How Curvy is the Phillips Curve?

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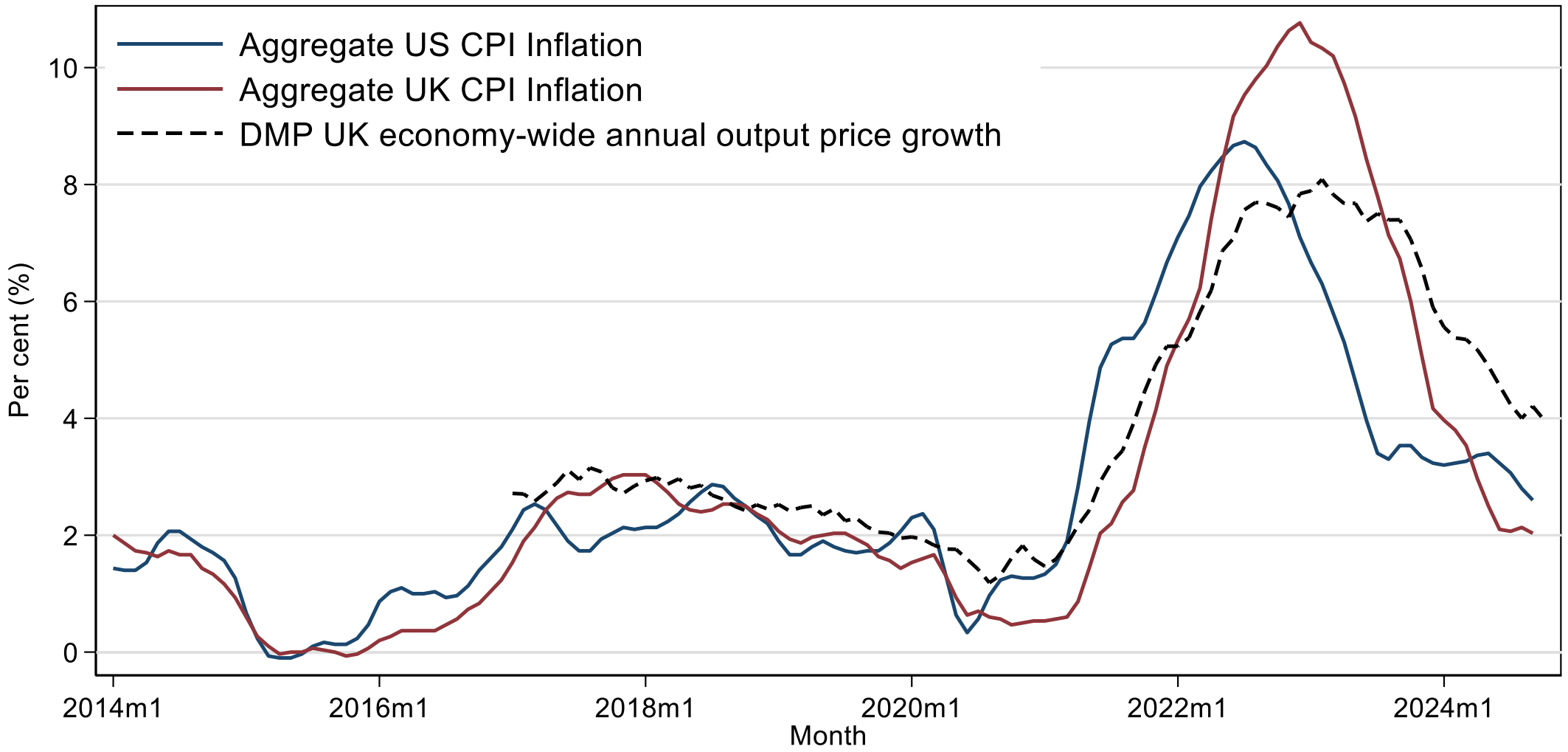
Motivation: Understanding the surge in inflation from 2021



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

Phillip (1958) noted a convex inflation unemployment relationship

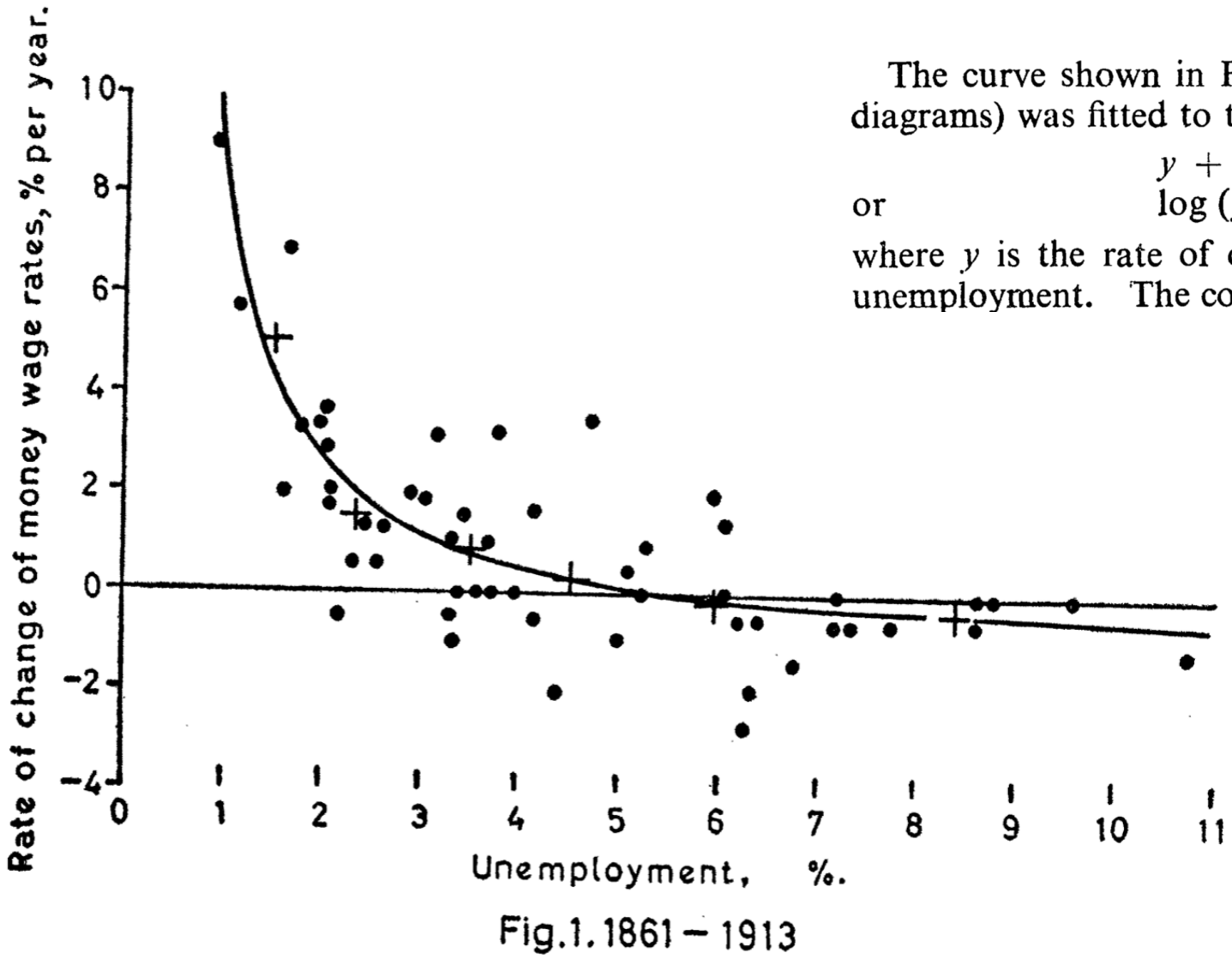


Fig.1. 1861 – 1913

The curve shown in Figure 1 (and repeated for comparison in later diagrams) was fitted to the crosses. The form of equation chosen was

$$y + a = bx^c$$

or

$$\log (y + a) = \log b + c \log x$$

where y is the rate of change of wage rates and x is the percentage unemployment. The constants b and c were estimated by least squares

Source: Phillips (1958), "The relation between unemployment and the rate of change of money wages in the United Kingdom, 1861-1957"

In contrast the Phillips curve is usually *modelled* as linear

I. Introduction

The Phillips curve is a formal statement of the common intuition that if demand is high in a booming economy, this will provoke workers to seek higher wages and firms to raise prices. A well-known formulation is the New Keynesian Phillips curve:

$$\pi_t = \beta E_t \pi_{t+1} - \kappa\left(u_t - u_t^n\right) + v_t. \tag{1}$$

According to this formulation, inflation π_t is determined by three factors: expected inflation $E_t\pi_{t+1}$, the output gap—measured here as the difference between unemployment u_t and the natural rate of unemployment u_t^n—and cost-push shocks v_t. The slope of the Phillips curve κ represents the sensitivity of inflation to the output gap (i.e., to an increase in demand).

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THE SLOPE OF THE PHILLIPS CURVE: EVIDENCE FROM U.S. STATES*

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Question: Is the Phillips curve significantly curvy (convex)?

Empirics:

- Macro: international panel data showing robust convex Phillips curve
- Micro: major new UK (and US) firm survey data, robust convex firm Phillips curve from three different empirical exercises.
    - convexity in response to firm-level demand and cost shocks
    - convexity only in higher inflation firms and industries
    - convexity only in short-run (first 1 to 2 years)

Model:

- Set-up a model with menu costs and positive trend inflation
- Show this matches empirical results and study implications for the aggregate Phillips Curve

Paper argues *convexity* remains a feature of Phillip's curve (notably for larger shocks)

Some related literature examples

Empirics on convex Phillips Curve
- Micro: Peltzman (2000) finds prices about 2x responsive to input price rises and falls
- Macro: Phillips (1958)…Forbes, Gagnon and Collins (2021), Ball, Leigh and Mishra (2022), Benigno and Eggertson (2024) find convex Philips curve in US and cross-country panel data

Mechanisms of convex Phillips Curve
- Wages: Benigno and Eggertsson (2023) build on Phillips (1958) downward nominal rigidity
- Demand: Harding, Linde and Trabandt (2023) generate demand convexity
- Capacity: Boehm and Pandalai-Nayar (2020) use Census QSPC on capacity constraints

Menu cost models
- Old literature on price changes like Mankiw (1985), Ball and Mankiw (1994 and 1995).
- Ss models Golosov and Lucas (2007), Gertler and Leahy (2008), Midrigan (2011) and Nakamura & Steinsson (2012), Auclert, Rigato, Rognlie & Straub (2024), Blanco, Boar, Jones & Midrigan (2024)

Approach:
- Mavroedis, Plagborg-Moller and Stock (2014), Beraja, Hurst and Ospina (2019), Hazell, Herreno, Nakamura and Steinsson (2022) use dis-aggregated (sub-macro) data

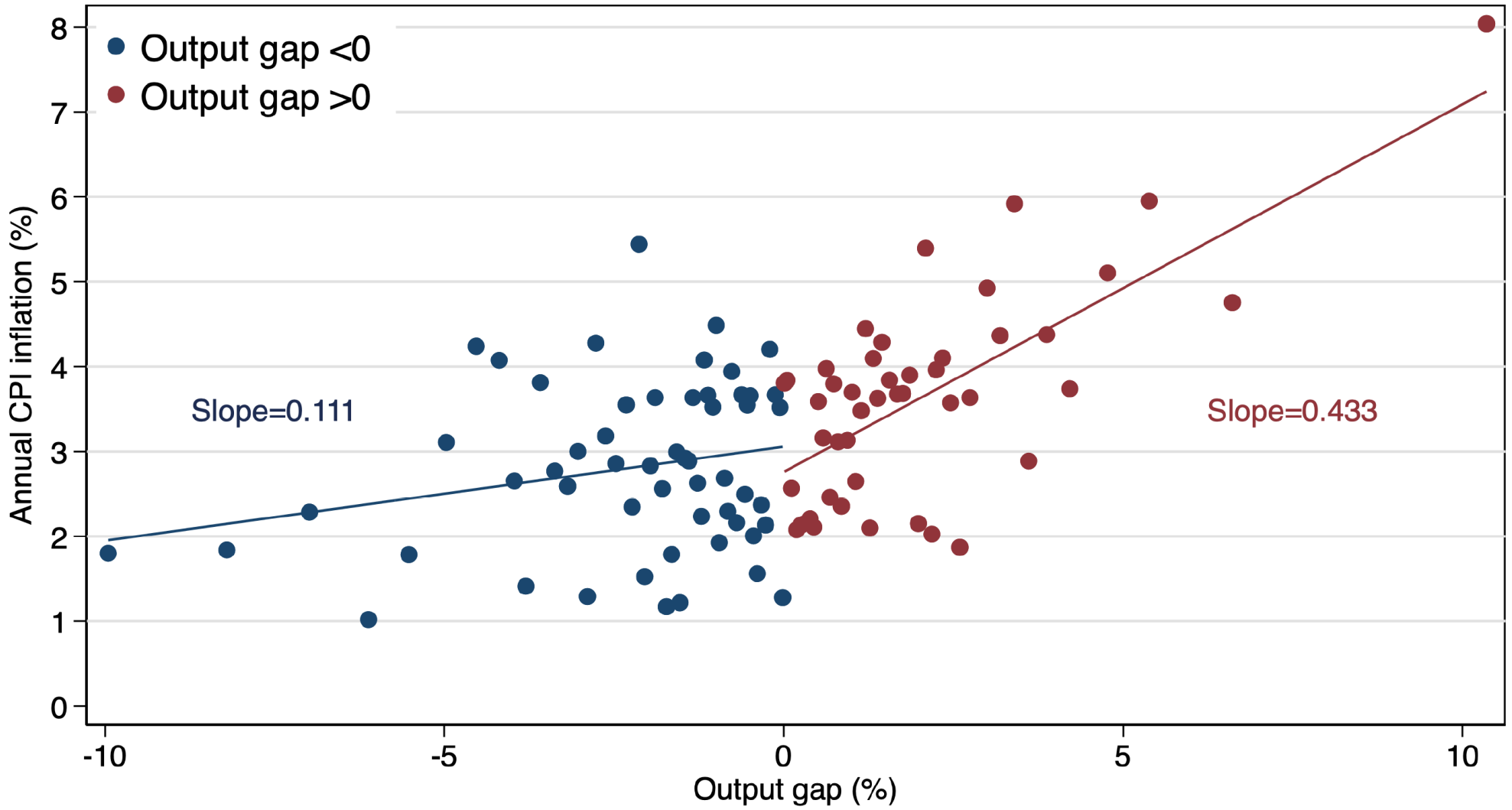
Macro Phillips Curves

Firm-level Phillips curves

Model and simulation results

Additional Data/Model Predictions

Raw macro data



Notes: This scatter plot covers 38 countries over the period 1990-2023. Each point represents 1% of the sample, split across the horizontal axis.

Macro data

Firm-level Phillips curves

Model and simulation results

Additional Data/Model Predictions

The Decision Maker Panel (DMP)

- Monthly online panel survey of UK businesses (5-10 minute survey).
- Mainly completed by CFOs/Finance Directors and CEOs of firms.
- Launched in late 2016. Jointly run by the Bank of England, University of Nottingham and King's College London.
- Large and representative survey.
- Around 2,500 monthly responses, covering around 4% of UK employment.
- Asks firms regular questions about recent developments and year-ahead expectations (including distribution of expectations) for sales, prices, employment, and investment + special questions.
- The DMP has been used to study multiple big policy issues, including Brexit, Covid-19, Russia-Ukraine war, and inflation.

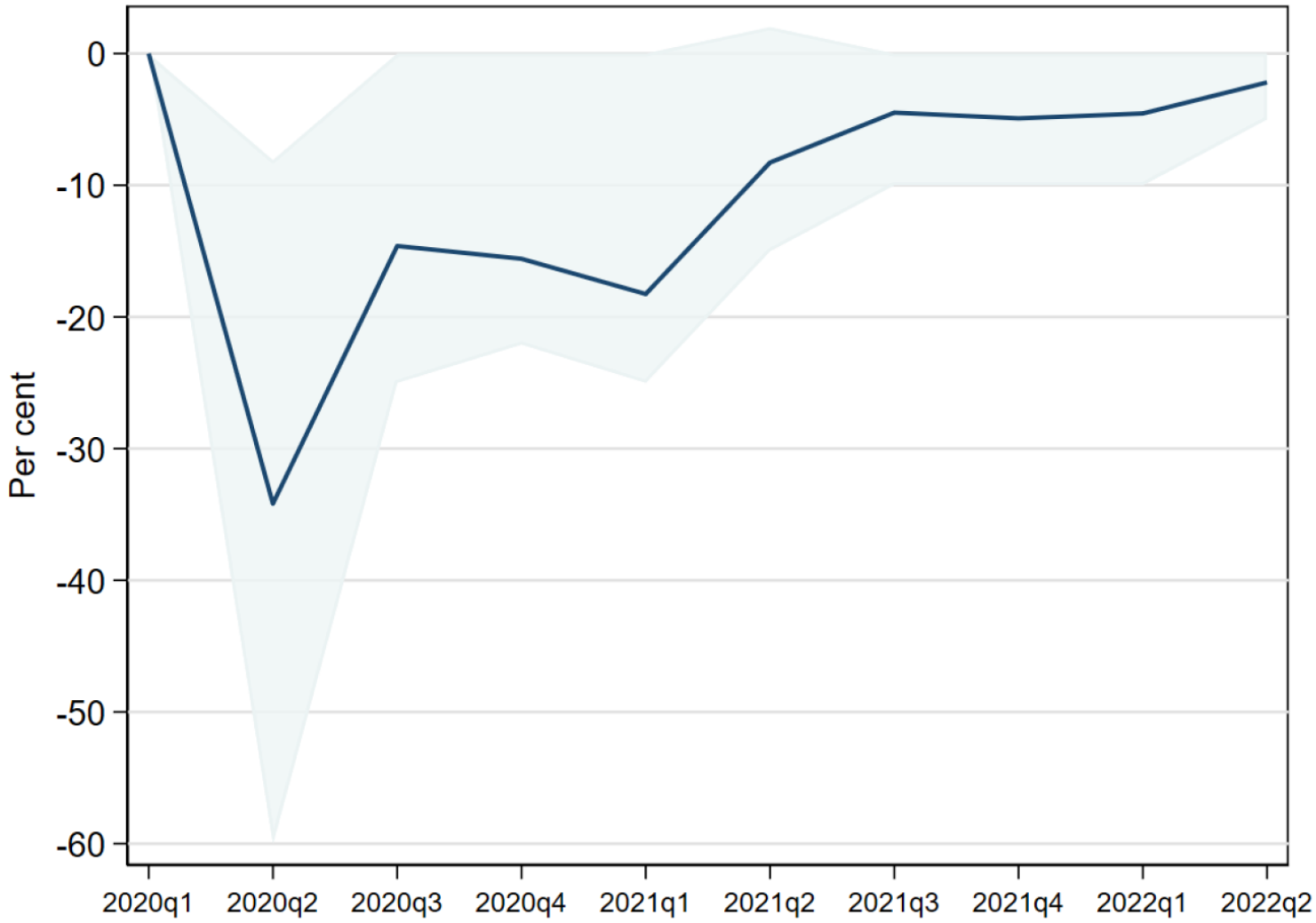
Show convexity of prices to demand shocks in three ways

1. Price response to COVID demand shocks
2. Price forecast errors vs sales forecast errors
3. Hypothetical question

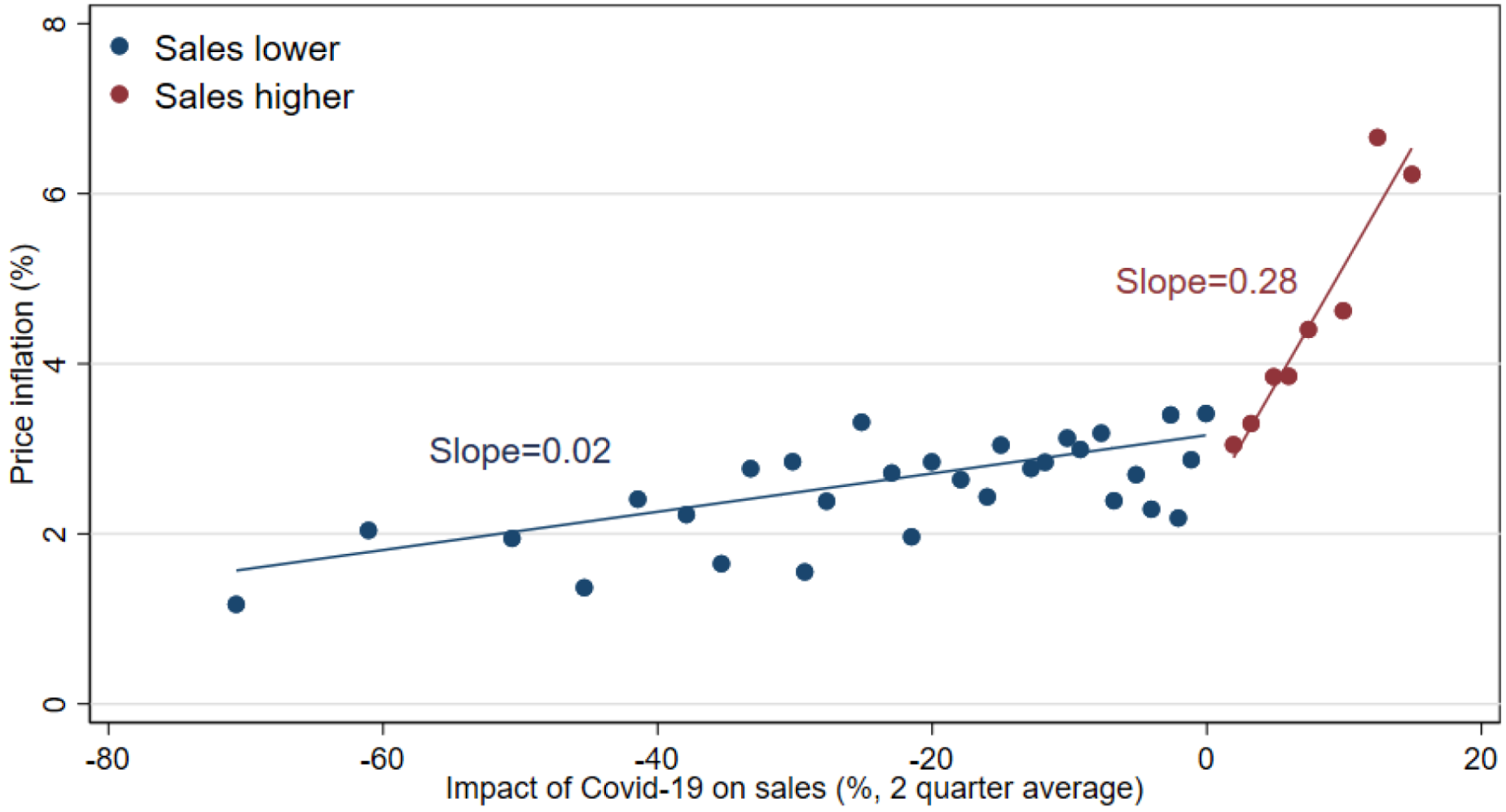
DMP collected COVID data – e.g. impact on firm sales

"*Relative to what would otherwise have happened, what is your estimate for the impact of the spread of Covid-19 on the sales of your business in each of the following periods?*"

The shaded area presents the interquartile range.



1. Convex firm response of prices to the *COVID shock*



Notes: Each dot represents 2% of observations (during the pandemic, 2020 Q2 to 2022 Q2), grouped by impact of Covid-19 on sales. The scatter plot is based on 11,343 observations from 3,694 firms.

1. Convex firm response of prices to the *COVID shock* - regression

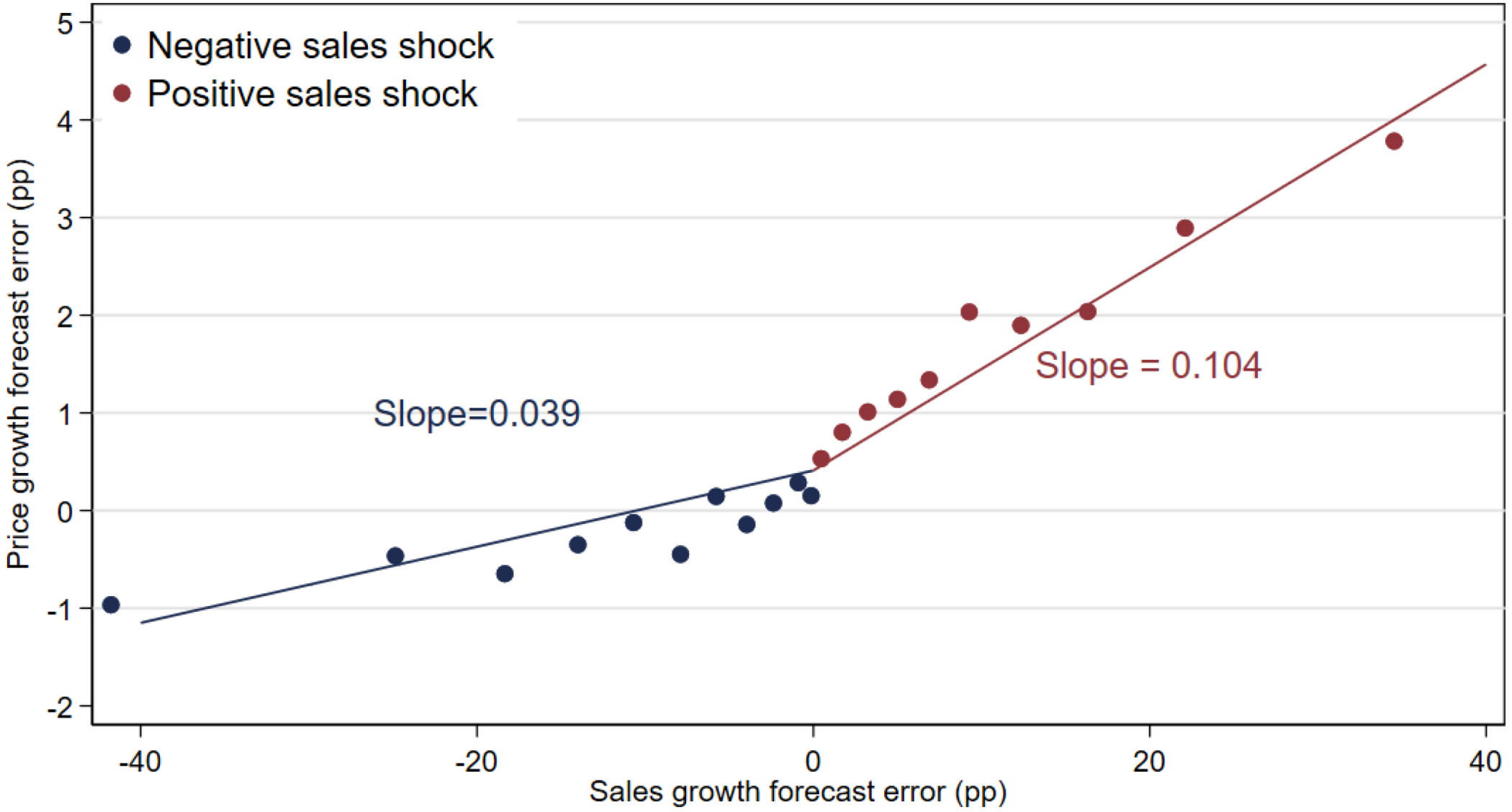
	(1)	(2)	(3)	(4)	(5)
Dependent variable:	Annual own-price inflation (%)				
Sample period:	2017Q1 to 2022Q2 (quarterly data)				
Covid impact on sales$_{it}$	0.0218***	0.0382***			
	(0.0031)	(0.0060)			
Covid impact on sales$^2_{it}$		0.0004***			
		(0.0001)			
Covid impact on sales$_{it}$ × sales impact postive$_{it}$			0.1247***	0.1038***	0.0900***
			(0.0256)	(0.0251)	(0.0245)
Covid impact on sales$_{it}$ × sales impact negative$_{it}$			0.0165***	0.0186***	0.0172***
			(0.0034)	(0.0034)	(0.0034)
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)
Supply-side controls	No	No	No	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes
R^2	0.546	0.546	0.546	0.560	0.582
Number of Observations	34,076	34,076	34,076	34,076	34,076
Test Covid impact on sales coefficients equal (p-value)			0.000	0.001	0.004

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

2. Convex relationship between price and sales *forecast errors*

- Use the strong panel dimension of the DMP to compare firm expectations about sales growth/price growth to their realizations a year later and construct forecast errors.
  - $\text{ForecastError}^{Y}_{i,t} = Y_{i,t} - E_{t-12}[Y_{i,t}]$
- Regress price forecast errors on sales forecast errors
  - $\text{ForecastError}^{\Pi}_{i,t} = \alpha + \beta \text{ForecastError}^{Y}_{i,t} + \varepsilon_{i,t}$
- Key advantage is longer time series going back to 2018, so can compare pre-pandemic years versus years since 2020.

2. Convex relationship between price and sales *forecast errors*



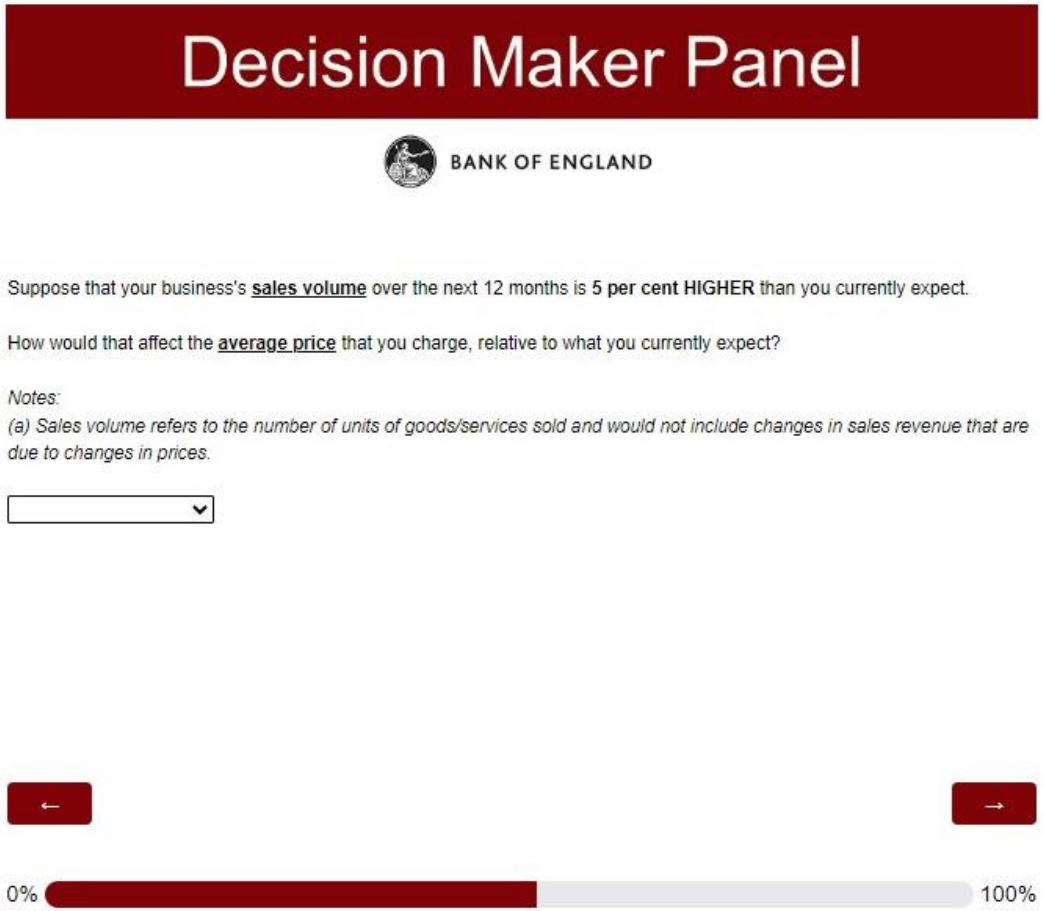
2. Convex relationship between price and sales *forecast errors*

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	Price growth forecast error (pp)				Price growth forecast error (pp)	
Sample period:	2018Q1 to 2024Q1				2018Q1-2019Q4	2020Q1-2024Q1
Sales growth forecast error	0.0514***	0.0545***				
	(0.0040)	(0.0041)				
Sales growth forecast error^2		0.0004***				
		(0.0001)				
Sales growth forecast error X Error ≥ 0			0.1017***	0.0734***	0.0522***	0.0738***
			(0.0071)	(0.0069)	(0.0127)	(0.0075)
Sales growth forecast error X Error < 0			0.0381***	0.0324***	0.0195	0.0365***
			(0.0046)	(0.0058)	(0.0127)	(0.0064)
Time fixed effects	Yes	Yes	No	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	No	Yes	Yes	Yes
R^2	0.382	0.383	0.046	0.383	0.463	0.405
Number of Observations	16,440	16,440	17,594	16,440	3,284	12,501
Test coefficients equal (p-value)			0.000	0.000	0.109	0.001

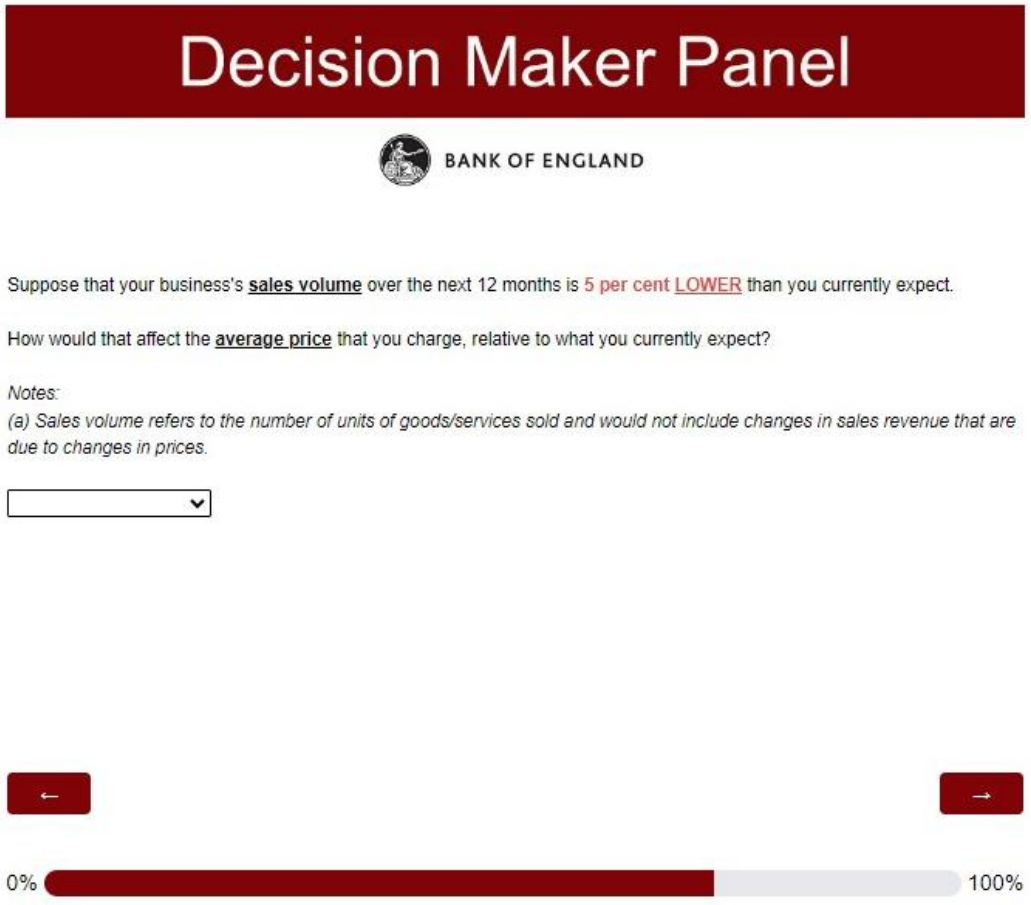
Notes: This table shows the relationship between nominal sales growth forecast errors and annual price growth forecast errors. Sales forecast errors are trimmed at the 5th and 95th percentiles by quarter. Price forecast errors are winsorised at the 1st and 99th percentiles. The constant of the regressions are also estimated but not reported. Standard errors are clustered at the firm level and are reported in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

3. Convex relationship between *hypothetical price and sales shocks*

Panel A: Main scenario

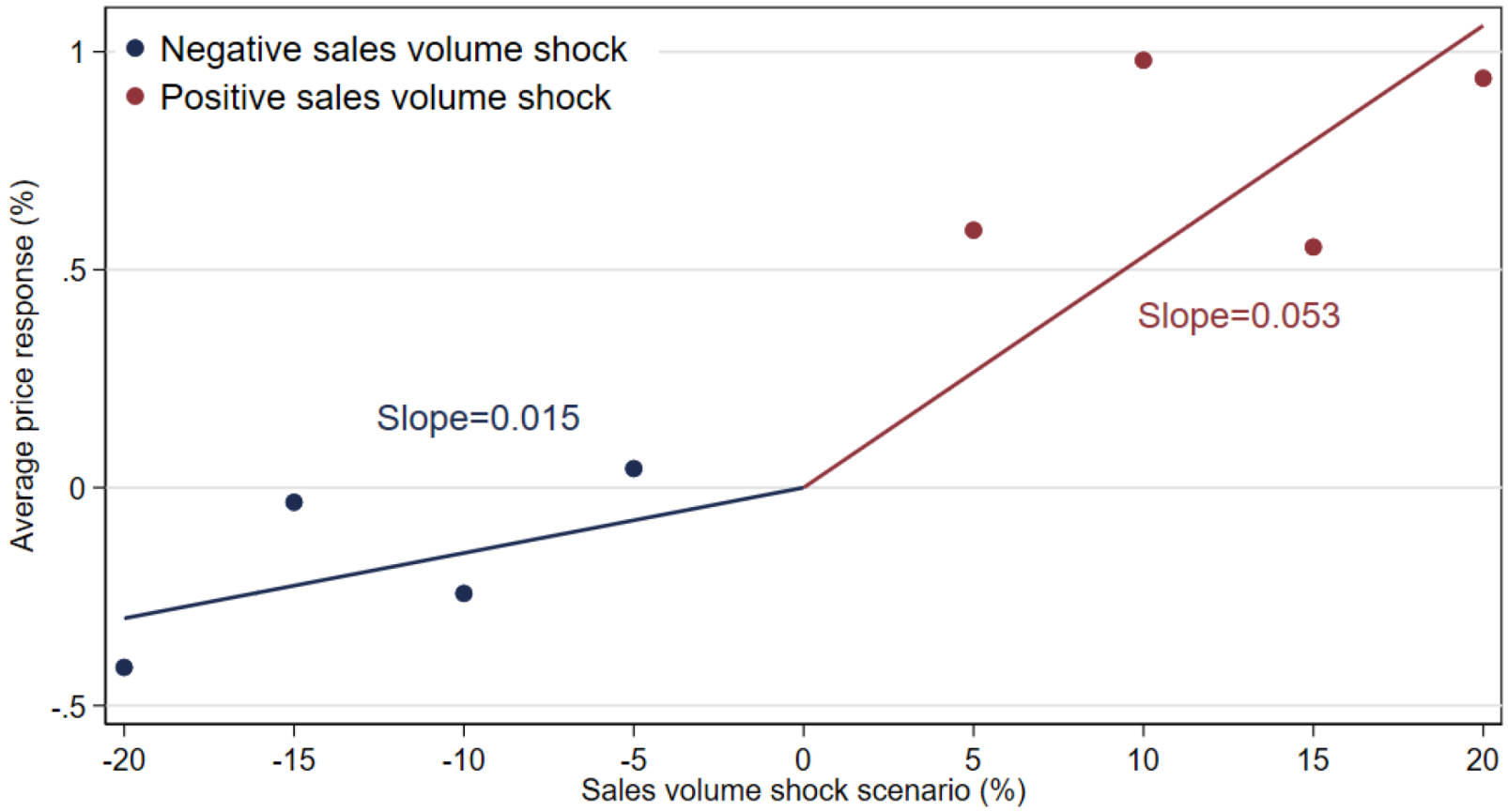


Panel B: Flipped scenario



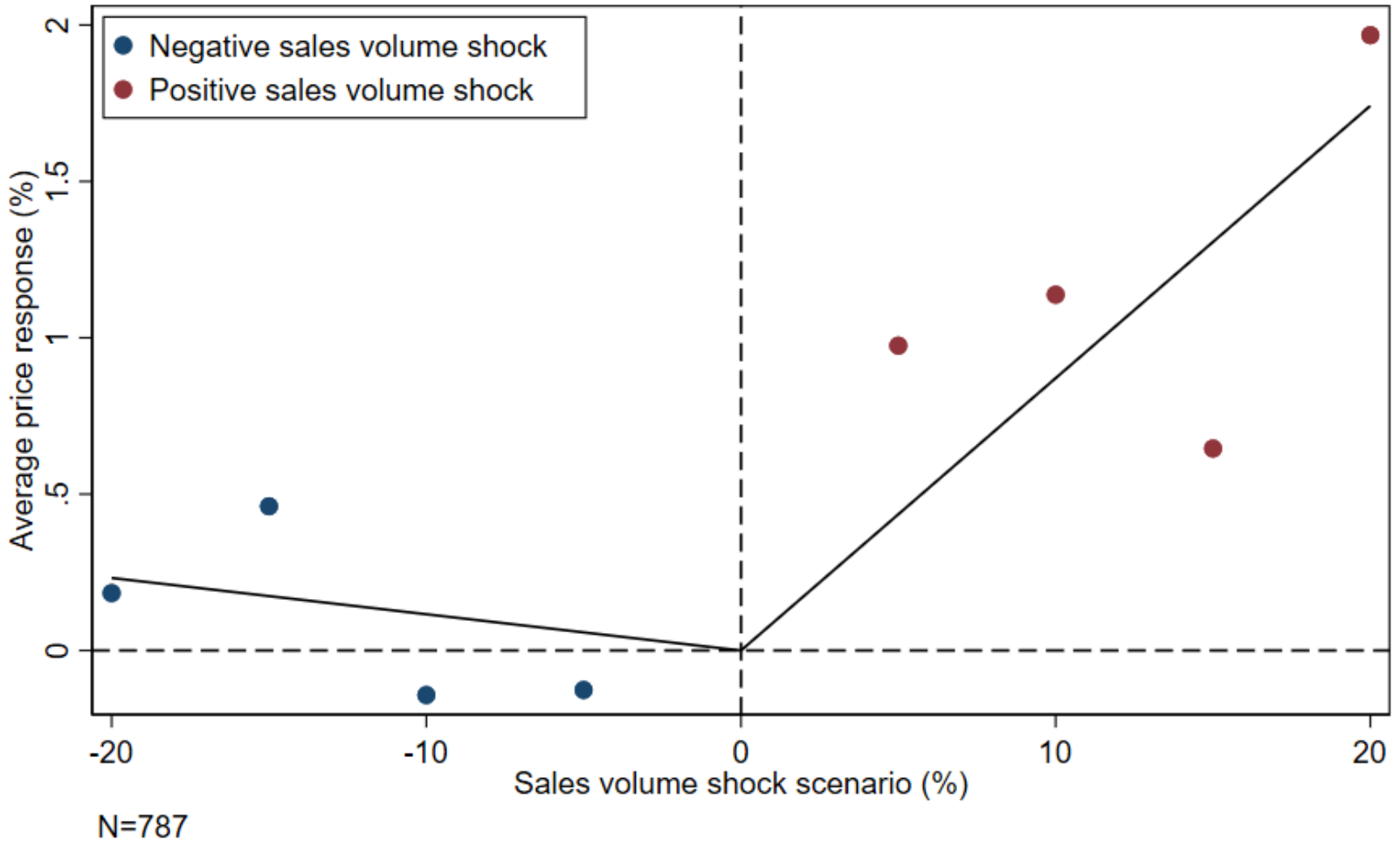
Notes: Firms are randomised into one of four scenarios for sales volume: ±5%, ±10%, ±15%, ±20%. Firms are presented with both the positive and negative values for a given scenario. These questions were asked in December 2023 to January 2024, and in August 2024 to October 2024.

3. Convex relationship between *hypothetical price and sales shocks*



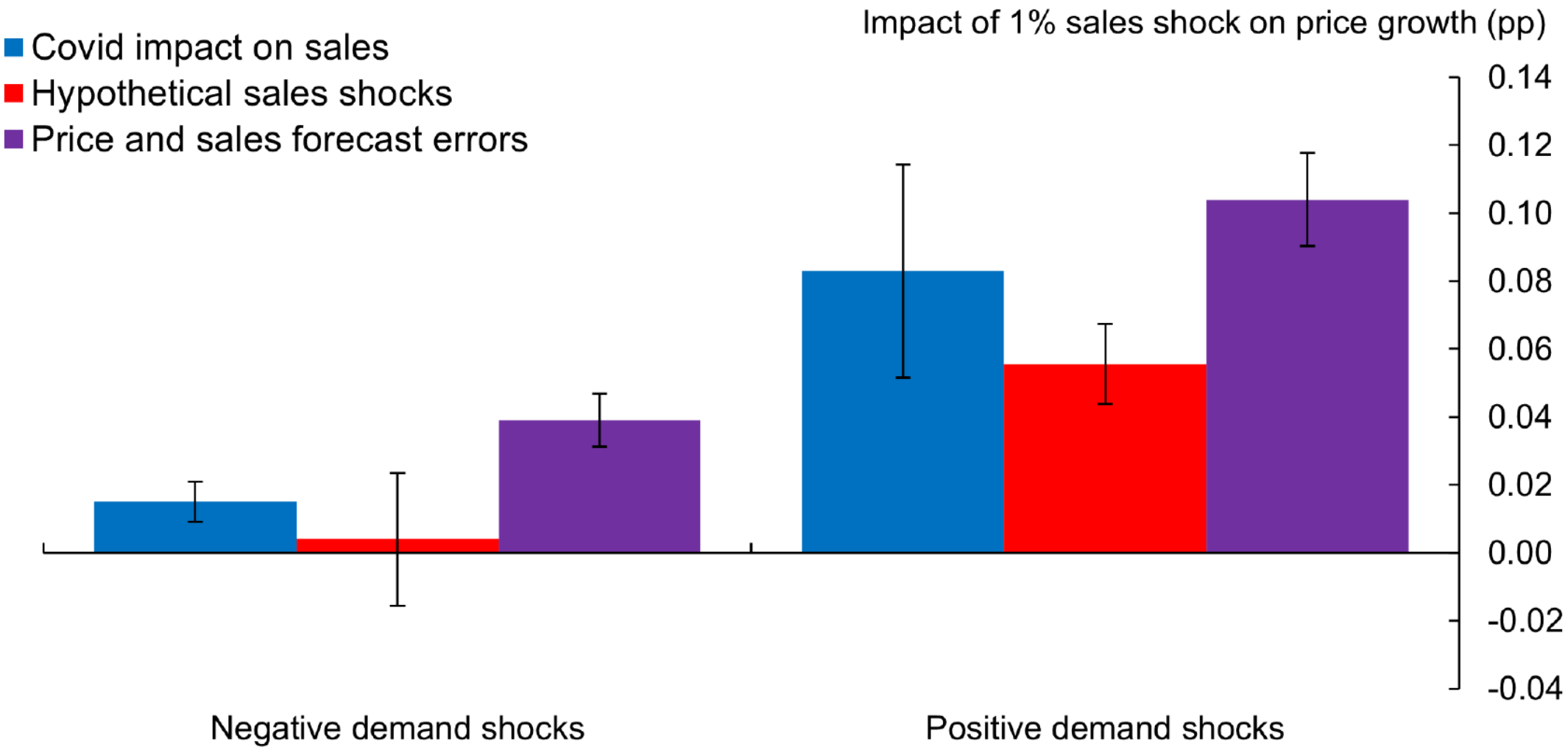
Notes: This figure reports responses to the question "Suppose that your business's sales volume over the next 12 months is X per cent higher/lower than you currently expect. How would that affect the average price you charge, relative to what you currently expect?" Firms are randomised into one of four scenarios for sales volume: ±5%, ±10%, ±15%, and ±20%. Firms are presented with both the positive and negative values for a given scenario. The scatter plot is based on 2,372 observations from 1,186 firms. The results are unweighted.

3. Also convex response for *US firms* from similar question in Atlanta Fed's Survey of Business Uncertainty



Notes: This figure reports responses to the question: "Suppose that your firm's sales volume over the next 12 months is [5/10/15/20] percent higher/lower than you currently expect. How would that affect the average price you charge, relative to what you currently expect? Sales volume refers to the number of units of goods or services sold and would not include changes in sales revenue that are due to changes in prices." These questions were fielded in the June 2024 survey wave of the Atlanta Fed's Survey of Business Uncertainty.

Similar non-linearity across our three empirical exercises



Macro data

Firm-level Phillips curves

Model and simulation

Additional Data/Model Predictions

Model description

- To rationalise our findings, we adapt and estimate a model of firm price-setting based on Nakamura & Steinsson (2008, 2010)
- The model has three key features:

  1) Menu costs: Firms will not change prices when the current price is ‘close’ to the optimal (i.e. there is a zone of inaction)

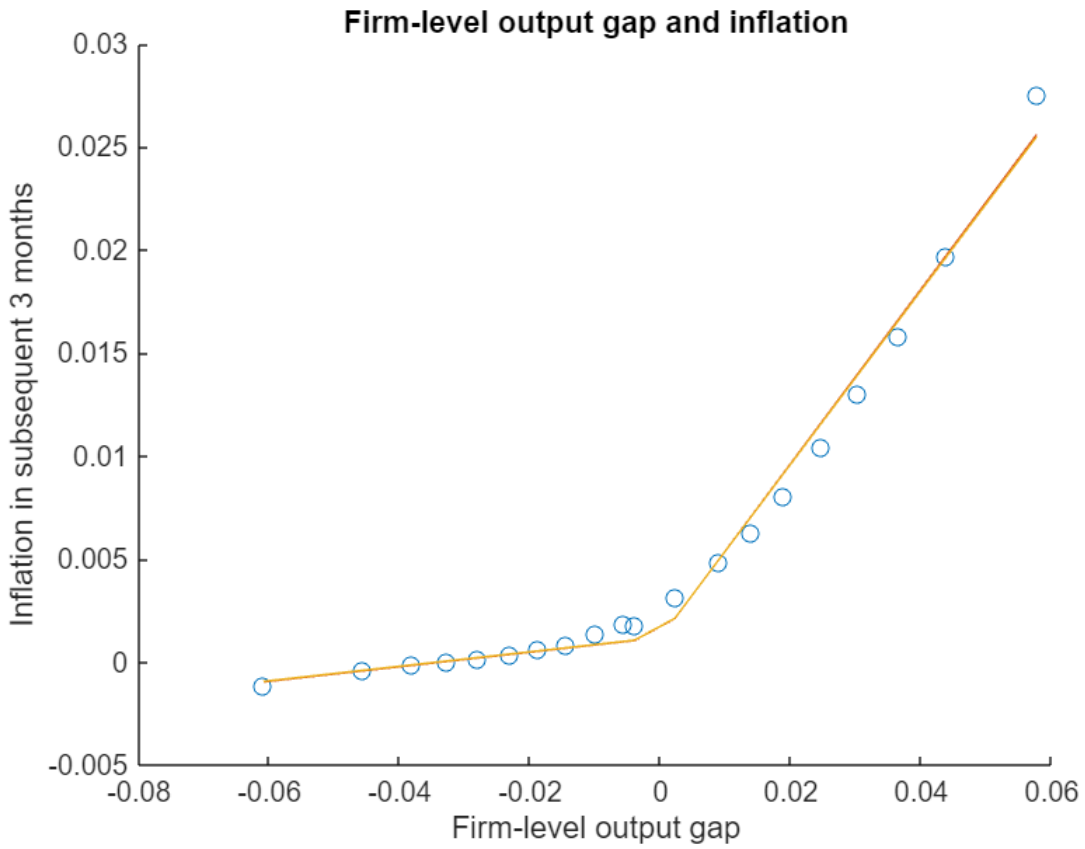
  2) Positive trend inflation: Inaction zone for price changes is asymmetric

  3) Decreasing returns to scale: Higher demand increases costs, so firms want to raise prices

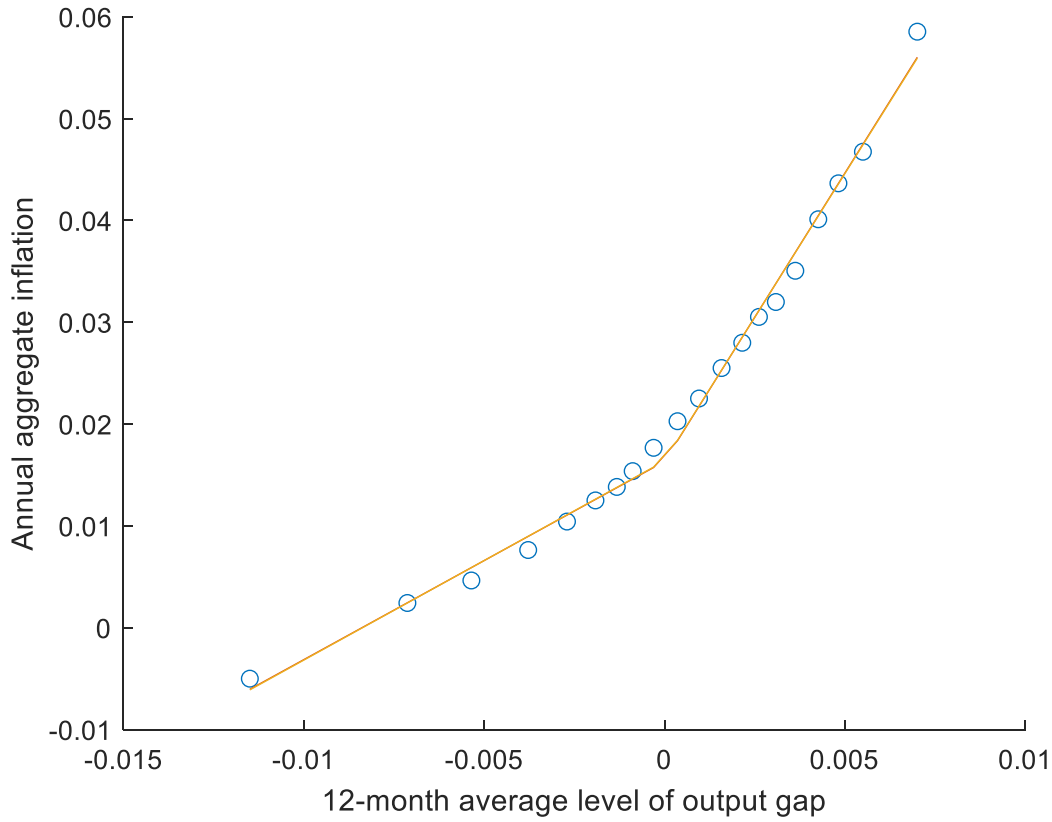
- We then simulate the model for 1000 firms and 20000 periods

Regressions on simulated data generate convex responses

Firm Simulated Data



Macro Simulated Data



***Good news*: menu costs model gives a "curvy" Phillips curve…..**

***Bad news*: other models also give a "curvy" Phillips curve, e.g.**

- **Capacity constraints**
- **Financial constraints**
- **Non-linear demand curves**
- **Non-linear wage responses**

So, to provide more evidence for the Menu Costs model we look at three more predictions from this model

Macro data

Firm-level Phillips curves

Model and simulation results

Additional Data/Model Predictions:

(i) Low and high-inflation sectors

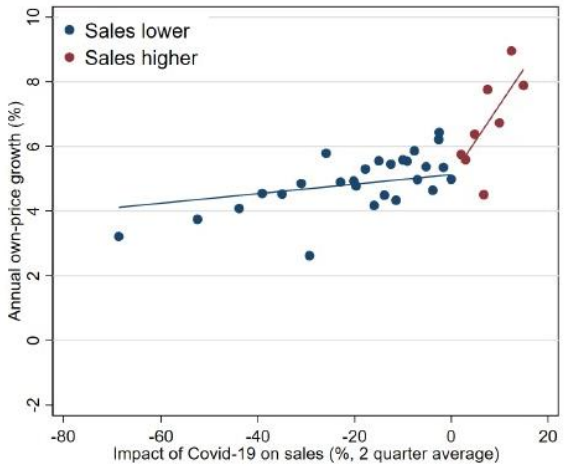
(ii) Longer-run responses

(iii) Cost-shocks

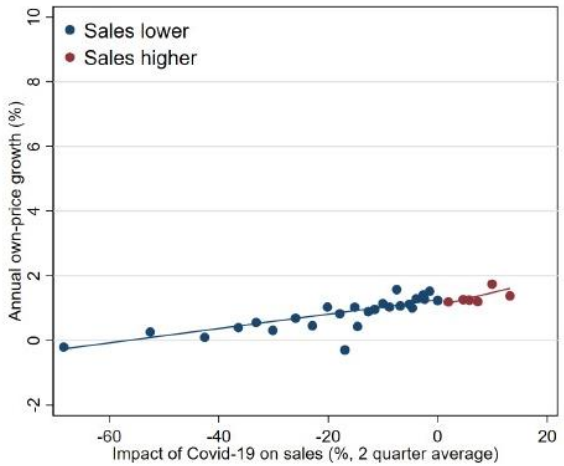
Firms (and Industries) with Higher Inflation are Convex

Covid demand shocks

Panel A: High inflation

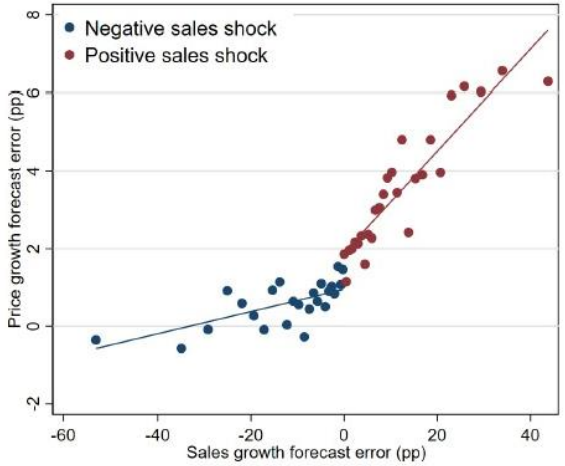


Panel B: Low inflation

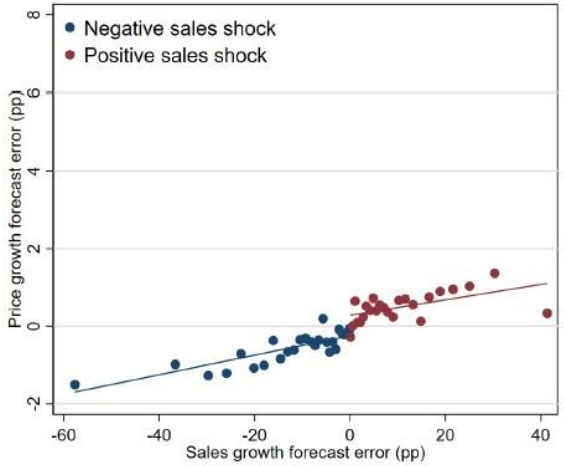


Sales growth forecast errors

Panel C: High inflation

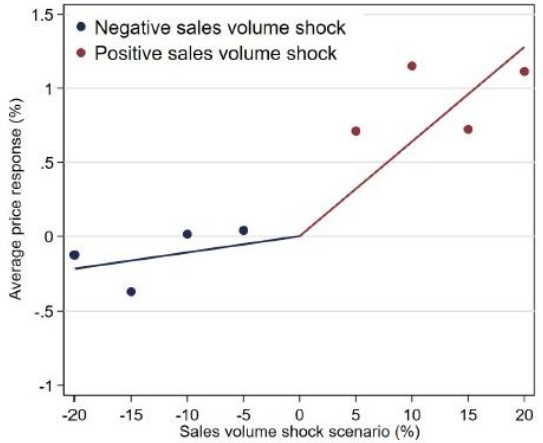


Panel D: Low inflation

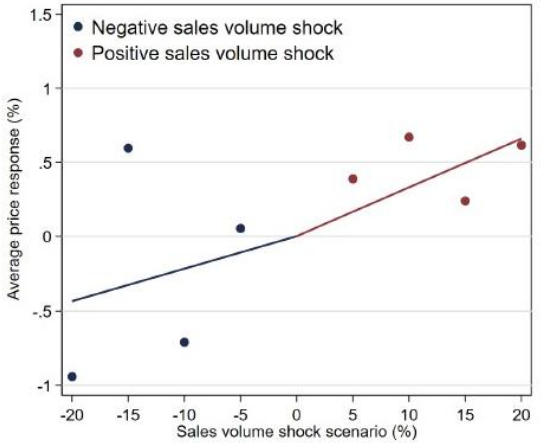


Hypothetical sales volume shocks

Panel E: High inflation

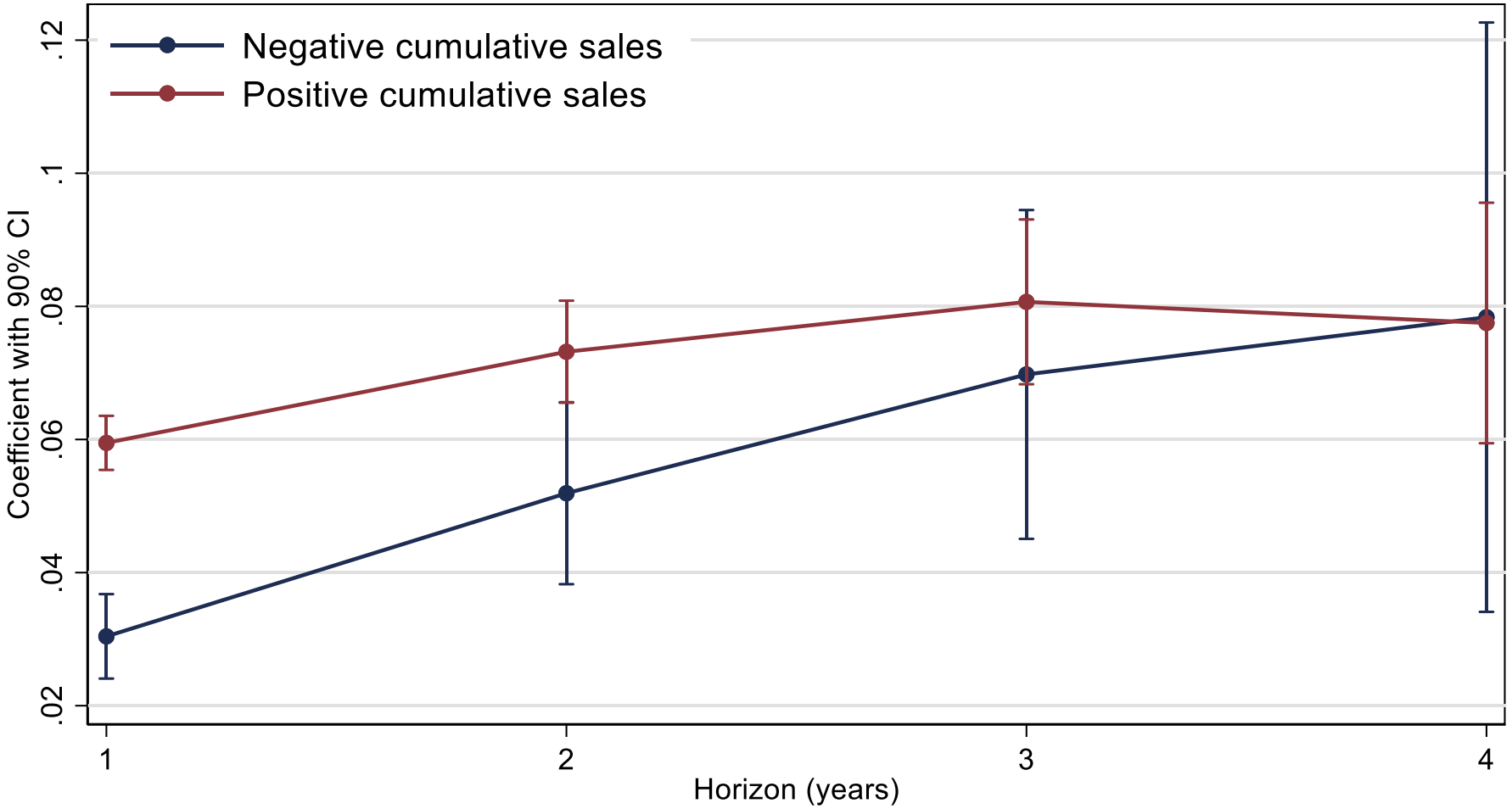


Panel F: Low inflation



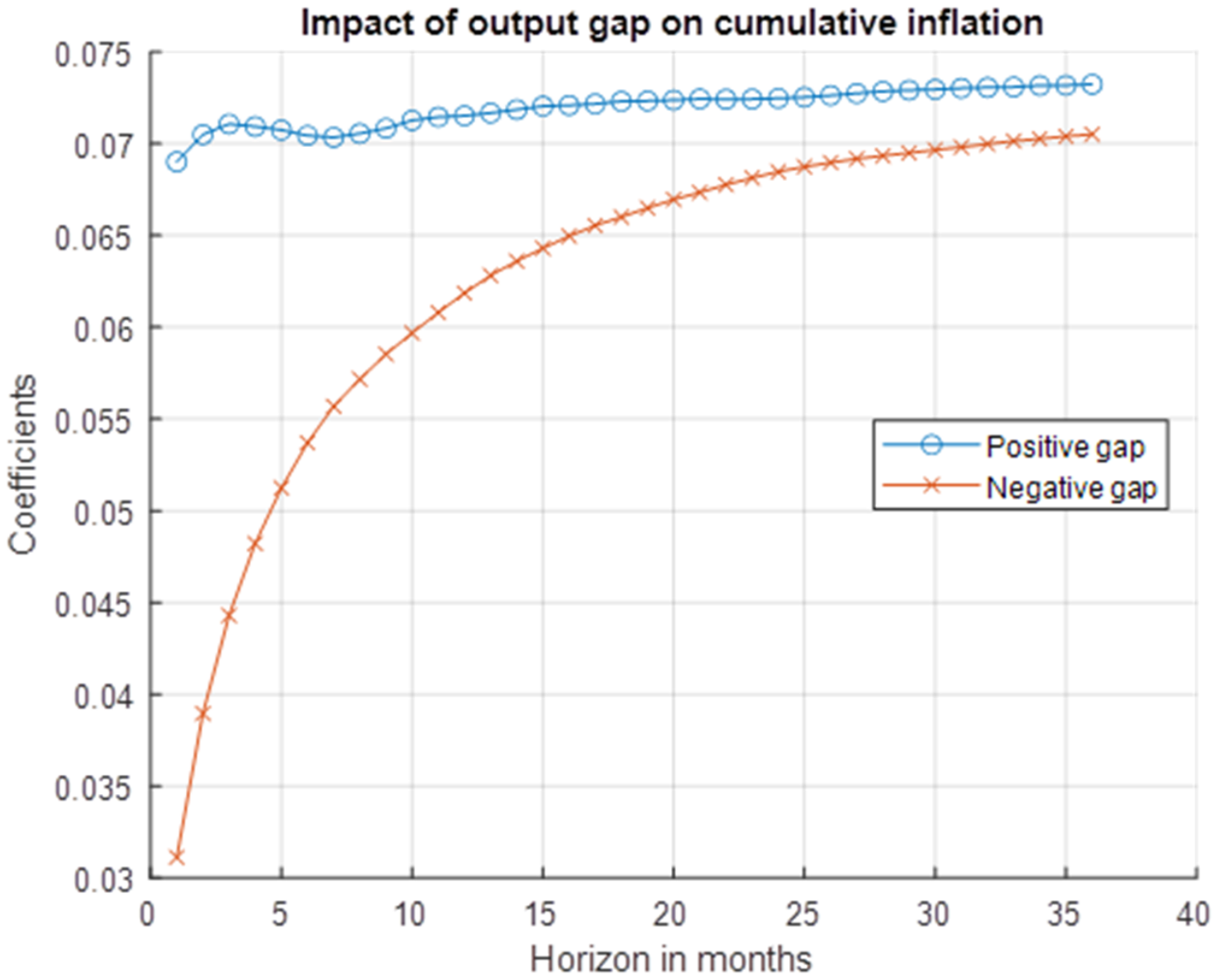
Note: Firms split by their average inflation over the sample period around the median value of 4%

Longer-run: by 3 years the convexity disappears

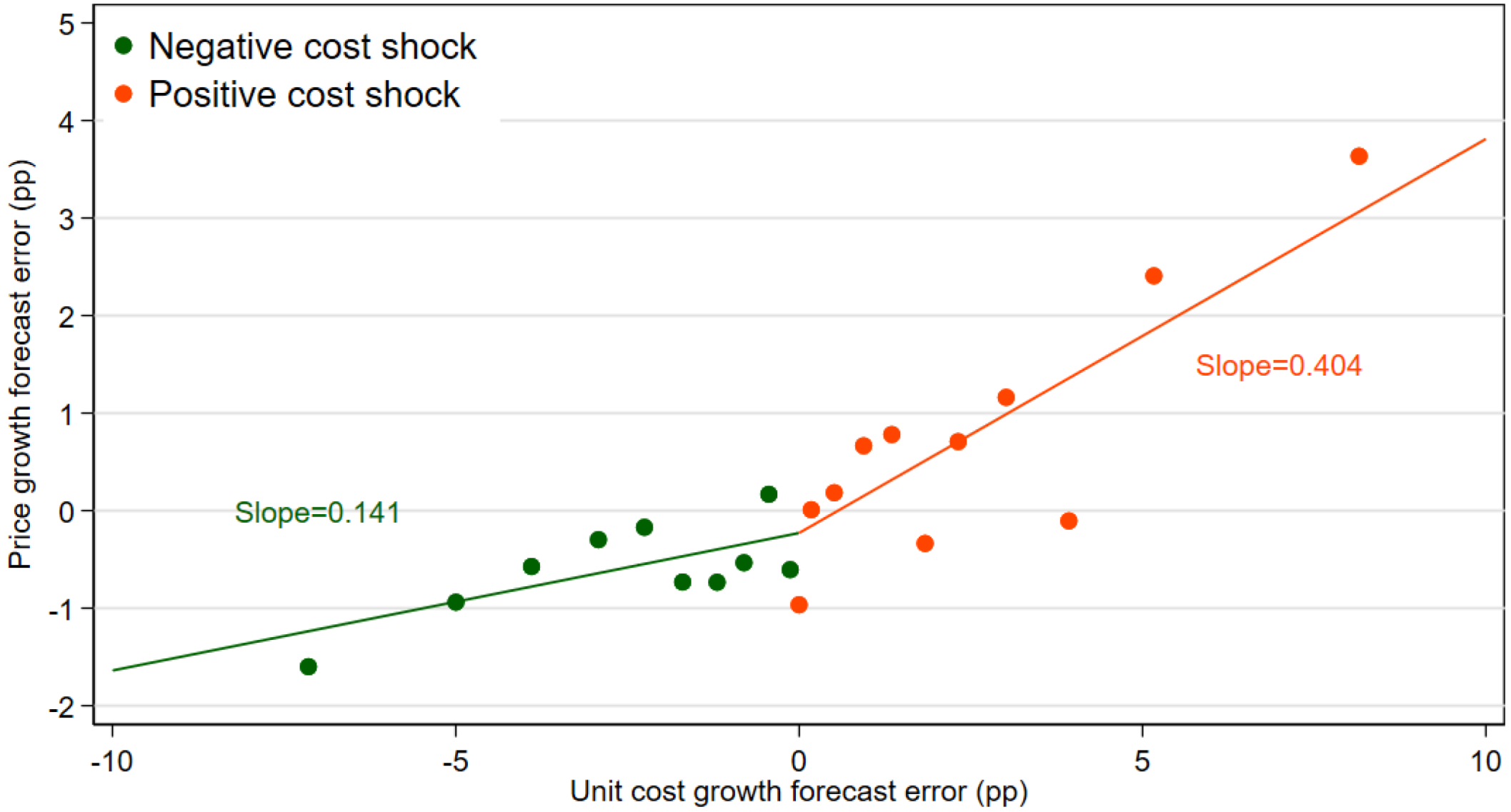


Notes: This figure presents the coefficients on regressions of cumulative own-price growth on cumulative nominal sales growth over horizons from one to four years. The coefficients on each horizon are based on separate regressions. Standard errors are clustered at the firm level and 90% confidence intervals are reported.

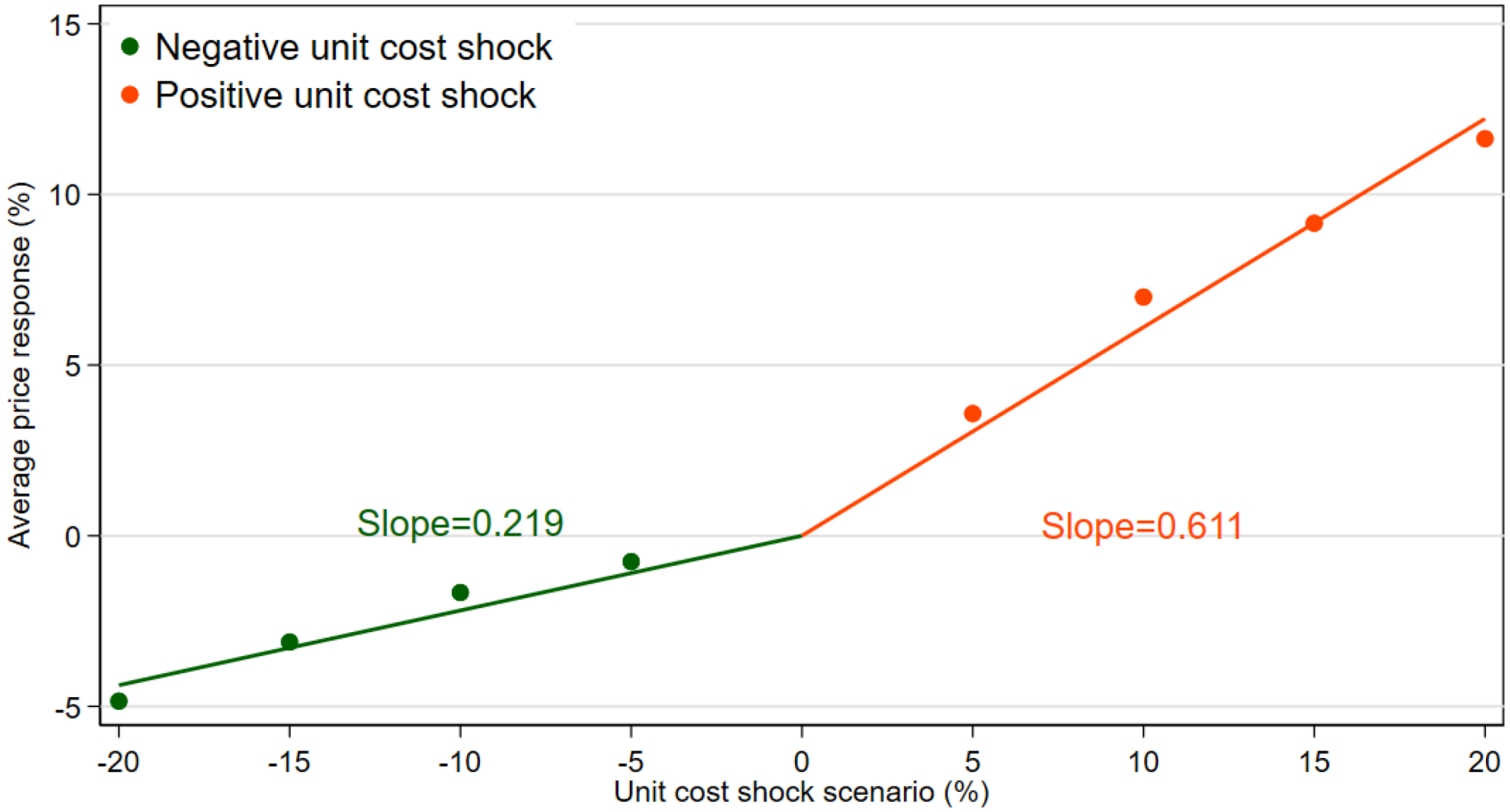
Simulated data from the model looks similar



Cost and price forecast errors – again a non-linear response



Also asked a hypothetical cost-shock question – similar results



Summary and next steps

1) Phillips curve at macro and micro level is convex (positive ≈ 2x to 4x negative slope)

2) Replicate this in a Ss menu costs model where inflation causes asymmetry

3) Menu-cost model fits additional micro data facts
   - Higher inflation greater asymmetry
   - Longer-run symmetry
   - Cost shock asymmetry

Maybe Phillips curve is ≈*flat* in normal times, *curvy* after big demand/supply shocks