# How Curvy is the Phillips Curve?

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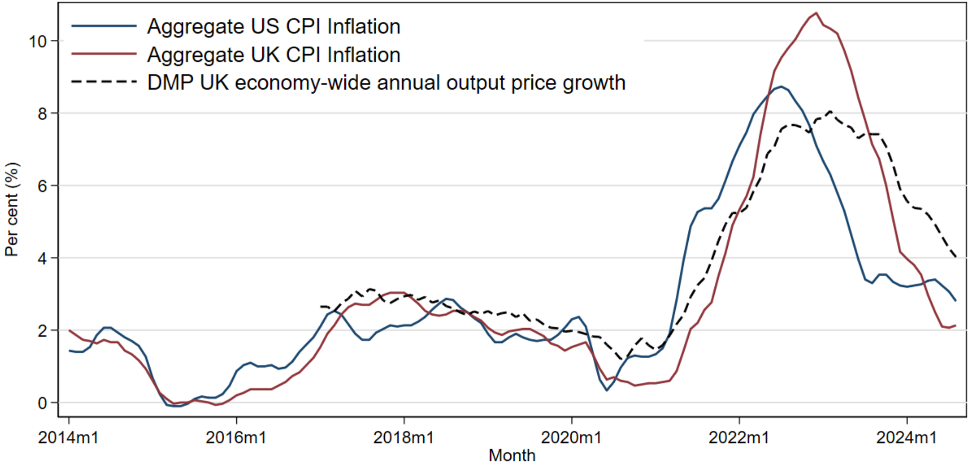
*The views expressed here are those of the authors, and not necessarily those of the Bank of England or its committees.*

# Motivation (1/3)

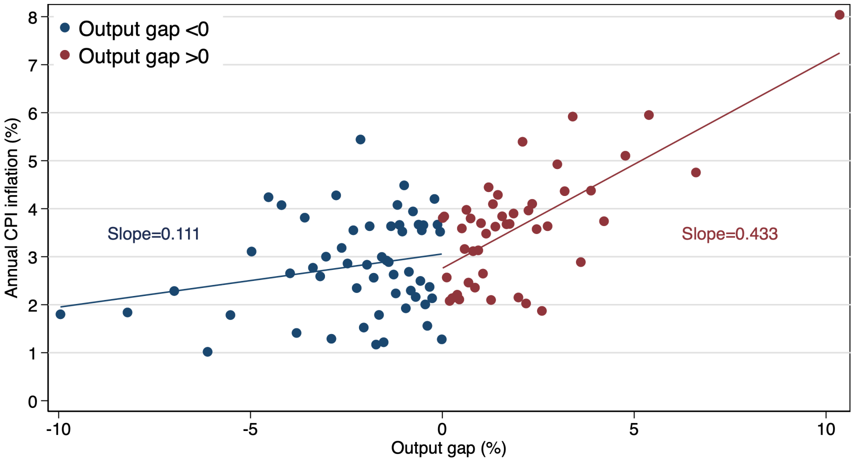


# Motivation (2/3)

*Empirical evidence suggested that inflation rose by only a small amount when unemployment declined, consistent with a* ***very flat Phillips curve****...Most inflation forecasts based on these models, including ours at the IMF,* ***significantly underpredicted inflation****....There* ***may also be important nonlinearities in the Phillips curve slope****: price and wage pressures from falling unemployment become more acute when the economy is running hot than when it's below full employment.*

Gita Gopinath (2023)
"Crisis and Monetary Policy"

# Motivation (3/3): Raw macro data, 38 countries, 1990-2023




▸ Country sample ▸ Regression Table

# This Paper

- **Research Questions:**
  1. Do firm prices respond asymmetrically to demand and cost shocks?
  2. What model of firm pricing behaviour is consistent with the empirical evidence?

# This Paper

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  1. Do firm prices respond asymmetrically to demand and cost shocks?
  2. What model of firm pricing behaviour is consistent with the empirical evidence?

- **Approach:**
  1. **Empirics**: Use three separate empirical exercises to test for the presence of convexities in price setting: (1) randomised survey experiments; (2) forecast errors; (3) Covid demand shocks.
  2. **Theory**: Build a model of price-setting with menu costs, trend inflation, and decreasing returns to scale and test how firm prices respond to shocks and to study aggregate implications.

# Three Main Results

1. We find significant evidence of non-linearity in firm price responses to **demand shocks** using three empirical exercises.
   * Price response to positive demand shocks at least twice as strong as the response to negative shocks.
   * The non-linearity is stronger for sectors with higher inflation, consistent with a state-dependent pricing model.

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2. There is a strong non-linearity in the price response to **cost shocks** using two separate empirical exercises.
    * 40-60% pass-through of positive cost shocks; 15-20% pass-through of negative cost shocks.
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   * 40-60% pass-through of positive cost shocks; 15-20% pass-through of negative cost shocks.
   * The main motivation for non-linearity is related to rebuilding margins.
3. We estimate a menu cost model with trend inflation to rationalise our findings and study implications for aggregate Phillips curve.

# Related Literature

1. **Benigno and Eggertsson (2023,2024):** Aggregate Phillips curve non-linear in labour market tightness - 'Slanted-L Phillips curve'. Model and estimation for US and seven advanced economies.
2. **Harding et al. (2022,2023):** Quasi-kinked demand schedule generates non-linear aggregate Phillips curve. Can account for inflation dynamics in Great Recession and post-Covid period.
3. **Boehm and Pandalai-Nayar (2023):** Capacity constraints amplify the impact of demand shocks on prices. Can generate convex Phillips curve.
4. **Ball et al. (2022):** Evidence of non-linear pass-through of labour market tightness and 'headline shock' to US core inflation.
5. **Forbes et al. (2021):** Non-linear Phillips curve in cross-country panel data. Stronger non-linearity when inflation is *low*.
6. And many others...

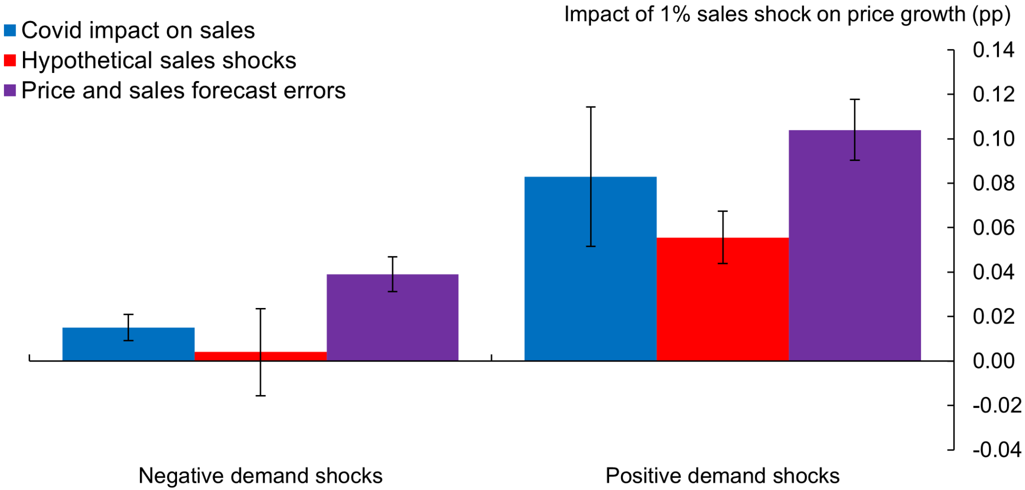
# Outline

# 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.
- Jointly organised by the Bank of England, University of Nottingham, and King's College London. Launched in late 2016.
- Around 2,500 monthly responses, covering around 4% of UK employment.
  ▸ Figure ▸ Industry and Size Distribution
- We ask firms about recent developments and year-ahead expectations for sales, prices, employment, and investment.
- Firms are asked to provide a five-point distribution for year-ahead expectations $\longrightarrow$ allows us to analyze the mean, standard deviation, and skewness of expectations at the *firm level*. ▸ Screenshot
- The DMP has been used to study multiple big policy issues, including Brexit, Covid-19, Russia-Ukraine war, and inflation.

# Outline

# Demand shocks and firm price growth: Summary of main results

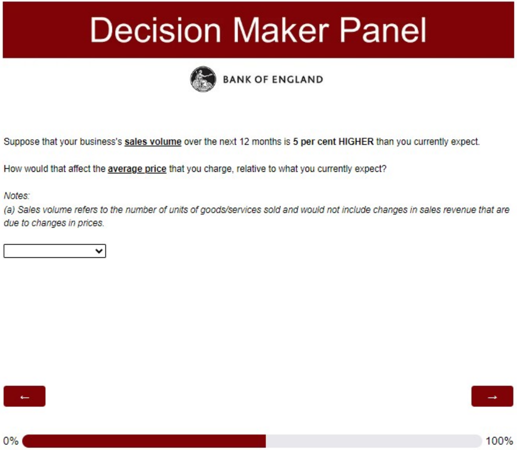


# Exercise 1: Hypothetical sales volume shocks

- In Dec-23 to Jan-24 and Aug-24 to Sep-24, firms were asked how they would change their prices in response to hypothetical *sales volume* shocks.
- Firms were assigned to one of four scenarios: $\pm5\%$, $\pm10\%$, $\pm15\%$, $\pm20\%$.
- Firms were randomly shown either the positive or negative scenario first, and then shown the flipped scenario.
- Over the four months, we received **2,564** responses from firms, meaning 5,128 responses overall (two scenarios per firm).
  - The randomization was implemented in the online survey platform. Around 600 firms were assigned to each of the four scenarios. We don't find significant differences across firms across a number of characteristics (e.g. firm size).

# Hypothetical sales volume shocks

## *Panel A:* Main scenario



Decision Maker Panel

BANK OF ENGLAND

Suppose that your business's **sales volume** over the next 12 months is **5 per cent HIGHER** than you currently expect.

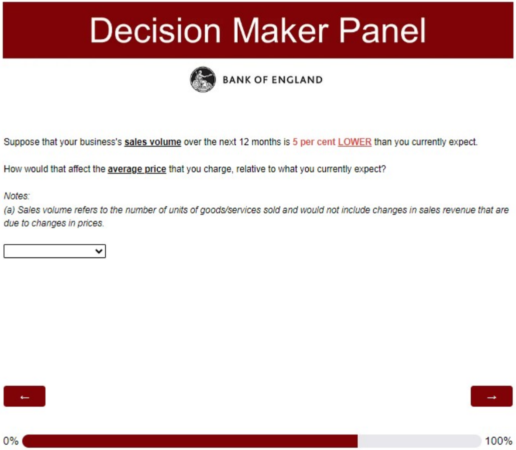
How would that affect the **average price** that you charge, relative to what you currently expect?

*Notes:*
*(a) Sales volume refers to the number of units of goods/services sold and would not include changes in sales revenue that are due to changes in prices.*

← →

0% 100%

## *Panel B:* Flipped scenario



Decision Maker Panel

BANK OF ENGLAND

Suppose that your business's **sales volume** over the next 12 months is 5 per cent LOWER than you currently expect.

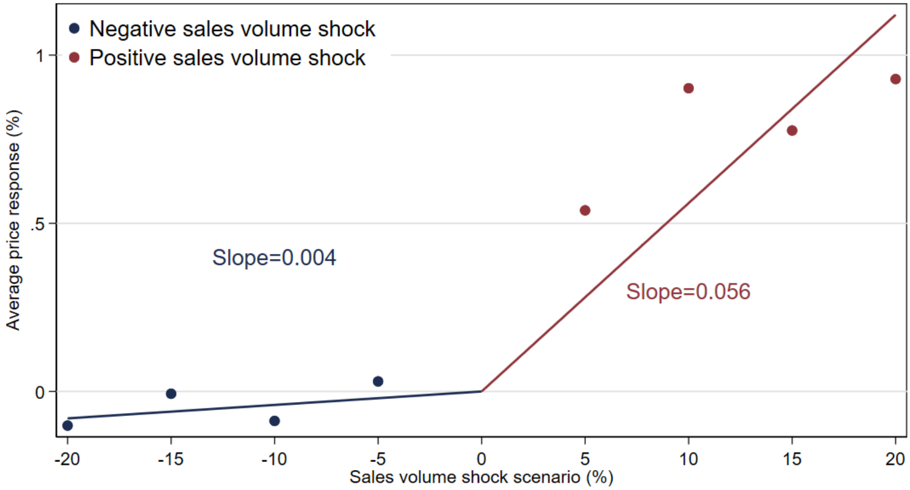
How would that affect the **average price** that you charge, relative to what you currently expect?

*Notes:*
*(a) Sales volume refers to the number of units of goods/services sold and would not include changes in sales revenue that are due to changes in prices.*

← →

0% 100%

# Hypothetical sales volume shocks

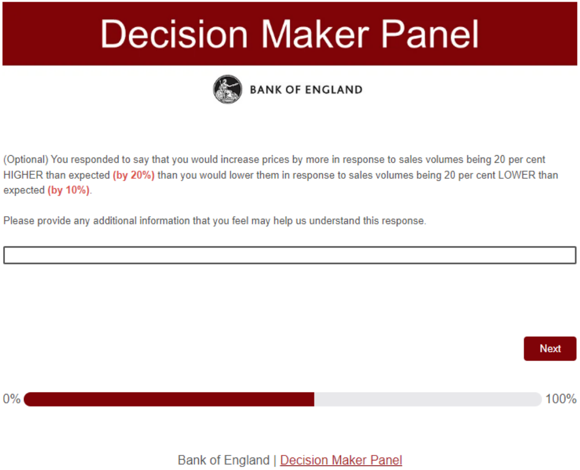


# Hypothetical sales volume shocks

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Dependent variable: | Average price response (%) | | | |
| Sample period: | Dec-23 to Jan-24; Aug-24 to Sep-24 | | | |
| Sales volume shock | 0.030*** | 0.030*** | | |
| | (0.005) | (0.005) | | |
| Sales volume shock$^2$ | | 0.001*** | | |
| | | (0.000) | | |
| Sales volume shock $\times$ Shock$> 0$ | | | 0.056*** | 0.056*** |
| | | | (0.006) | (0.011) |
| Sales volume shock $\times$ Shock$< 0$ | | | 0.004 | -0.003 |
| | | | (0.008) | (0.016) |
| $R^2$ | 0.010 | 0.016 | 0.018 | 0.016 |
| Number of Observations | 5,128 | 5,128 | 5,128 | 5,092 |
| Test coefficients equal (p-value) | | | 0.000 | 0.000 |

Notes: The results in Column 4 are weighted by industry and employment. Standard errors are clustered at the firm level and are reported in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

# Hypothetical sales volume shocks: Open-text questions



Decision Maker Panel

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(Optional) You responded to say that you would increase prices by more in response to sales volumes being 20 per cent HIGHER than expected (by 20%) than you would lower them in response to sales volumes being 20 per cent LOWER than expected (by 10%).

Please provide any additional information that you feel may help us understand this response.

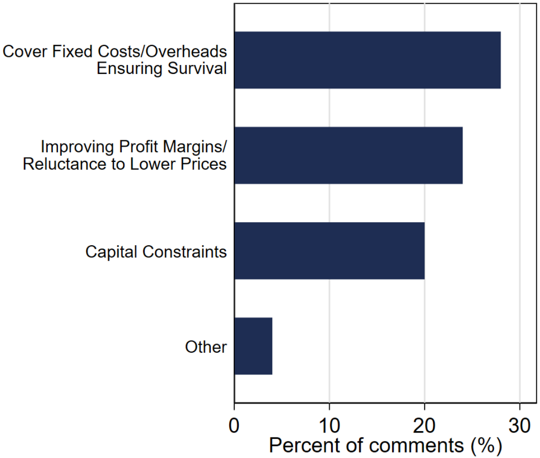
Next

0% 100%

Bank of England | Decision Maker Panel

- In Aug-24 and Sep-24, we also ask firms which give a 'nonlinear' response to sales volume shocks about further details.
- In August 2024, we received 272 nonlinear responses and 159 comments (58% comment rate)
- Hand-code responses into several categories.

# Hypothetical sales volume shocks: Open-text questions

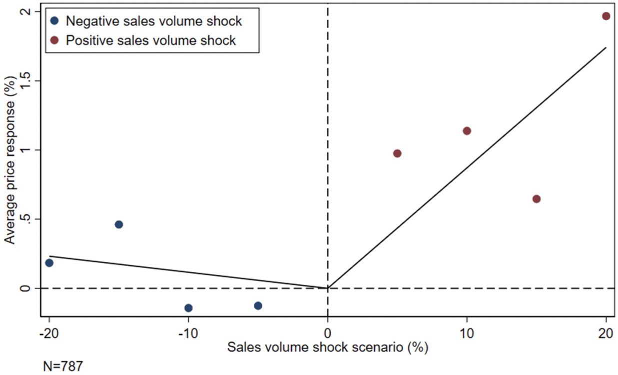



- **Cover fixed costs:** "'Attempt to cover fixed costs and therefore retain some profitability"
- **Improve profit margin:** "If busier and all working harder then we would try to make a better margin"
- **Capacity constraint:** "If volume increased we would try to reduce demand due to hiring challenges"

# International evidence: US Survey of Business Uncertainty

## Price responses to sales volume surprises – bin-scatter plot

*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.*



# Exercise 2: Sales growth forecast errors

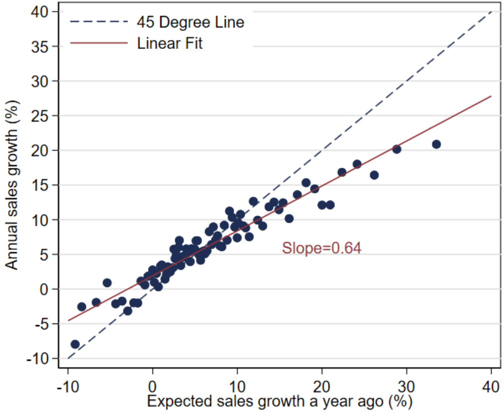
- We use the strong panel dimension of the DMP to compare firm expectations about sales growth/price growth to their realizations a year later.

$$ForecastError^{Y}_{i,t} = Y_{i,t} - E_{t-12}[Y_{it}]$$

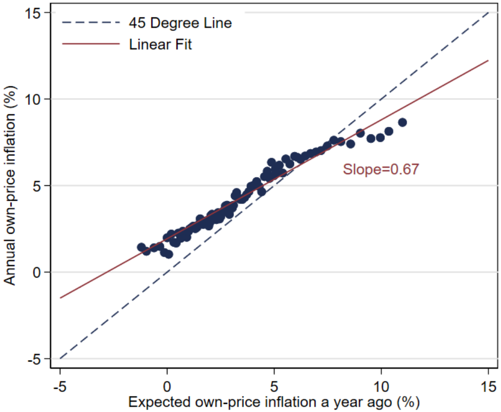
- Key advantage is longer time series going back to 2018:
  - Can compare pre-pandemic years versus years since 2020.
  - Can include demanding firm and month fixed effects in the regressions.
  - Can perform heterogeneity analysis due to larger sample.

# Comparison of firm year-ahead expectations with realisations

*Panel A:* Sales growth

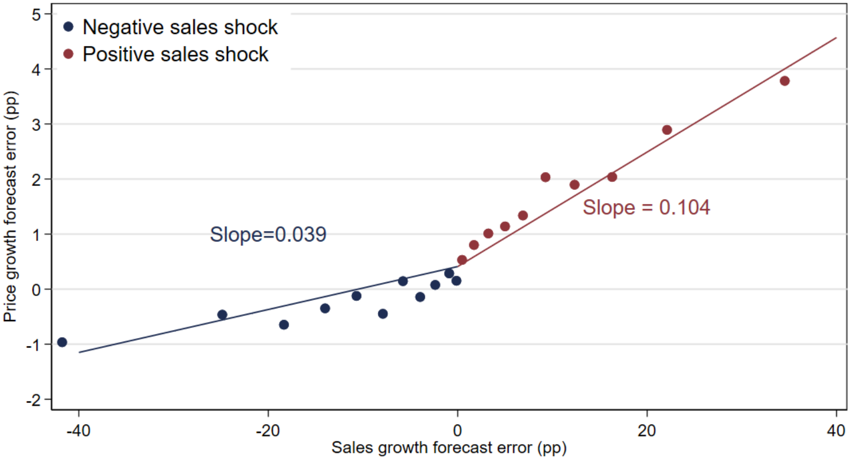



*Panel B:* Price growth




▸ Forecast error trends

# Relationship between sales growth and price growth forecast errors



# Relationship between sales growth and price growth forecast errors

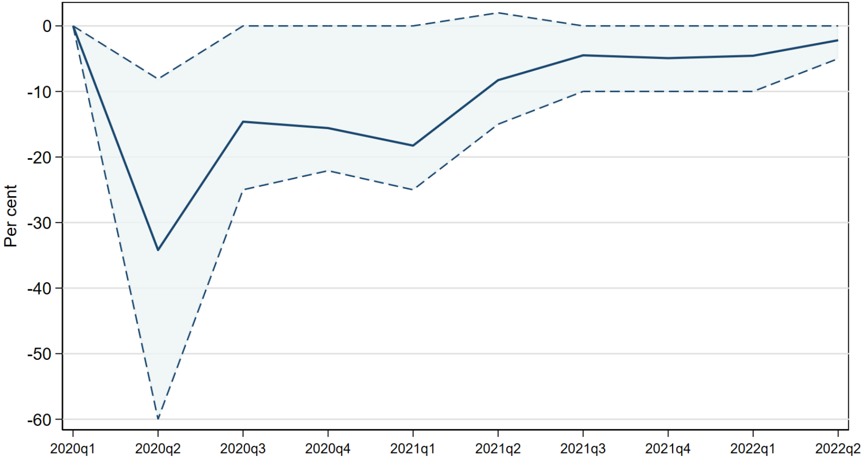
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| Dependent variable: | Price growth forecast error (pp) | | | | | Price growth forecast error (pp) | |
| Sample period: | 2018Q1 to 2024Q3 | | | | | 2018Q1-2019Q4 | 2020Q1-2024Q3 |
| Sales growth forecast error | 0.0529*** | 0.0563*** | | | | | |
| | (0.0039) | (0.0040) | | | | | |
| Sales growth forecast error$^2$ | | 0.0005*** | | | | | |
| | | (0.0001) | | | | | |
| Sales growth forecast error X Error $\geq 0$ | | | 0.1044*** | 0.0758*** | 0.0732*** | 0.0520*** | 0.0768*** |
| | | | (0.0070) | (0.0069) | (0.0070) | (0.0127) | (0.0073) |
| Sales growth forecast error X Error $< 0$ | | | 0.0391*** | 0.0336*** | 0.0319*** | 0.0197 | 0.0373*** |
| | | | (0.0045) | (0.0055) | (0.0053) | (0.0127) | (0.0060) |
| Expected price growth | | | | | 0.1932*** | | |
| | | | | | (0.0360) | | |
| Time fixed effects | Yes | Yes | No | Yes | Yes | Yes | Yes |
| Firm fixed effects | Yes | Yes | No | Yes | Yes | Yes | Yes |
| $R^2$ | 0.368 | 0.370 | 0.046 | 0.369 | 0.387 | 0.461 | 0.389 |
| Number of Observations | 18,484 | 18,484 | 19,675 | 18,484 | 17,931 | 3,274 | 14,560 |
| Test coefficients equal (p-value) | | | 0.000 | 0.000 | 0.000 | 0.114 | 0.000 |

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

# Exercise 3: Covid demand shocks

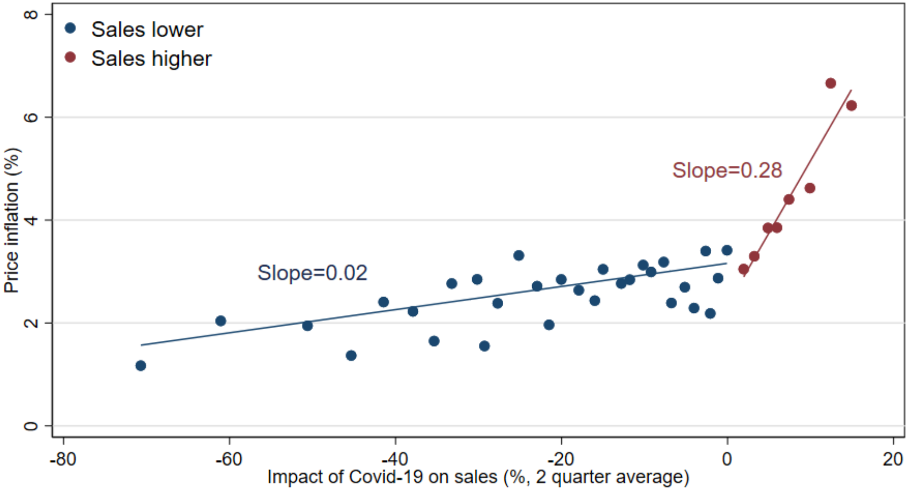
- We use firm-level regressions to estimate the response of prices to the Covid-19 demand shock.
- The impact of Covid on demand is based on the question: 'Relative to what would otherwise have happened, what is your estimate for the impact of the spread of Covid-19 on the sales of your business in each of the following periods?'
    - Firms are asked to provide an estimate for the past quarter, current quarter, as well as for one and two quarters ahead.

# Impact of Covid-19 on firm sales




*Notes:* The dashed lines outline the interquartile range.

# Covid demand shocks and firm price growth



# Covid demand shocks and firm price growth

| | (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$_{it}\times$ sales impact postive$_{it}$ | | | 0.1247*** | 0.1038*** | 0.0900*** |
| | | | (0.0256) | (0.0251) | (0.0245) |
| Covid impact on sales$_{it}\times$ 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. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

▸ Full Table

# Covid demand shocks and firm price growth: Additional Results

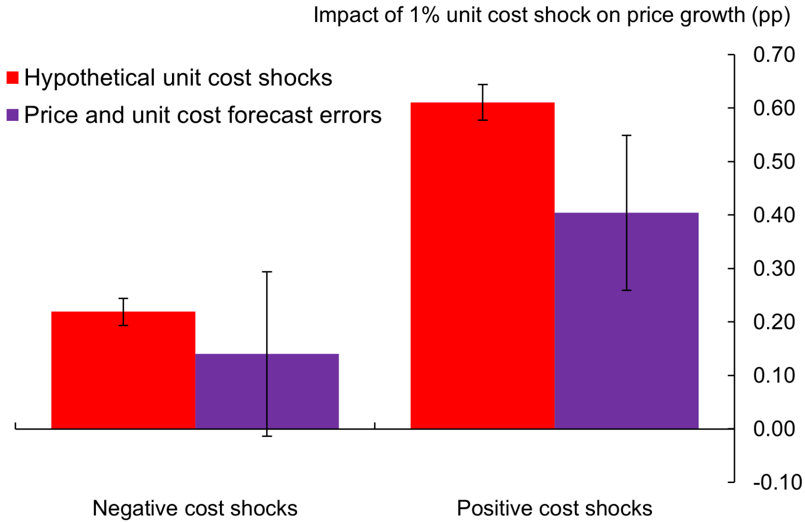
- Goods vs. services sector firms ▸ Table
  - ∗ Asymmetric response to Covid demand is present in both goods sector and service sector firms.
- Sample splits ▸ Table
  - ∗ Asymmetric response to Covid is present in both the first year (2020Q2-2021Q1) and second year (2021Q2-2022Q2) of the pandemic.
- Heterogeneity by pre-Covid liquidity ▸ Table
  - ∗ Asymmetric response is present for firms with both above average and below average Pre-Covid liquidity (i.e. cash/total assets).
- Demand shock persistence ▸ Table
  - ∗ Negative Covid demand shocks are *more* persistent.
- Comparison to Phillips Curve estimates in the literature ▸ Figure
- Results on market power ▸ Results

# Outline

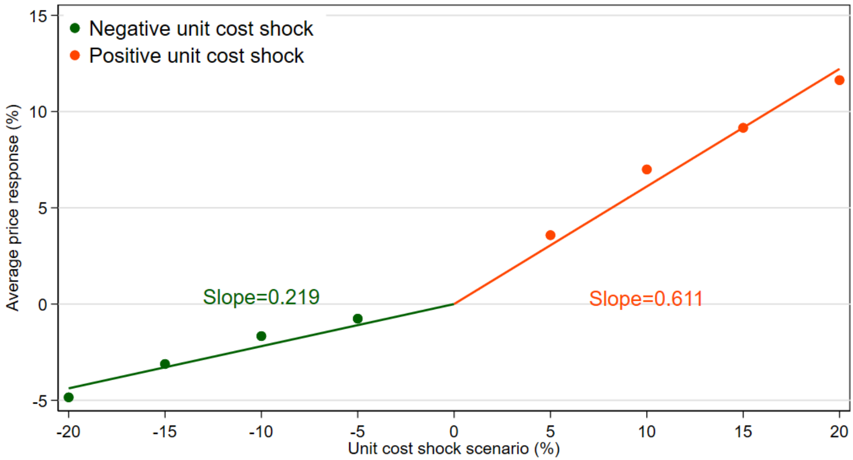
# Cost shocks and firm prices: Overview

- We also analyse the pass-through of cost shocks to firm prices and test for the presence of non-linearities.
- Use two separate empirical exercises:
  1. Hypothetical unit cost shock questions - asked in Aug-24 and Sep-24
  2. Unit cost growth forecast errors
- **Result:** There is a significant evidence of non-linearity: 40-60% pass-through of positive cost shocks; 15-20% pass-through of negative shocks.

# Cost shocks and firm prices: Summary of main results

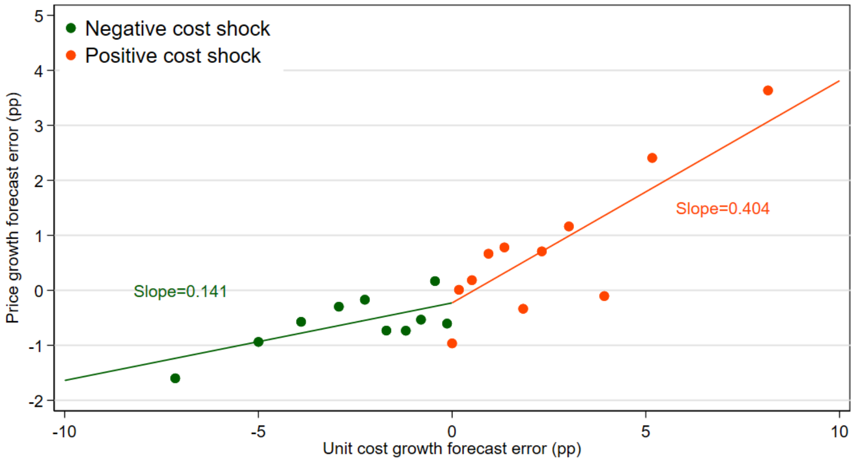


# Exercise 1: Hypothetical unit cost shocks




▸ Screenshots ▸ Regression Table ▸ Open-text responses

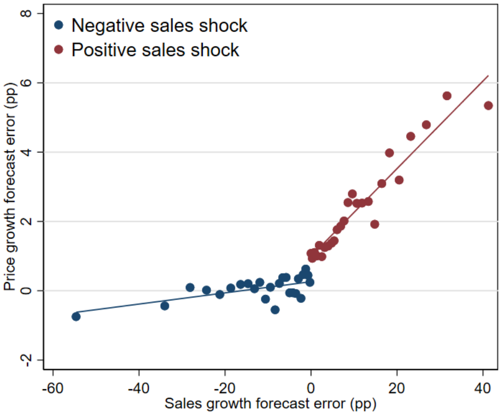
# Exercise 2: Unit cost growth forecast errors



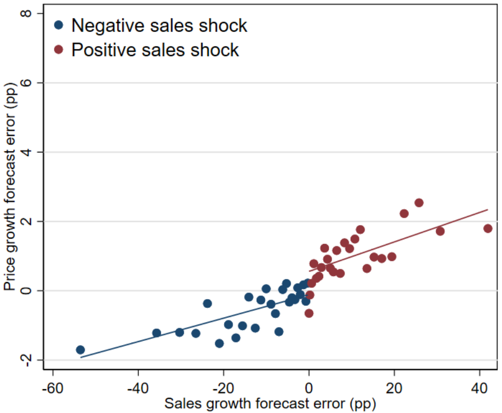

▸ Distribution ▸ Regression Table

# High vs. low inflation sectors ▸ Regression Table

*Panel A:* High inflation

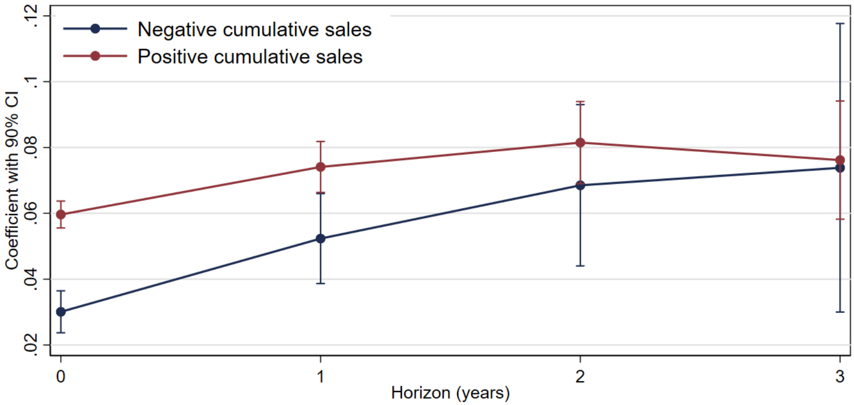



*Panel B:* Low inflation




High-inflation is constructed as firms for which the average SIC3 price growth (excluding firm i) in a given year exceeds the average price growth in the same year.

# Longer-run responses



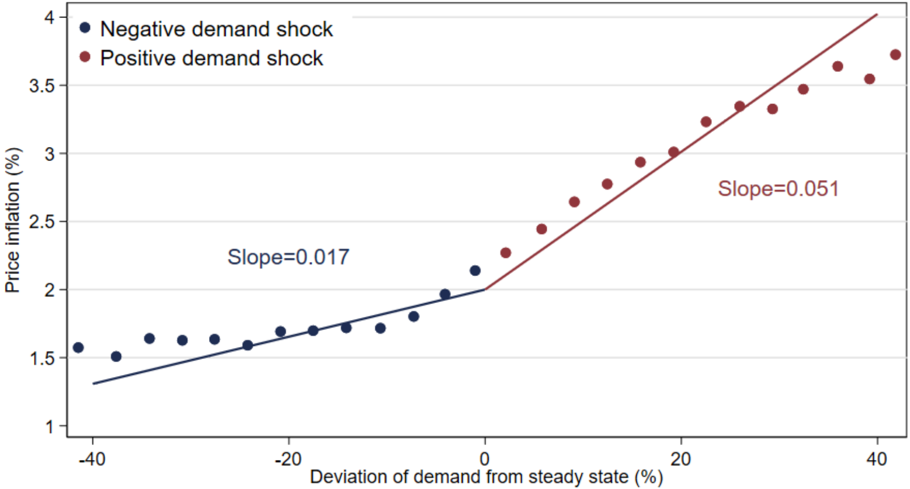

LHS: Cumulative price growth
RHS: Cumulative sales growth
No fixed effects

# Outline

# Overview

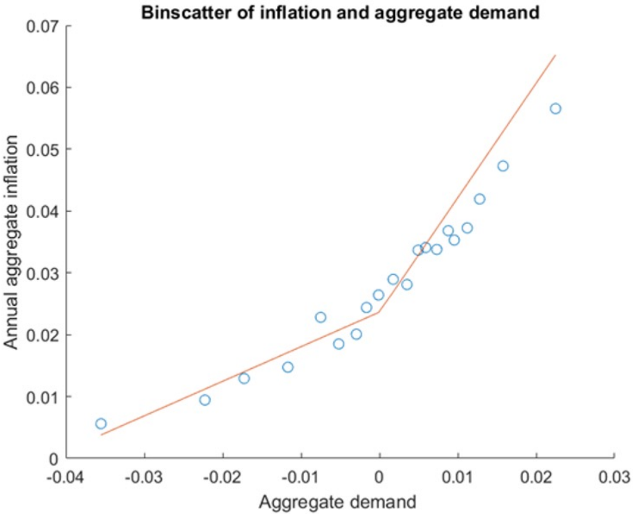
- To rationalise our findings, we adapt and estimate a model of firm price-setting based on Nakamura & Steinsson (2008, 2010)
- The model has three key features:
  1. **Menu costs:** Firms will not change prices when the current price is 'close' to the optimal (i.e. there is a zone of inaction)
  2. **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
- When asked, over 50% of firms report they set prices in response to events (i.e. state-dependent) rather than at fixed intervals (i.e. time dependent).
  ▸ Figure ▸ Table
- Model setup and implementation ▸ Model Details

# Menu cost model: Firm-level Phillips curve




*Notes:* This figure present results from the simulated menu cost model.

# Menu cost model: Aggregate Phillips Curve



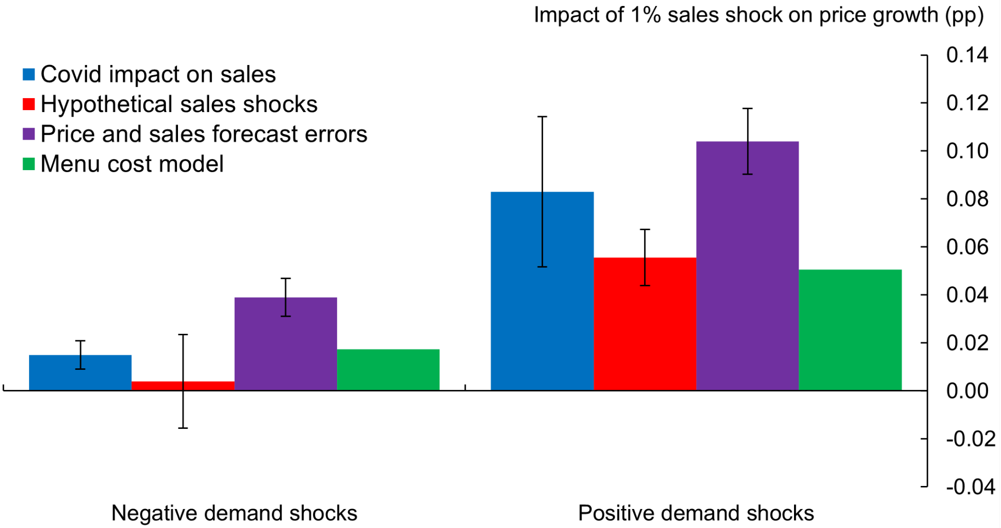

*Notes:* This figure present results from the simulated menu cost model.

# Outline

# Conclusions

- The period since 2020 has been characterised by a series of large shocks.
- In this environment, understanding how shocks are passed through (both in terms of speed and magnitude) to prices is critical.
- Three separate empirical exercises find significant evidence of a convex relationship between firm prices and demand shocks.
  - This convexity is present in both 2018-2019 and 2020-2024.
  - Also find strong convexity in pass-through of cost shocks to prices.
- A menu cost model with trend inflation helps rationalise our findings and allows us to conduct further counterfactual analysis.
- Our results highlight the importance of taking asymmetries in pricing behavior into consideration, both in empirical and theoretical work.

# Conclusions



# Thank you!

# Raw macro data: Sample of countries

Return

| Country | Number of observations | Country | Number of observations | Country | Number of observations |
|---|---|---|---|---|---|
| Australia | 34 | Greece | 29 | New Zealand | 34 |
| Austria | 34 | Hungary | 25 | Norway | 34 |
| Belgium | 34 | Iceland | 31 | Poland | 27 |
| Bulgaria | 23 | Ireland | 29 | Portugal | 34 |
| Canada | 34 | Israel | 29 | Romania | 20 |
| Chile | 31 | Italy | 34 | Slovak Republic | 29 |
| Croatia | 14 | Japan | 34 | Slovenia | 28 |
| Czech Republic | 27 | Korea, Rep. | 34 | Spain | 34 |
| Denmark | 34 | Latvia | 25 | Sweden | 34 |
| Estonia | 26 | Lithuania | 21 | Switzerland | 34 |
| Finland | 34 | Luxembourg | 29 | United Kingdom | 34 |
| France | 34 | Mexico | 24 | United States | 34 |
| Germany | 33 | Netherlands | 34 | | |

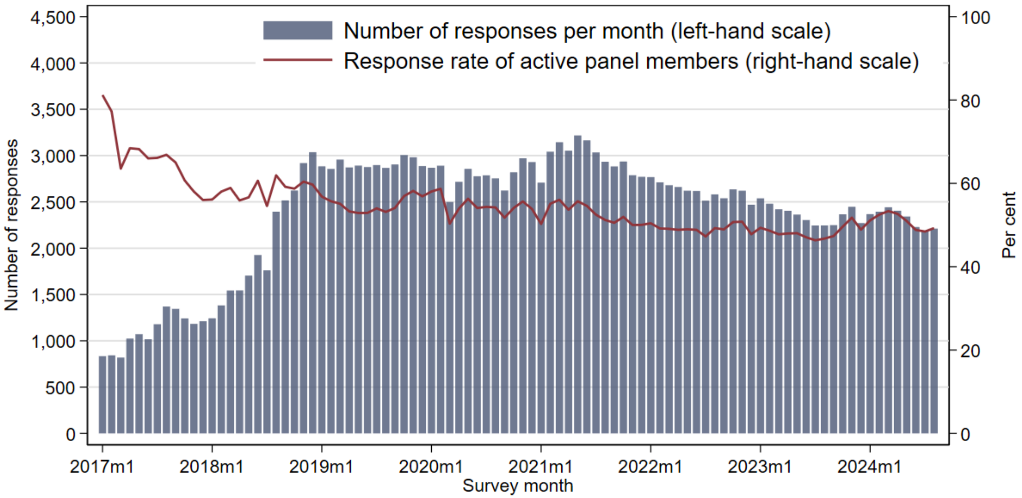
# Raw macro data: Regression table ◂ Return

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| Dependent variable: | Annual headline CPI inflation (%) | | | | | | |
| Sample period: | 1990-2023 | | | | | 1990-2019 | 2020-2023 |
| Output $\text{Gap}_{it}$ | 0.223*** | 0.154*** | 0.120*** | 0.128*** | | | |
| | (0.029) | (0.041) | (0.024) | (0.022) | | | |
| Output $\text{Gap}^2_{it}$ | | | | 0.008*** | | | |
| | | | | (0.002) | | | |
| Output $\text{Gap}_{it}$ X OG $\geq 0$ | | | | | 0.197*** | 0.188*** | 0.461** |
| | | | | | (0.046) | (0.044) | (0.179) |
| Output $\text{Gap}_{it}$ X OG $< 0$ | | | | | 0.064* | 0.070* | -0.083 |
| | | | | | (0.034) | (0.038) | (0.086) |
| $\text{Inflation}_{i,t-1}$ | | | 0.484*** | 0.481*** | 0.481*** | 0.495*** | 0.257*** |
| | | | (0.037) | (0.038) | (0.039) | (0.042) | (0.049) |
| $E_{t+5}[\text{Inflation}_{i,t}]$ | | | 0.668*** | 0.682*** | 0.688*** | 0.684*** | 0.022 |
| | | | (0.098) | (0.100) | (0.103) | (0.112) | (0.800) |
| Country fixed effects | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Time fixed effects | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Difference coefficients positive/negative OG | | | | | 0.133 | 0.117 | 0.545 |
| Test coefficients equal (p-value) | | | | | 0.046 | 0.095 | 0.017 |
| $R^2$ | 0.061 | 0.599 | 0.800 | 0.802 | 0.801 | 0.770 | 0.896 |
| Observations | 1,146 | 1,146 | 1,115 | 1,115 | 1,115 | 969 | 146 |

Notes: The estimation sample covers 38 countries over the period 1990-2023. Standard errors are clustered at the country level and are reported in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

# DMP Response Rate

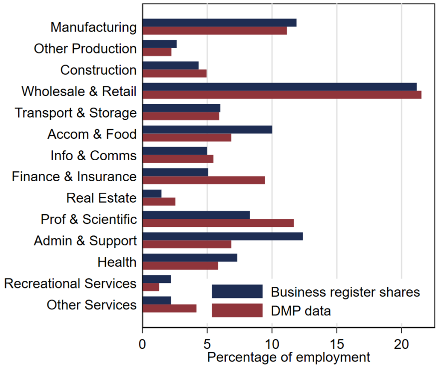
Return



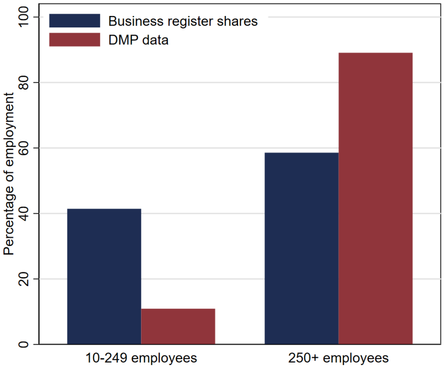
# DMP vs. UK industrial and size distribution

Return

*Panel A:* By Industry




*Panel B:* By Size



# DMP survey example question: Expected own-price growth

Return

## *Panel A:* Scenarios

Decision Maker Panel

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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: | 2 | % |
| A LOW % change in my prices would be about: | 3 | % |
| A MIDDLE % change in my prices would be about: | 4 | % |
| A HIGH % change in my prices would be about: | 5 | % |
| The HIGHEST % change in my prices would be about: | 8 | % |

## *Panel B:* Probabilities

Decision Maker Panel

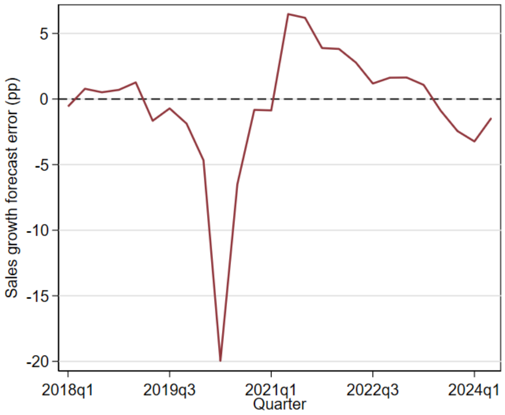
BANK OF ENGLAND

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

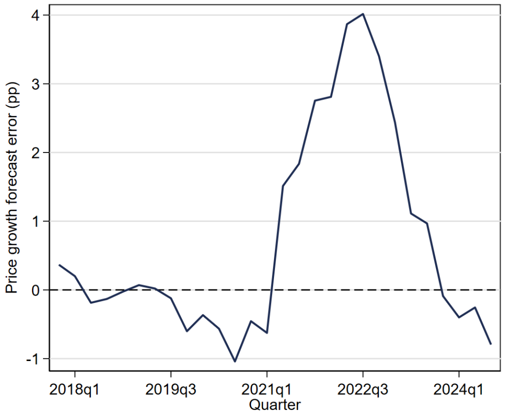
| | | |
|---|---|---|
| LOWEST: The likelihood of realising about **2%** would be: | 5 | % |
| LOW: The likelihood of realising about **3%** would be: | 15 | % |
| MIDDLE: The likelihood of realising about **4%** would be: | 25 | % |
| HIGH: The likelihood of realising about **5%** would be: | 20 | % |
| HIGHEST: The likelihood of realising about **8%** would be: | 35 | % |
| Total | 100 | % |

# Trends in average forecast errors, 2018-2024

## *Panel A:* Sales growth

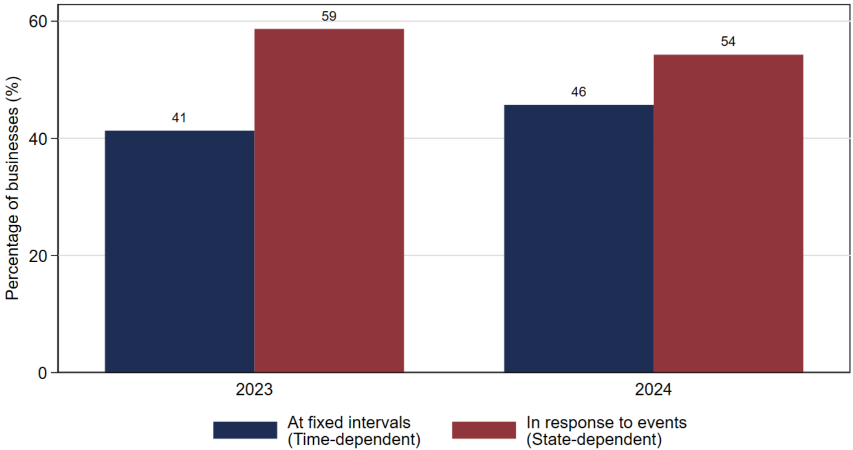



## *Panel B:* Price growth




Return

# How firms typically set prices: State- vs. time-dependent pricing




◂ Return

# Convexities in price-setting: State- vs. time-dependent pricing

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Dependent variable: | Annual own-price growth (%) | | Average price response (%) | | Price growth forecast error (pp) | |
| Sample: | 2017Q1 to 2022Q2 | | Dec-23 to Jan-24 | | 2018Q1 to 2024Q1 | |
| Price-setting: | Time-dependent | State-dependent | Time-dependent | State-dependent | Time-dependent | State-dependent |
| Covid impact on sales$_{it}$ $\times$ sales impact postive$_{it}$ | 0.124$^{**}$ | 0.118$^{**}$ | | | | |
| | (0.056) | (0.047) | | | | |
| Covid impact on sales$_{it}$ $\times$ sales impact negative$_{it}$ | 0.017$^{***}$ | 0.015$^{**}$ | | | | |
| | (0.007) | (0.007) | | | | |
| Sales volume shock $\times$ Shock $> 0$ | | | 0.027$^{**}$ | 0.041$^{***}$ | | |
| | | | (0.012) | (0.014) | | |
| Sales volume shock $\times$ Shock $< 0$ | | | 0.015 | 0.023 | | |
| | | | (0.017) | (0.019) | | |
| Sales growth forecast error X Error $\geq 0$ | | | | | 0.041$^{***}$ | 0.095$^{***}$ |
| | | | | | (0.010) | (0.013) |
| Sales growth forecast error X Error $< 0$ | | | | | 0.027$^{***}$ | 0.047$^{***}$ |
| | | | | | (0.010) | (0.012) |
| Time fixed effects | Yes | Yes | No | No | Yes | Yes |
| Firm fixed effects | Yes | Yes | No | No | Yes | Yes |
| $R^2$ | 0.523 | 0.549 | 0.009 | 0.013 | 0.321 | 0.383 |
| Number of Observations | 4,637 | 7,290 | 596 | 842 | 4,261 | 5,683 |
| Test coefficients equal (p-value) | 0.058 | 0.034 | 0.518 | 0.351 | 0.398 | 0.011 |

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

Return

# Covid demand shocks and firm price growth

Return

| Dependent variable: Realized price inflation<br>Sample period: 2017Q1 to 2022Q2 (quarterly data) | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| Covid impact on sales$_{it}$ × sales impact postive$_{it}$ | 0.2614*** | 0.2440*** | 0.1247*** | 0.0832*** | | 0.1038*** | 0.0900*** |
| | (0.0322) | (0.0311) | (0.0256) | (0.0163) | | (0.0251) | (0.0245) |
| Covid impact on sales$_{it}$ × sales impact negative$_{it}$ | 0.0131*** | 0.0055 | 0.0165*** | 0.0153*** | | 0.0186*** | 0.0172*** |
| | (0.0026) | (0.0035) | (0.0034) | (0.0034) | | (0.0034) | (0.0034) |
| Dummy for Covid impact on sales positive$_{it}$ | -0.2439 | -0.7020*** | -0.4119** | | | -0.3979** | -0.3966** |
| | (0.2172) | (0.2123) | (0.1776) | | | (0.1723) | (0.1677) |
| Covid impact on sales$_{it}$ | | | | | 0.0382*** | | |
| | | | | | (0.0060) | | |
| Covid impact on sales$^2_{it}$ | | | | | 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) |
| Firm fixed effects | No | No | Yes | Yes | Yes | Yes | Yes |
| Time fixed effects | No | Yes | Yes | Yes | Yes | Yes | Yes |
| $R^2$ | 0.019 | 0.138 | 0.546 | 0.546 | 0.546 | 0.560 | 0.582 |
| Number of Observations | 34,076 | 34,076 | 34,076 | 34,076 | 34,076 | 34,076 | 34,076 |
| Test Covid impact on sales coefficients equal (p-value) | 0.000 | 0.000 | 0.000 | 0.000 | | 0.001 | 0.004 |

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

# Covid demand shocks and firm price growth: Goods vs. services

| | (1) | (2) | (3) |
|---|---|---|---|
| Dependent variable: | Realized price inflation | | |
| Sample: | 2017 Q1 to 2022 Q2 (quarterly data) | | |
| Sector: | All | Goods | Services |
| Covid impact on sales$_{it}$ $\times$ sales impact negative$_{it}$ | 0.016*** | 0.012** | 0.021*** |
| | (0.003) | (0.005) | (0.005) |
| Covid impact on sales$_{it}$ $\times$ sales impact postive$_{it}$ | 0.125*** | 0.141*** | 0.110*** |
| | (0.026) | (0.033) | (0.040) |
| Dummy for Covid impact on sales positive$_{it}$ | -0.412** | -0.592** | -0.216 |
| | (0.178) | (0.238) | (0.266) |
| Constant | 2.958*** | 3.355*** | 2.518*** |
| | (0.023) | (0.032) | (0.033) |
| Firm fixed effects | Yes | Yes | Yes |
| Month fixed effects | Yes | Yes | Yes |
| Test Covid impact on sales coefficients equal (p-value) | 0.000 | 0.000 | 0.027 |
| Observations | 34,076 | 17,900 | 16,176 |

Notes: Standard errors are reported in parentheses, stars indicate *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Return

# Covid demand shocks and firm price growth: Sample splits

| | (1) | (2) | (3) |
|---|---|---|---|
| Dependent variable: | Realized price inflation | | |
| Sample: | Full | Excluding 2020Q2-2021Q1 | Excluding 2021Q2-2022Q2 |
| Covid impact on sales$_{it}\times$ sales impact negative$_{it}$ | 0.016$^{***}$ | 0.017$^{**}$ | 0.014$^{***}$ |
| | (0.003) | (0.007) | (0.003) |
| Covid impact on sales$_{it}\times$ sales impact postive$_{it}$ | 0.125$^{***}$ | 0.131$^{***}$ | 0.082$^{***}$ |
| | (0.026) | (0.031) | (0.032) |
| Dummy for Covid impact on sales positive$_{it}$ | -0.412$^{**}$ | -0.341 | -0.207 |
| | (0.178) | (0.240) | (0.211) |
| Constant | 2.958$^{***}$ | 3.207$^{***}$ | 2.314$^{***}$ |
| | (0.023) | (0.023) | (0.019) |
| Firm fixed effects | Yes | Yes | Yes |
| Month fixed effects | Yes | Yes | Yes |
| Test Covid impact on sales coefficients equal (p-value) | 0.000 | 0.000 | 0.032 |
| Observations | 34,076 | 27,162 | 26,754 |

Notes: Standard errors are reported in parentheses, stars indicate *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

◂ Return

# Covid demand shocks and firm price growth: Pre-Covid liquidity split

| | (1) | (2) | (3) |
|---|---|---|---|
| Dependent variable: | Realized price inflation | | |
| Sample: 2017 Q1 to 2022 Q2 (quarterly data) | | | |
| | All | Pre-Covid liquidity below average | Pre-Covid liquidity above average |
| Covid impact on $\text{sales}_{it} \times$ sales impact $\text{negative}_{it}$ | 0.016*** | 0.011** | 0.023*** |
| | (0.003) | (0.005) | (0.005) |
| Covid impact on $\text{sales}_{it} \times$ sales impact $\text{postive}_{it}$ | 0.125*** | 0.116*** | 0.143*** |
| | (0.026) | (0.032) | (0.044) |
| Dummy for Covid impact on sales $\text{positive}_{it}$ | -0.412** | -0.457* | -0.415 |
| | (0.178) | (0.244) | (0.272) |
| Constant | 2.958*** | 3.100*** | 2.809*** |
| | (0.023) | (0.034) | (0.033) |
| Firm fixed effects | Yes | Yes | Yes |
| Month fixed effects | Yes | Yes | Yes |
| Test Covid impact on sales coefficients equal (p-value) | 0.000 | 0.001 | 0.006 |
| Observations | 34,076 | 18,398 | 14,659 |

Notes: Standard errors are reported in parentheses, stars indicate *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Return

# Persistence of Covid demand effects

| | (1) | (2) | (3) |
|---|---|---|---|
| Dependent variable: | Covid impact on sales | | |
| Sample: | 2020Q2 to 2022 Q2 (quarterly data) | | |
| Covid impact on sales$_{it-1}\times$ sales impact negative$_{it-1}$ | 0.593$^{***}$ | 0.597$^{***}$ | 0.577$^{***}$ |
| | (0.011) | (0.012) | (0.012) |
| Covid impact on sales$_{it-1}\times$ sales impact postive$_{it-1}$ | 0.406$^{***}$ | 0.408$^{***}$ | 0.409$^{***}$ |
| | (0.026) | (0.026) | (0.026) |
| Dummy for Covid impact on sales positive$_{it-1}$ | 0.994$^{***}$ | 0.616$^{**}$ | 0.652$^{**}$ |
| | (0.295) | (0.293) | (0.292) |
| Constant | -1.491$^{***}$ | -1.267$^{***}$ | -1.630$^{***}$ |
| | (0.254) | (0.256) | (0.260) |
| Firm fixed effects | No | No | Yes |
| Quarter fixed effects | No | Yes | Yes |
| Test lagged Covid impact coefficients equal (p-value) | 0.000 | 0.000 | 0.000 |
| Observations | 30,872 | 30,872 | 30,872 |

Notes: Standard errors are reported in parentheses, stars indicate *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Return

# Covid demand shocks and firm price growth: Similarity to the literature

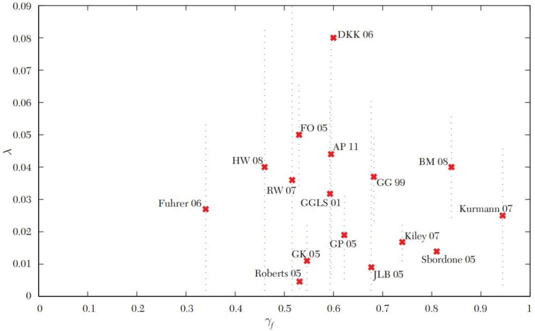



*Figure* 3. Point Estimates Reported in the Literature

*Notes:* Point estimates of $\lambda$ (vertical axis) and $\gamma_f$ (horizontal axis) reported in the literature. Only estimates that use U.S. data and the labor share as forcing variable are plotted. For some papers the semistructural point estimates have been imputed from point estimates of deeper parameters. The dotted blue lines indicate 95 percent confidence intervals for $\lambda$ where available. We include papers with readily available estimates and more than twenty-five Google Scholar citations as of mid-September 2012: Galí and Gertler (1999); Galí, Gertler, and López-Salido (2001); Fuhrer and Olivei (2005); Gagnon and Khan (2005); Guay and Pelgrin (2005); Henzel and Wollmershäuser (2008); Jondeau and Le Bihan (2005); Roberts (2005); Sbordone (2005); Dufour, Khalaf, and Kichian (2006); Fuhrer (2006); Kiley (2007); Kurmann (2007); Rudd and Whelan (2007); Brissimis and Magginas (2008); and Adam and Padula (2011).

*Source:* Mavroeidis, Plagborg-Moller, Stock (2014 JEL).

# Results on market power

1. To the extent that market power is fixed across time for a given firm, it will be captured by firm fixed effects.
2. We see a significant asymmetry in industries with high and low sales concentration (captured by a Hirfindahl-Hirschman Index) ▸ Table
3. We see a significant asymmetry in both cases when splitting firms by above vs. below median profit margins ▸ Table
4. Kink in response to Covid demand shock present across different firm sizes (strongest asymmetry for mid-sized firms) ▸ Table

◂ Return

# Covid demand shocks and firm price growth: Split by industry concentration (HHI)

| | (1) | (2) | (3) |
|---|---|---|---|
| Dependent variable: | Realized price inflation | | |
| Sample: 2017 Q1 to 2022 Q2 (quarterly data) | | | |
| | All firms | Low industry concentration | High industry concentration |
| Covid impact on sales$_{it}\times$ sales impact negative$_{it}$ | 0.016*** | 0.021*** | 0.010** |
| | (0.003) | (0.005) | (0.005) |
| Covid impact on sales$_{it}\times$ sales impact postive$_{it}$ | 0.125*** | 0.120*** | 0.136*** |
| | (0.026) | (0.035) | (0.037) |
| Dummy for Covid impact on sales positive$_{it}$ | -0.412** | -0.346 | -0.521* |
| | (0.178) | (0.233) | (0.274) |
| Firm fixed effects | Yes | Yes | Yes |
| Month fixed effects | Yes | Yes | Yes |
| Test Covid impact on sales coefficients equal (p-value) | 0.000 | 0.005 | 0.001 |
| Observations | 34,076 | 21,410 | 12,666 |

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

Return

# Covid demand shocks and firm price growth: Split by profit margins

| | (1) | (2) | (3) |
|---|---|---|---|
| Dependent variable: | Realized price inflation | | |
| Sample: 2017 Q1 to 2022 Q2 (quarterly data) | | | |
| | All firms | Below median profit margin | Above median profit margin |
| Covid impact on sales$_{it}\times$ sales impact negative$_{it}$ | 0.016*** | 0.012** | 0.020*** |
| | (0.003) | (0.005) | (0.005) |
| Covid impact on sales$_{it}\times$ sales impact postive$_{it}$ | 0.125*** | 0.146*** | 0.116*** |
| | (0.026) | (0.039) | (0.037) |
| Dummy for Covid impact on sales positive$_{it}$ | -0.412** | -0.605** | -0.342 |
| | (0.178) | (0.297) | (0.237) |
| Firm fixed effects | Yes | Yes | Yes |
| Month fixed effects | Yes | Yes | Yes |
| Test Covid impact on sales coefficients equal (p-value) | 0.000 | 0.001 | 0.009 |
| Observations | 34,076 | 13,809 | 16,914 |

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

Return

# Covid demand shocks and firm price growth: Split by firm size

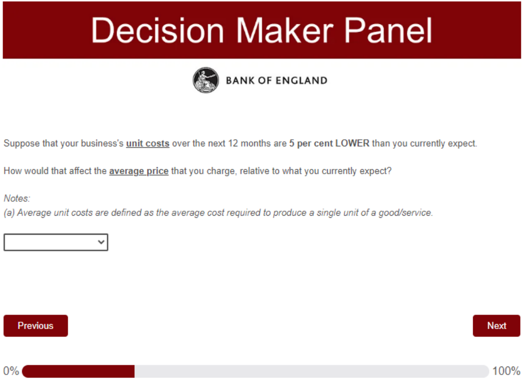
| Dependent variable: Sample: 2017 Q1 to 2022 Q2 (quarterly data) | (1) Realized price inflation All firms | (2) 10-49 employees | (3) 50-99 employees | (4) 100-249 employees | (5) 250+ employees |
|---|---|---|---|---|---|
| Covid impact on sales$_{it}\times$ sales impact negative$_{it}$ | 0.016$^{***}$ | 0.017$^{**}$ | 0.018$^{***}$ | 0.019$^{***}$ | 0.013$^{**}$ |
| | (0.003) | (0.008) | (0.007) | (0.006) | (0.006) |
| Covid impact on sales$_{it}\times$ sales impact postive$_{it}$ | 0.125$^{***}$ | 0.060 | 0.125$^{**}$ | 0.182$^{***}$ | 0.078$^{*}$ |
| | (0.026) | (0.050) | (0.049) | (0.056) | (0.045) |
| Dummy for Covid impact on sales positive$_{it}$ | -0.412$^{**}$ | -0.117 | -0.564 | -0.586 | -0.092 |
| | (0.178) | (0.354) | (0.397) | (0.361) | (0.306) |
| Firm fixed effects | Yes | Yes | Yes | Yes | Yes |
| Month fixed effects | Yes | Yes | Yes | Yes | Yes |
| Test Covid impact on sales coefficients equal (p-value) | 0.000 | 0.406 | 0.033 | 0.004 | 0.157 |
| Observations | 34,076 | 8,256 | 7,985 | 8,813 | 8,600 |

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

Return

# Hypothetical unit cost shocks: Screenshots

*Panel A:* Main scenario


Decision Maker Panel

BANK OF ENGLAND

Suppose that your business's **unit costs** over the next 12 months are **5 per cent** LOWER than you currently expect.

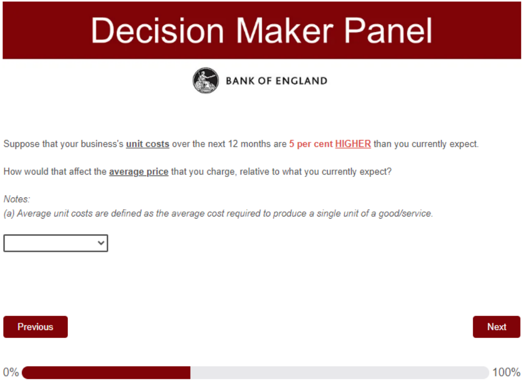
How would that affect the **average price** that you charge, relative to what you currently expect?

*Notes:*
*(a) Average unit costs are defined as the average cost required to produce a single unit of a good/service.*

Previous Next

0% 100%

*Panel B:* Flipped scenario


Decision Maker Panel

BANK OF ENGLAND

Suppose that your business's **unit costs** over the next 12 months are 5 per cent HIGHER than you currently expect.

How would that affect the **average price** that you charge, relative to what you currently expect?

*Notes:*
*(a) Average unit costs are defined as the average cost required to produce a single unit of a good/service.*

Previous Next

0% 100%

Return

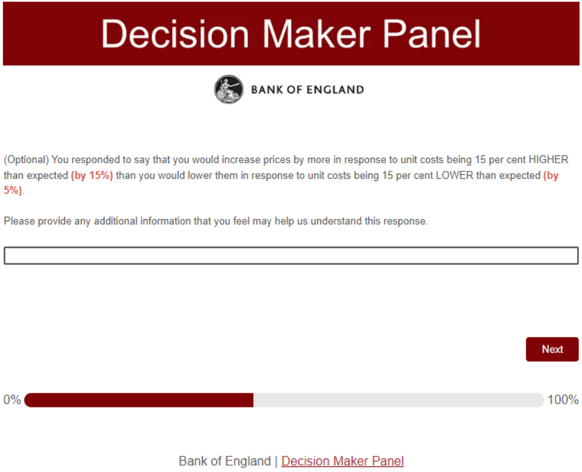
# Hypothetical unit cost shocks: Main results

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Dependent variable: | Average price response (%) | | | |
| Sample period: | Aug-24 to Sep-24 | | | |
| Unit cost shock | 0.415*** | 0.415*** | | |
| | (0.012) | (0.012) | | |
| Unit cost shock$^2$ | | 0.011*** | | |
| | | (0.001) | | |
| Unit cost shock $\times$ Shock$>0$ | | | 0.611*** | 0.630*** |
| | | | (0.017) | (0.025) |
| Unit cost shock $\times$ Shock$<0$ | | | 0.219*** | 0.254*** |
| | | | (0.013) | (0.021) |
| $R^2$ | 0.402 | 0.480 | 0.492 | 0.534 |
| Number of Observations | 2,496 | 2,496 | 2,496 | 2,470 |
| Test coefficients equal (p-value) | | | 0.000 | 0.000 |

Notes: The results in Column 4 are weighted by industry and employment. Standard errors are clustered at the firm level and are reported in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Return

# Hypothetical unit cost shocks: Open-text questions
Return


Decision Maker Panel

BANK OF ENGLAND

(Optional) You responded to say that you would increase prices by more in response to unit costs being 15 per cent HIGHER than expected **(by 15%)** than you would lower them in response to unit costs being 15 per cent LOWER than expected **(by 5%)**.

Please provide any additional information that you feel may help us understand this response.

Next

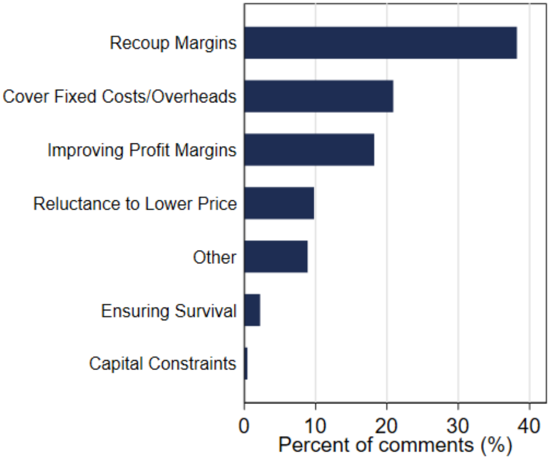
0% 100%

Bank of England | Decision Maker Panel

- In Aug-24 and Sep-24, we also ask firms which give a 'nonlinear' response to unit cost shocks about further details.
- In August 2024, we received 444 nonlinear responses and 273 comments (61% comment rate)
- Hand-code responses into several categories.

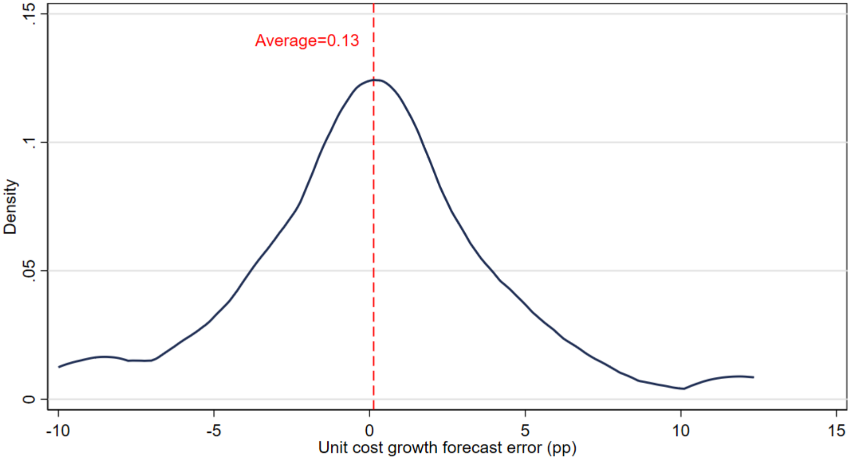
# Hypothetical unit cost shocks: Open-text questions

Return




- **Recoup margins:** "margins have been eroded too much over last 4 years"
- **Cover fixed costs:** "Our pricing isn't on a mark up basis and it pretty fixed. In times of high inflation we might seek to increase prices if necessary to avoid losses."
- **Reluctance to lower prices:** "May hold prices but very rare to decrease price"

# Distribution of unit cost forecast errors ◂ Return



# Unit cost growth forecast errors: Main results

Return

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Dependent variable: | Price growth forecast error (pp) | | | | |
| Sample period: | 2018Q1 to 2024Q3 (with gaps) | | | | |
| Unit cost growth forecast error | 0.2846*** | 0.2770*** | | | |
| | (0.0874) | (0.0879) | | | |
| Unit cost growth forecast error$^2$ | | 0.0073 | | | |
| | | (0.0161) | | | |
| Unit cost growth forecast error X Error $\geq 0$ | | | 0.4036*** | 0.3771** | 0.3892*** |
| | | | (0.0737) | (0.1520) | (0.1469) |
| Unit cost growth forecast error X Error $< 0$ | | | 0.1407* | 0.1795 | 0.1255 |
| | | | (0.0786) | (0.1610) | (0.1541) |
| Expected price growth | | | | | 0.5133*** |
| | | | | | (0.1368) |
| Time fixed effects | Yes | Yes | No | Yes | Yes |
| Firm fixed effects | Yes | Yes | No | Yes | Yes |
| $R^2$ | 0.513 | 0.513 | 0.042 | 0.514 | 0.551 |
| Number of Observations | 902 | 902 | 1,621 | 902 | 889 |
| Test coefficients equal (p-value) | | | 0.035 | 0.447 | 0.289 |

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

# High vs. low inflation sectors ◂ Return

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Dependent variable: | Annual own-price growth (%) | | Price growth forecast error (pp) | | Average price response (%) | |
| Sample period: | 2017Q1 to 2022Q2 | | 2018Q1 to 2024Q1 | | Dec-23 to Jan-24 | |
| Sample: | High Inflation | Low Inflation | High Inflation | Low Inflation | High Inflation | Low Inflation |
| Covid impact on sales$_{it}\times$ sales impact postive$_{it}$ | 0.145$^{***}$ | 0.064$^{*}$ | | | | |
| | (0.034) | (0.035) | | | | |
| Covid impact on sales$_{it}\times$ sales impact negative$_{it}$ | 0.013$^{***}$ | 0.018$^{***}$ | | | | |
| | (0.005) | (0.005) | | | | |
| Sales growth forecast error X Error $\geq 0$ | | | 0.093$^{***}$ | 0.048$^{***}$ | | |
| | | | (0.011) | (0.008) | | |
| Sales growth forecast error X Error $< 0$ | | | 0.039$^{***}$ | 0.030$^{***}$ | | |
| | | | (0.008) | (0.007) | | |
| Sales volume shock $\times$ Shock$> 0$ | | | | | 0.058$^{***}$ | 0.053$^{***}$ |
| | | | | | (0.008) | (0.007) |
| Sales volume shock $\times$ Shock$< 0$ | | | | | -0.022$^{**}$ | 0.032$^{***}$ |
| | | | | | (0.011) | (0.011) |
| Time fixed effects | Yes | Yes | Yes | Yes | No | No |
| Firm fixed effects | Yes | Yes | Yes | Yes | No | No |
| $R^2$ | 0.614 | 0.578 | 0.448 | 0.439 | 0.021 | 0.023 |
| Number of Observations | 14,379 | 15,550 | 8,987 | 8,791 | 2,720 | 2,408 |
| Test coefficients equal (p-value) | 0.000 | 0.201 | 0.000 | 0.131 | 0.000 | 0.071 |
| Difference coefficients positive/negative | 0.132 | 0.045 | 0.054 | 0.018 | 0.080 | 0.022 |
| Average firm price growth in sample (%) | 3.679 | 2.164 | 5.402 | 3.148 | 6.405 | 4.996 |

# Menu cost model with trend inflation

Return

- Firm produces a single good:

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

- Demand for firm's good:

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

- **Menu cost:** Firm must hire K units of labour in order to change its price
- Constant real wage rate:

$$\frac{W_t}{P_t} = \alpha \frac{\theta - 1}{\theta}$$

# Menu cost model with trend inflation
Return

- Log of nominal aggregate demand is a random walk with drift, with $\eta_t \sim N(0, \sigma_\eta^2)$

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

- Labour productivity follows an AR(1) process, with $\varepsilon_t(z) \sim N(0, \sigma_a^2)$

$$\log(A_t(z)) = \rho_a \log(A_{t-1}(z)) + \varepsilon_t(z)$$

# Menu cost model with trend inflation ◂ Return

- Log of demand shock, $d_t(z)$, follows an AR(1) process

$$\log(d_t(z)) = \rho_d \log(d_{t-1}(z)) + \varepsilon_t^d(z)$$
$$\varepsilon_t^d(z) \sim N(0, \sigma_{d,t}^2)$$

# Menu cost model with trend inflation ◂ Return

- Real profits

$$\Pi_t(z) = \left[\frac{p_t(z)}{P_t}\right]^{1-\theta} d_t(z) - \left[\frac{p_t(z)}{P_t}\right]^{-\theta/\alpha} d_t(z)^{1/\alpha} - \alpha\frac{\theta-1}{\theta} K I_t(z)$$

- Firm maximises profits discounted at a constant rate $\beta$

$$V\left(\frac{p_{t-1}(z)}{P_t}, A_t(z), d_t(z), \sigma^2_{d1,t}, \sigma^2_{d2,t}\right) =$$
$$\max_{p_t(z)} \left[\Pi_t(z) + \beta E_t V\left(\frac{p_t(z)}{P_{t+1}}, A_{t+1}(z), d_{t+1}(z), \sigma^2_{d1,t+1}, \sigma^2_{d2,t+1}\right)\right]$$

# Menu cost model with trend inflation: Implementation ◂ Return

1. Begin with a law of motion for inflation that is linear in aggregate demand and aggregate volatility (in the spirit of Krusell-Smith)
2. Solve the firms' decision rules (using value function iteration)
3. Aggregate the decisions to obtain aggregate inflation dynamics
4. Update the law of motion in Step 1
5. Iterate until convergence
6. After convergence, simulate the model for 1,000 firms and 20,000 periods

# Menu cost model with trend inflation: Implementation

Return

- Discount factor: $\beta = 0.96^{1/12}$
- Elasticity of demand: $\theta = 4$
- Labour productivity: $\rho_a = 0.7$ and $\sigma_a = 0.0425$
- Price level equation: $\mu = 0.0021$ and $\sigma_\eta = 0.001$
- Returns to scale: $\alpha = 0.9$
- Demand shock: $\rho_d = 0.7$ and $\sigma_d = 0.0425$
- Menu cost: $\frac{K}{C} \in [0.018, 0.09]$