a large and unexpected demand shock, and is therefore valuable to study how inflation responds to such shocks.[4] Starting in April 2020, soon after the start of the pandemic, firms in the DMP have been asked to estimate how Covid-19 has affected their sales, relative to what would have otherwise happened.[5] An important assumption we make when using this data is that respondents are providing estimates of the impact of Covid-19 on the location of their businesses demand curve, not an estimate of the impact on sales that includes their supply response – i.e. the change in the location of the intersection of the supply and demand curves.

[4] Although the focus of this estimation is on the effects of Covid demand shocks, the pandemic has also affected the supply side of the economy (e.g. Brinca et al. (2021) and del Rio-Chanona et al. (2020) analyze the demand versus supply-side effects of Covid-19 in the US). In column 5 of Table 1, we control for several supply-side factors, such as the impact of Covid on firm costs, recruitment difficulties, and supply shortages, in order to test the robustness of our findings.

[5] The precise wording of the question is 'Relative to what would otherwise have happened, what is your best estimate for the impact of the spread of Covid-19 on the sales of your business in each of the following periods?'. Firms have typically been asked about the effects in the previous quarter and their expectations for the current quarter and next two quarters ahead. Realized data are used where available, but expectations or imputed estimates based on responses from earlier quarters are used where realized data are missing.

Firms estimate that, on average, sales in 2020 Q2 were over 30% lower than they otherwise would have been because of Covid-19 as government restrictions were introduced (see Figure A4 for details). Since the middle of 2020, sales have recovered steadily, such that by 2022 Q2, firms were reporting that the level of sales was, on average, around 2% lower than they otherwise would have been. But these aggregate statistics mask significant heterogeneity across industries and firms where sectors that are more heavily dependent on face-to-face interaction with customers were hardest hit. This provides us with substantial variation to estimate the effects of changes in demand on inflation. On average between 2020 Q2 and 2022 Q2, 64% of respondents to the DMP survey reported that Covid-19 had lowered their sales, it had no impact for 19% of firms, and a positive impact for 16% of firms.

One of our main results is that inflation responded asymmetrically to demand shocks during the pandemic. When sales were lowered, demand only had a small impact on inflation. But for firms that experienced a positive demand shock, the relationship between demand and inflation was significantly stronger. Figure 2 shows the relationship graphically. Column 1 of Table 1 shows it in regression form, including time but not firm fixed effects. The coefficient on the Covid impact on sales variable is significantly larger when the impact of Covid-19 on sales is positive than when it is negative. In column 2, we also include firm fixed effects. The non-linearity is still clear and highly significant, although the coefficients move a little closer together than in column 1. In the last row of the table, we test for the statistical equality of the coefficients on the positive versus negative impact of Covid-19 on sales; in all cases, the difference is highly significant at the 1% level. Our results are consistent with recent work by Forbes et al. (2021) who also find evidence of non-linearity of the Phillips curve using cross-country panel data.

Columns 3 and 4 of Table 1 provide some more robustness checks on the asymmetry result. Column 3 shows how the non-linearity is not dependent on whether a control is included for whether the demand shock is positive or negative. In Column 4, instead of allowing the coefficient on Covid impact on growth to vary according to the sign of that variable, we instead include a quadratic term. The coefficient on that squared term is positive and highly significant, meaning that the relationship between inflation and the Covid impact on sales is convex.

The asymmetry in the demand/inflation relationship is also found to be present for both goods and services producers (as shown in Table A1). It also holds for sub-periods of the pandemic. In Table A1 we show how it is present if we limit the estimation period to only run to 2021 Q1, or if we exclude the first year of the pandemic. That implies the smaller response to negative shocks is not just a result of firms being less likely to change prices during lockdowns.[6] Neither does the asymmetry seem to be explained by whether firms went into the pandemic with high or low levels of liquidity.[7]

[6] Government restrictions were most severe during the first year of the pandemic in the UK (2020 Q2 to 2021 Q1). Similarly, the asymmetry result also holds excluding very large demand shocks of more than 50% or more than 25%.

[7] Gilchrist et al. (2017) show that during the financial crisis liquidity constrained firms increased prices, while their unconstrained counterparts cut prices. We do not observe big differences in pricing behaviour for more/less

Finally, we test whether the persistence of demand shocks is different depending on whether they are positive versus negative. If positive shocks are more persistent, for example, this could explain the stronger inflation response in Table 1. In Table A2, we estimate a simple autoregressive specification of the Covid impact on sales interacted with an indicator for whether the impact was positive or negative. Across all columns, we find that the negative effects are more persistent. The difference in coefficients for negative versus positive shocks is statistically significant, although both are significantly different from zero. Therefore, we conclude that a difference in persistence is not the main driver of the non-linear effects of demand shocks on inflation.

In Column 5 of Table 1 we introduce several supply-side factors that are likely to have affected inflation over recent years. These variables largely represent changes in relative prices that would be likely to shift the position of the short-run Phillips curve rather than lead to movements along it. We include controls for Covid-related costs, supply and labor shortages, import intensity, energy prices and additional costs relating to the end of the Brexit transition period.[8] The additional variables that we add in column 5 are from DMP questions where data is generally not available for all quarters.[9] Or in the case of energy intensity, we just have two-digit industry level data from 2019. To address this, we calculate an average of each variable for each firm over the period in which data are available, and then allow the coefficient on that time-invariant firm average to vary over time.[10] For brevity we only report results in Table 1 that interacted with a single time dummy (for 2021 Q2 to 2022 Q2 except for Covid-related costs, which is 2020 Q2 to 2022 Q2), but in Figure A6 of the Appendix we show the individual coefficients on interactions with quarterly time dummies from 2020 Q2 to 2022 Q2.

Including supply-side factors in Column 5 of Table 1 slightly reduces the coefficient on positive demand shocks, but a clear and statistically significant asymmetry in the response of inflation to positive and negative demand shocks remains. Covid-related costs, supply shortages, labor shortages, import prices, energy prices and extra costs relating to the end of the Brexit transition period are all estimated to have had positive and statistically significant effects on inflation since 2021 Q2.

As well as measures of the business cycle and supply side factors, aggregate Phillips curves also usually contain measures of expected aggregate inflation too. Ideally we would include a firm level measure of expected aggregate CPI inflation. The history of this data within the survey is relatively short (it was introduced from May 2022), but we do have measures of

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liquidity constrained firms during the pandemic, although the nature of the Covid shock was also very different to the financial crisis. The was not a sharp tightening in credit conditions and substantial Government support was available to firms.

[8] The control for Covid related costs represents the effect of Covid on the level of unit costs. This fits better than a cost growth term, implying that firms have continued to pass on higher costs in the later part of the pandemic despite cost growth turning negative. Figure A4 shows the data on Covid-related costs.

[9] So for example, the question on supply shortages was only included in the survey in from 2021 Q4 onwards.

[10] This relies on the assumption that there is not substantial variation for a firm during the period over which we take averages. Figures A4 and A5 in the Appendix show that the variation is relatively modest, in aggregate.

expected own price inflation back to 2016. In column 6 we also add measures of lagged and expected own price inflation (the lagged term can help account for the fact expectations may be partially backward looking). Although the direction of causality is unclear using own price expectations, it shows how our other results are robust to the inclusion of the extra variable. Some of the coefficients become smaller, reflecting the fact these factors are also likely to be correlated with expected future inflation too.

To quantify the economic significance of the difference factors affecting inflation, we use the coefficients from our regressions to construct contributions to changes in inflation since the end of 2019. This is shown in Figure 3, based on the version without expected inflation.[11]

The non-linearity that we identify in inflation responses to changes in demand helps to explain why inflation only fell modestly in the first year of the pandemic.[12] However, it cannot explain much of the pickup in inflation beyond that because Covid still represented a negative demand shock for the majority of firms, even as late as 2022. Energy prices and shortages of labor and materials account for most of the rise in inflation, although these may also be linked, indirectly and in part, to the impact of Covid elsewhere in the economy.

The largest contribution to the rise in inflation since early 2021 is estimated to have come from energy input prices, which reaches 1.7pp by 2022 Q2. Wholesale energy prices have increased substantially over this period. The large energy contribution is consistent with firms across the economy already having raised prices because they are passing on increases in their own energy costs. Note this represents firms passing on increases in their own energy costs into prices, not the utility bills and petrol prices faced by households like in the aggregate CPI data. Utility bills and petrol prices influence CPI inflation directly, and are *in addition* to the indirect effect of firms passing on increases in their own costs.

The second largest contribution to the rise in inflation is estimated to come from supply shortages. Around 15% of non-labor inputs are estimated by firms to have been disrupted, on average, between October 2021 and June 2022. Input disruption is estimated to have added 1.1pp to inflation in 2022 Q2, and this contribution has been growing in recent quarters. The impact rises to 1.4pp if the effects of higher import prices are added too, which may themselves have been affected by supply disruption. Whilst these supply disruptions may not be entirely due to Covid, it is likely to have played a substantial role in interrupting supply chains and the availability of raw materials around the world.

Covid may have also affected inflation via its effects on the labor market. Since 2021 Q4 around 60% of firms in the DMP have reported that it was much hard than normal to recruit

[11] Figure A7 in the Appendix shows an alternative version that includes expected inflation. The inclusion of the expected inflation term reduces the size of the contributions of other factors, given they are likely to be correlated with expected inflation too, but overall it explains a similar amount of the rise in inflation.
[12] The non-linearity at the firm level is related to theoretical work by Harding et al. (2022) who develop a model with a kinked Phillips curve to explain the small fall in inflation during the Great Recession as well as the surge in inflation since 2021

new employees. In particular, those effects were larger for firms who reduced their headcount during the pandemic, and then faced difficulty recruiting new staff when demand recovered. Labor shortages are estimated to have added around 0.7pp to inflation by 2022 Q2, which is less than the effects of supply disruption.

Our framework can also be used to help explain why goods price inflation has risen by more than services inflation. The asymmetry in the demand/inflation relationship is found to be present for both goods and services producers. The demand shock was larger for services than for goods producers in the first part of the pandemic and so it weighed a little more on inflation. But in our estimates, the faster pickup in goods price inflation can be mostly explained by goods producers being more affected by higher energy prices and supply disruption (Figure A8).

Section 4: The distribution of inflation

4.1 Recent developments in the distribution of realized and expected inflation

In addition to developments in average realized inflation (i.e. the first moment), there has also been a significant change in higher-order moments - dispersion and skewness - since the start of the Covid pandemic. In this section we document these changes and analyze the relationship between the different moments. The demand and cost shocks that we describe in the previous section are likely to be important explanations for these developments, but we do not formally link them here.

Figure 4 summarizes how realized price growth has evolved since 2017 across percentiles of the distribution. Note this represents the average price charged by each firm, and not the price of each individual product sold. In the pre-pandemic period, the distribution was relatively stable. Elevated inflation in 2017/2018 was largely explained by higher inflation rates in the upper part of the distribution; by 2019, this upside pressure had subsided. However, since the start of 2020, there has been a more striking change in the shape of the distribution.

First, price growth is now more dispersed – firms in the 90th percentile reported inflation rates above 15% in 2022 Q2, up from around 5% in early 2021. In contrast, firms in the 10th percentile still reported no price change over the past 12 months, as they have done for most of the time since 2017. This can be clearly seen in Figure 5, which plots the standard deviation of both realized price growth *across* firms. The standard deviation has increased from around 4% prior in 2019 to a peak of around 7% in 2022. Increased dispersion during Covid is consistent with the findings of Davies (2021) using the UK CPI microdata.

Secondly, the skewness of price growth has also changed since the start of 2020 (Figure 5).[13] In the first months of the pandemic, skewness briefly became negative as firms in the 10th

[13] Note that this figure reports the normalized third moment of realized and expected price growth, rather than the *coefficient* of skewness.

percentile experienced negative inflation. However, since the start of 2021, skewness has become increasingly right-skewed, with price growth in the right tail quickly rising much faster than in the lower parts of the distribution. Nevertheless, inflation rates have still risen for most of the distribution. That increase in skewness is likely to be explained, at least in part, by rises in energy prices and by supply and labor shortages affecting some firms by much more than others.

As well as realized inflation, the DMP survey also asks about expected own-price inflation over the next year. Expected inflation initially fell back at the very start of the Covid pandemic, but started to rise from the middle of 2020 (Figure 6) ahead of actual inflation starting to increase. Expected inflation continued to increase since the middle of 2020, although firms heavily underestimated the extent of what actually happened. Figure 5 shows that the dispersion and skewness of firms' mean own-price inflation expectations has also risen since the start of the pandemic, following a similar pattern to realized inflation, although the increases for expected inflation have been less dramatic than for realized, which again speaks to the unprecedented nature of the shock faced by companies in the UK.[14]

Since the DMP survey asks firms about the distribution of their expectations rather than for a point estimate it is possible to calculate measures of within-firm subjective uncertainty and skewness around their expectations. During the early part of the Covid pandemic, this measure of subjective price uncertainty increased by less than subjective sales uncertainty (Figure 7). But since the start of 2021, as uncertainty about sales was mostly declining, uncertainty about inflation rose. Price uncertainty reached a new peak in 2022 following the Russian invasion of Ukraine.[15] Figure A10 shows how the distribution of inflation uncertainty has shifted to the right during the pandemic, with fewer firms reporting low uncertainty and more firms reporting high uncertainty. Within-firm skewness about future inflation has also risen since 2020. Section 5 below contains a more detailed discussion of the drivers of within-firm uncertainty.

4.2 Relationship between price inflation and dispersion/skewness

Next, we show that the cross-sectional variation in inflation dispersion and skewness is strongly correlated with the price growth reported by firms. We begin the analysis by following the methodology of Ball and Mankiw (1995), who analyze the relationship between the standard deviation and skewness of relative price changes using annual PPI data at the four-digit industry level.[16] In our setting, we collapse our firm-level data to an industry-month panel, using two-digit Standard Industrial Classification (SIC) codes. There are 88 two-digit industries in the SIC classification, such as 'Food and beverage service activities' and 'Manufacture of electrical equipment'.[17] For each industry-month, we calculate average

[14] Figure A9 in the appendix contains further analysis of the distribution of expected inflation.

[15] See Anayi et al. (2022) for a more detailed analysis of the effects of the Ukraine war on uncertainty.

[16] This analysis is also related to the findings of Meeks and Monti (2019), who show that the full distribution of inflation expectations from survey data have an important role in explaining inflation dynamics.

[17] In our baseline specification we drop industries for which there are few observations in our panel. In particular, we drop two-digit SIC industries with fewer than 30 industry-month observations. This leaves us with 73 SIC2 industries for the main estimation. In addition, we drop industry-months with fewer than three firms.

realized and expected price growth, as well as the dispersion and skewness of prices across firms. We proceed to estimate the following equation, where i denotes industry and t denotes month:

$$\pi_{i,t} = \alpha_i + \beta_t + \lambda\pi_{i,t-1} + \gamma E_t\left[\pi_{i,t+12}\right] + \sigma\pi_{i,t}^{SD} + \omega\pi_{i,t}^{SKEW} + \epsilon_{i,t} \tag{2}$$

In particular, we regress realized price growth over the past 12 months on (i) a measure of lagged realized price growth, (ii) expected price growth over the next 12 months, (iii) the dispersion, and (iv) skewness of realized price growth across firms in a given industry. We include industry fixed effects, α_i, which control for time-invariant differences in price-setting across industries. Thus, our identification comes from *within-industry* variation in the dispersion and skewness of relative price changes. Monthly fixed effects, β_t, are also included to capture secular trends in price growth, such as the recent increase in inflation. Finally, standard errors are clustered at the two-digit industry level.

Table 2 presents the main results from this specification. Column 1 reports the results without industry and month fixed effects, and Column 2 is our preferred specification with those additional fixed effects included. We note a strong positive relationship between expected and realized price growth, consistent with the standard formulation of the Phillips curve, where expected inflation enters as a determinant of realized inflation. In addition, we find that both the second and third moments of the distribution have positive and highly significant effects on price growth. Further analysis shows that these results are not driven exclusively by the pandemic period; indeed, we find similar effects of dispersion and skewness in both the 2017-2019 and 2020-2022 periods.

From the coefficients in Columns 1 and 2, it is difficult to gauge the quantitative significance of these variables. We can make some progress in this respect by standardizing each variable in Column 1 by its standard deviation. Doing this, we see that the inflation skewness has the strongest effect on realized price growth: a one standard deviation increase in skewness is associated with a 0.43 standard deviation increase in price growth. Meanwhile, the standardized coefficients for inflation dispersion and expected inflation are 0.17 and 0.37, respectively. Thus, the findings from Table 2 emphasize the importance of inflation skewness, both quantitatively and statistically.

Having data on expectations of price growth at the firm level allows us go further and analyze whether a similar relationship between the second and third moments exists over the year ahead. In columns 3 and 4 of Table 2, we estimate the following specification, again at the industry-month level:

$$E_t\left[\pi_{i,t+12}\right] = \alpha_i + \beta_t + \gamma\pi_{i,t} + \lambda E_t\left[\pi_{i,t+12}^{SD}\right] + \sigma E_t\left[\pi_{i,t+12}^{SKEW}\right] + \epsilon_{i,t}$$

The results in column 4, which also include industry and month fixed effects largely corroborate the findings on realized price growth. Expected inflation dispersion and skewness both correlate very strongly with expected price growth, suggesting that firms are behaving in a similar way when forming their expectations for the year ahead as when setting actual prices.

Finally, due to unique nature of the DMP survey, it also possible to estimate the relationship between expected price growth, expected inflation dispersion, and expected inflation skewness at the *firm* level. Using the five-point distribution of expected price growth provided by firms, we can construct within-firm measures of subjective uncertainty and skewness at the monthly level. Table 3 presents the main results of the firm-level analysis. These findings provide further support for our industry-level results: both subjective price uncertainty and skewness have positive and highly significant correlations with expected price growth. In particular, column 3 shows that these relationships remain robust to including firm fixed effects in our estimation, and thus exploiting only within-firm variation in uncertainty and skewness. Overall, the results of this section show that the relationship between price growth and higher-order moments holds when looking at expectations and when using firm-level data.

Our empirical results are potentially consistent with a model of menu costs in the presence of trend inflation.[18] This may be able to explain both the positive relationship between inflation and skewness and the asymmetric response of inflation to demand shocks that we discussed in section 2. In this framework firms do not adjust to small deviations from their optimal price, but do adjust in response to 'large' shocks. For instance, a positively skewed distribution, with more weight in the right tail, would lead in a larger proportion of firms increasing prices versus decreasing them, and therefore result in higher aggregate price growth. This could be exacerbated by the presence on trend inflation which will tend to move firms towards their upper Ss price-adjustment threshold.

Section 5: Price uncertainty and forecast errors

In this section we assess the determinants of our novel measure of subjective within-firm price uncertainty in more detail. Uncertainty about future inflation is linked to the same factors that have been pushing up realized inflation. Table 4 reports some regressions that investigate the determinants of price uncertainty. First, we show how price uncertainty is related to uncertainty/volatility in demand. In column 1 we just include the impact of Covid-19 on sales. We find that price uncertainty increases are positively correlated with demand when the impact of Covid-19 on sales is positive, but negatively correlated when the demand shock is negative. This gives a V shape to the relationship between the Covid demand shock and inflation uncertainty that is illustrated in Figure 8. In column 2 we also add a measure of subjective uncertainty about future sales and some of the other determinants of recent realized and

[18] There is an extensive literature using menu costs to model firm price-setting behavior. Early work by Ball and Mankiw (1994, 1995) demonstrates how (asymmetric) shocks to relative prices can have effects on aggregate inflation. More recent work has focused on assessing the degree of monetary non-neutrality depending on the precise menu cost modelling framework (see Golosov and Lucas 2007, Nakamura and Steinsson 2010, Midrigan 2011, Alvarez et al. 2016). Werning (2022) discusses the pass-through of inflation expectations to current inflation in several price-setting models, including the menu costs framework. Our results are also similar to the work by Karadi and Reiff (2019), who use a menu cost model with trend inflation and fat-tailed product-level shocks to explain an asymmetric response in prices to VAT changes in Hungary.

expected inflation. There is also a significant relationship with uncertainty about future sales growth. And as well as effects via demand, firms more affected by supply and labor shortages and who are in industries that are more intensive users of energy have also reported higher price uncertainty since the middle of 2021.

In columns 3 and 4 we add in measures of realized and expected inflation at the firm level. Both have a positive and significant relationship with inflation uncertainty, although the coefficient in expected inflation is around four times larger than that on realized inflation. The positive correlation between expected inflation and within-firm uncertainty is similar to that discussed in section 4.2. Firms are typically more uncertain at higher rates of inflation, and particularly when expected inflation is higher. Including realized and expected inflation lowers the coefficient on some of the other variables in the regression like supply shortages and energy prices given that these are also determinants of realized/expected inflation (column 4).

Firms are also typically more uncertain about future inflation when they have just made larger forecast errors. Column 5 estimates the relationship between uncertainty and absolute forecast errors. Column 6 shows that this still holds even once realized and expected inflation are also included, and the coefficient size is only reduced modestly. Firms may to some extent just extrapolate forward from past experience when providing a distribution of expected inflation. But there may also be other reasons why higher inflation and forecast errors linked to large shocks are associated with higher inflation uncertainty. For example, they may create more uncertainty about how monetary policymakers will respond in the future, as in the model of Ball (1992). Figure 9 shows how, on average, firms made relatively accurate predictions of their own prices between 2018 and 2020, but they heavily underestimated the extent of the increase in inflation from 2021.[19] This is also likely to be factor behind the more recent increases in inflation uncertainty.

Finally, we consider why uncertainty about inflation might matter. One reason it might matter is if firms turn out to make less accurate predictions when uncertainty is high at the point they are made. That is relevant to the interpretation of the expected inflation data, but it may also have implications for the firms themselves if they are able to less accurate predict their future prices. Figure 10 confirms that firms overall make reasonably accurate predictions for future inflation in the cross section, but they become less accurate when uncertainty is higher. Table A3 in the Appendix shows this in regression form. This still holds after the inclusion of firm fixed effects, although the estimated coefficient roughly halves.

Uncertainty about inflation and making prediction errors can matter to firms because it makes it harder them to plan ahead and allocate resources efficiently. Tanaka et al. (2020) show that firms making errors in forecasting aggregate GDP predicts lower profitability and productivity. In Table 5 we carry out a similar exercise, but instead using in relation to own price forecast errors. To do this we collapse the DMP data down to annual form, taking averages across all

[19] Figure 9 also shows the distribution of inflation forecast errors.

variables within a financial year, and match up with annual accounting data from Bureau van Dijk, since profits and productivity are not asked about in the DMP.

We find that when firms make errors in forecasting their own future prices this is typically associated with lower profits and productivity too (column 1 and column 3 of Table 5). These equations include firm fixed effects, and so this result should not just explained by better managed firms always making more accurate forecasts and also being more profitable and productive. Uncertainty at the time for the forecast was made is also associated with subsequent lower profits and productivity (columns 2 and 4). The result that inflation forecast errors are associated with lower profits and TFP still holds after controlling for sales forecast errors (columns 5 to 8 in Table 4). Inflation forecast errors are linked to lower profits and productivity no matter which direction the forecast error happens to be i.e. an over- or an under-estimate (shown in Table A4).[20]

Section 7: Conclusion

Inflation is now at levels not seen for 40 years following the exceptional economic shock of the Covid-19 pandemic. In this paper, we use firm-level data from the Decision Maker Panel to study inflation dynamics and how firms have set prices during this extraordinary period.

We show that inflation responded asymmetrically to movements in demand during the pandemic. The correlation between demand shocks and inflation is estimated to have been stronger when demand was growing than when it was falling. We also show how inflation is positively correlated with both dispersion and skewness, and that both of these are now well above pre-pandemic levels.

This non-linear relationship between demand and inflation can help to explain why inflation only fell modestly during the first year of the Covid pandemic. However, it cannot explain much of the sharp rise in inflation since the middle of 2021. Energy prices and shortages of labor and materials account for most of the rise in inflation, although these may also be linked, in part, to the impact of Covid elsewhere.

We also introduce a novel measure of within-firm inflation uncertainty. We show that this increased early in the pandemic, but by less than sales uncertainty. Subsequently inflation uncertainty has risen by more as sales uncertainty has fallen back. Uncertainty about inflation matters because it is associated with firms making larger subsequent forecast errors. That can lead to resource misallocation, and we show how it is associated with lower profits and productivity.

[20] For productivity, the coefficients are not significantly different for positive and negative inflation forecast errors. For profit margins the coefficient is significantly larger when prices rise by less than expected compared to when prices turn out higher than expected. However, an important caveat here is that there are relatively few observations for 2021 onward in the estimation sample used given that accounting data on profits and productivity are only available with a lag.

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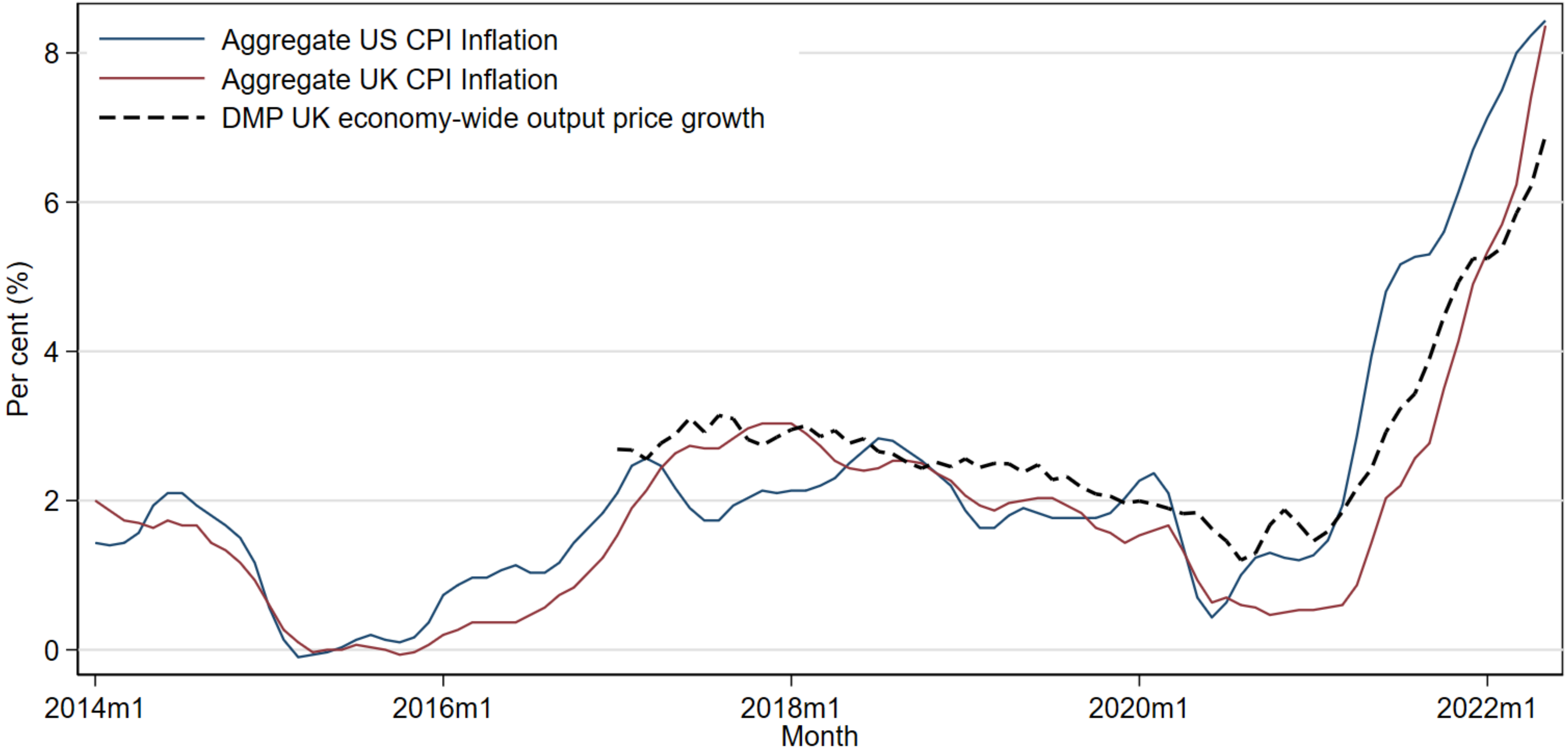
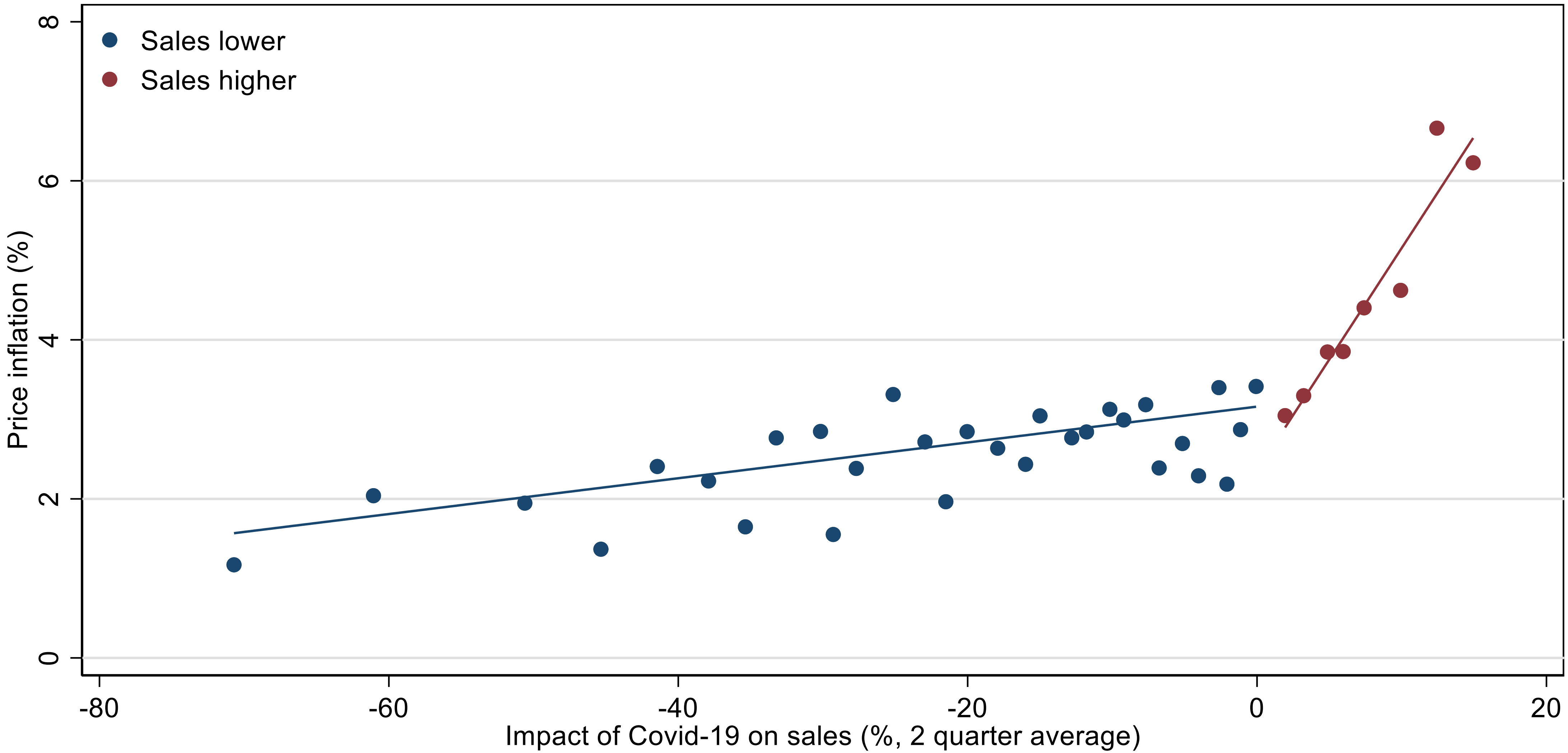
Figure 1: Measures of inflation



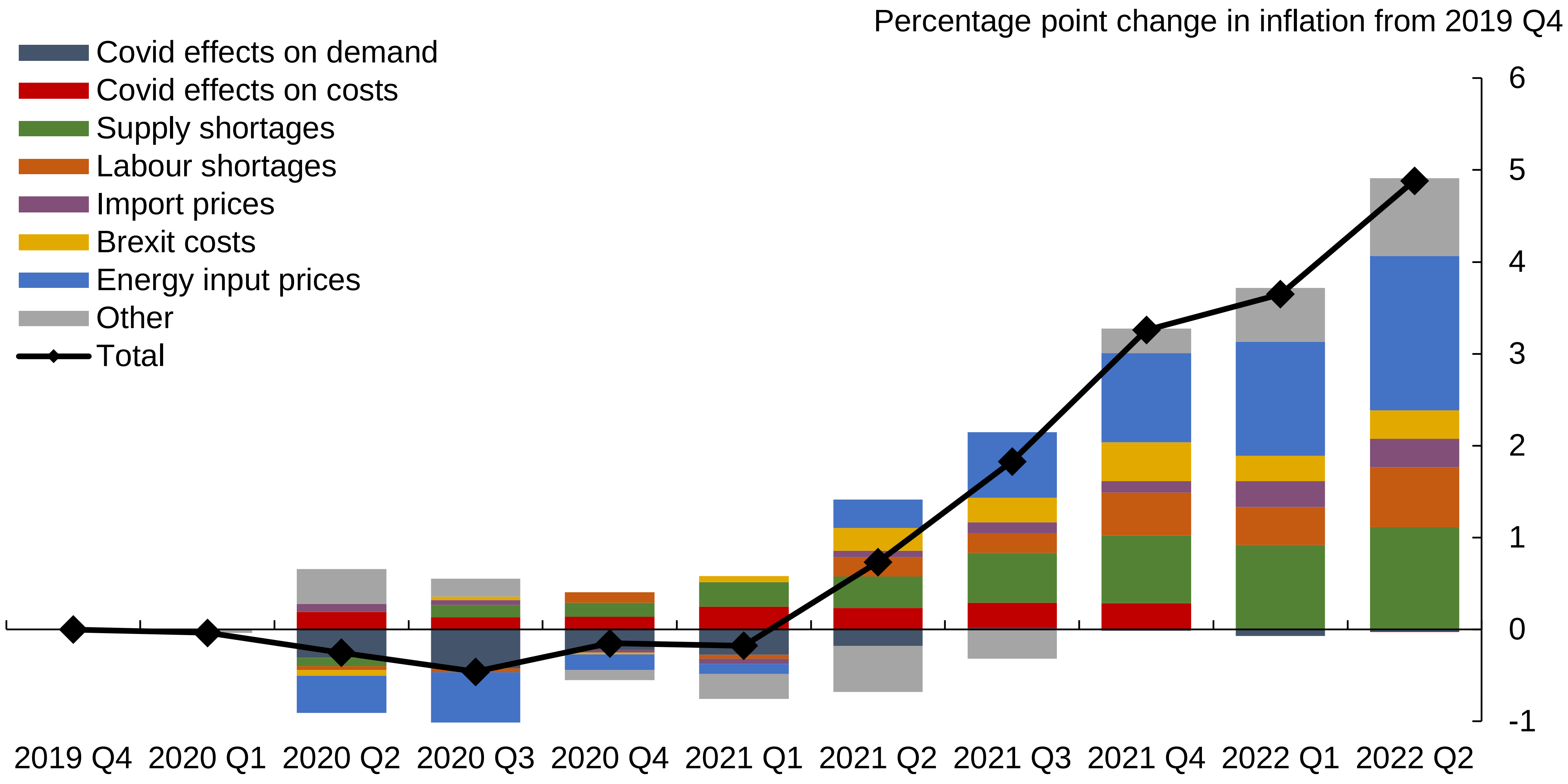
Notes: Data are 3 month moving averages. Sources: DMP, UK Office for National Statistics and US Bureau of Labor Statistics

Figure 2: Realized inflation and impact of Covid-19 on sales



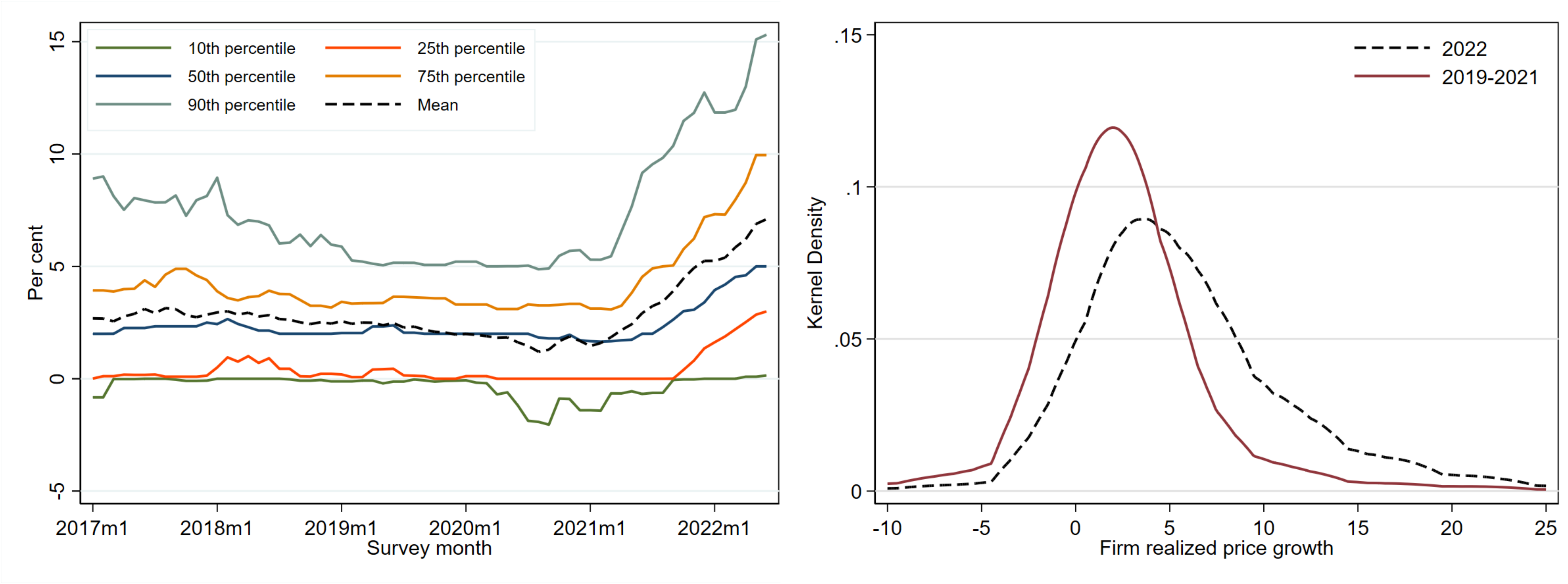
Notes: Each dot represents 2% of observations (during the pandemic, 2020 Q2 to 2022 Q2), grouped by impact of Covid-19 on sales. Zero responses are excluded. See notes to Figure A4 for survey question asked on the impact of Covid-19 on sales.

Figure 3: Contributions to changes in realized DMP inflation since 2019 Q4



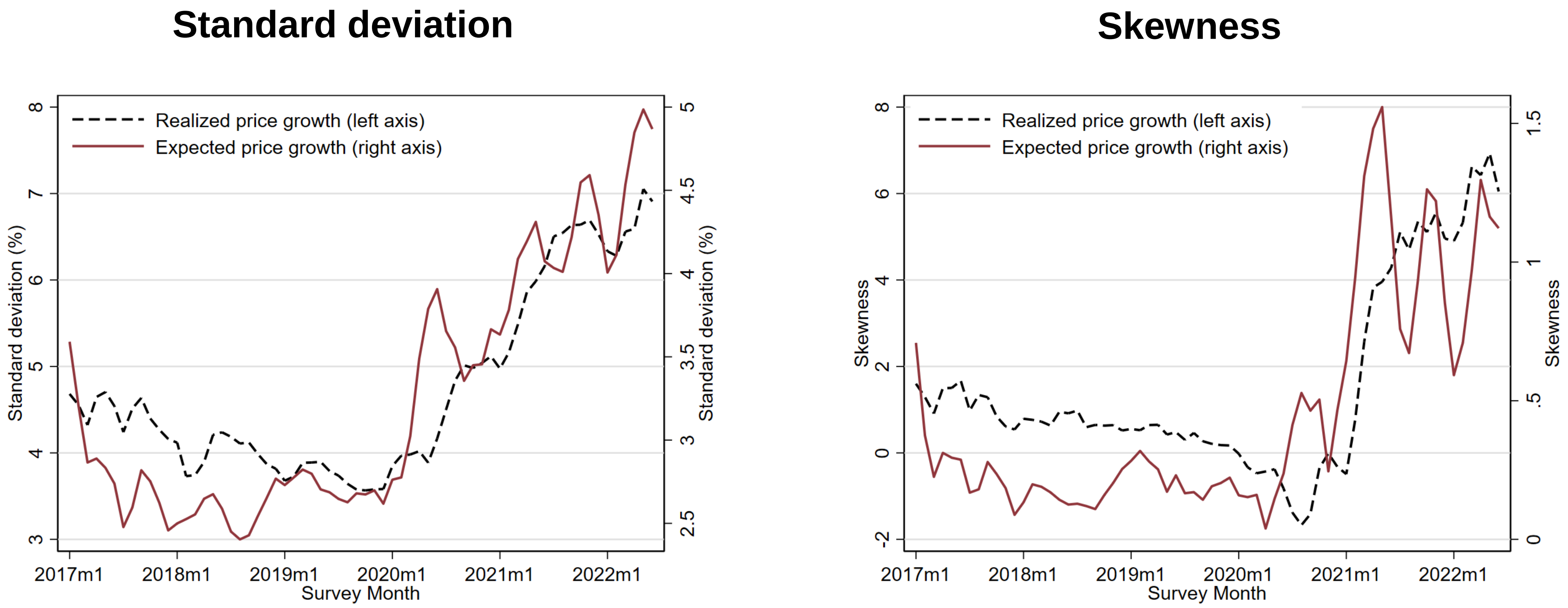
Notes: Constructed from a version of equation 5 in Table 1 where coefficients on the time invariant variables (everything except the Covid effects on demand) are allowed to vary by quarter. See notes to Table 1 for more details on the equation estimated and the Appendix for further details on the explanatory variables.

Figure 4: Distribution of realized price growth



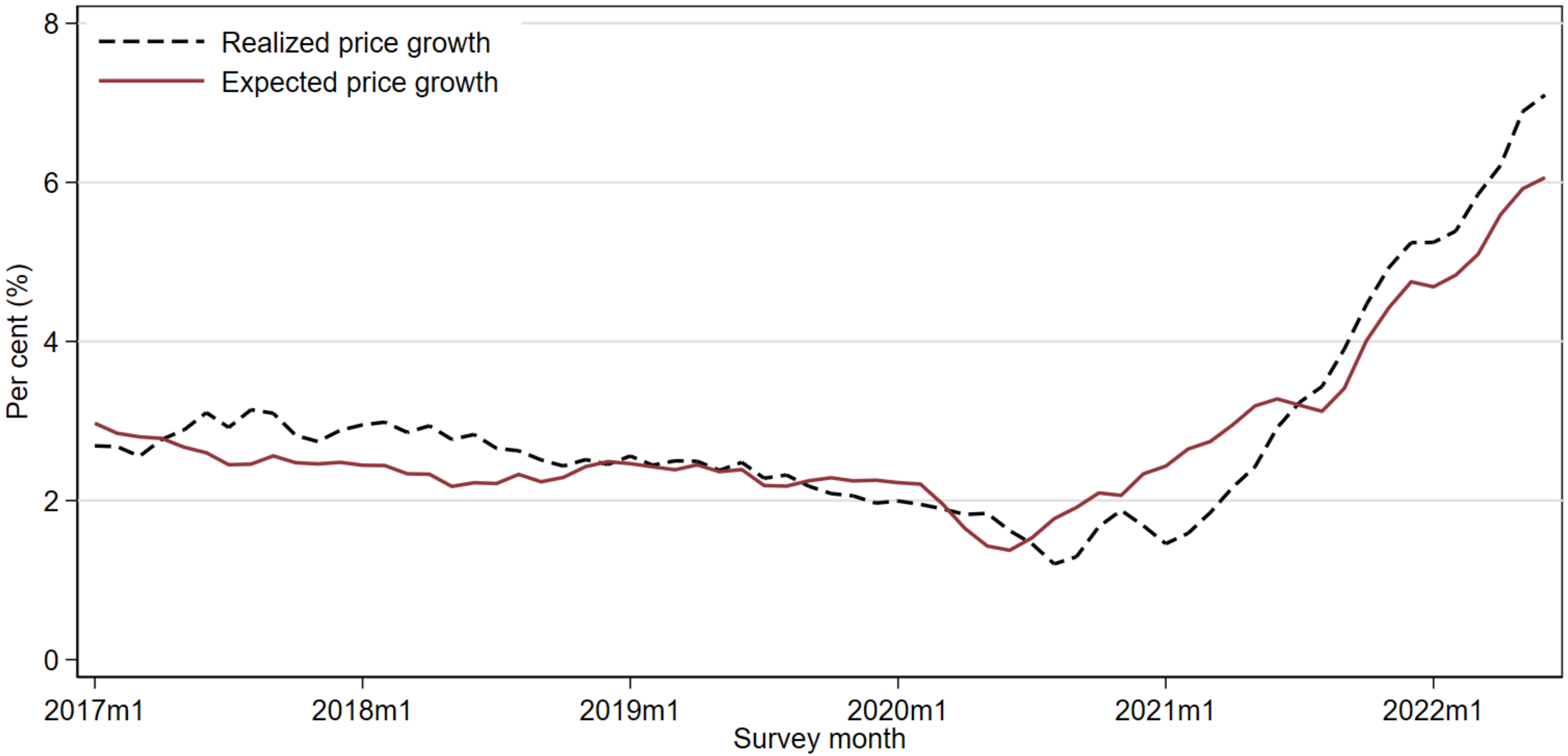
Notes: Data are for the average price charges and changes are relative to a year earlier. Data on the left hand chart are 3 month moving averages.

Figure 5: Standard deviation and skewness of DMP realized price inflation



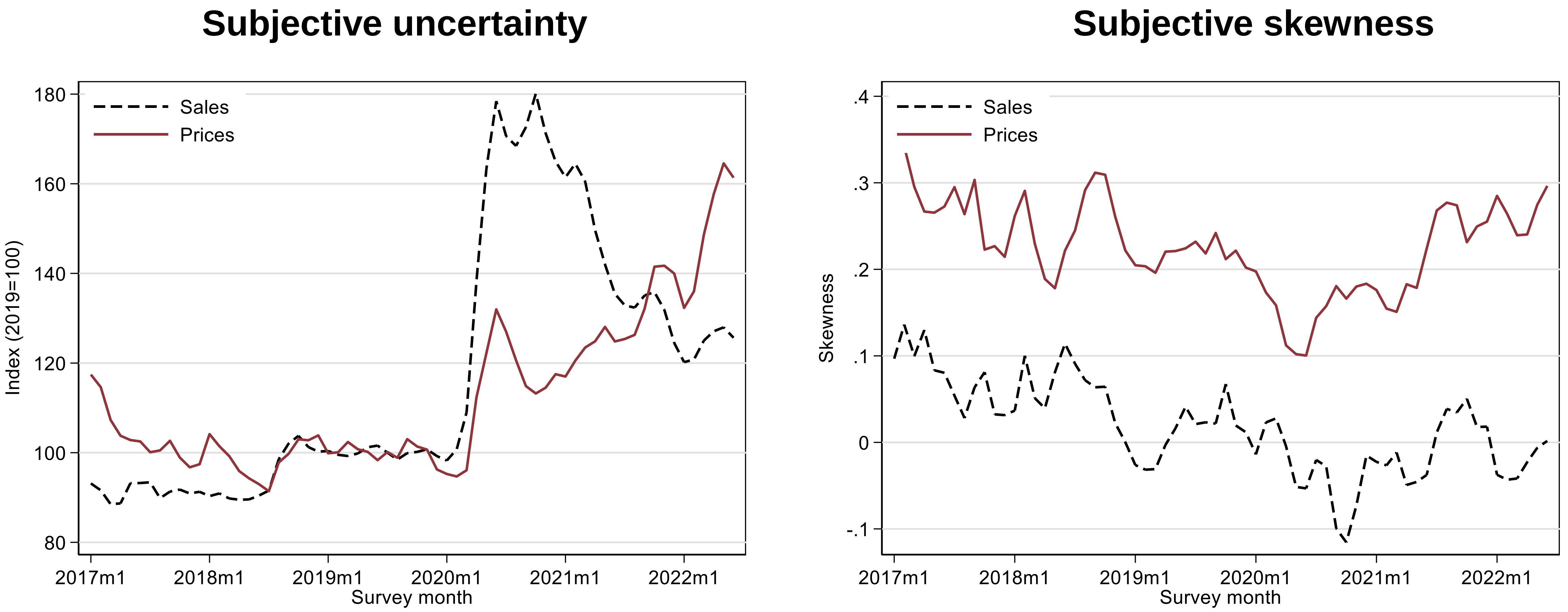
Notes: Panel A reports the cross-sectional standard deviation of realized (expected) price growth over the past 12 months (next 12 months). Panel B reports the cross-sectional skewness of realized (expected) price growth over the past 12 months (next 12 months). Data are 3 month moving averages.

Figure 6: Realized and expected inflation in the DMP



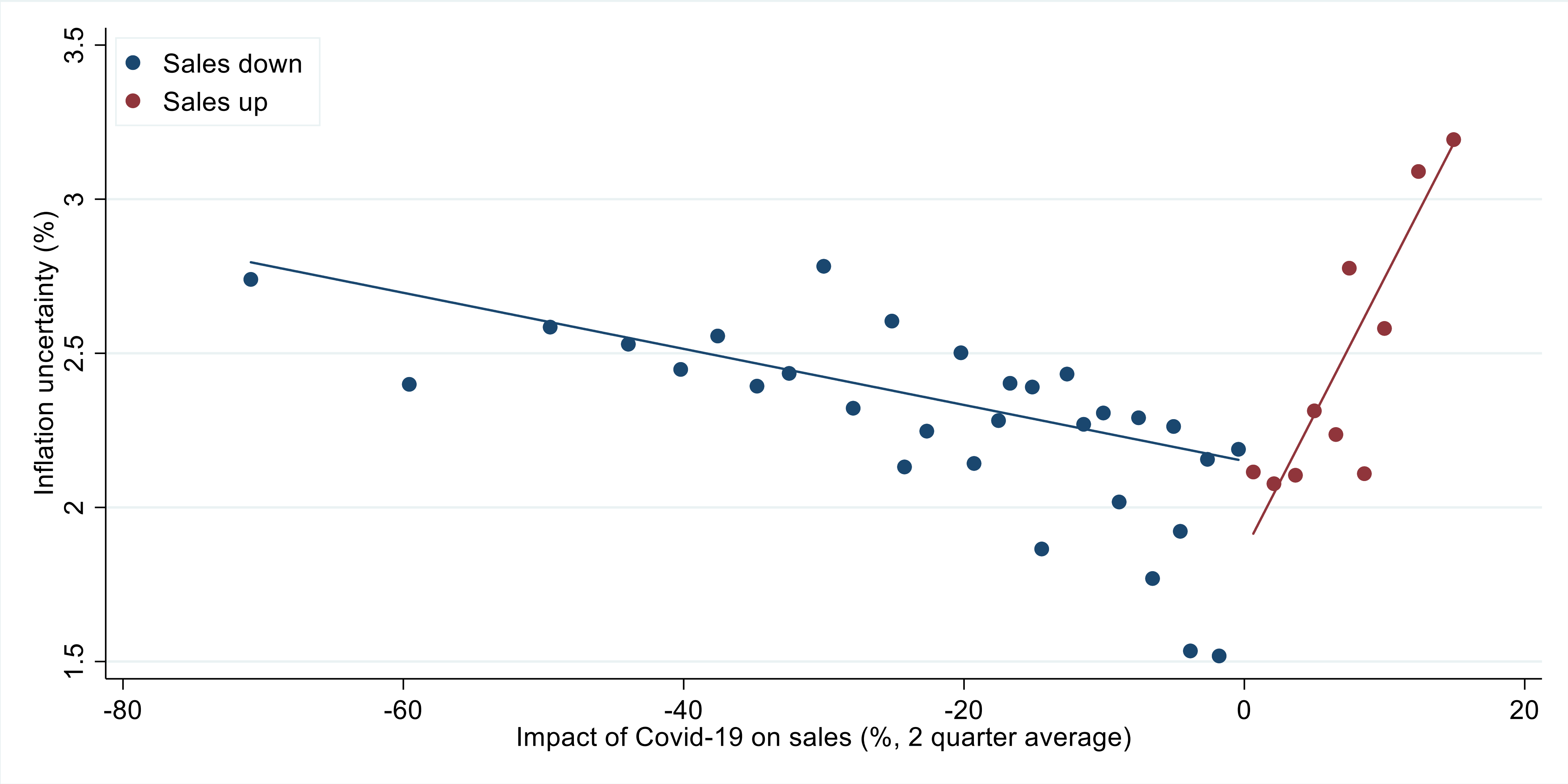
Notes: Data are 3 month averages.

Figure 7: Measures of within-firm uncertainty and skewness



Notes: Data are 3 month averages.

Figure 8: Inflation uncertainty and impact of Covid-19 on sales



Notes: Each dot represents 2% of observations (during the pandemic, 2020 Q2 to 2022 Q2), grouped by impact of Covid-19 on sales. Zero responses are excluded. See notes to Figure A4 for survey question asked on the impact of Covid-19 on sales.

Figure 9: Inflation forecast errors

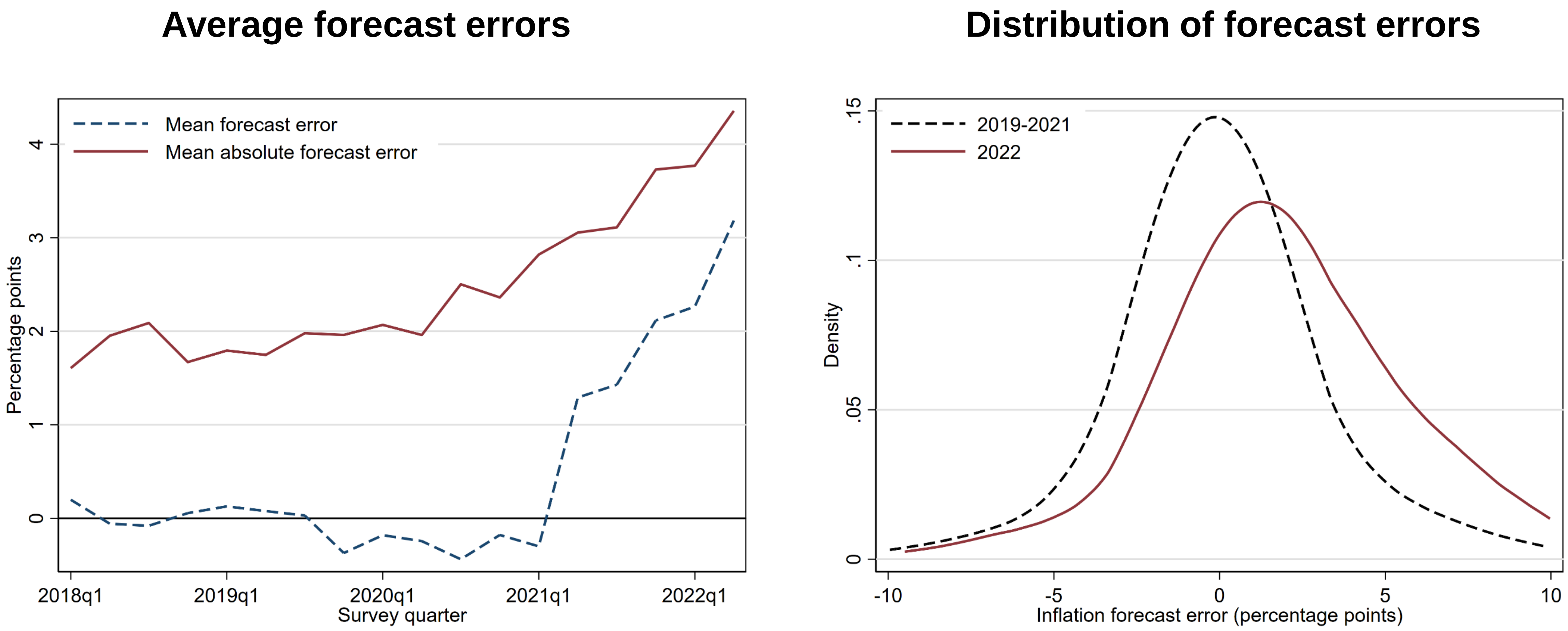
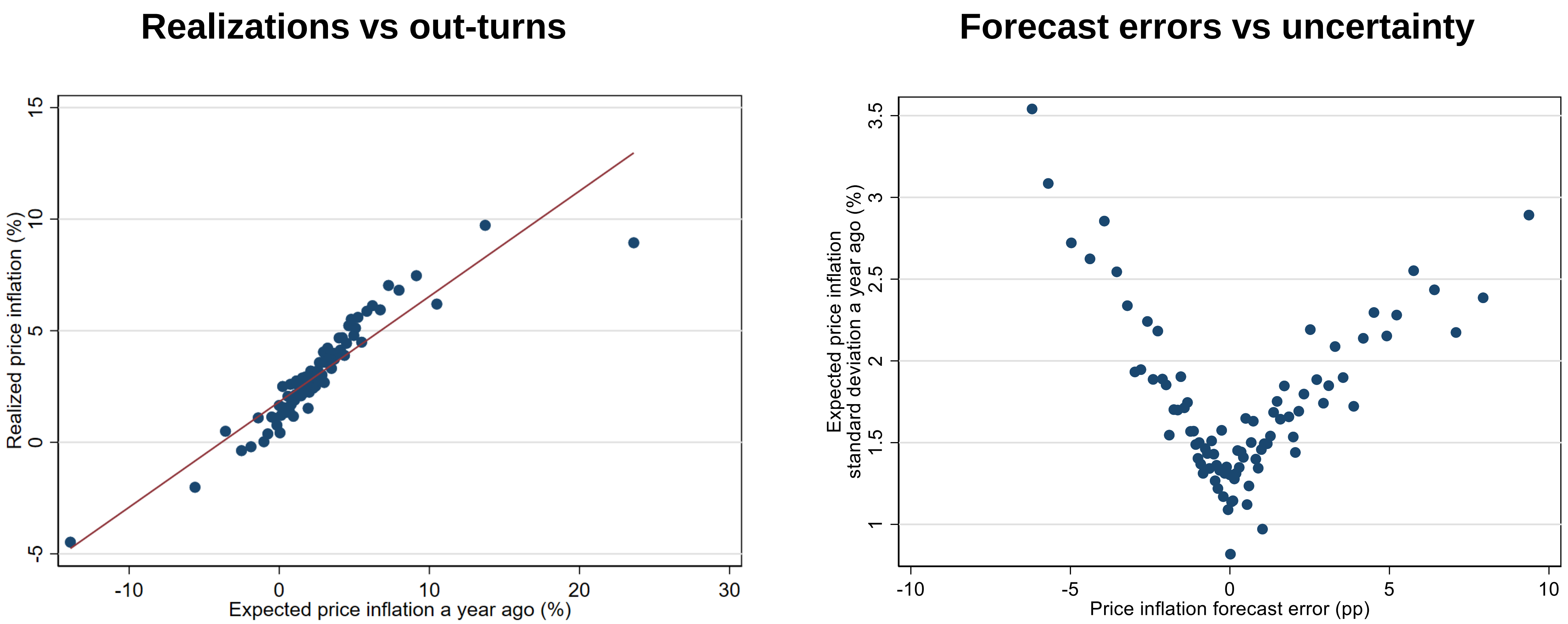


Figure 10: Inflation forecast accuracy



Notes: Each dot represents 1% of observations, grouped by expected price inflation/price inflation forecast error respectively. Data are for 2018 Q1 to 2022 Q2.

Table 1: Realized inflation regressions

Dependent variable: realized price inflation Sample period: 2017 Q1 to 2022 Q2 (quarterly data)	(1)	(2)	(3)	(4)	(5)	(6)
Covid impact on sales_{it}#sales impact negative_{it}	0.0055	0.0165***	0.0153***		0.0186***	0.0172***
	(0.0035)	(0.0034)	(0.0034)		(0.0034)	(0.0034)
Covid impact on sales_{it}#sales impact postive_{it}	0.2440***	0.1247***	0.0832***		0.1038***	0.0900***
	(0.0311)	(0.0256)	(0.0163)		(0.0251)	(0.0245)
Dummy for Covid impact on sales positive_{it}	-0.7020***	-0.4119**			-0.3979**	-0.3966**
	(0.2123)	(0.1776)			(0.1723)	(0.1678)
Covid impact on sales growth_{it}				0.0382***		
				(0.0060)		
(Covid impact on sales $\text{growth}_{it})^2$				0.0004***		
				(0.0001)		
Covid impact on unit costs_i#2020Q2-2022Q2					0.0415**	0.0276*
					(0.0173)	(0.0158)
% of non-labour inputs disrupted_i#2021Q2-2022Q2					0.0402***	0.0305***
					(0.0062)	(0.0060)
Recruitment much harder than normal_i#2021Q2-2022Q2					0.6126***	0.5329**
					(0.2281)	(0.2174)
Import intensity_i#2021Q2-2022Q2					0.0082**	0.0068**
					(0.0035)	(0.0033)
Brexit impact on unit costs (2021 vs $2020)_i$#2021Q2-2022Q2					0.1573***	0.1318***
					(0.0359)	(0.0336)
Percentage of costs that are petrol/coal (2 digit industry $\text{data})_i$#2021Q2-2022Q2					0.1617***	0.1332***
					(0.0502)	(0.0478)
Percentage of costs that are electricity/gas (2 digit industry $\text{data})_i$#2021Q2-2022Q2					0.5734***	0.4938***
					(0.1078)	(0.1050)
Realised price inflation a year ago_{it} (firm level)						0.0818***
						(0.0157)
Expected price inflation a year ahead_{it} (firm level)						0.3132***
						(0.0166)
Test coefficient on Covid impact on sales is equal for postive and negative impacts (p-value)	0.0000***	0.0000***	0.0001***	-	0.0009***	0.0036***
Firm fixed effects	No	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	34,076	34,076	34,076	34,076	34,076	34,076

Notes: Standard errors are clustered at the firm level and are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All variables except the Covid effects on demand are time invariant for each firm and the coefficients on those variables are allowed to vary over time. Impact of Covid on sales is an average of the current and previous quarter. Impact of Covid on unit costs is an average from 2020 Q2 to 2022 Q2. The percentage of non-labour costs disrupted and whether a firm reports recruitment is much harder than normal (a dummy variable) are both averages between 2021 Q4 and 2022 Q2. Import intensity is the percentage of costs that were imports in 2016 H1. The impact of Brexit on unit costs is the percentage point change between 2021 and 2020. Industry energy cost data are for 2019 and are from the ONS Supply and Use tables. All other data used are from the DMP survey. See the Appendix for further details on these explanatory variables and exact questions asked. Data is not available for all variables for all firms. Where data are missing for a particular variable a dummy variable is included to account for that (results not reported), except for the impact of Covid on sales where all observations included in the regressions have data.

Table 2: Realized inflation and the distribution of price changes (industry-level)

	(1)	(2)	(3)	(4)
Dependent Variable:	Realized price inflation		Expected price inflation	
Sample period: Jan 2017 – Jun 2022 (monthly)				
Realized Inflation$_{i,t}$			0.266***	0.116***
			(0.0375)	(0.0357)
			[0.35]	
Realized Inflation$_{i,t-1}$	0.243***	0.0837**		
	(0.0374)	(0.0332)		
	[0.233]			
Expected Inflation$_{i,t}$	0.407***	0.285***		
	(0.0594)	(0.0562)		
	[0.316]			
Inflation Dispersion$_{i,t}$	0.147***	0.142***		
	(0.0353)	(0.0355)		
	[0.16]			
Inflation Skewness$_{i,t}$	0.103***	0.100***		
	(0.0104)	(0.00895)		
	[0.494]			
Expected Inflation Dispersion$_{i,t}$			0.253***	0.250***
			(0.0535)	(0.0509)
			[0.257]	
Expected Inflation Skewness$_{i,t}$			0.140***	0.134***
			(0.0261)	(0.0242)
			[0.289]	
Constant	0.242	1.037***	1.218***	1.644***
	(0.164)	(0.210)	(0.141)	(0.156)
Industry fixed effects		Yes		Yes
Month fixed effects		Yes		Yes
Observations	2904	2903	3365	3365

Notes: Data are for 2 digit SIC industries and are generated from DMP firm level data. Realized price inflation refers to changes in prices over the past 12 months; expected inflation refers to changes over the next 12 months. In Columns 1 and 3, standardized coefficients are reported in square brackets. Standard errors are clustered at the industry level and are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 3: Expected inflation and the distribution of price changes (firm-level)

	(1)	(2)	(3)
Dependent Variable:		Expected price inflation	
Sample period: Jan 2017 – Jun 2022 (monthly)			
Realized Inflation$_{i,t}$	0.362***	0.296***	0.152***
	(0.00772)	(0.00786)	(0.00860)
Subjective Price Uncertainty$_{i,t}$	0.281***	0.282***	0.412***
	(0.0211)	(0.0205)	(0.0224)
Subjective Price Skewness$_{i,t}$	0.0171***	0.0137***	0.00808***
	(0.00125)	(0.00121)	(0.00122)
Constant	1.154***	1.367***	1.539***
	(0.0355)	(0.0371)	(0.0470)
Industry fixed effects		Yes	
Month fixed effects		Yes	Yes
Firm fixed effects			Yes
Observations	36770	36770	34376

Notes: Realized inflation refers to changes in prices over the past 12 months; expected price inflation refers to price expectations over the next 12 months. Subjective price uncertainty and skewness are calculated based on the standard deviations/skewness of expected firm-level price growth over the next 12 months. Standard errors are clustered at the firm level and are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Subjective inflation uncertainty regressions

Dependent variable: inflation uncertainty Sample period: 2017 Q1 to 2022 Q2 (quarterly data)	(1)	(2)	(3)	(4)	(5)	(6)
Realized price inflation$_{it}$			0.0433***	0.0391***		0.0215***
			(0.0052)	(0.0040)		(0.0058)
Expected price inflation$_{it}$			0.1330***	0.1279***		0.1256***
			(0.0078)	(0.0068)		(0.0099)
Absolute inflation forecast error$_{it}$					0.1057***	0.0784***
					(0.0061)	(0.0065)
Sales growth uncertainty$_{it}$		0.0622***		0.0593***		0.0395***
		(0.0032)		(0.0031)		(0.0040)
Covid impact on sales$_{it}$#sales impact negative$_{it}$	-0.0063***	-0.0013		-0.0027**		-0.0019
	(0.0012)	(0.0013)		(0.0013)		(0.0016)
Covid impact on sales$_{it}$#sales impact postive$_{it}$	0.0402***	0.0315***		0.0196**		0.0058
	(0.0081)	(0.0082)		(0.0076)		(0.0095)
Dummy for Covid impact on sales positive$_{it}$	-0.1034*	-0.0727		-0.0504		0.0473
	(0.0604)	(0.0602)		(0.0559)		(0.0716)
Covid impact on unit costs$_{i}$#2020Q2-2022Q2		0.0089		0.0014		0.0109
		(0.0066)		(0.0061)		(0.0077)
% of non-labour inputs disrupted$_{i}$##2021Q2-2022Q2		0.0058***		0.0009		0.0002
		(0.0017)		(0.0014)		(0.0019)
Recruitment much harder than normal$_{i}$##2021Q2-2022Q2		0.1401**		0.0516		0.0262
		(0.0656)		(0.0582)		(0.0769)
Import intensity$_{i}$##2021Q2-2022Q2		0.0008		-0.0002		-0.0008
		(0.0009)		(0.0008)		(0.0010)
Brexit impact on unit costs (2021 vs 2020)$_{i}$##2021Q2-2022Q2		0.0252**		0.0105		0.0013
		(0.0108)		(0.0093)		(0.0119)
Percentage of costs that are petrol/coal (2 digit industry data)$_{I}$##2021Q2-2022Q2		0.0427***		0.0237**		0.0178
		(0.0123)		(0.0112)		(0.0127)
Percentage of costs that are electricity/gas (2 digit industry data)$_{I}$##2021Q2-2022Q2		0.1192***		0.0595**		0.0361
		(0.0314)		(0.0271)		(0.0365)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	30,017	27,776	33,062	27,659	11,898	10,915

Notes: Standard errors are clustered at the firm level and are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Inflation/sales growth uncertainty is the within-firm standard deviation of expected own price/sales growth over the next year. Realised inflation is the change in own prices over the last year. Expected inflation is the expected percentage change in own price inflation over the next year. Absolute forecast error is own price inflation over the year less own price inflation for that period estimated a year earlier. Impact of Covid on sales is an average of the current and previous quarter. The following variables are time invariant and are averages from the stated periods. In the regressions, coefficients on the time invariant variables are allowed to vary over time allowed to vary over time. Impact of Covid on unit costs is an average from 2020 Q2 to 2022 Q2. The percentage of non-labour costs disrupted and whether a firm reports recruitment is much harder than normal (a dummy variable) are both averages between 2021 Q4 and 2022 Q2. Import intensity is the percentage of costs that were imports in 2016 H1. The impact of Brexit on unit costs is the percentage point change between 2021 and 2020. Industry energy cost data are for 2019 and are from the ONS Supply and Use tables. All other data used are from the DMP survey. See the Appendix for further details on these explanatory variables and exact questions asked. Data is not available for all variables for all firms. Where data are missing for a particular variable a dummy variable is included to account for that (results not reported), except for the impact of Covid on sales, realised/expected inflation, inflation forecast errors and sales uncertainty where all observations included in the regressions have data.

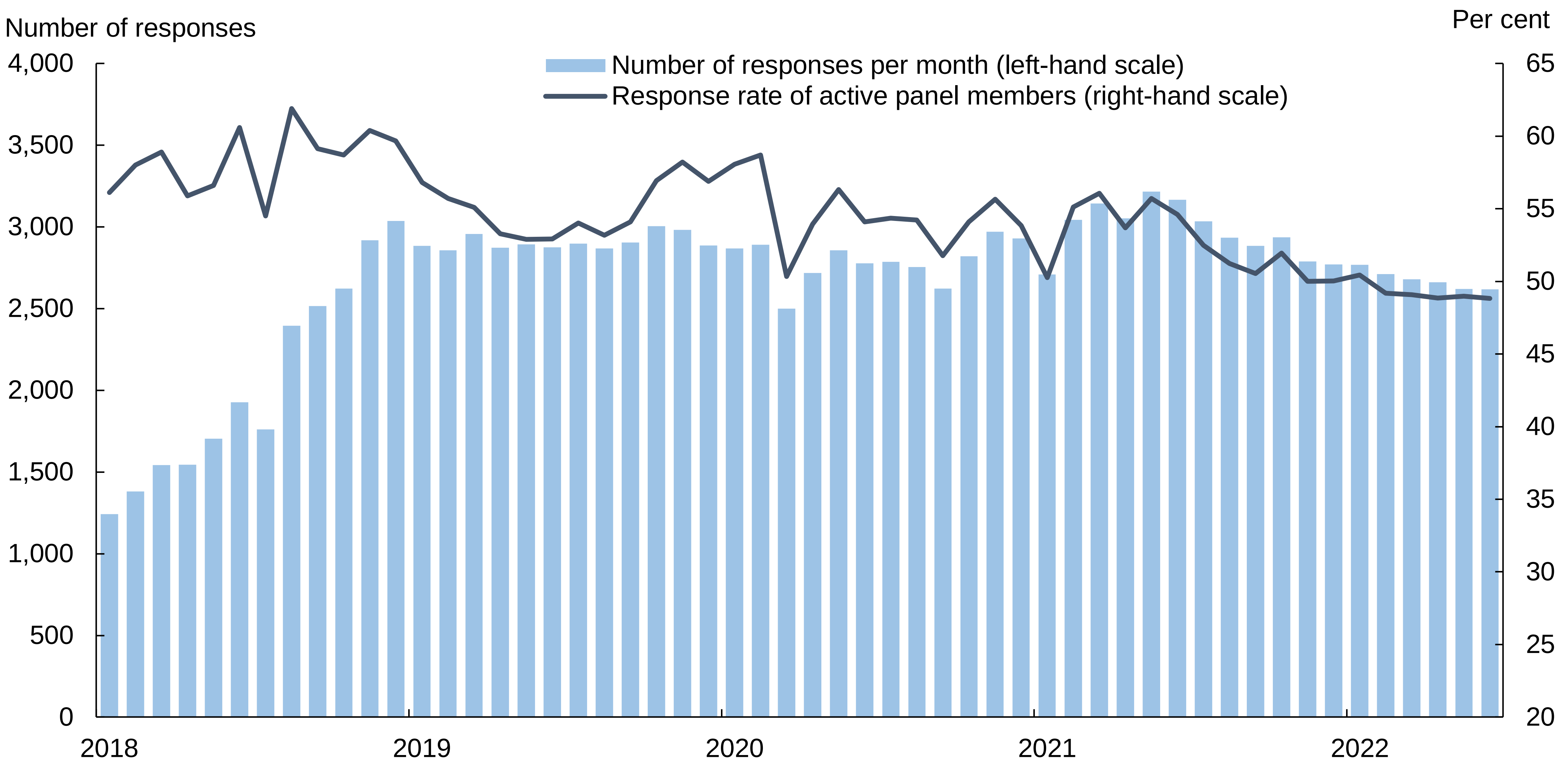
Table 5: Inflation forecast errors and profits/productivity

Dependent variable:	Profit margin		Log TFP		Profit margin		Log TFP	
Sample period: 2017 to 2021 (financial years)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Price inflation absolute forecast error$_{it}$	-0.0076***		-0.0077**			-0.0076**		-0.0057**
	(0.0014)		(0.0019)			(0.0019)		(0.0014)
Standard deviation of expected price inflation a year earlier$_{it}$		-0.0037*		-0.0101**				
		(0.0014)		(0.0026)				
Sales growth absolute forecast error$_{it}$					-0.0022***	-0.0009***	-0.0017***	-0.0009
					(0.0003)	(0.0001)	(0.0002)	(0.0004)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,509	6,841	3,229	6,225	4,684	3,161	4,299	2,922

Notes: Driscoll–Kraay standard errors to allow for cross-sectional interdependence are reported in parentheses, clustered by firm. *** p<0.01, ** p<0.05, * p<0.1. Profit margins are defined as operating profit/sales. TFP is calculated as the residual from a production function $\ln(Y_{it}) = 0.63\ln(L_{it})+0.37\ln(K_{it})$, normalised by 5 digit industry, 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). Profit margins and TFP are annual and are calculated using accounting data from Bureau Van Dijk FAME database. Forecast errors and uncertainty data are from the DMP, quarterly data are collapsed to annual averages (in financial years) and then merged with accounting data. Equations are estimated in financial years (April to March in the following calendar year).

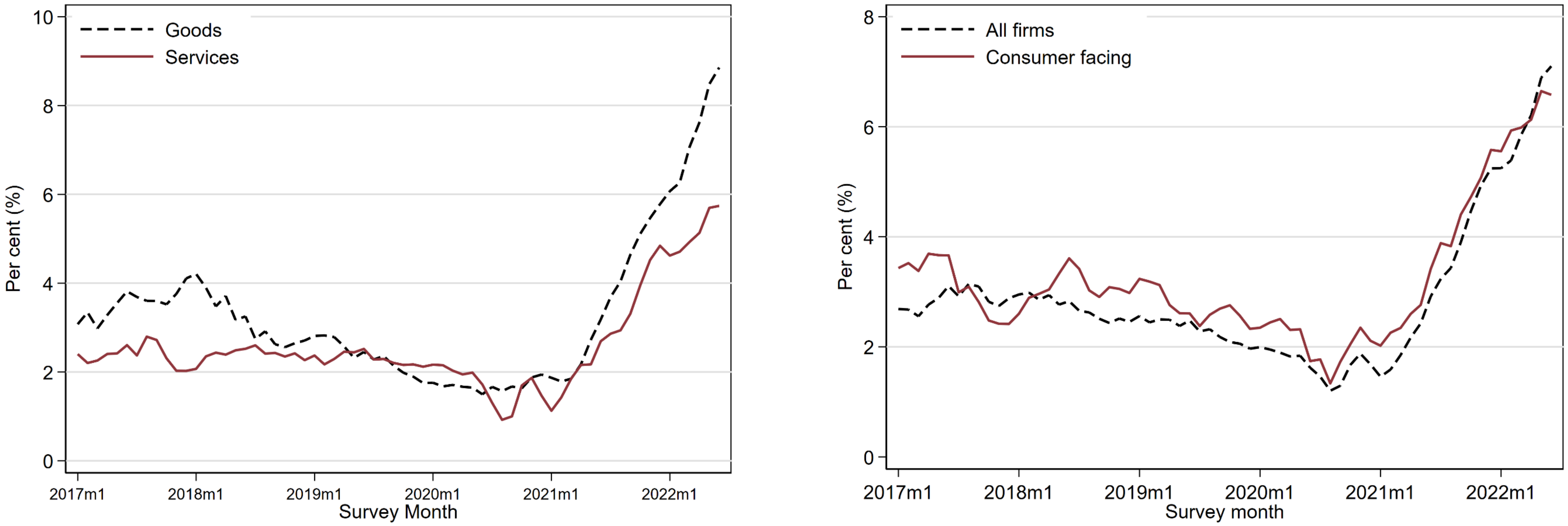
Appendix

Figure A1: DMP response rate



Notes: The response rate of active panel members is calculated as the percentage of panel members who had completed at least one survey over the last twelve months who responded to the survey in a given month.

Figure A2: Breakdowns of DMP realized price inflation



Notes: Data are 3 month averages. Goods prices are defined as the prices charged by firms on production and wholesale and retail. Services' prices are the prices charged by all service sector firms other than those in wholesale and retail.

Figure A3: Expected inflation questions

Decision Maker Panel

BANK OF ENGLAND

Looking ahead, from now to 12 months from now, what approximate % change in your AVERAGE PRICE would you expect in each of the following scenarios?

Note:
Price growth scenarios should be ordered from the lowest to the highest.

The LOWEST % change in my prices would be about:	0	%
A LOW % change in my prices would be about:	1	%
A MIDDLE % change in my prices would be about:	2	%
A HIGH % change in my prices would be about:	4	%
The HIGHEST % change in my prices would be about:	10	%

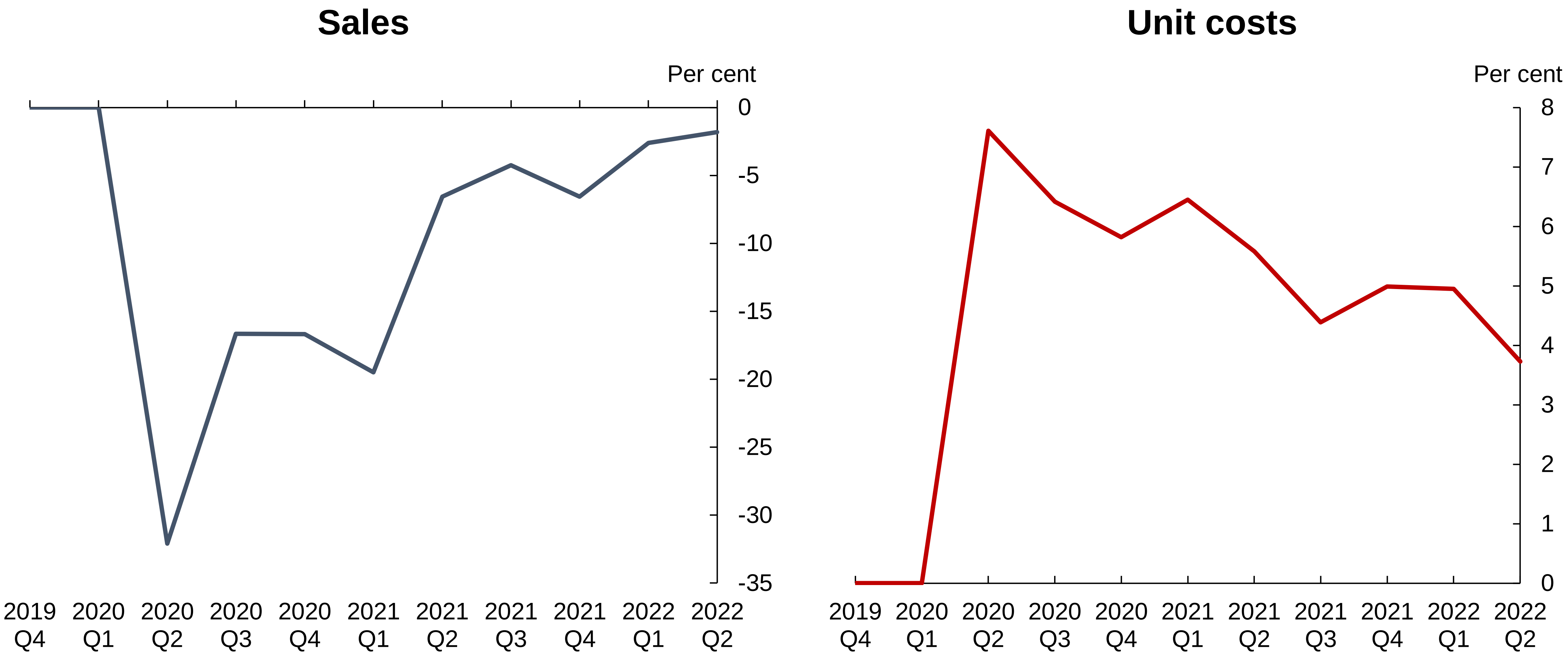
Decision Maker Panel

BANK OF ENGLAND

Please assign a percentage likelihood (probability) to the % changes in your AVERAGE PRICES you entered (values should sum to 100%).

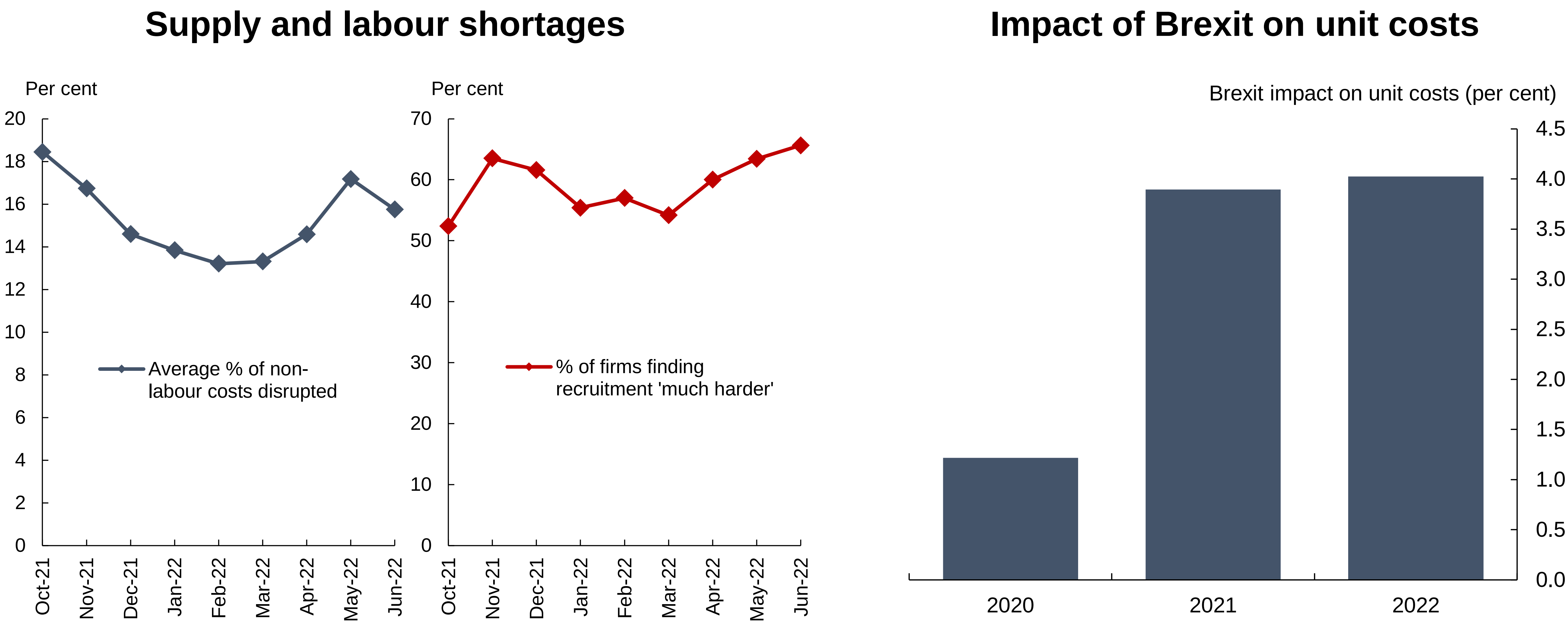
LOWEST: The likelihood of realising about **0%** would be:	10	%
LOW: The likelihood of realising about **1%** would be:	20	%
MIDDLE: The likelihood of realising about **2%** would be:	40	%
HIGH: The likelihood of realising about **4%** would be:	20	%
HIGHEST: The likelihood of realising about **10%** would be:	10	%
Total	100	%

Figure A4: Impact of Covid-19 on sales and unit costs



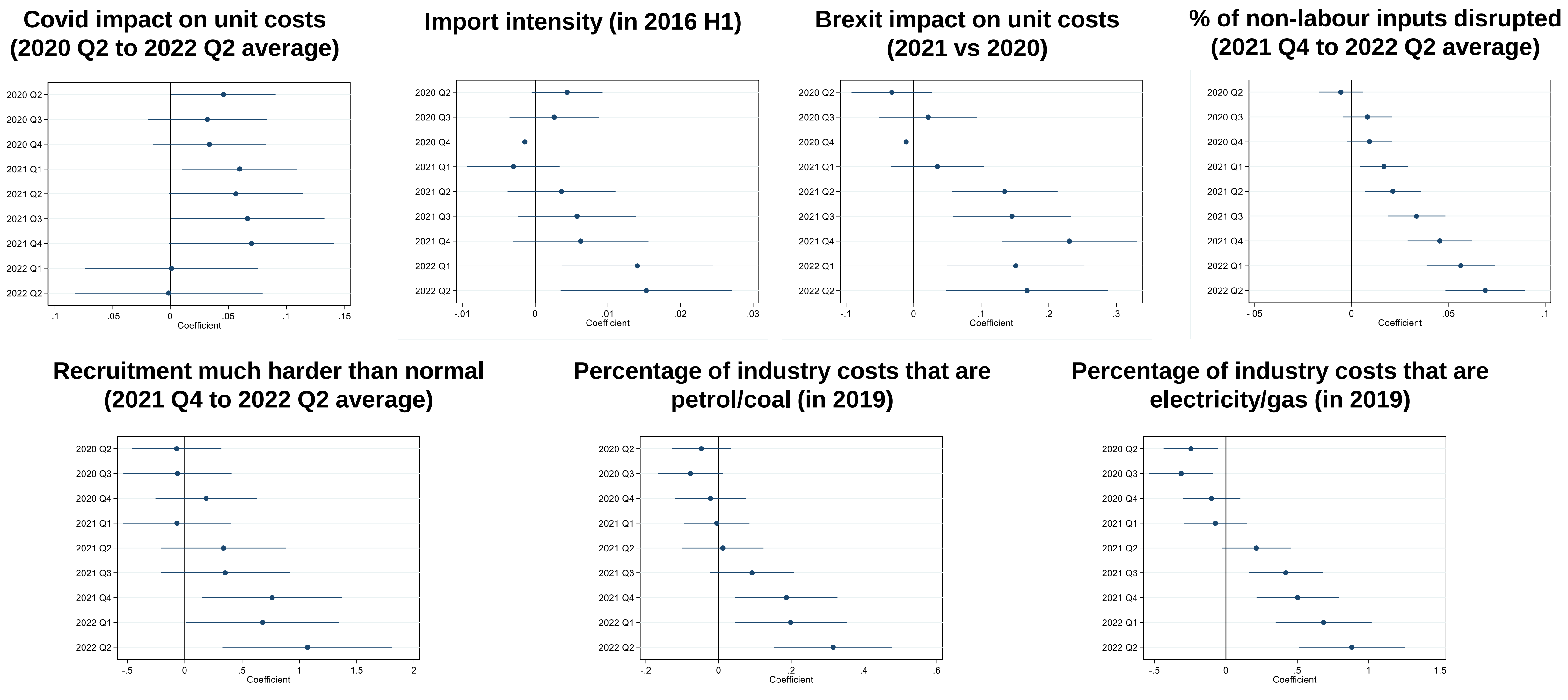
Notes: The results are based on the questions: 'Relative to what would otherwise have happened, what is your best estimate for the impact of the spread of Covid-19 on the sales of your business in each of the following periods?'; 'Relative to what would otherwise have happened, what is your best estimate for the impact of measures to contain coronavirus (social distancing, hand washing, masks and other measures) on the average unit costs of your business in each of the following periods?'.

Figure A5: Supply and labor shortages and Brexit costs



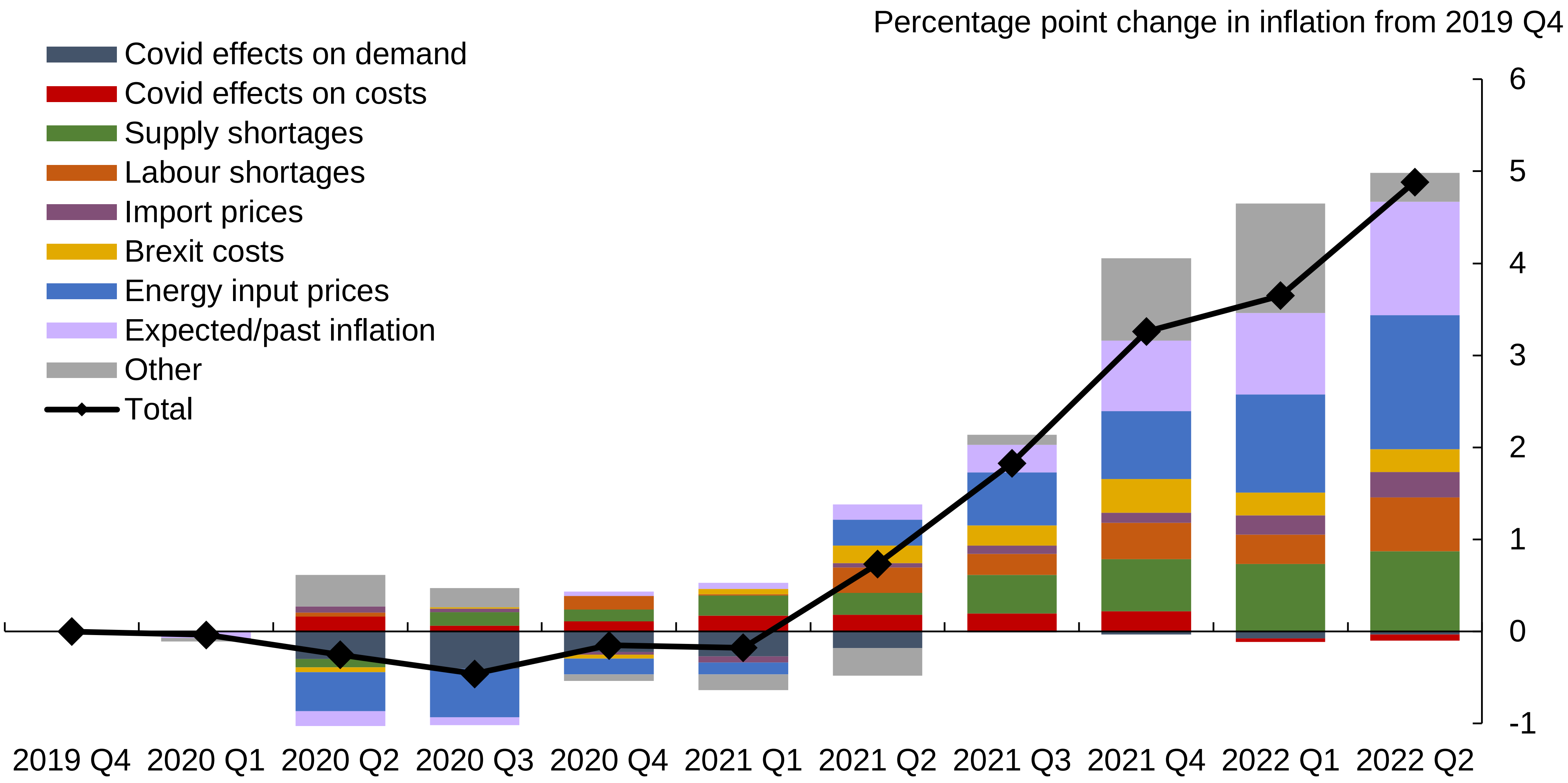
Notes: Supply shortage data are based on responses to the question: 'Over the past month, has the availability of the non-labour inputs that your business uses been disrupted? Please estimate the percentage of non-labour costs for which availability of inputs has been disrupted'. Labour shortage data are based on responses to the question: 'Are you finding it easier or harder than normal to recruit new employees at the moment?' The six response categories are: i) much easier, ii) a little easier, iii) about normal, iv) a little harder, v) much harder, vi) not applicable - not recruiting at the moment. Supply and labour shortage questions were both asked between October 2021 and June 2022. Impact of Brexit on unit cost data are based on responses to the question; 'Relative to what would otherwise have happened if the UK had remained a member of the EU, what is your best estimate for the impact of UK's decision to leave the EU on the average unit costs of your business in each of the following periods?'. This question asked between May and July 2021.

Figure A6: Coefficients and quarterly time interactions from realized inflation regressions



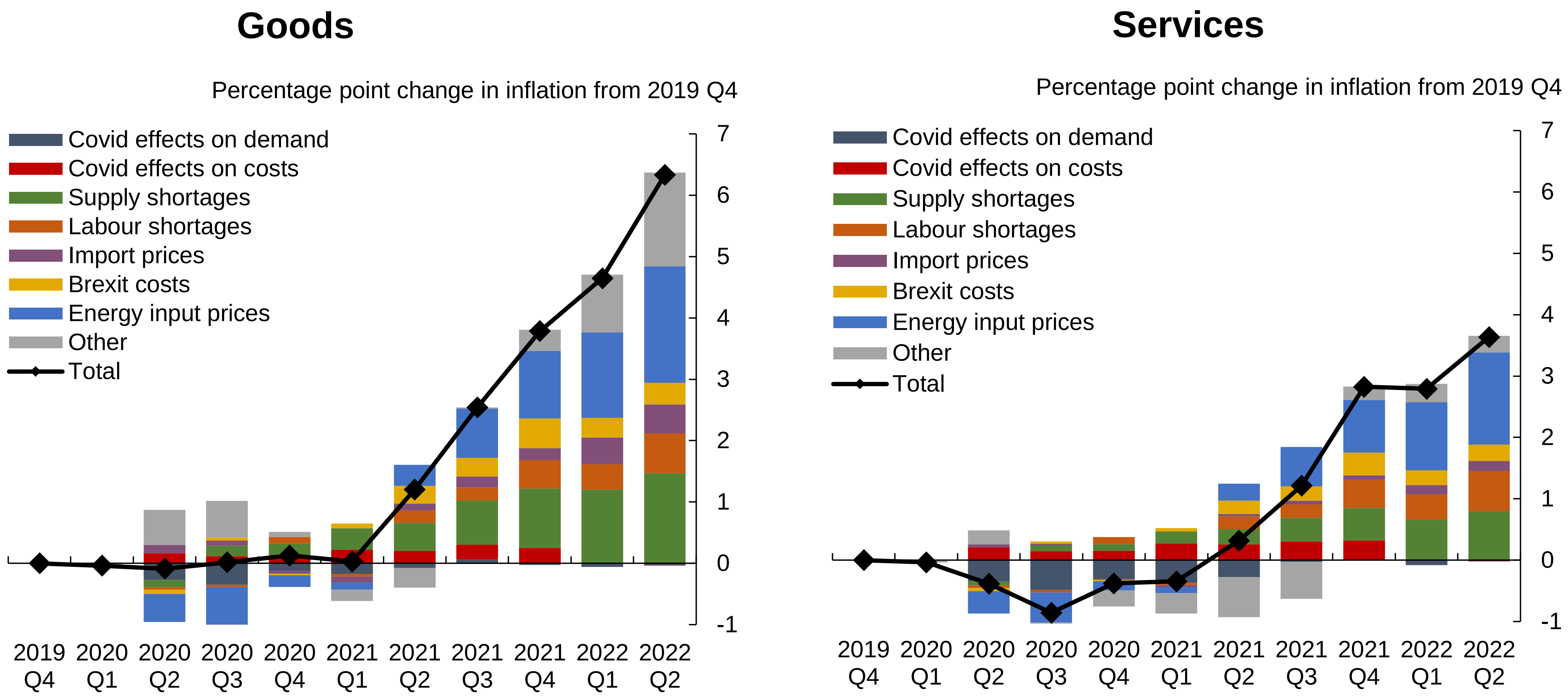
Notes: The charts show 95% confidence intervals around the coefficients. Based a version of column 5 in Table 1 that allows coefficients on time invariant variables to vary by quarter from 2020 Q2 to 2022 Q2.

Figure A7: Contributions to changes in realized DMP inflation since 2019 Q4



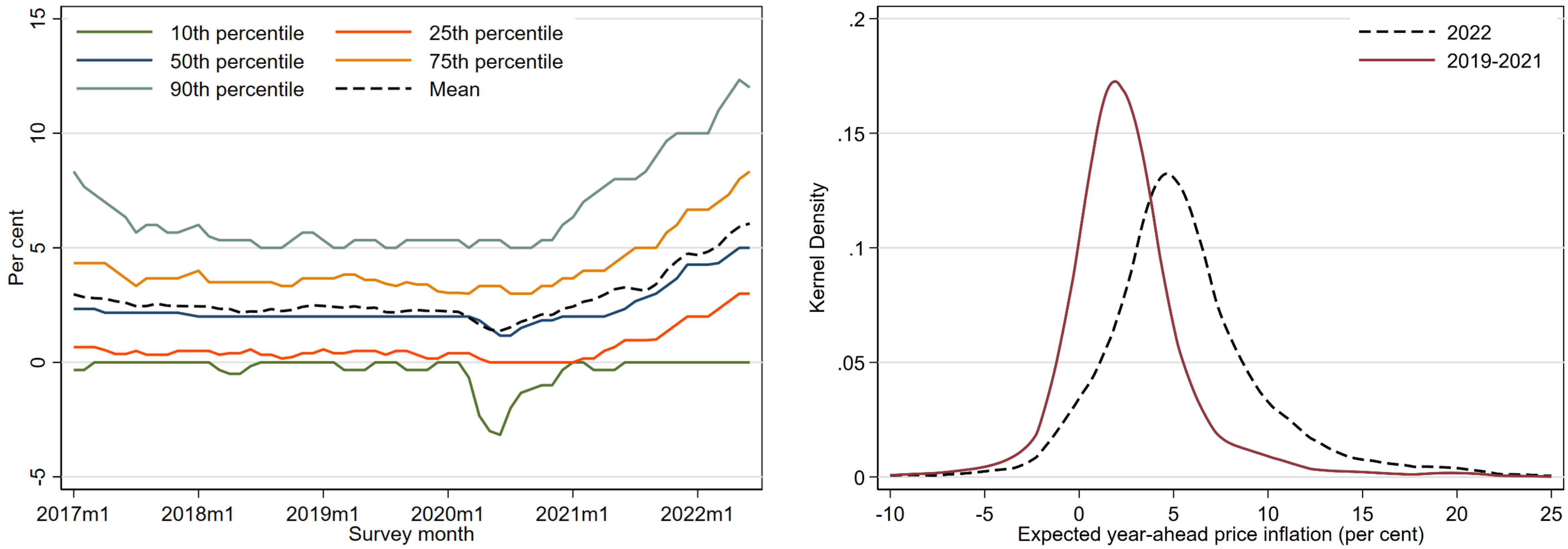
Notes: Constructed from a version of equation 6 in Table 1 where coefficients on the time invariant variables (everything except the Covid effects on demand) are allowed to vary by quarter. See notes to Table 1 for more details on the equation estimated and the Appendix for further details on the explanatory variables.

Figure A8: Contributions to changes in realized DMP inflation since 2019 Q4



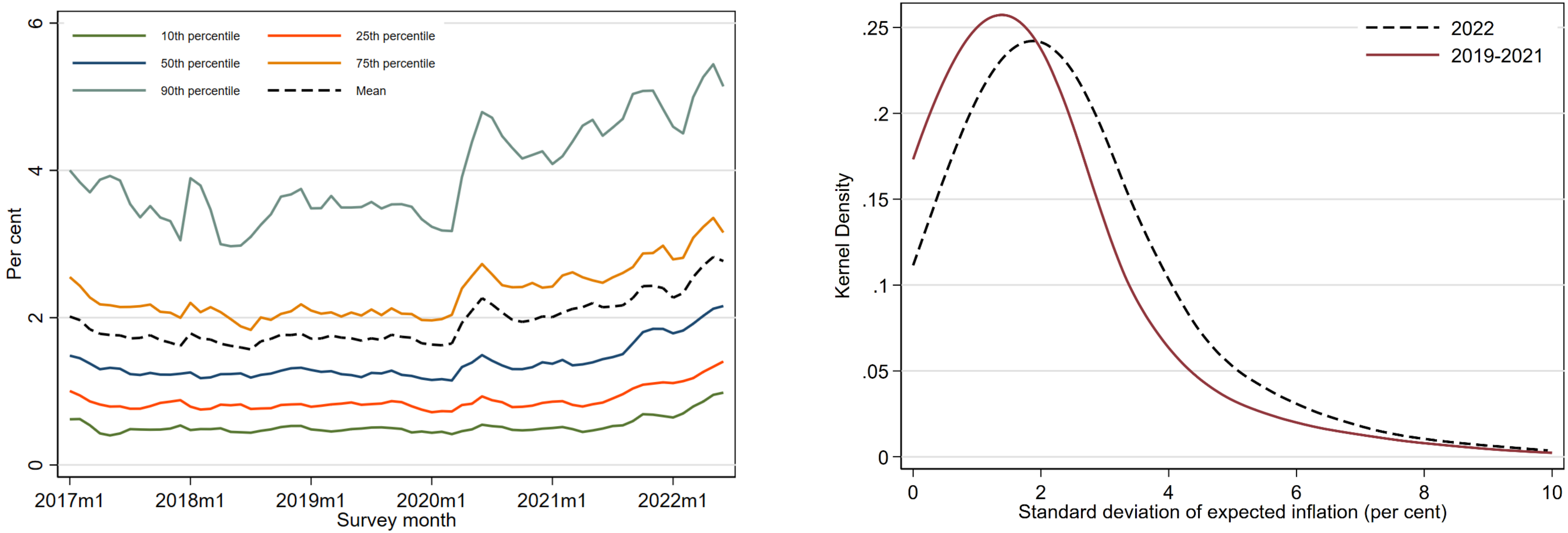
Notes: Constructed from a version of equation 5 in Table 1 that is estimated quarterly. Coefficients are the same for goods and services, the differences arise from explanatory variables having different values for the two groups. Goods prices are defined as the prices charged by firms on production and wholesale and retail. Services' prices are the prices charged by all service sector firms other than those in wholesale and retail.

Figure A9: Distribution of expected DMP price inflation



Notes: Data are for the average price charged and are central expectations for the percentage change over the next year. Data on the left hand chart are 3 month moving averages.

Figure A10: Distribution of price uncertainty



Notes: Data are 3 month moving averages.

Table A1: Further realized inflation regression results

Dependent variable: realized price inflation Sample period: 2017 Q1 to 2022 Q2 (quarterly data)	(1) All firms	(2) Goods	(3) Services	(4) Excluding 2020 Q2-2021 Q1	(5) Excluding 2021 Q2-2022 Q2	(6) Pre-Covid liqudity below average	(7) Pre-Covid liqudity above average
Covid impact on $sales_{it}$#sales impact $negative_{it}$	0.0165***	0.0118**	0.0208***	0.0167**	0.0137***	0.0110**	0.0229***
	(0.0034)	(0.0047)	(0.0048)	(0.0067)	(0.0032)	(0.0049)	(0.0049)
Covid impact on $sales_{it}$#sales impact $postive_{it}$	0.1247***	0.1414***	0.1097***	0.1314***	0.0820***	0.1156***	0.1434***
	(0.0256)	(0.0328)	(0.0400)	(0.0307)	(0.0315)	(0.0317)	(0.0440)
Dummy for Covid impact on sales $positive_{it}$	-0.4119**	-0.5916**	-0.2159	-0.3412	-0.2071	-0.4572*	-0.4148
	(0.1776)	(0.2379)	(0.2655)	(0.2396)	(0.2114)	(0.2443)	(0.2722)
Test coefficient on Covid impact on sales is equal for postive and negative impacts (p-value)	0.0000***	0.0001***	0.0272**	0.0003***	0.0318**	0.0013***	0.0065***
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Month fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	34,076	17,900	16,176	27,162	26,754	18,398	14,659

Notes: Standard errors are clustered at the firm level and are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Goods prices are defined as the prices charged by firms on production and wholesale and retail. Services' prices are the prices charged by all service sector firms other than those in wholesale and retail. Pre-Covid liquidity is defined using the ratio of cash to total assets in financial year 2019, calculated using accounting data from Bureau Van Dijk FAME database.

Table A2: Persistence of Covid demand shocks

Dependent variable: Covid impact on sales Sample period: 2020Q2 – 2022 Q2 (quarterly data)	(1)	(2)	(3)
Covid impact on $sales_{it-1}$#Sales impact $negative_{it-1}$	0.593***	0.597***	0.577***
	(0.0114)	(0.0116)	(0.0116)
Covid impact on $sales_{it-1}$#Sales impact $positive_{it-1}$	0.406***	0.408***	0.409***
	(0.0257)	(0.0258)	(0.0258)
Dummy for Covid impact on sales $positive_{it-1}$	0.994***	0.616**	0.649**
	(0.295)	(0.293)	(0.292)
Test coefficient on lagged Covid impact is equal for positive and negative impacts (p-value)	0.0000***	0.0000***	0.0000***
Quarter fixed effects	No	Yes	Yes
Industry fixed effects	No	No	Yes
Observations	30,872	30,872	30,872

Notes: Standard errors are clustered at the firm level and are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A3: Regressions for forecast inflation errors

Dependent variable:	Realized price inflation		Price inflation absolute forecast error	
Sample period: 2018 Q1 to 2022 Q2	(1)	(2)	(3)	(4)
Expected price inflation a year earlier$_{it}$	0.4504***	0.2319***		
	(0.0329)	(0.0385)		
Standard deviation of expected price inflation a year earlier$_{it}$			0.9030***	0.4198***
			(0.0324)	(0.0390)
Firm fixed effects	No	Yes	No	Yes
Month fixed effects	Yes	Yes	Yes	Yes
Observations	14,724	13,654	14,724	13,654

Notes: Standard errors are clustered at the firm level and are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table A4: Inflation forecast errors and profits/productivity

Dependent variable:	Profit margin	Log TFP	Profit margin	Log TFP
Sample period: 2017 to 2021 (financial years)	(1)	(2)	(3)	(4)
Price inflation forecast error$_{it}$#Error negative$_{it}$	-0.0103***	-0.0096**		
	(0.0014)	(0.0027)		
Price inflation forecast error$_{it}$#Error positive$_{it}$	-0.0047**	-0.0061**		
	(0.0011)	(0.0016)		
Price inflation absolute forecast error$_{it}$			-0.0076***	-0.0073**
			(0.0015)	(0.0017)
Standard deviation of expected price inflation a year earlier$_{it}$			-0.0011	-0.0090
			(0.0023)	(0.0046)
Test coefficient on forecast error is equal for postive and negative impacts (p-value)	0.0002***	0.2202	-	-
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	3,511	3,229	3,511	3,229

Notes: Driscoll–Kraay standard errors to allow for cross-sectional interdependence are reported in parentheses, clustered by firm. *** p<0.01, ** p<0.05, * p<0.1. Profit margins are defined as operating profit/sales. TFP is calculated as the residual from a production function $\ln(Y_{it}) = 0.63\ln(L_{it})+0.37\ln(K_{it})$, normalised by 5 digit industry, 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). Profit margins and TFP are annual and are calculated using accounting data from Bureau Van Dijk FAME database. Forecast errors and uncertainty data are from the DMP, quarterly data are collapsed to annual averages (in financial years) and then merged with accounting data. Equations are estimated in financial years (April to March in the following calendar year).