Firming up Price Inflation, Expectations and Uncertainty

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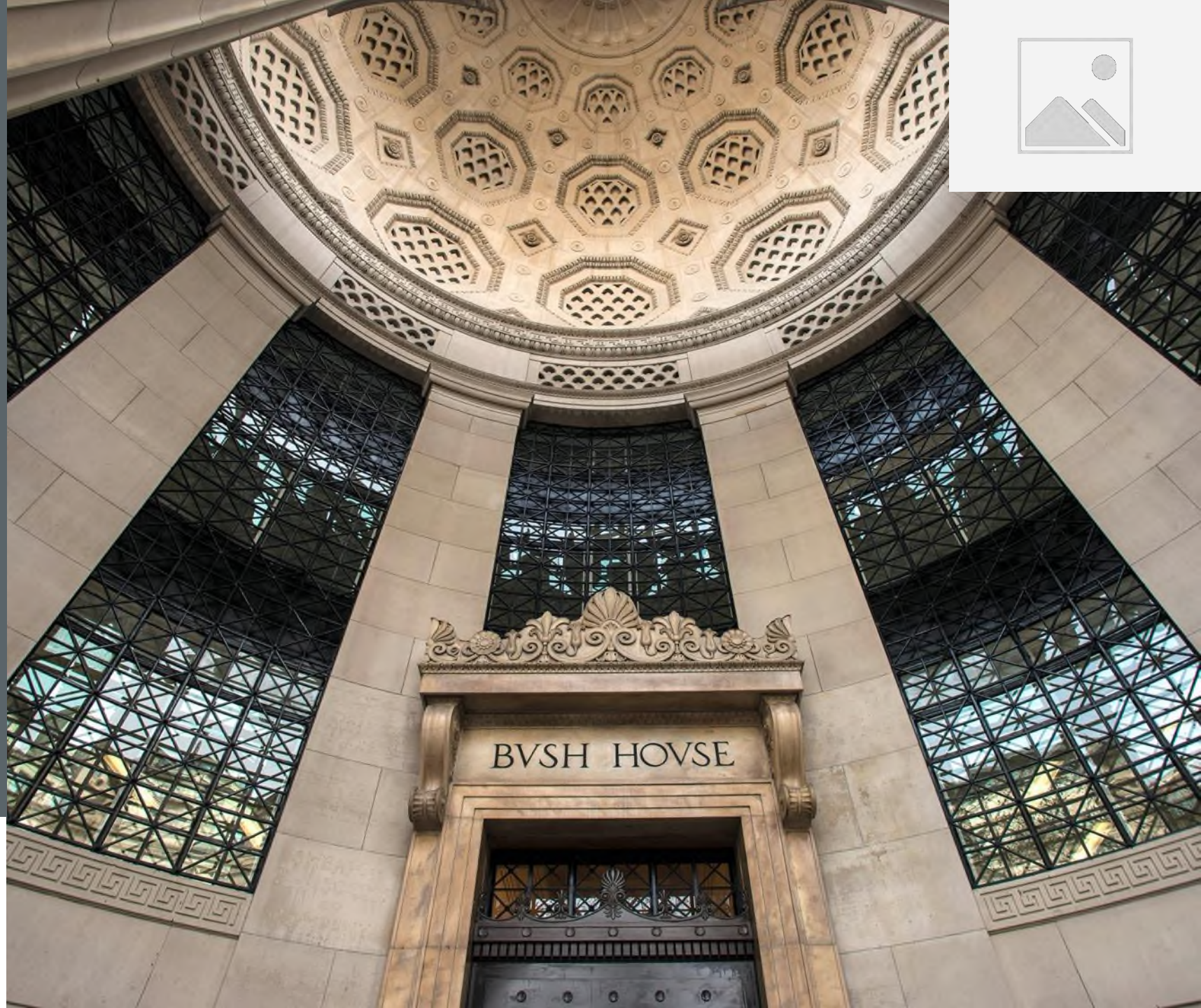
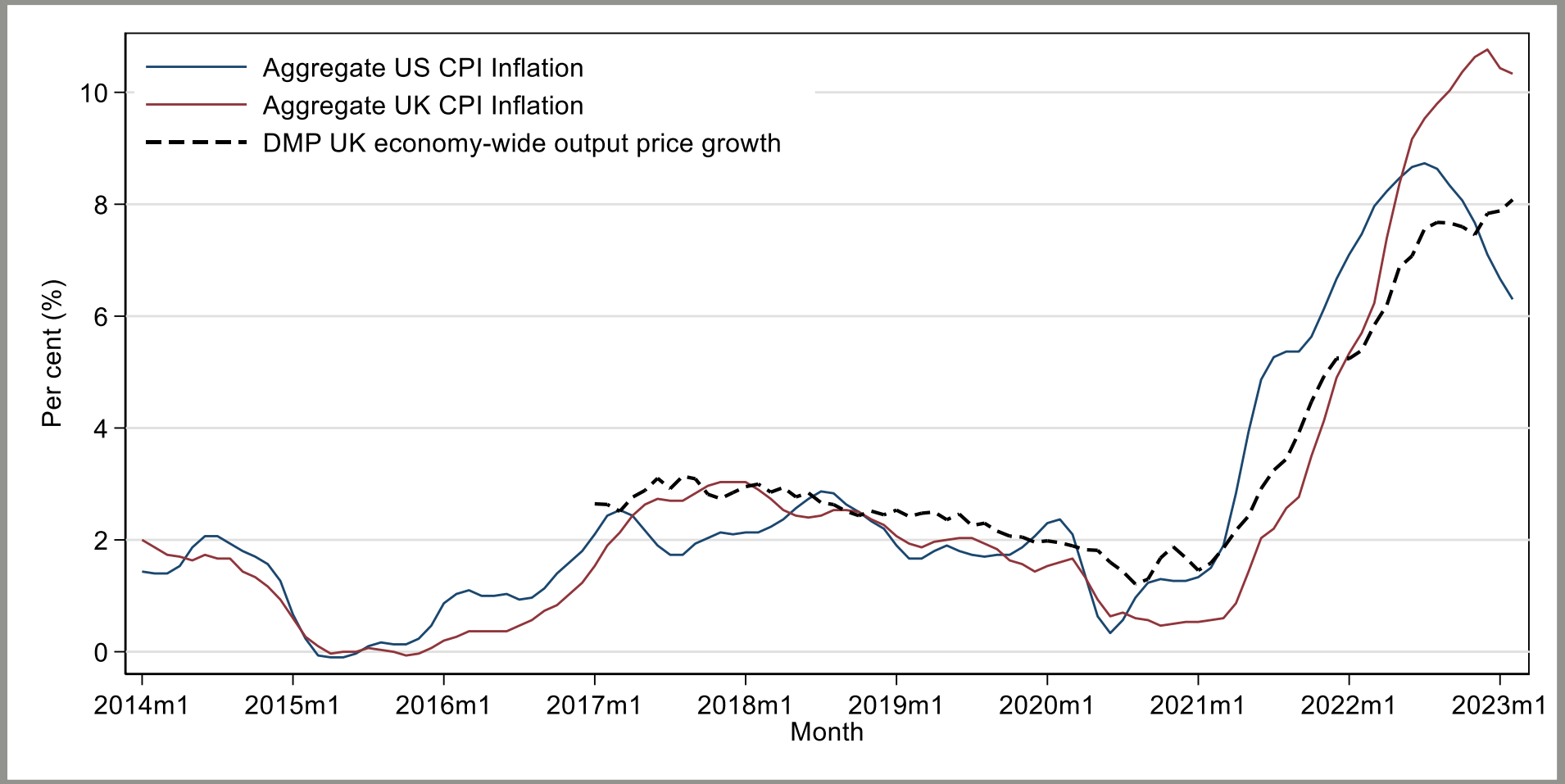
Portsmouth, 7 September 2023



There has been a renewed interest inflation since 2021 when inflation surged unexpectedly.

“Central bankers and most outside economists failed to predict the sharp rise in inflation that began in 2021, and policymakers, both in the United States and in other advanced economies, were accordingly slow to react.” Bernanke and Blanchard, NBER wp 31417 (2023)

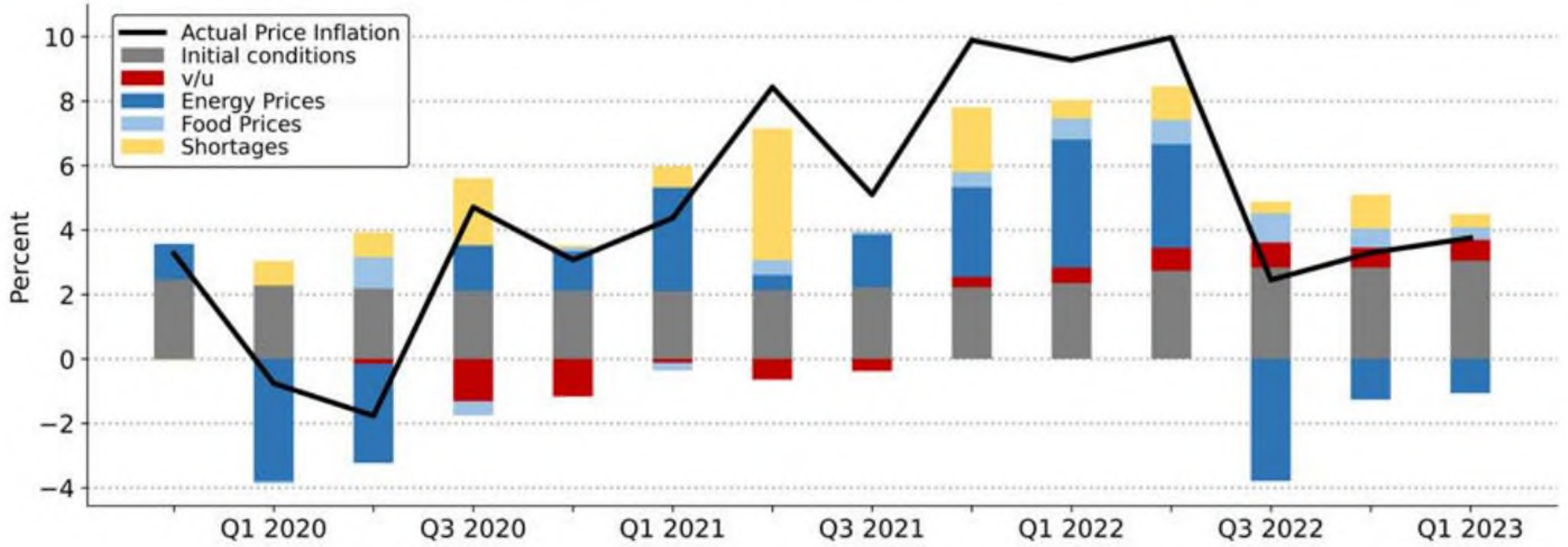

Aggregate US CPI Inflation
Aggregate UK CPI Inflation
DMP UK economy-wide output price growth
Per cent (%)
0
2
4
6
8
10
2014m1
2015m1
2016m1
2017m1
2018m1
2019m1
2020m1
2021m1
2022m1
2023m1
Month

Upward pressures on prices from Covid and Ukraine shocks explain much of the increase.

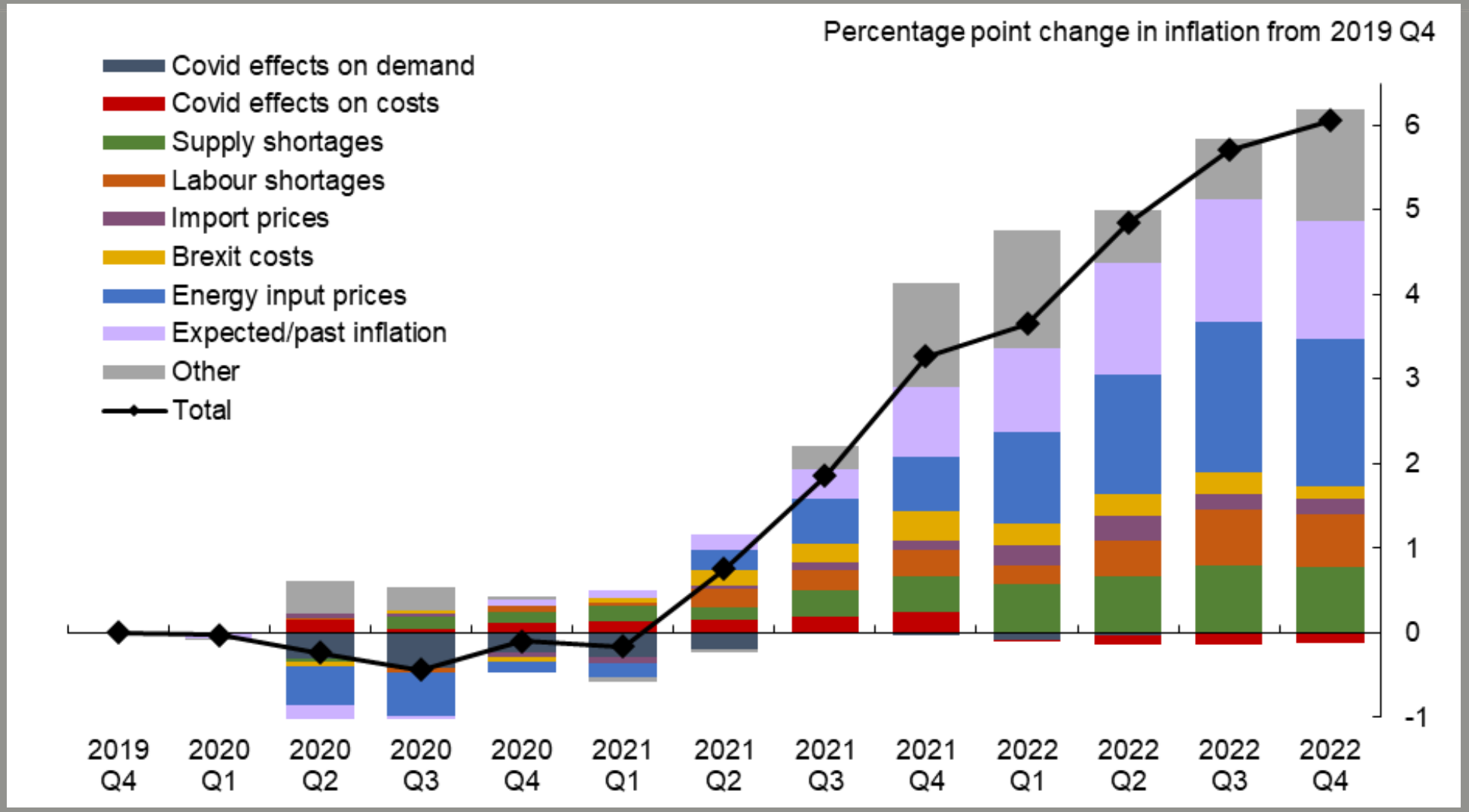
There has been fresh assessment of the drivers of inflation and public commitment to bear down on it, because it has been more persistent than expected. Broadbent (2023), Pill (2023), Powell (2023).

And there is new evidence of a steeper Phillips curve e.g. Bernanke and Blanchard (2023), Gagliardone et al (2023) which connects supply and demand pressures to the inflation surge.

FIGURE 12. THE SOURCES OF PRICE INFLATION, 2020Q1 to 2023Q1



Note: The figure shows a decomposition of the sources of inflation, 2020Q1 to 2023Q1, based on the solution of the full model and the implied impulse response functions. The continuous line shows actual inflation, and the total net heights of the bars are the model's forecast of inflation in each period, given initial conditions through 2019Q4 and excluding the effects of equation residuals. The grey portion of each bar shows the contribution of pre-2020 data (and also include the contributions of productivity shocks). Colored segments of each bar show the general equilibrium, fully dynamic contribution of each exogenous variable to inflation in that period, as implied by the estimated model.


Percentage point change in inflation from 2019 Q4
Covid effects on demand
Covid effects on costs
Supply shortages
Labour shortages
Import prices
Brexit costs
Energy input prices
Expected/past inflation
Other
Total
6
5
4
3
2
1
0
-1
2019 Q4
2020 Q1
2020 Q2
2020 Q3
2020 Q4
2021 Q1
2021 Q2
2021 Q3
2021 Q4
2022 Q1
2022 Q2
2022 Q3
2022 Q4

1. DMP data and UK firm’s prices and inflation
2. Firm-level Phillips curves
3. Inflation and higher moments of inflation
4. Model and simulation results
5. Conclusions

We study the dynamics of inflation at the firm level using a unique survey of UK firms and the 2020-22 period as a laboratory

We address 2 questions – one specific, one timeless:

- What shocks account for the behaviour of inflation during 2020-2022?
- What explains the behaviour of inflation at the firm level?

We have three related findings:

- Covid effects were large on demand but small on inflation
- The Phillips curve is kinked at the firm level
- Inflation is positively related to the variance and skewness of shocks to inflation

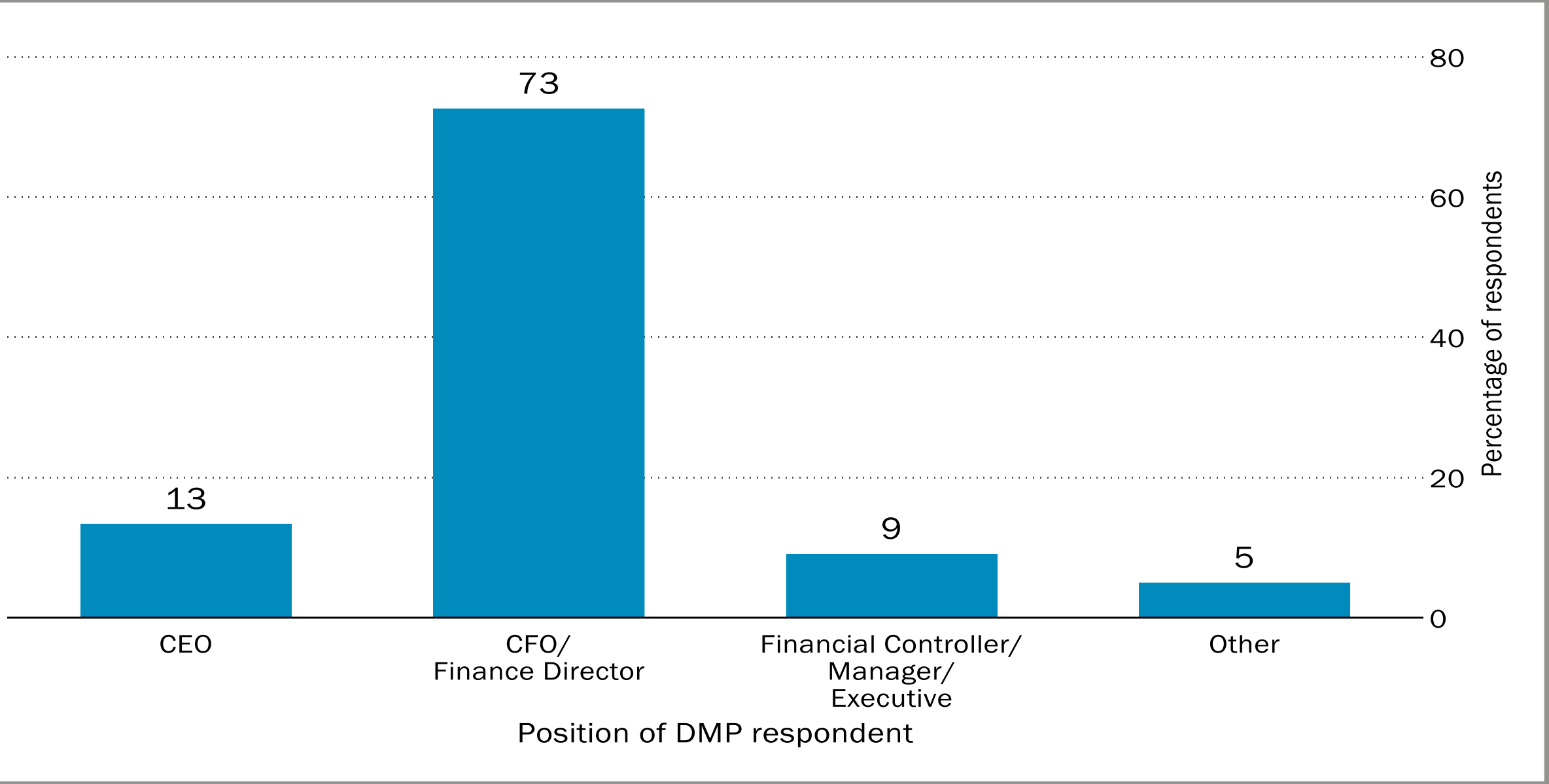
We reproduce the last two findings in a model with positive trend inflation, menu costs and decreasing returns to scale.

Recent findings from DMP

In Aug 2016, a Bank-Nottingham-Stanford team started the Decision Maker Panel (DMP)

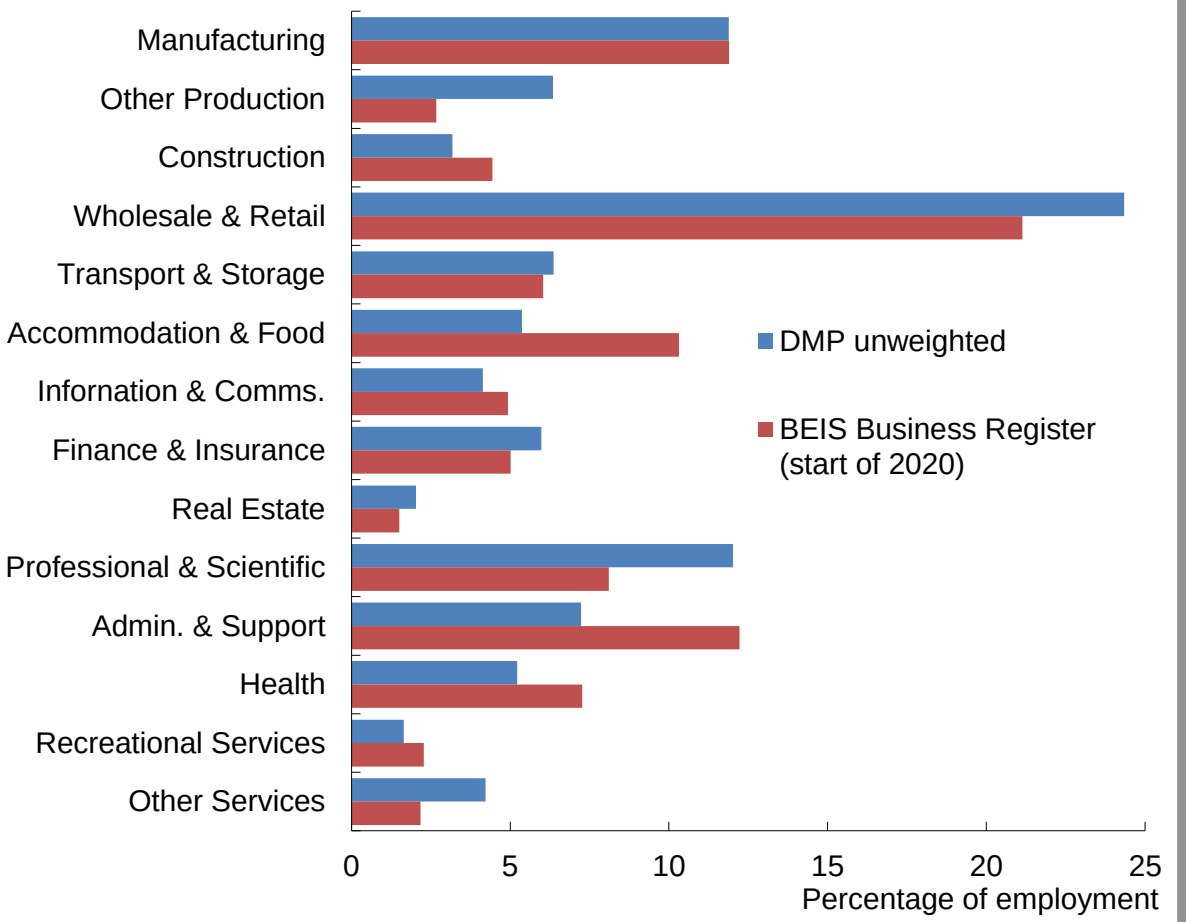
- Monthly 5-minute online survey
- Recruit randomly from population 42K firms (from Amadeus) with 10+ employees
- Panel 10K, ~ 3K firms respond per month, ≈14% private employment
- Similarities with Survey of Business Uncertainty (Atlanta Fed) and Duke CFO survey – but an order of magnitude larger.

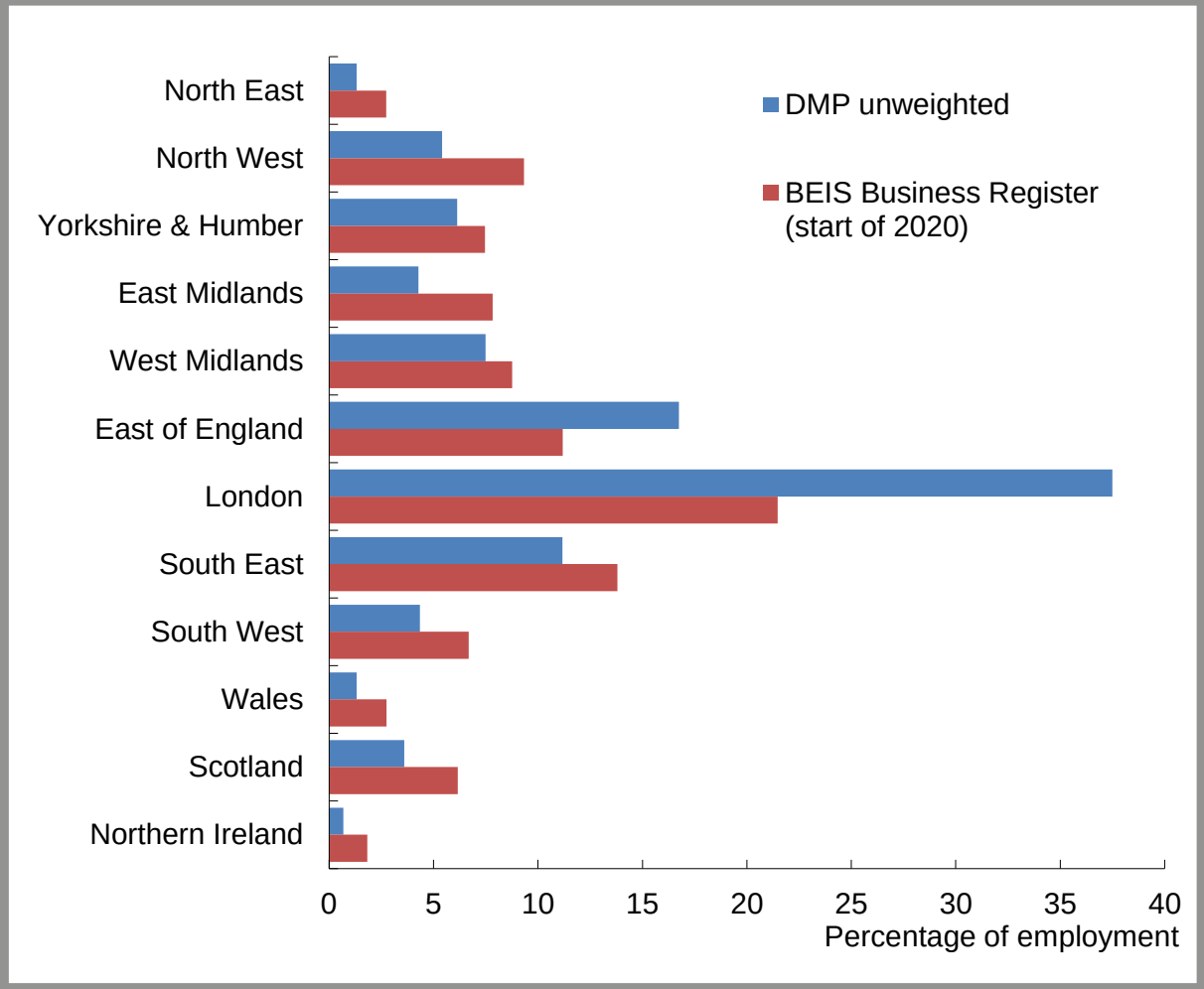
86% respondents CEOs or CFOs (median firm has 60 employees)



Source: Results are based on the question: 'Could you tell us the position of the person in your business that typically completes the Decision Maker Panel Survey?' and respondents were asked to choose from the following options: 'CFO', 'CEO', 'Other (please state): …'.

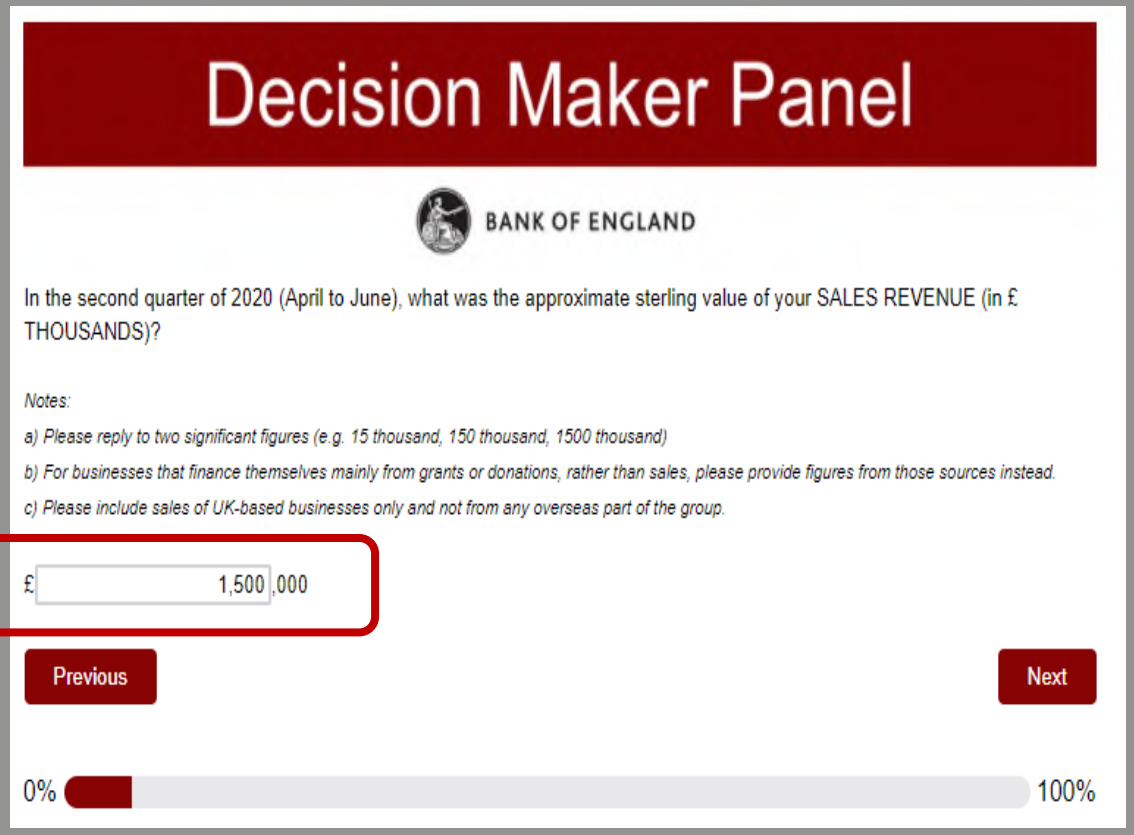
DMP covers UK industry and regional breakdowns

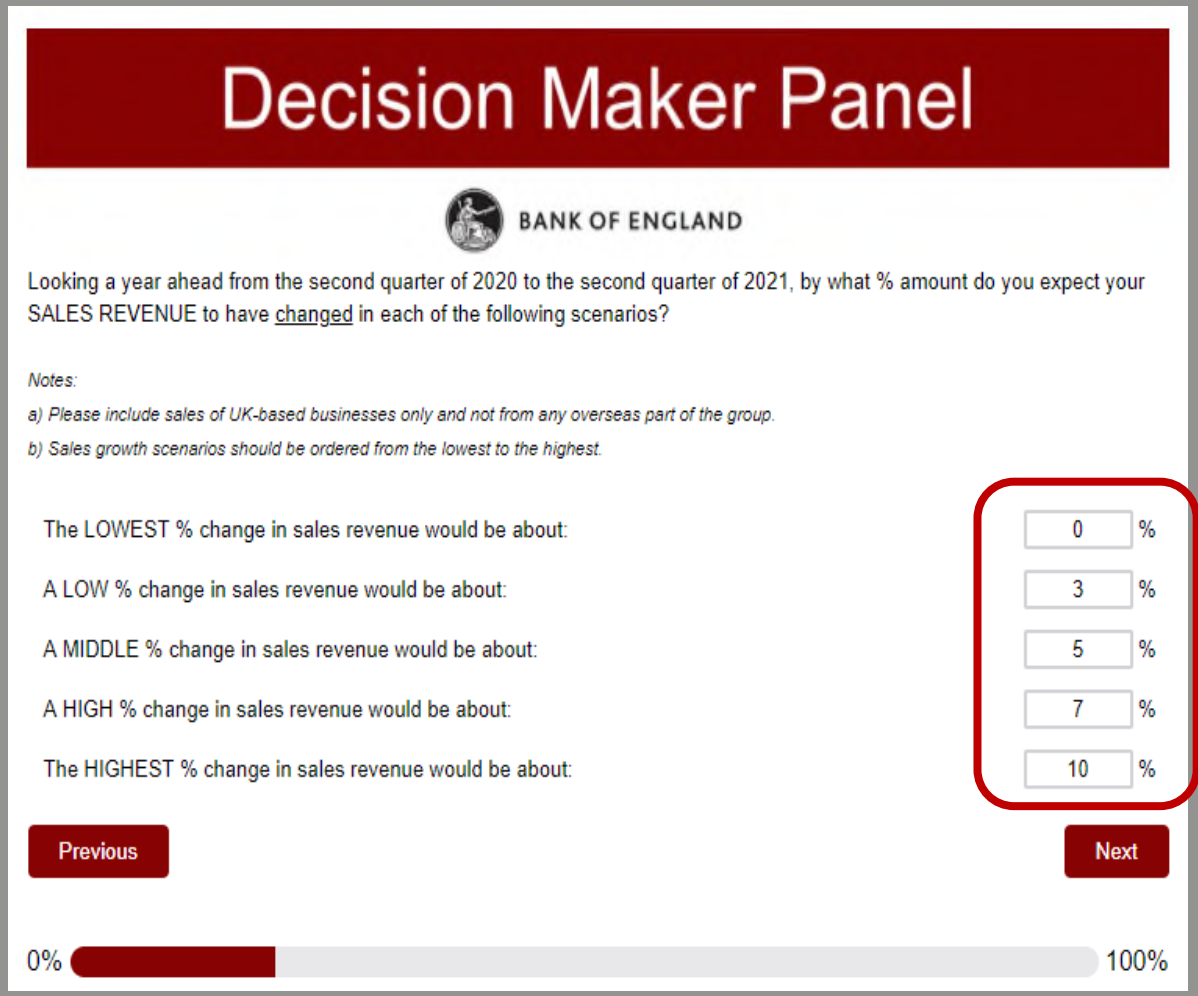




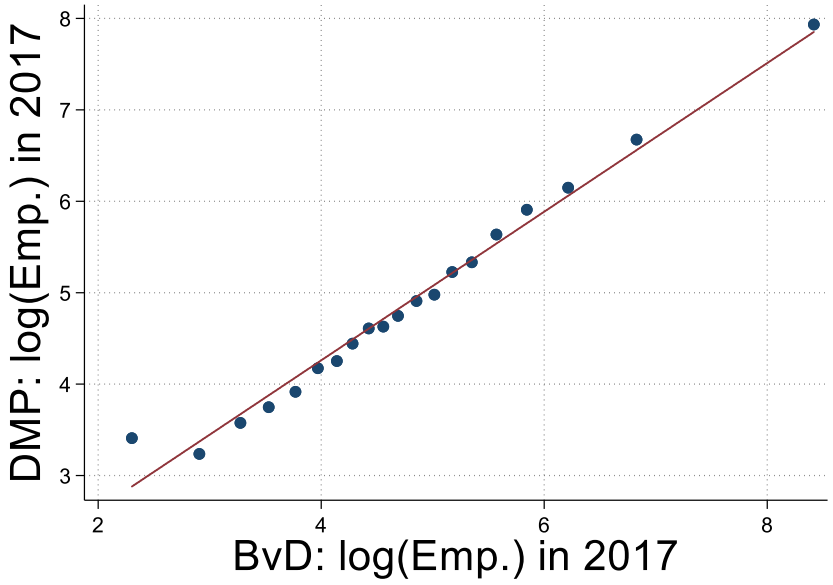
Notes: DMP members who were sent the September 2020 survey. BEIS Business Register data from the start of 2020.

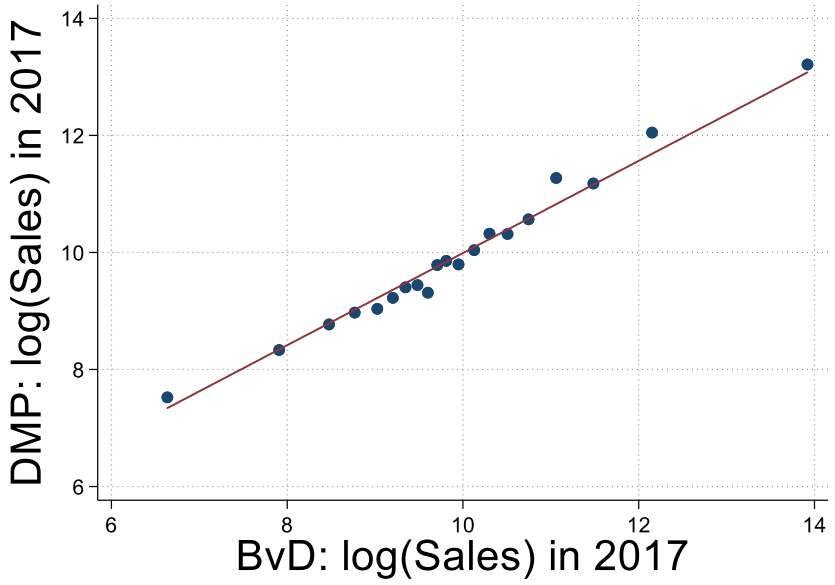
Ask a range of questions about past, present and future e.g. sales

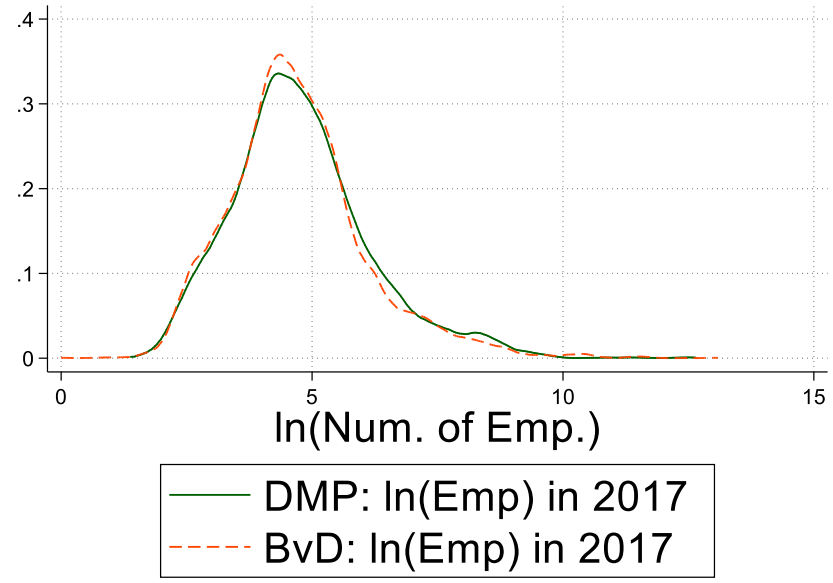


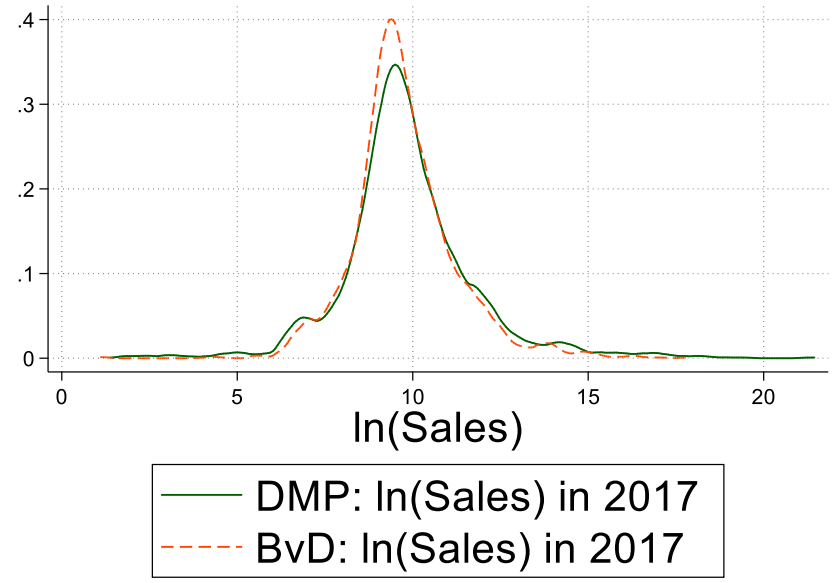


DMP data looks highly quality – e.g. matches accounts data





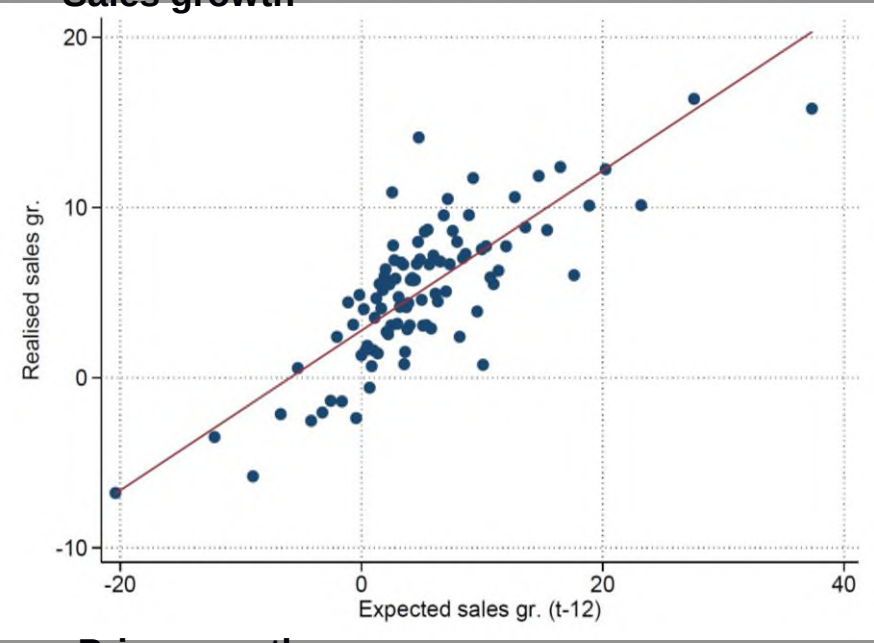




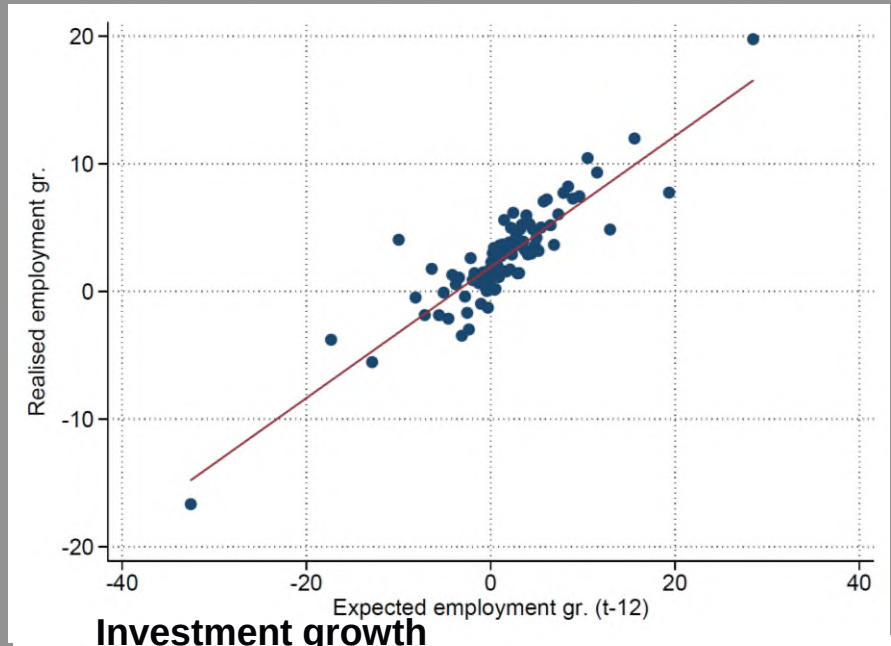
Notes: Sales values from the DMP survey are based on annualised quarterly sales reported by businesses plotted here against Bureau Van Dijk (BVD) Amadeus Company Accounts data (includes public and private firms)

Forecasts that DMP respondents provide also appear accurate

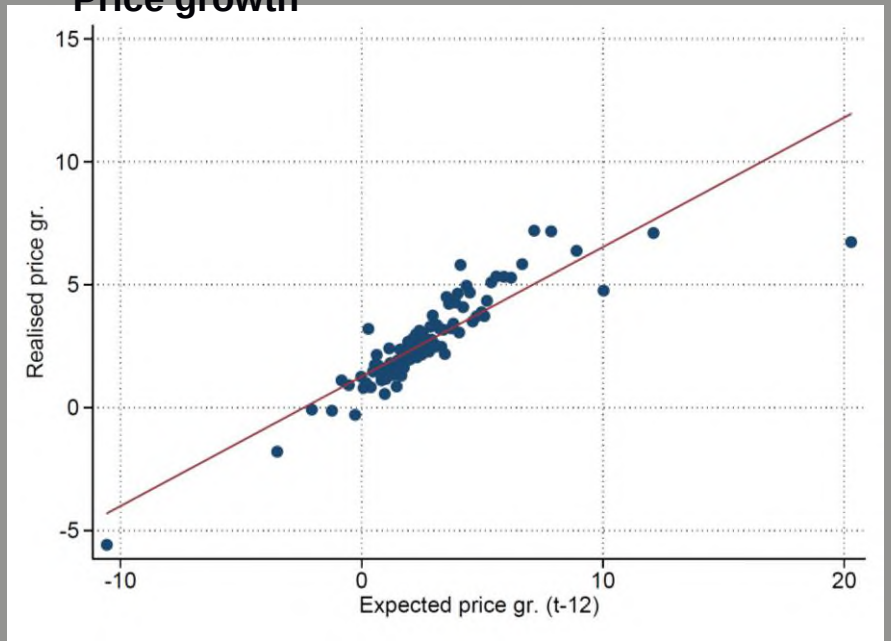
Sales growth



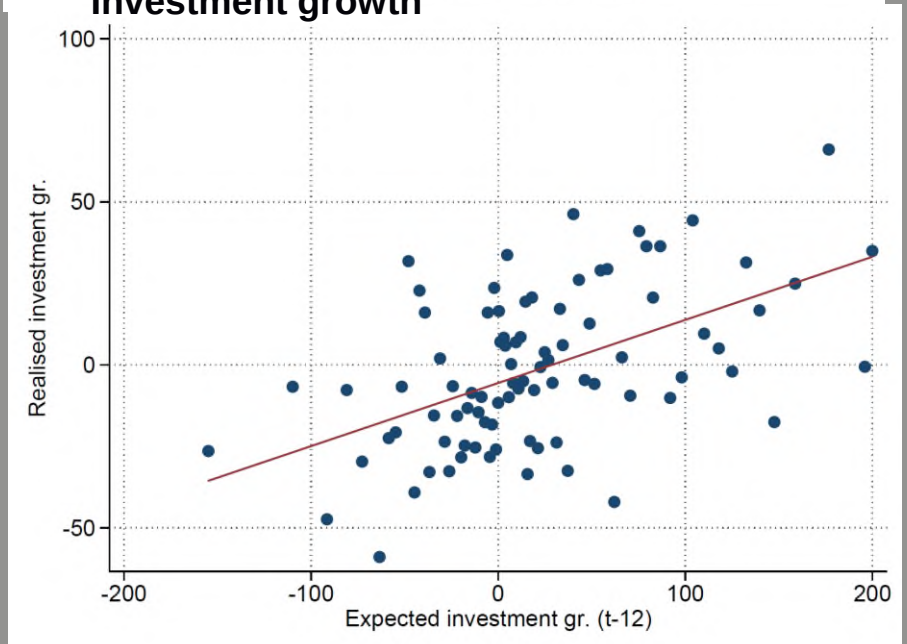
Employment growth



Price growth



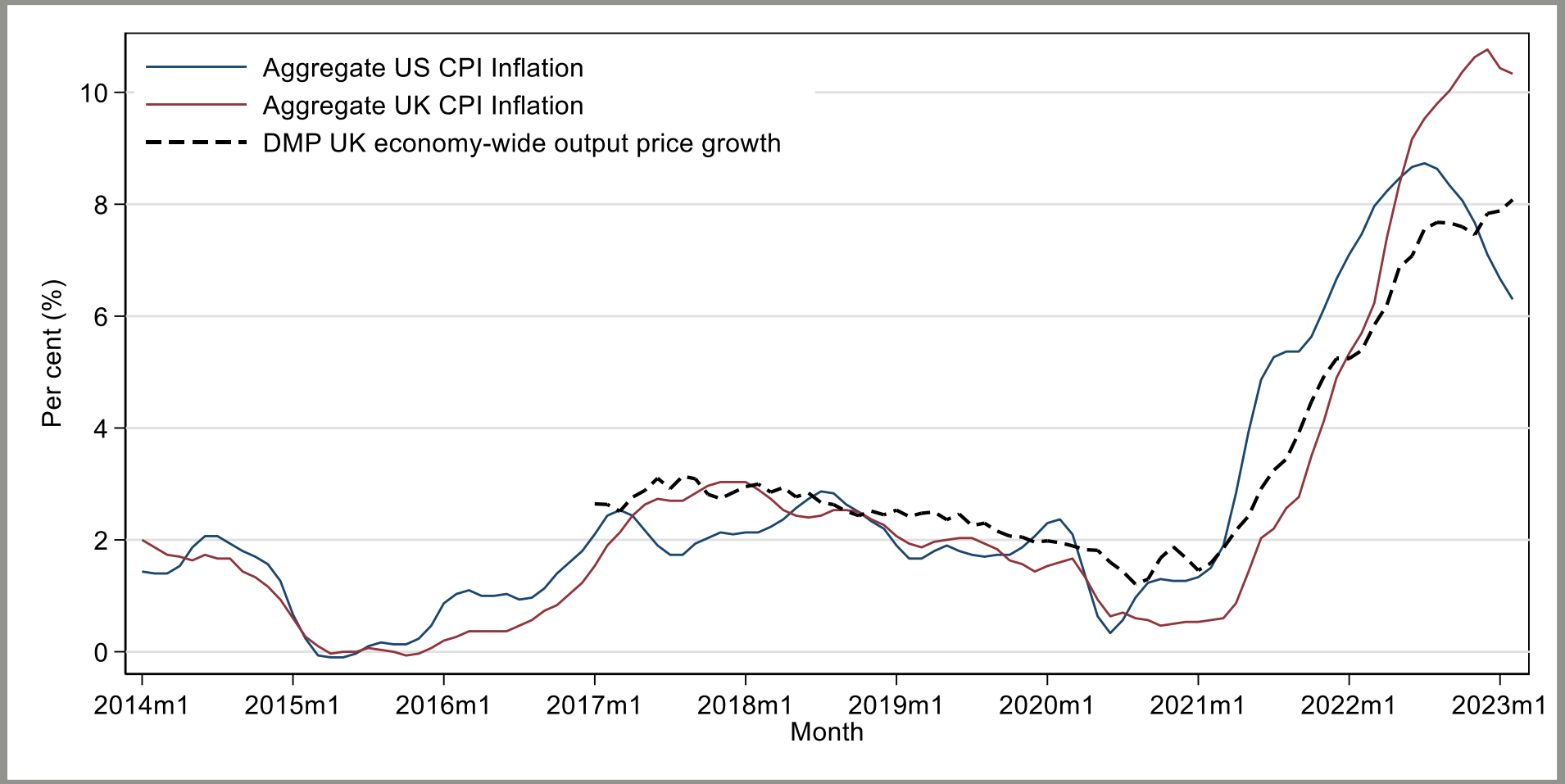
Investment growth

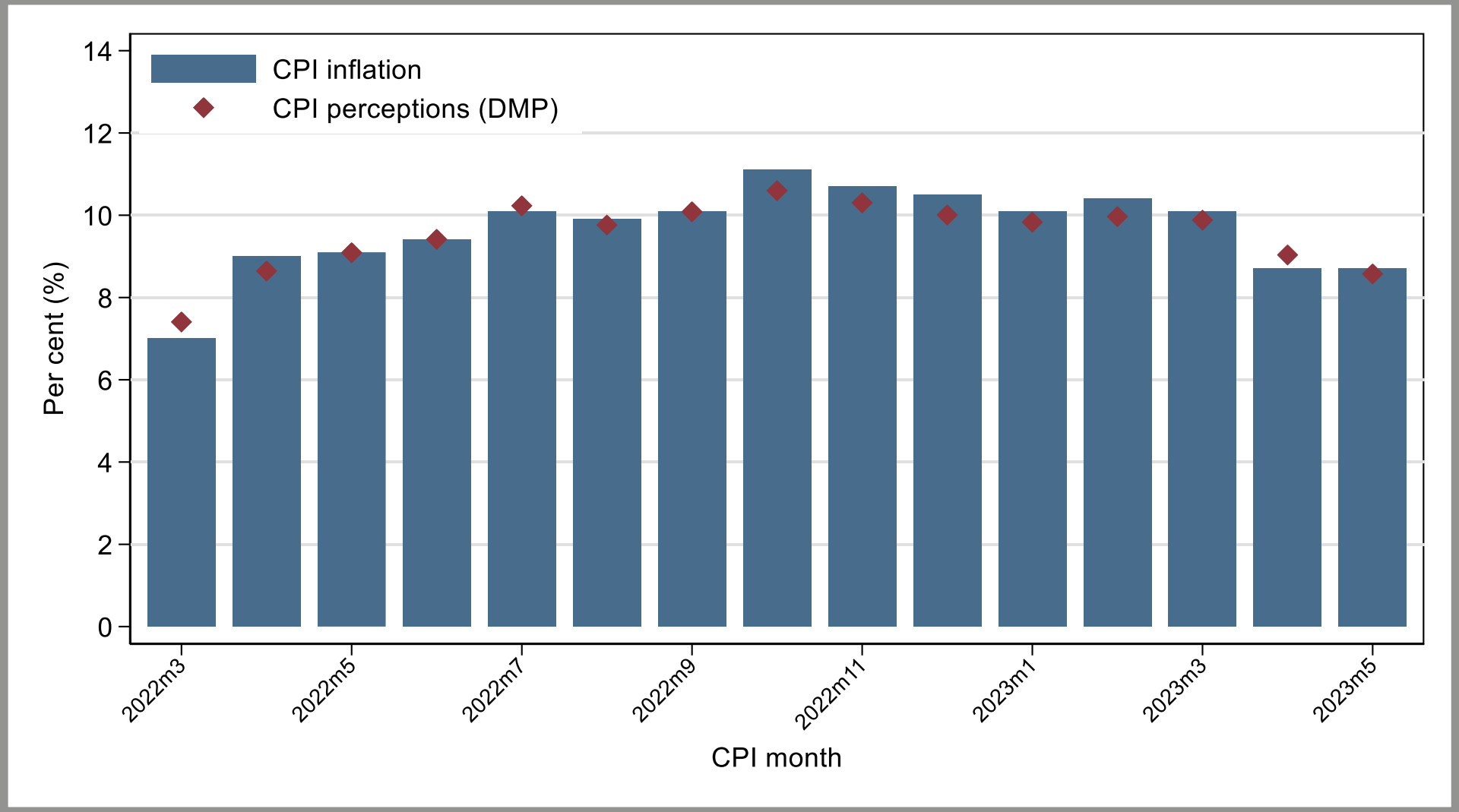


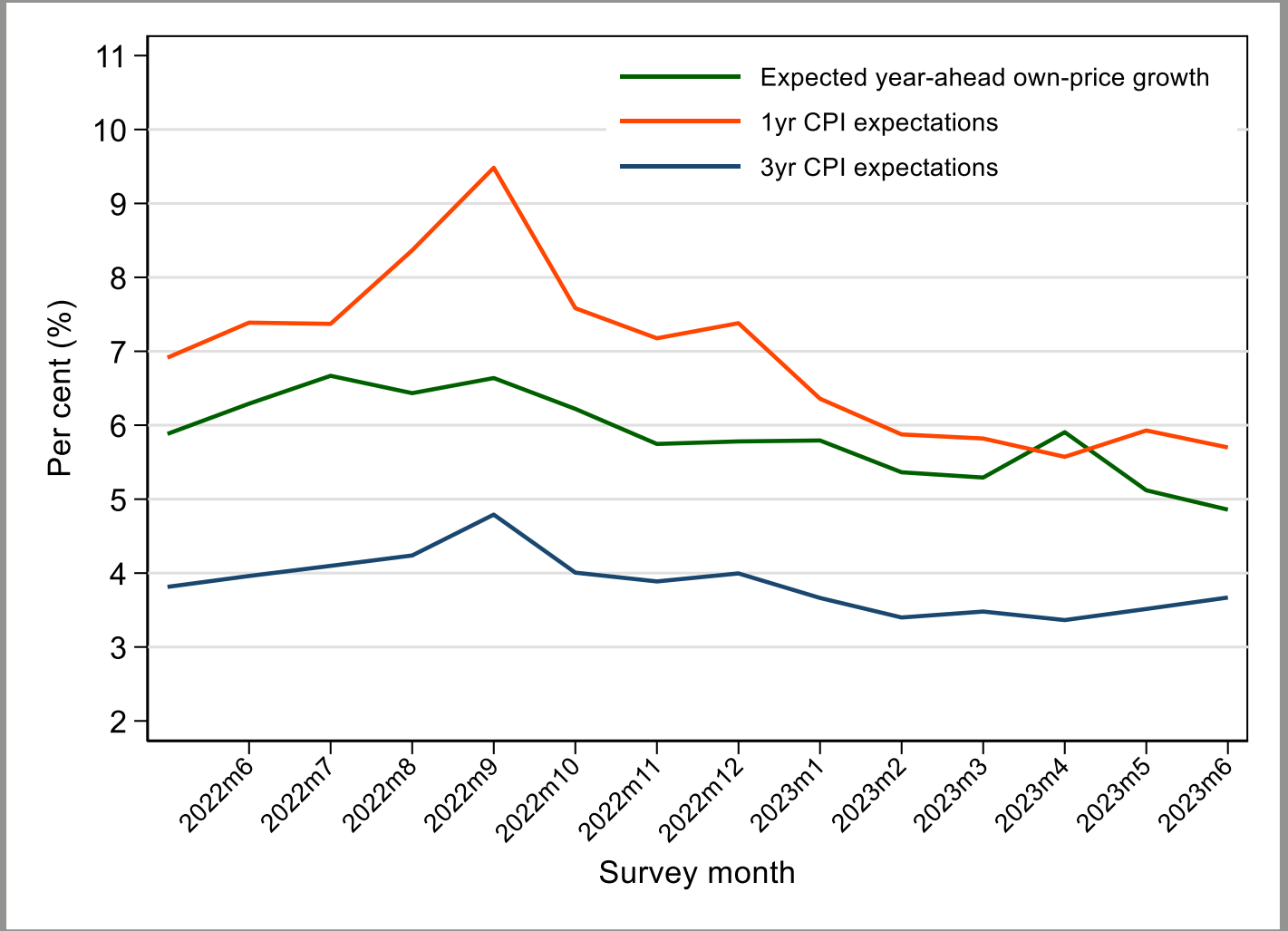
Notes: Y-axes show realised growth in sales, employment, prices, and investment. X-axes show expectations for year-ahead growth rates calculated from the 5-bin outcomes and probabilities. Forecasts made between September 2016 and June 2018. Binscatter plots which split responses into 100 groups

- We ask firms about realised and expected inflation
- For expected inflation, we ask firms to give 5 outcomes and place mass on them
- We can construct a subjective pdf using the values in and mass on these 5 bins
- We can then calculate moments of realised inflation at the industry level, and expected inflation at both the firm and industry levels

- “Firming up Price Inflation” – NBER WP
- “Firm Inflation Uncertainty” – AEA P&P and NBER WP
- “Firm inflation perceptions and expectations” – Bank Underground
- “Firm price setting in a high-inflation environment” – Agents’ Box
- “Firm inflation expectations in quantitative and text data” – VoxEU


Aggregate US CPI Inflation
Aggregate UK CPI Inflation
DMP UK economy-wide output price growth
Per cent (%)
0
2
4
6
8
10
2014m1
2015m1
2016m1
2017m1
2018m1
2019m1
2020m1
2021m1
2022m1
2023m1
Month

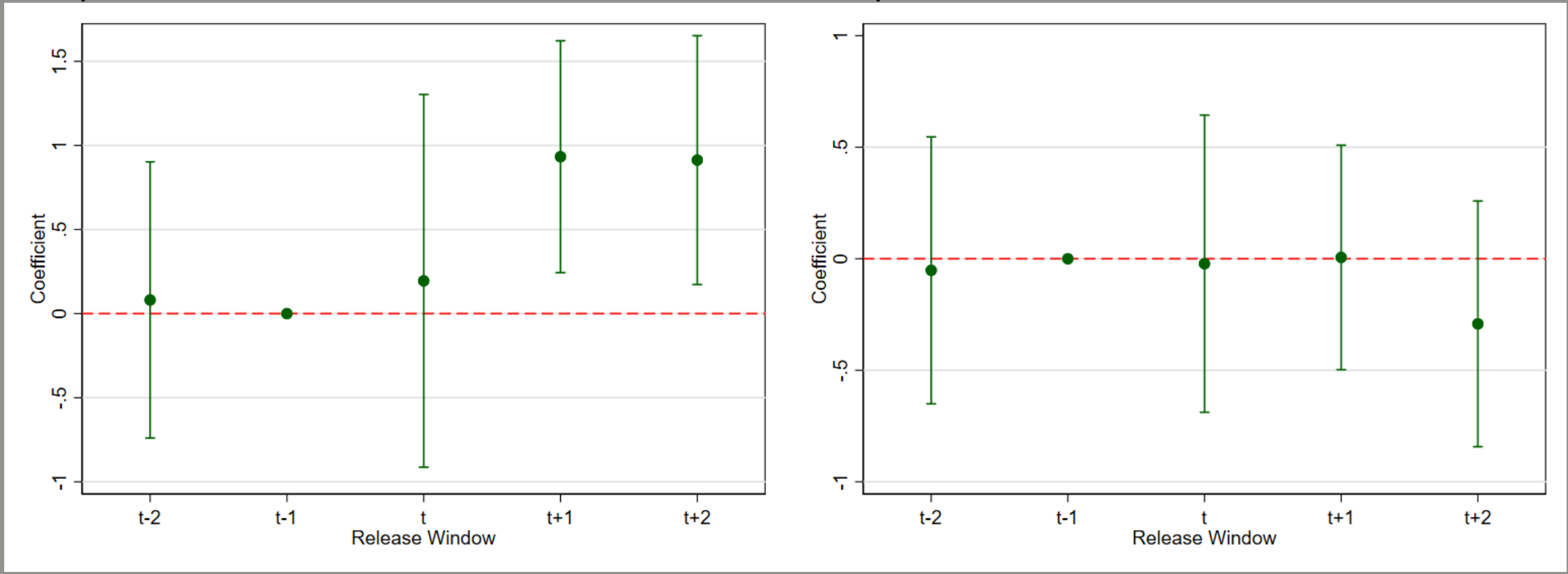

CPI inflation
CPI perceptions (DMP)
Per cent (%)
0
2
4
6
8
10
12
14
2022m3
2022m5
2022m7
2022m9
2022m11
2023m1
2023m3
2023m5
CPI month


Expected year-ahead own-price growth
1yr CPI expectations
3yr CPI expectations
Per cent (%)
11
10
9
8
7
6
5
4
3
2
2022m6
2022m7
2022m8
2022m9
2022m10
2022m11
2022m12
2023m1
2023m2
2023m3
2023m4
2023m5
2023m6
Survey month

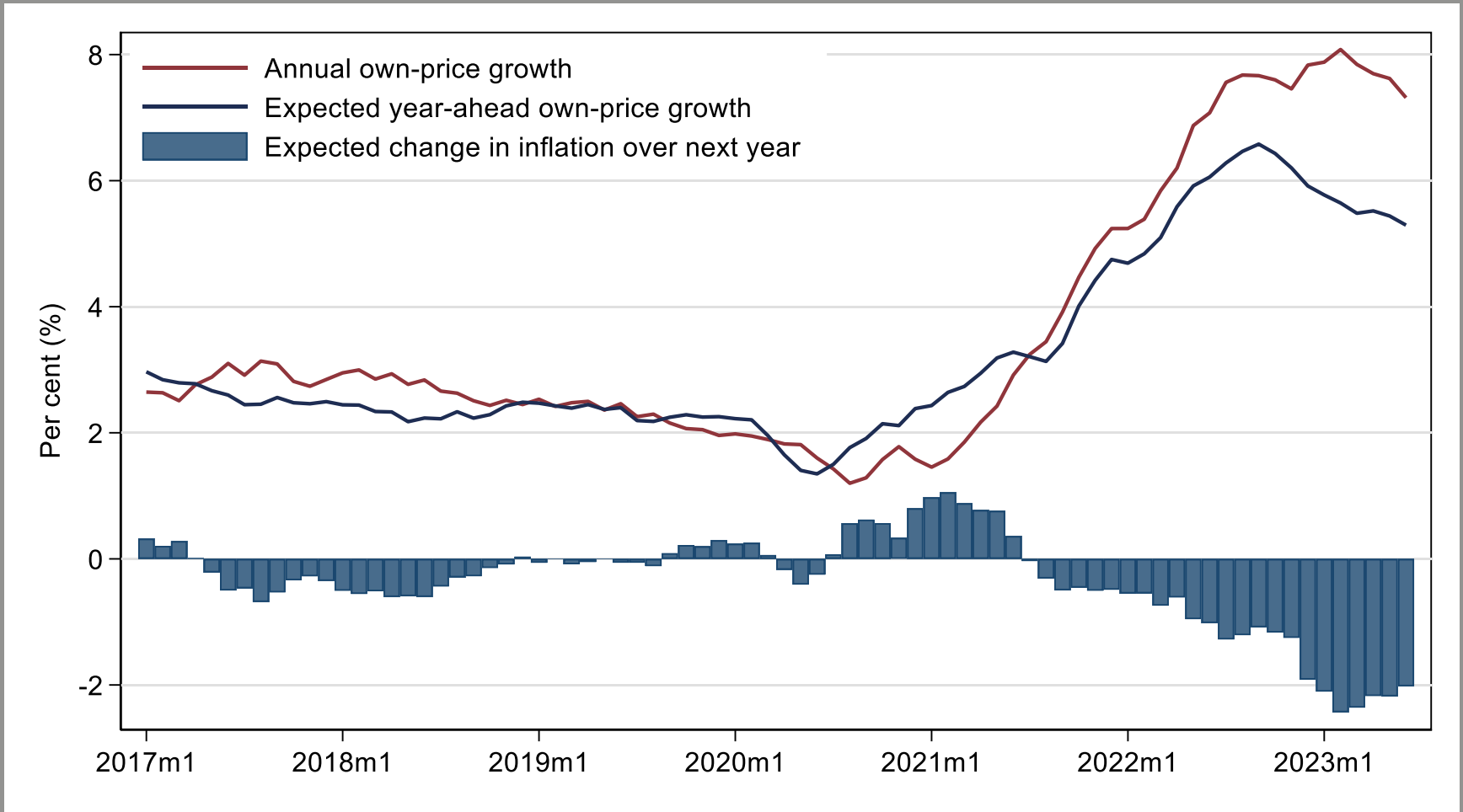
Firms' own price expectations also respond significantly to CPI outturns in 2022-23. There is no similar effect in 2018-2021.

Panel A: Response of own price expectations to CPI outturns, 2022-2023

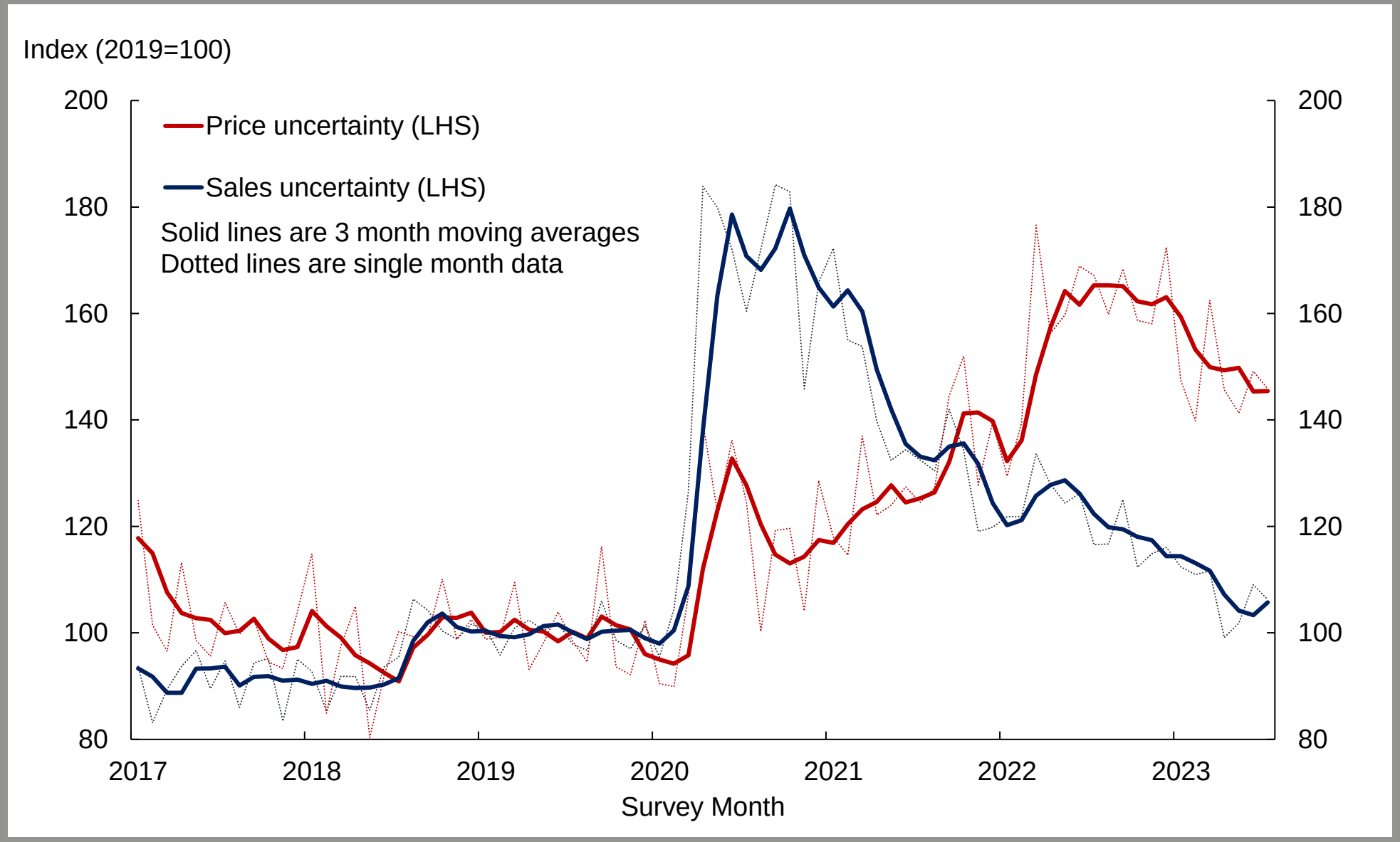
Panel B: Response of own price expectations to CPI outturns, 2018-2021

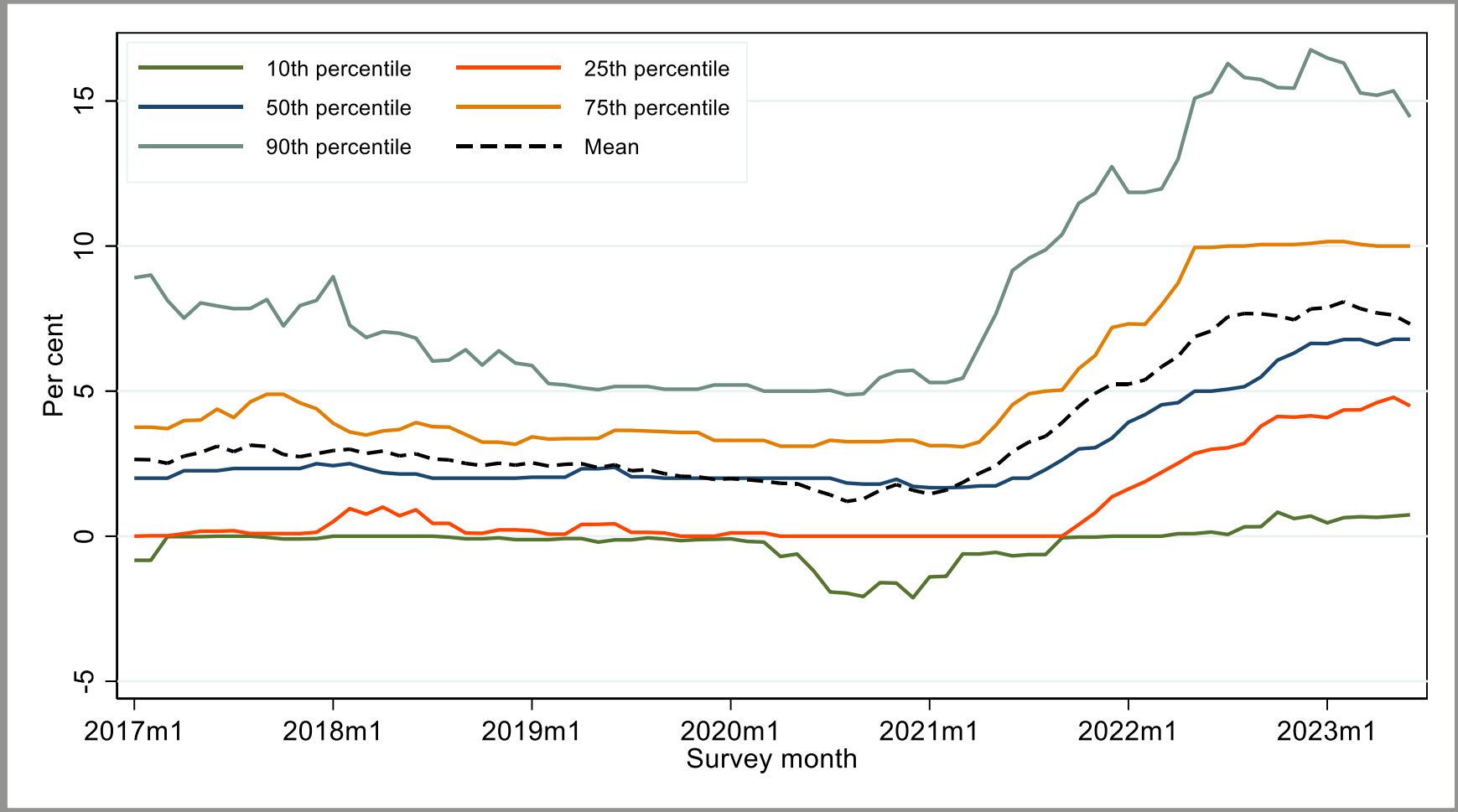


Notes: These figure report coefficient estimates from an event study design. The dependent variable is expected year-ahead own-price growth. The independent variable are changes in annual CPI inflation rates. Standard errors are clustered at the firm level and 90% confidence intervals are reported.



Notes: The series in this figure are three-month moving averages.


Index (2019=100)
Price uncertainty (LHS)
Sales uncertainty (LHS)
Solid lines are 3 month moving averages
Dotted lines are single month data
200
180
160
140
120
100
80
2017
2018
2019
2020
2021
2022
2023
Survey Month



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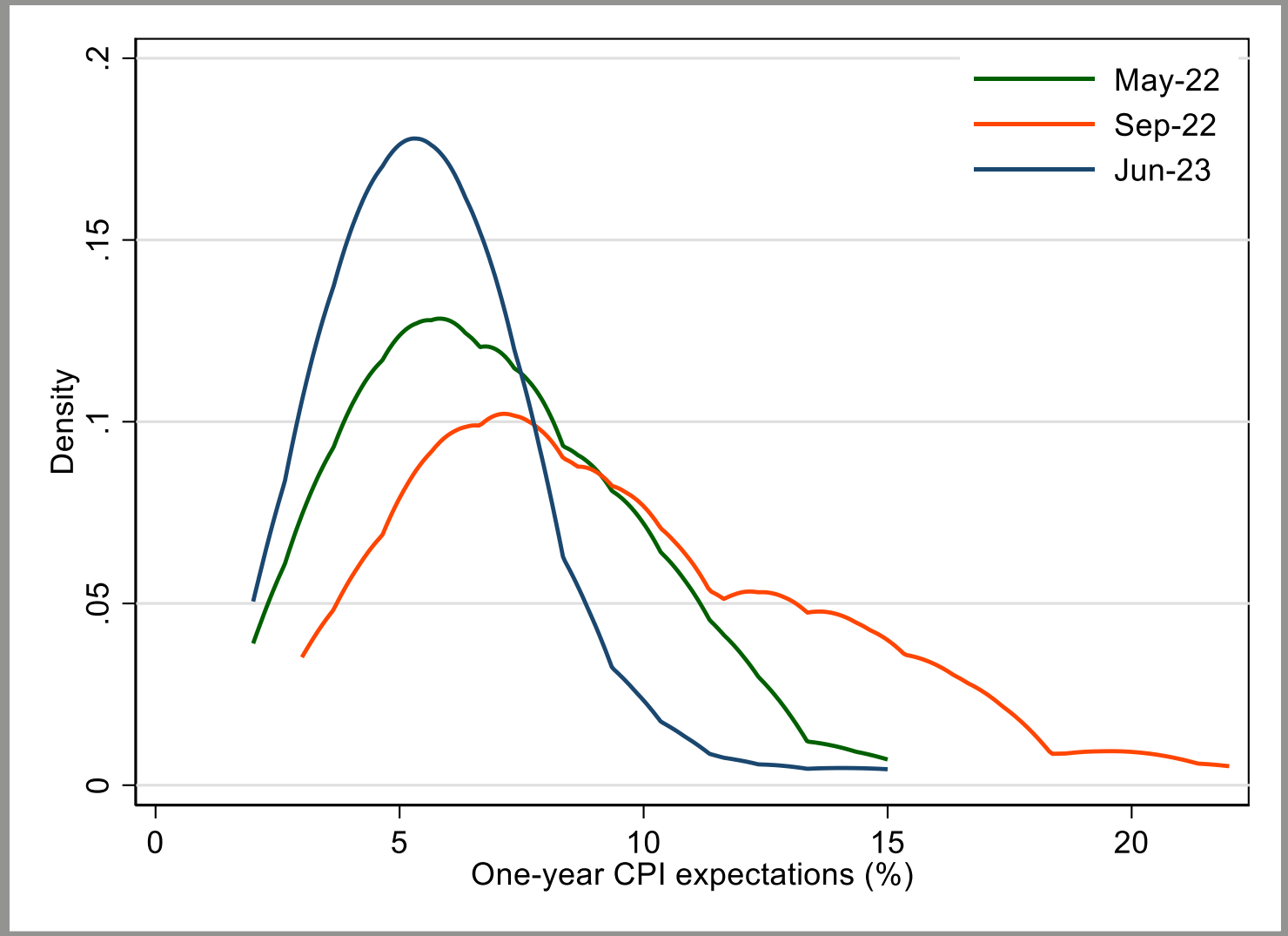
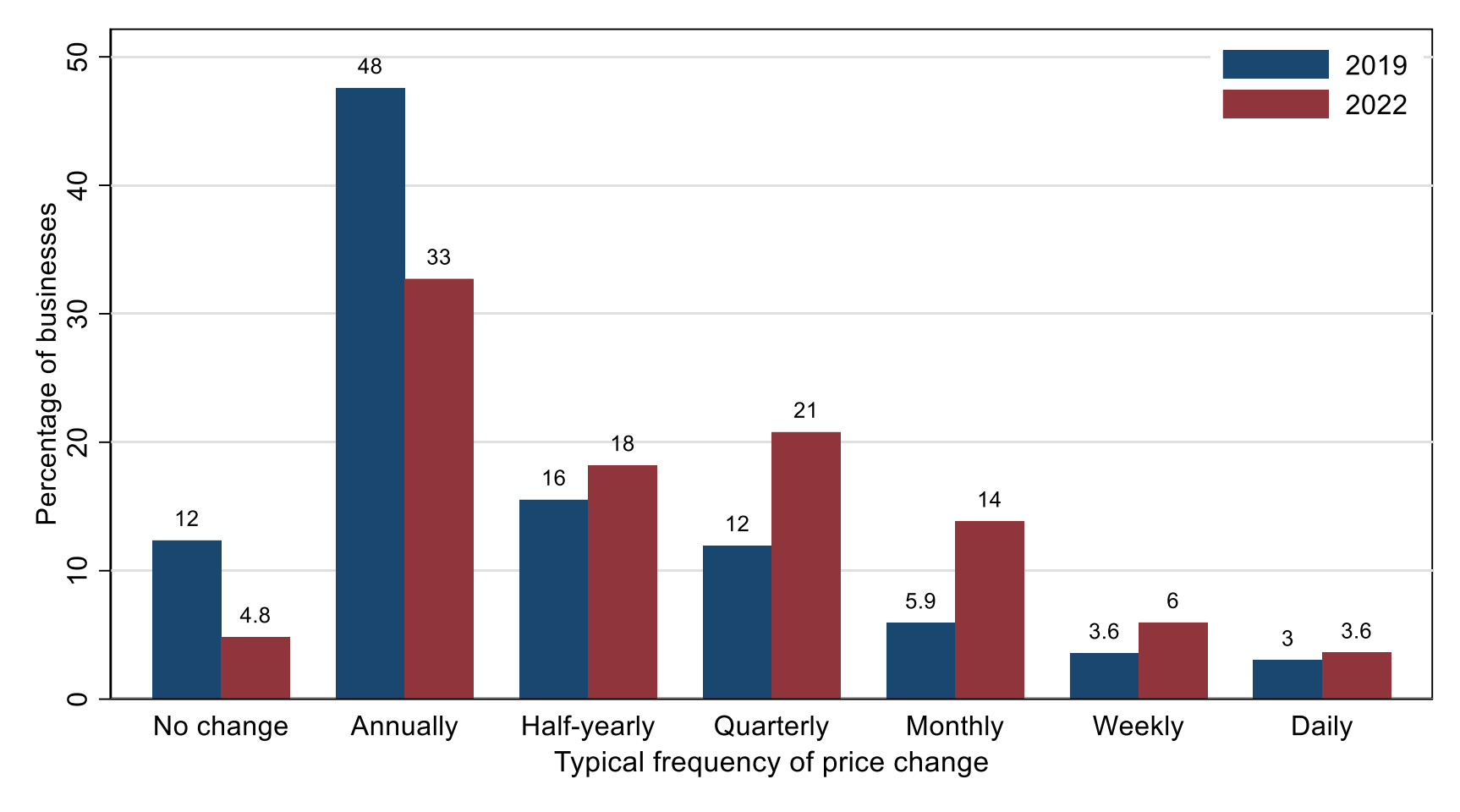
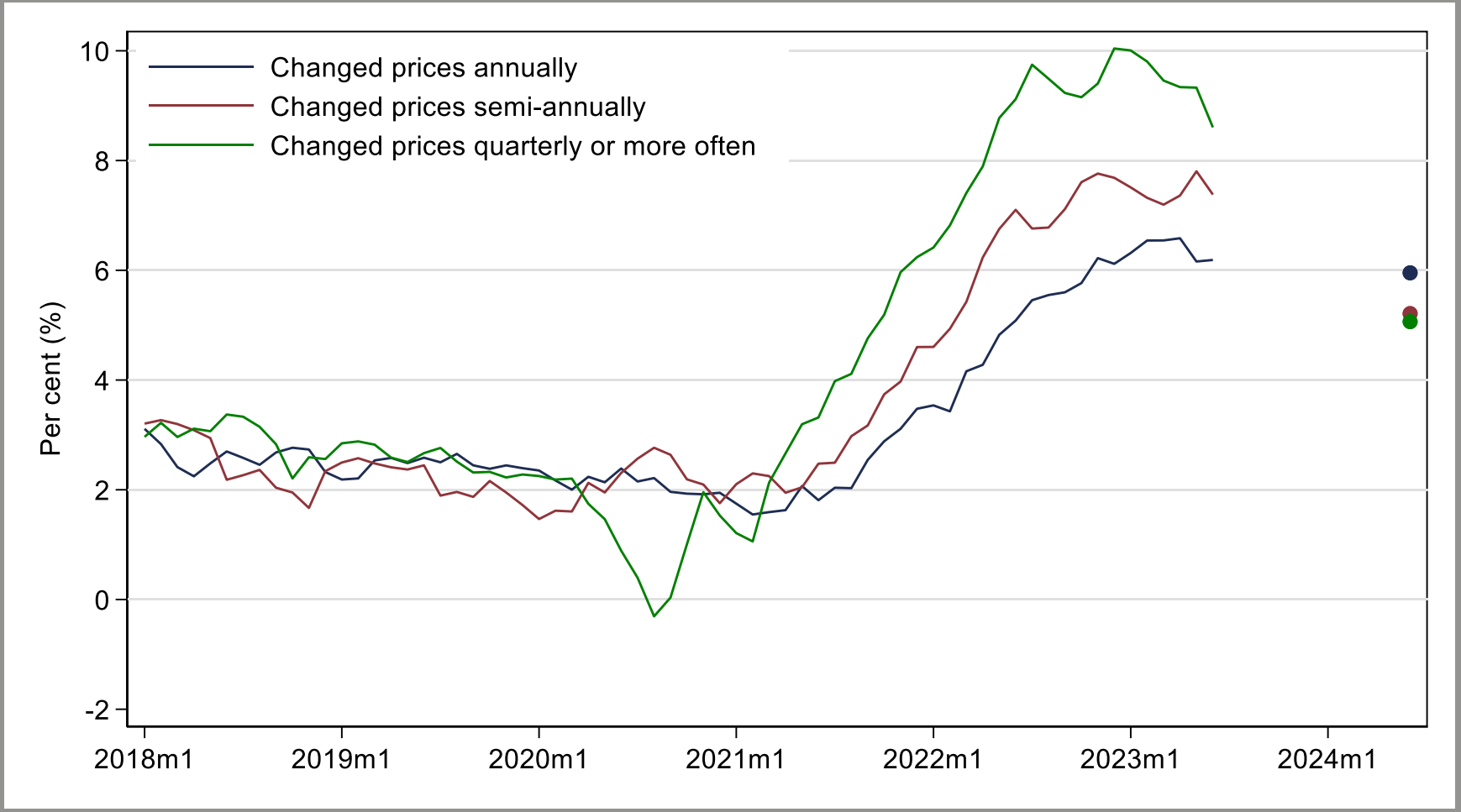
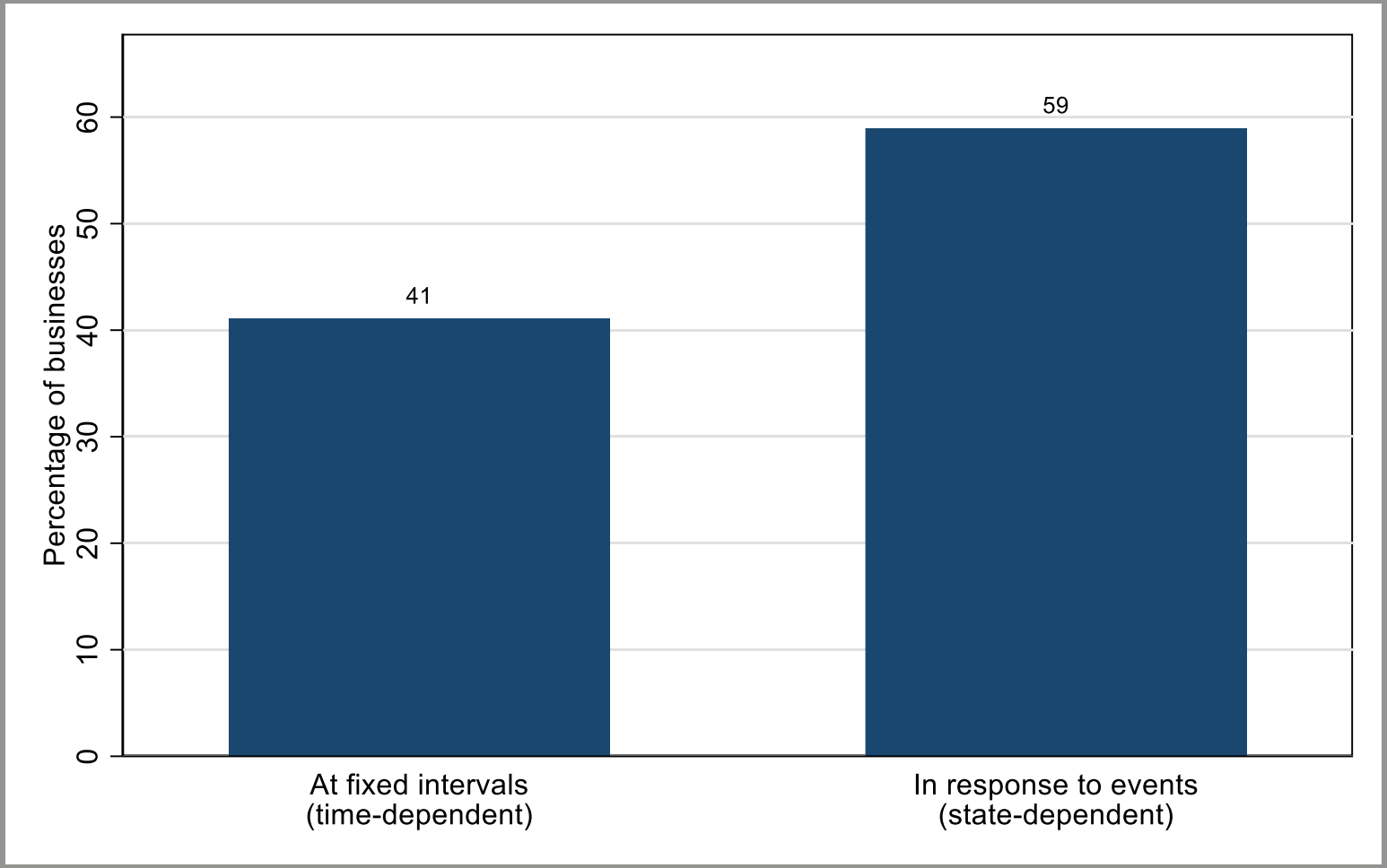
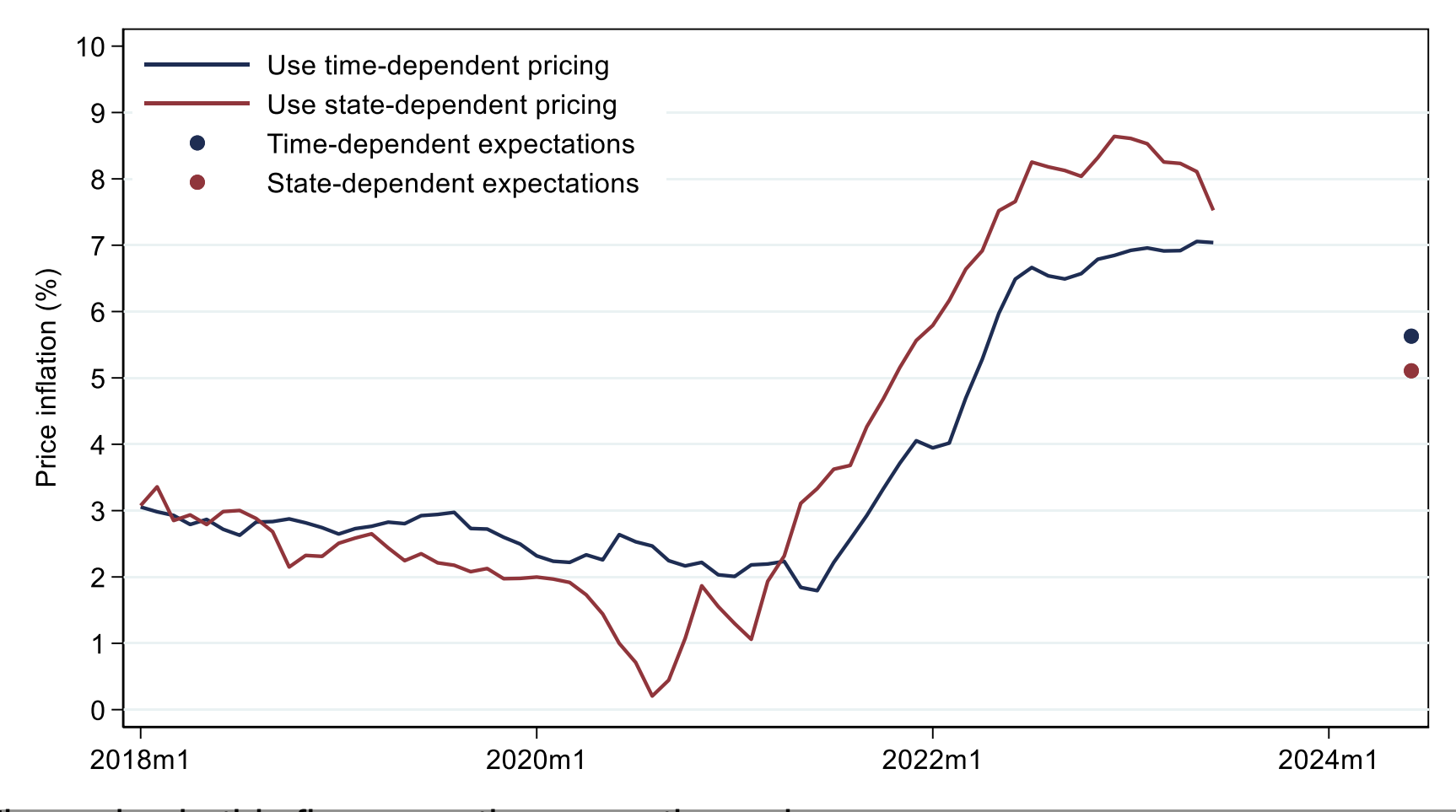

May-22
Sep-22
Jun-23
Density
0
.05
.1
.15
.2
0
5
10
15
20
One-year CPI expectations (%)


2019
2022
Percentage of businesses
0
10
20
30
40
50
12
4.8
48
33
16
18
12
21
5.9
14
3.6
6
3
3.6
No change
Annually
Half-yearly
Quarterly
Monthly
Weekly
Daily
Typical frequency of price change



Notes: The series in this figure are three-month moving averages.


Percentage of businesses
0
10
20
30
40
50
60
41
59
At fixed intervals
(time-dependent)
In response to events
(state-dependent)



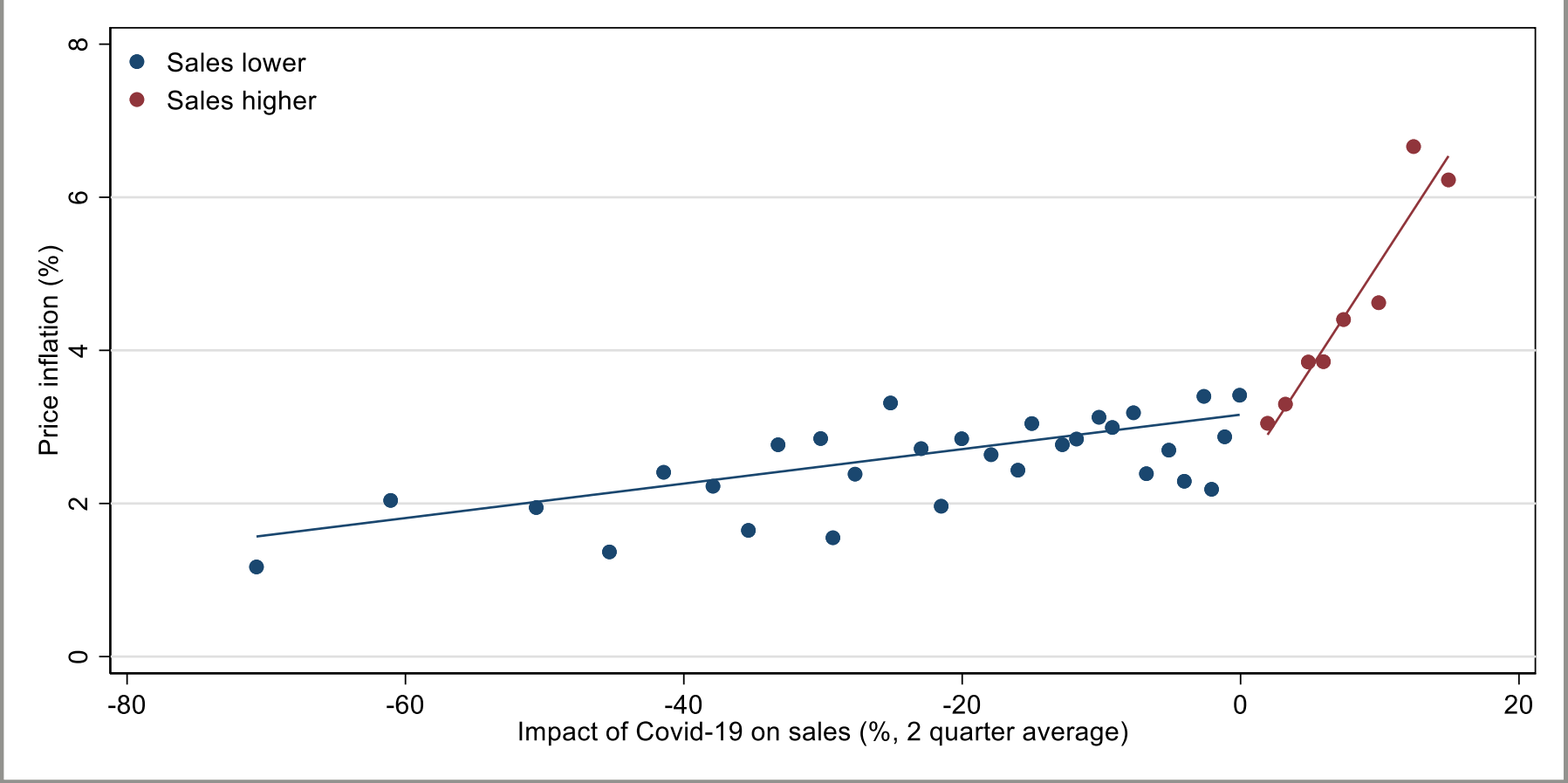
Notes: The series in this figure are three-month moving averages.

- Elevated realised and expected inflation at firm level
- Link between firm expectations and CPI at macro level
- More dispersed realised and expectations of inflation (greater variation)
- Skewed distribution of firm level inflation
- More state contingent price setting

Kinked Phillips curve at the firm level

Decision Maker Panel data

Realized inflation and impact of Covid-19 on sales



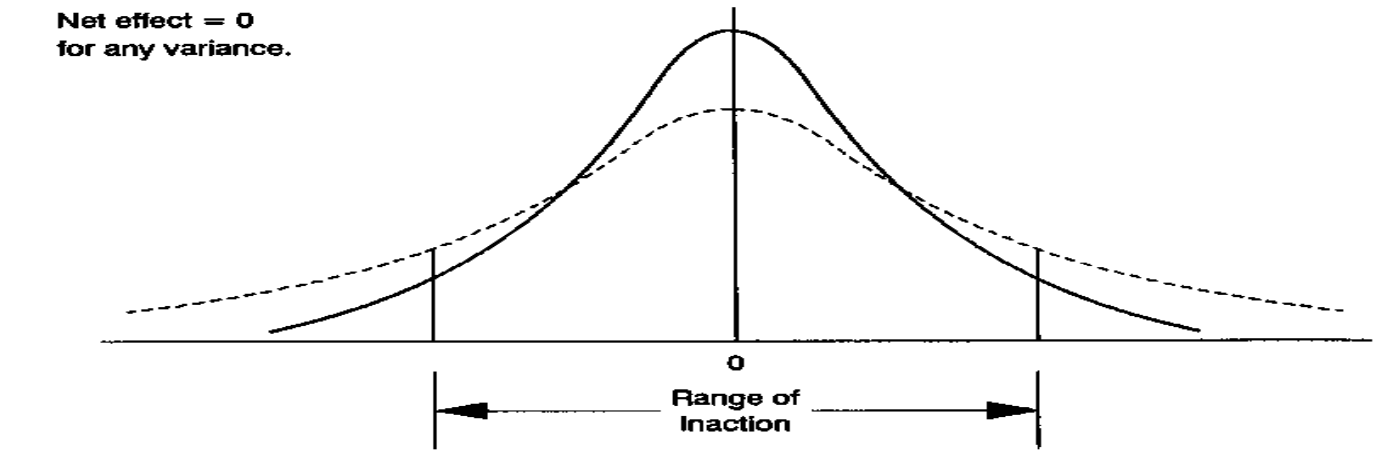
Notes: Each dot represents 2% of observations (during the pandemic, 2020 Q2 to 2022 Q2), grouped by impact of Covid-19 on sales. Zero responses are excluded. See notes to Figure A4 for survey question asked on the impact of Covid-19 on sales.

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 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 data)$_i$#2021Q2-2022Q2					0.1617***	0.1332***
					(0.0502)	(0.0478)
Percentage of costs that are electricity/gas (2 digit industry 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

Inflation and higher moments of inflation

Section subtitle

A. Symmetric Distribution



B. Skewed Distribution

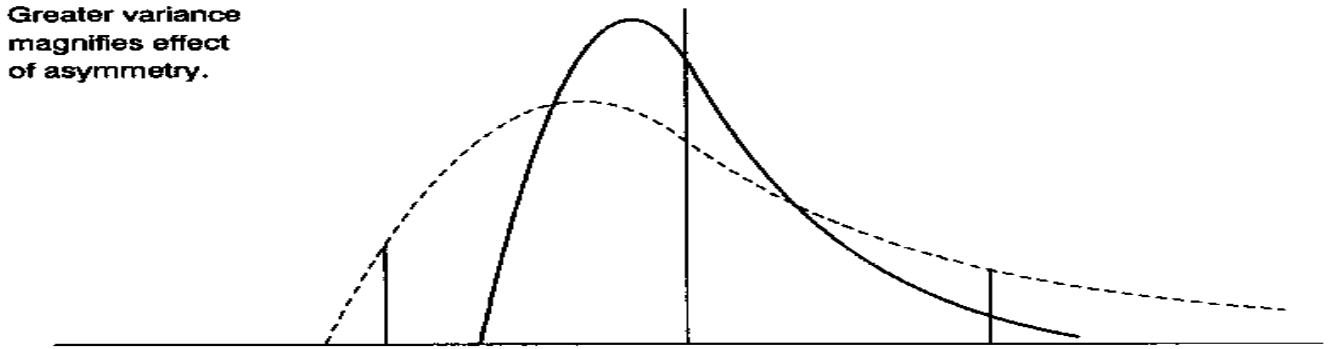


FIGURE II

TABLE IIIA

INFLATION AND THE DISTRIBUTION OF PRICE CHANGES

	Dependent variable: Inflation Unweighted measures of dispersion					
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	0.016	0.010	0.016	0.012	0.013	0.012
	(0.008)	(0.019)	(0.007)	(0.017)	(0.006)	(0.015)
Lagged inflation	0.527	0.490	0.619	0.597	0.736	0.728
	(0.134)	(0.176)	(0.121)	(0.158)	(0.110)	(0.142)
Standard deviation		0.087		0.053		0.019
		(0.264)		(0.233)		(0.202)
Skewness			0.011	0.011	−0.020	−0.020
			(0.003)	(0.003)	(0.009)	(0.009)
Skew*SD					0.357	0.356
					(0.097)	(0.098)
$\overline{R}^2$	.265	.248	.428	.414	.571	.559
D.W.	1.56	1.57	1.78	1.79	1.68	1.68
s.e.e.	0.040	0.041	0.036	0.036	0.031	0.031

- Here we follow Ball and Mankiw (1995) and calculate the first three moments of inflation at the industry-month level
- We replicate their results showing realized inflation and the distribution of (industry-level) price changes are increasing in volatility and skewness

Dependent Variable: Sample period: Jan 2017 – Jun 2022 (monthly)	(1)	(2) Realized price inflation	(3)	(4) Expected price inflation
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

Explaining our findings with a model

Section subtitle

- We rationalise our 2 key findings (kinked PC and Ball-Mankiw regressions) in a model, adapting Nakamura and Steinsson (2010)
- Continuum of firms subject to persistent idiosyncratic demand and productivity shocks. Face CES demand from consumers.
- Those shocks have stochastic second and third moments driven by independent Markov processes
- Three key ingredients
  - Menu costs
    - Generating an inaction zone where prices are not changed
  - Positive trend inflation
    - Inaction zone is asymmetric
  - Decreasing returns to scale at the firm level
    - Higher demand at the firm level increases costs, so that firms want to raise prices

- There is a continuum of firms producing differentiated consumption goods indexed by z using labour L. A parameter λ indexes the degree of decreasing returns to scale

$$y_t(z) = A_t(z)L_t^{\lambda}(z)$$

- Technology (labour productivity) is an AR(1) process, independent and mean zero across firms

$$\log\big(A_t(z)\big) = \rho \log\big(A_{t-1}(z)\big) + \epsilon_t(z)$$

- Consumers maximise the PDV of utility over a composite consumption good C and labour supply L

$$E_t \sum_{\tau=0}^{\infty} \beta^{\tau} \left[\frac{1}{1-\gamma} C_{t+\tau}^{1-\gamma} - \frac{\omega}{\varphi+1} L_{t+\tau}^{1+\varphi} \right]$$

- The composite consumption good is a CES aggregate over the varieties z, where consumer demand is subject to shocks d(z) which are independent across firms

$$C_t = \left[\int_0^1 \boldsymbol{d_t}(\boldsymbol{z}) c_t(z)^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}$$

- The result is the following demand curve for firms

$$c_t(z) = C \boldsymbol{d_t}(\boldsymbol{z}) \left(\frac{p_t(z)}{P_t} \right)^{-\theta}$$

- The demand shock d(z) is an AR(1) process. The innovations to the demand process are independently distributed across firms according to a mean zero ‘split normal distribution’ shock

$$\log\left(d_t(z)\right) = \rho_d \log\left(d_{t-1}(z)\right) + \epsilon_t^d$$

$$\epsilon_t^d \sim SN(0, \sigma_{d1,t}^2, \sigma_{d2,t}^2)$$

- The variance and skewness of this distribution are driven by independent two-state Markov processes

- The money supply process ensures the aggregate price level is given by a random walk with drift

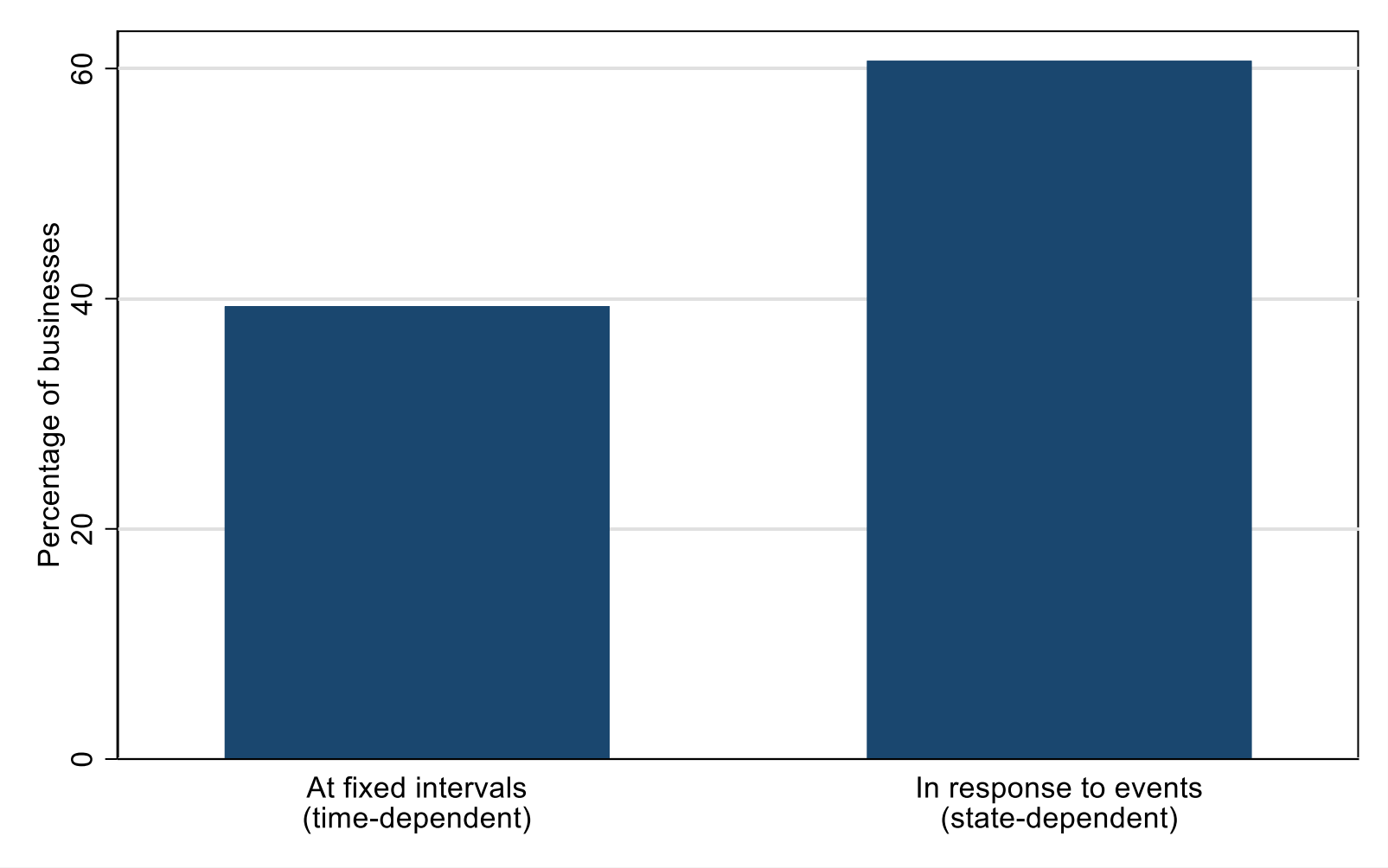
$$\log P_t = \mu + \log P_{t-1} + \eta_t$$

- Firms can adjust their own prices by paying a menu cost worth K units of labour. $I_t(z)$ is an indicator variable of whether the firm has changed its price. So per-period profits are given by

$$\Pi_t(z) = Cd_t(z)\left(\frac{p_t(z)}{P_t}\right)^{1-\theta} - \left(\frac{p_t(z)}{P_t}\right)^{-\frac{\theta}{\lambda}} \frac{\lambda(\theta-1)}{\theta} - \frac{\lambda(\theta-1)}{\theta} KI_t(z)$$

- Firms maximise the PDV of profits

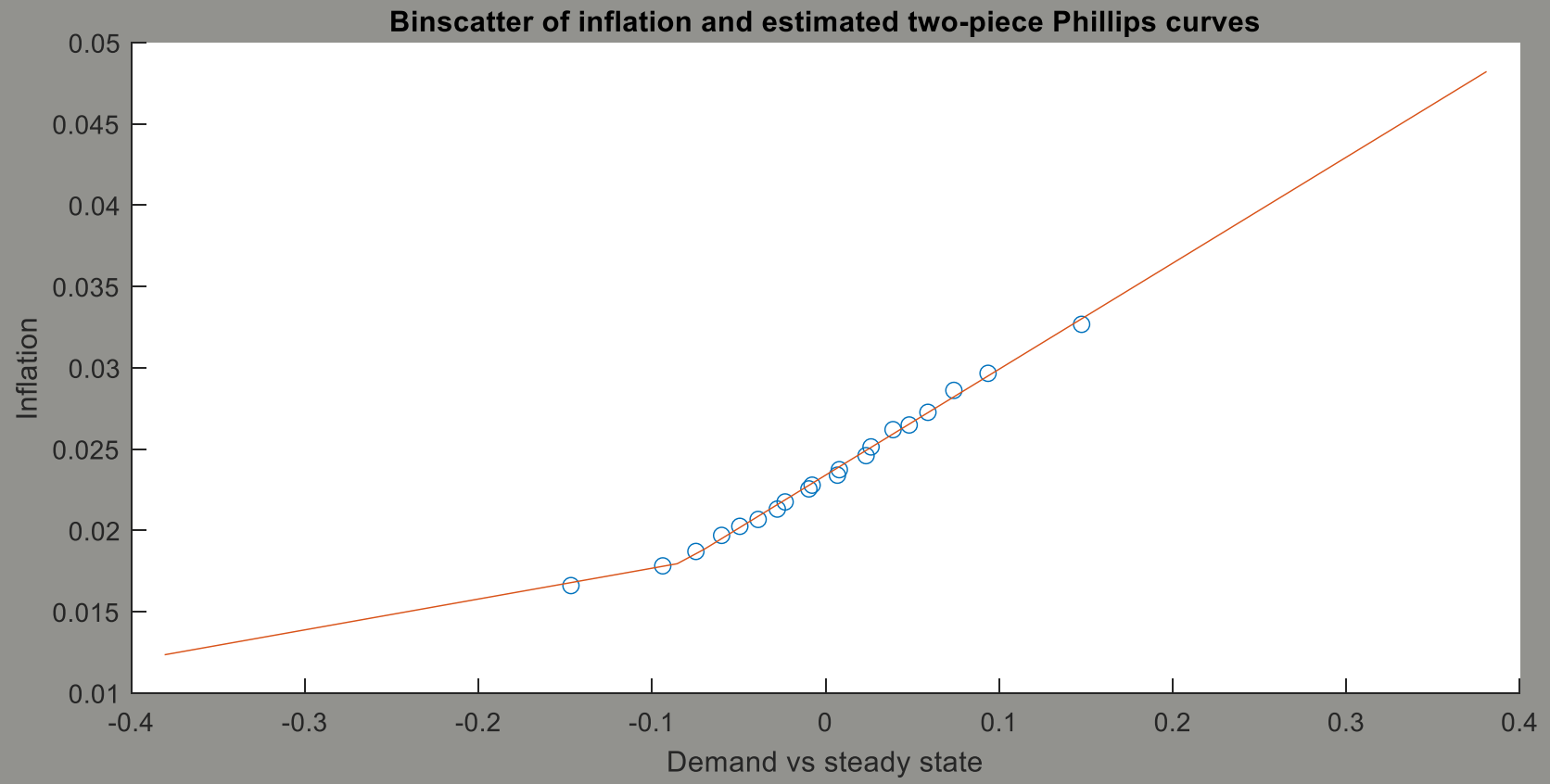
$$V\left(\frac{p_{t-1}(z)}{P_t}, A_t(z), d_t\,(z), \sigma_{d1,t}, \sigma_{d2,t}\right)$$
$$= \max_{p_t(z)}\left[\Pi_t(z) + \beta E_t V\left(\frac{p_t(z)}{P_{t+1}}, A_{t+1}(z), d_{t+1}(z), \sigma_{d1,t+1}, \sigma_{d2,t+1}\right)\right]$$



Notes: DMP question 'Which of the following best describes how your business usually sets prices?'; (i) 'Mostly change prices in response to specific events (eg changes in costs or demand)'; 'Mostly change prices at fixed intervals (eg once a year or once a quarter, etc)'.

- We solve the model by:
    1. Conjecturing a law of motion for inflation that is a linear function of aggregate demand and aggregate volatility (in the spirit of Krusell-Smith)
    2. Solving for the firms' decision rules (using value function iteration)
    3. Aggregating the decisions to obtain aggregate inflation dynamics
    4. Updating the law of motion in Step 1
    5. Iterating until convergence
- We then simulate the model for 1,000 firms and 20,000 periods

Binscatter of firm level inflation and two-piece estimated Phillips curve

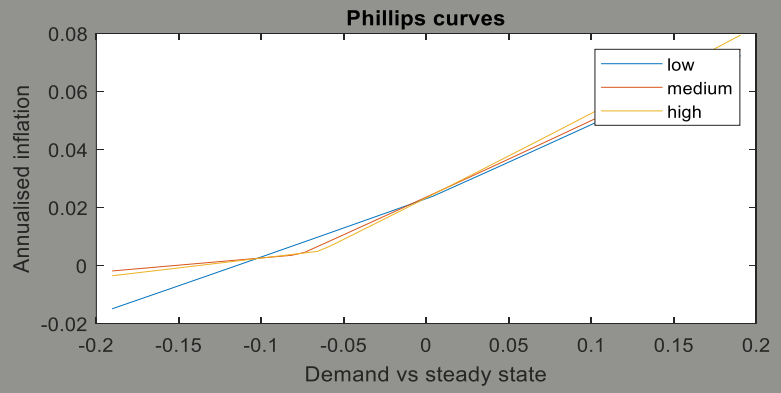


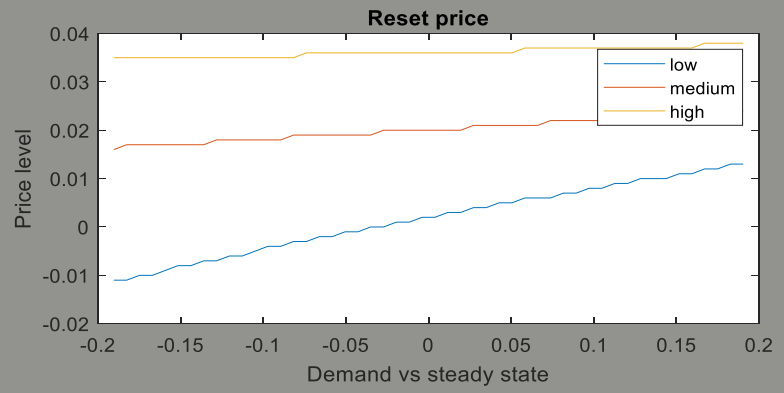
Model qualitatively replicates volatility/skewness regressions – the magnitudes depend on the assumptions for model parameters

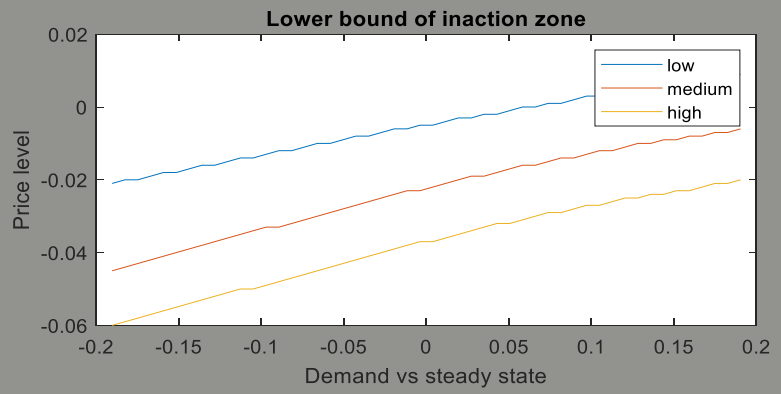
	Monthly inflation
Std deviation of inflation across firms	0.34
[t-stat]	23.0603
Skewness of inflation across firms	100.26
[t-stat]	5.6250

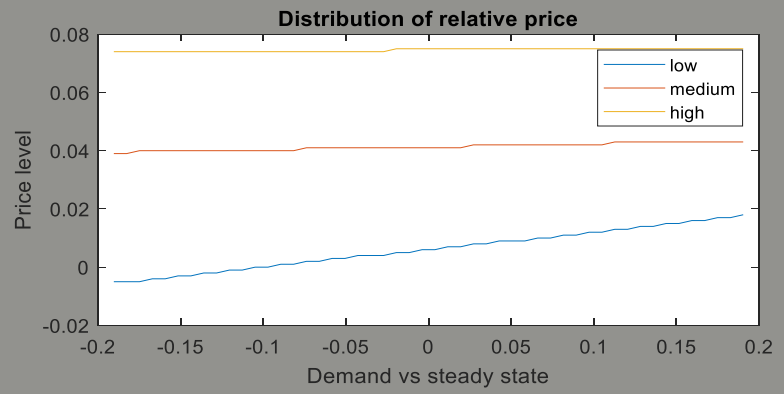
- We vary the following parameters of the model to see which are important to generate our key results
  - **Trend inflation**: lower inflation flattens the PC and reduces the asymmetry
  - **Menu costs**: lower menu costs shrink the inaction zone and remove kink from the PC
  - **Decreasing returns to scale**: CRS yields a flat PC at the firm level

Menu costs

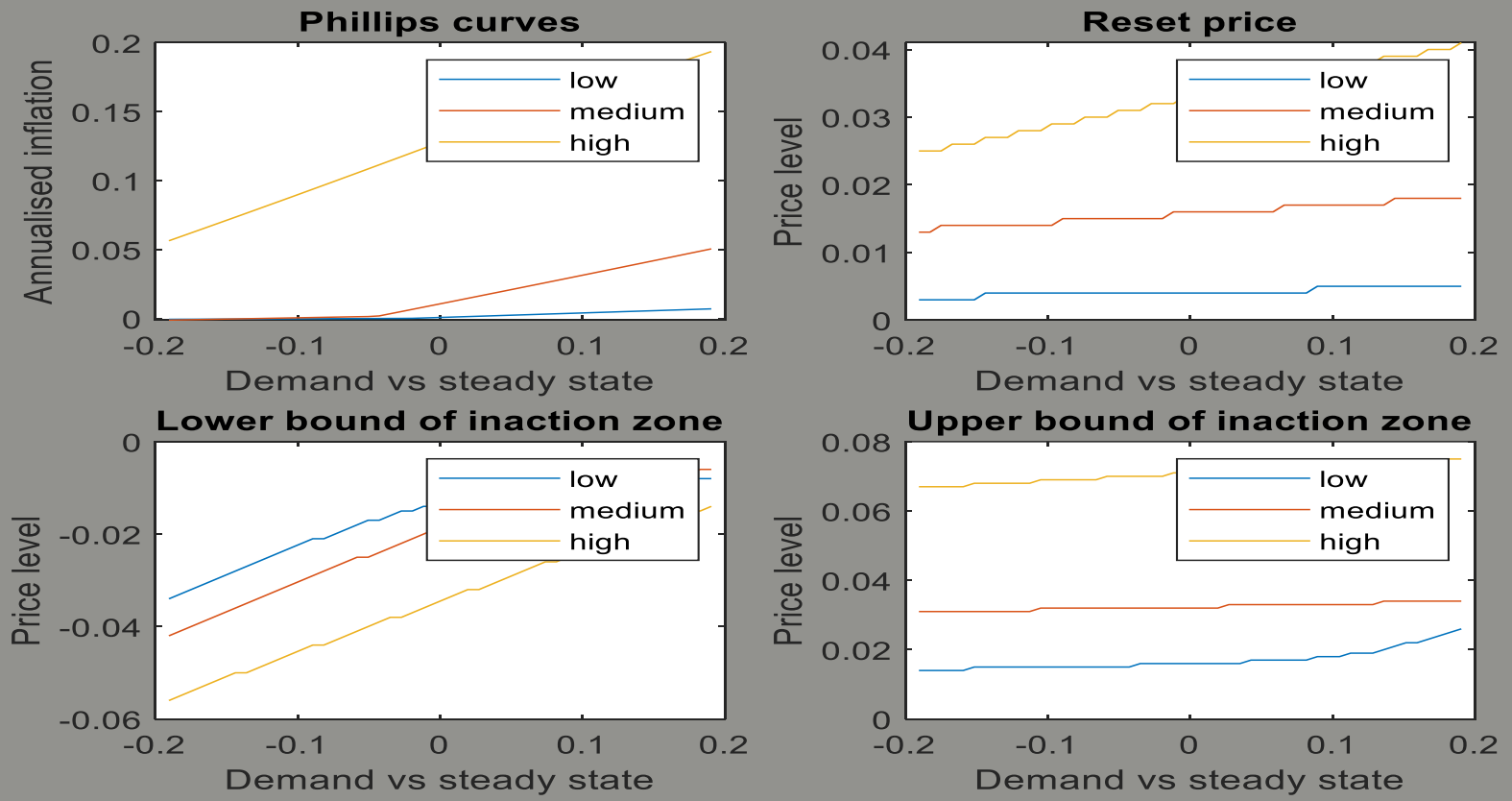

Phillips curves
Annualised inflation
Demand vs steady state
low
medium
high


Reset price
Price level
Demand vs steady state
low
medium
high

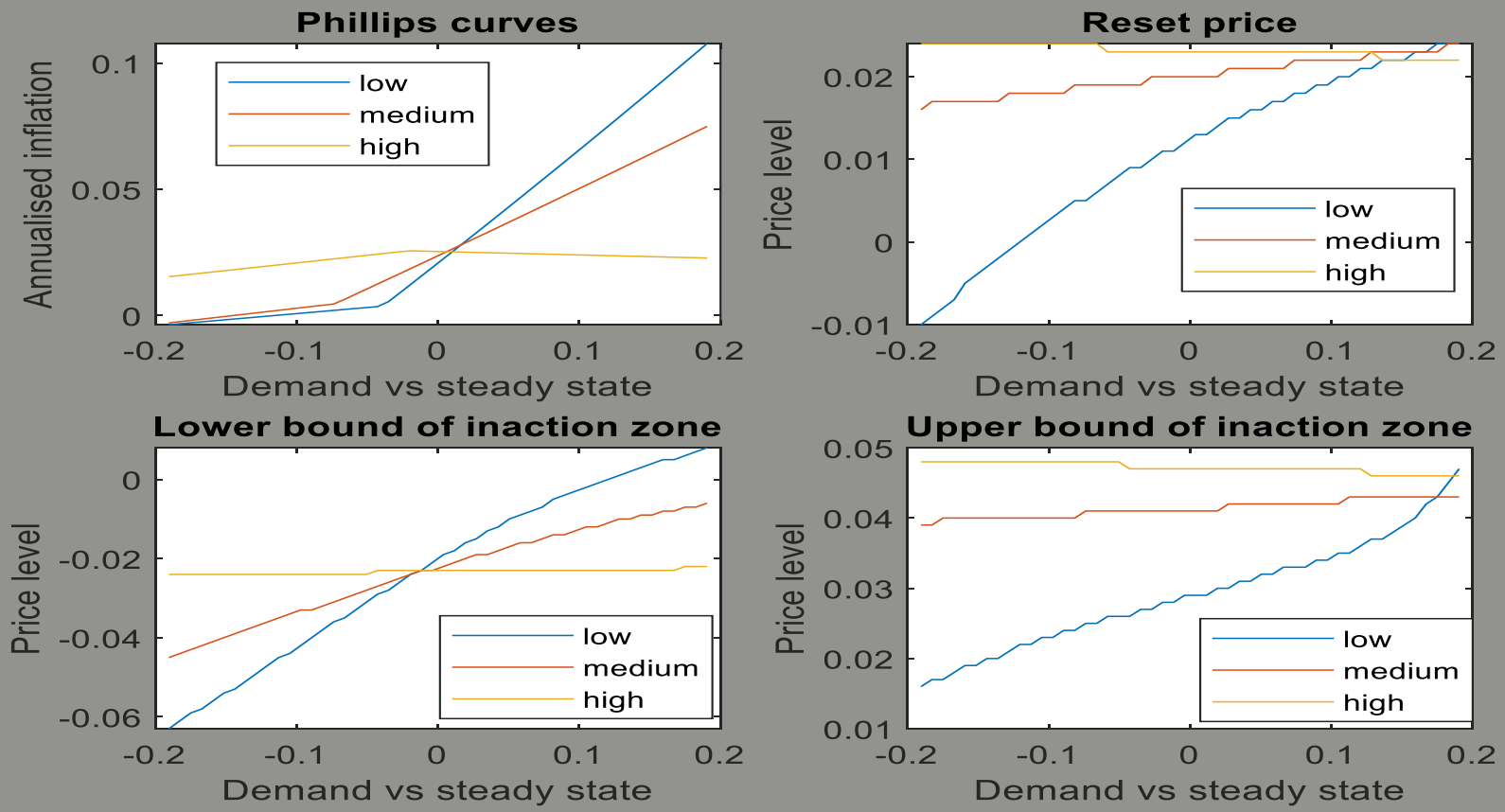

Lower bound of inaction zone
Price level
Demand vs steady state
low
medium
high


Distribution of relative price
Price level
Demand vs steady state
low
medium
high

Trend inflation



Returns to scale



- We study the dynamics of inflation at the firm level using the unique DMP survey of UK firms and the 2020-22 period as a laboratory
- We address 2 questions – one specific, one timeless:
  - what shocks account for the behaviour of inflation during 2020-2022?
  - what explains the behaviour of inflation at the firm level?
- We have three related findings:
  - Covid effects were large on demand but small on inflation
  - The Phillips curve is kinked at the firm level
  - Inflation is positively related to the variance and skewness of shocks to inflation
- We reproduce the last two findings in a model with positive trend inflation, menu costs and decreasing returns to scale, and show that we need all three.
- Coming soon:
  - Improve accuracy of model solution algorithm and calibration
  - Compare simulations more carefully to empirical results at the firm level
  - Look for kink in simulated aggregate Phillips curves (key point for policymakers)

Conclusions

Section subtitle