Inflation Expectations and the Supply Chain

Elias Albagli
Central Bank of Chile

Francesco Grigoli
IMF

Emiliano Luttini
Central Bank of Chile

ASSA 2023 Annual Meeting
January 6–8, 2023

The views expressed in this presentation are those of the authors and do not necessarily represent those of the IMF, its Executive Board, its management, or the Central Bank of Chile.

Motivation

- How firms form expectations is key to MP, which targets aggregates that depend on firms' expectations and decisions

Motivation

- How firms form expectations is key to MP, which targets aggregates that depend on firms' expectations and decisions

- Firms look at same easy-to-consult aggregate statistics, yet information rigidity results in forecast disagreement and inattention (Mankiw and Reis, 2002; Sims, 2003; Coibion and Gorodnichenko, 2015)

Motivation

- How firms form expectations is key to MP, which targets aggregates that depend on firms' expectations and decisions

- Firms look at same easy-to-consult aggregate statistics, yet information rigidity results in forecast disagreement and inattention (Mankiw and Reis, 2002; Sims, 2003; Coibion and Gorodnichenko, 2015)

- So, what do firms look at when forecasting inflation?
  - Information on the price expectations of businesses who are, after all, the price setters is particularly scarce (Bernanke, 2007)
  - Evidence from surveys of firms substantially different from professional forecasters and households (Candia et al., 2022)

Motivation

- How firms form expectations is key to MP, which targets aggregates that depend on firms' expectations and decisions

- Firms look at same easy-to-consult aggregate statistics, yet information rigidity results in forecast disagreement and inattention (Mankiw and Reis, 2002; Sims, 2003; Coibion and Gorodnichenko, 2015)

- So, what do firms look at when forecasting inflation?
  - Information on the price expectations of businesses who are, after all, the price setters is particularly scarce (Bernanke, 2007)
  - Evidence from surveys of firms substantially different from professional forecasters and households (Candia et al., 2022)

  $\rightarrow$ Firms may learn from their surroundings/network and assign an *aggregate* value to *local* signal (Lucas, 1972)

Motivation

- How firms form expectations is key to MP, which targets aggregates that depend on firms' expectations and decisions

- Firms look at same easy-to-consult aggregate statistics, yet information rigidity results in forecast disagreement and inattention (Mankiw and Reis, 2002; Sims, 2003; Coibion and Gorodnichenko, 2015)

- So, what do firms look at when forecasting inflation?
  - Information on the price expectations of businesses who are, after all, the price setters is particularly scarce (Bernanke, 2007)
  - Evidence from surveys of firms substantially different from professional forecasters and households (Candia et al., 2022)

  $\rightarrow$ Firms may learn from their surroundings/network and assign an *aggregate* value to *local* signal (Lucas, 1972)

- **This paper**
  1. Do firms' supply chains affect their inflation expectation formation?
  2. Do these beliefs affect firms' sales pricing decisions?

Unique data

- Chile during Jan 2015–Sep 2021
  - Great setting $\rightarrow$ CPI inflation moved between 1.4% and 5.2%

Unique data

- Chile during Jan 2015–Sep 2021
  - Great setting → CPI inflation moved between 1.4% and 5.2%

- (Matched) data sources
  1. Expectation survey
     - Monthly, since December 2004
     - Key question: *"What do you think inflation will be in the next 12 months (measured by the Consumer Price Index CPI)?"*

Unique data

- Chile during Jan 2015–Sep 2021
  - Great setting → CPI inflation moved between 1.4% and 5.2%

- (Matched) data sources
  1. Expectation survey
     - Monthly, since December 2004
     - Key question: *"What do you think inflation will be in the next 12 months (measured by the Consumer Price Index CPI)?"*
  2. VAT registry
     - B2B transaction data since 2014 to identify supply chain
     - p and q for all products purchased and sold
  3. Customs
     - p and q for all products imported and exported

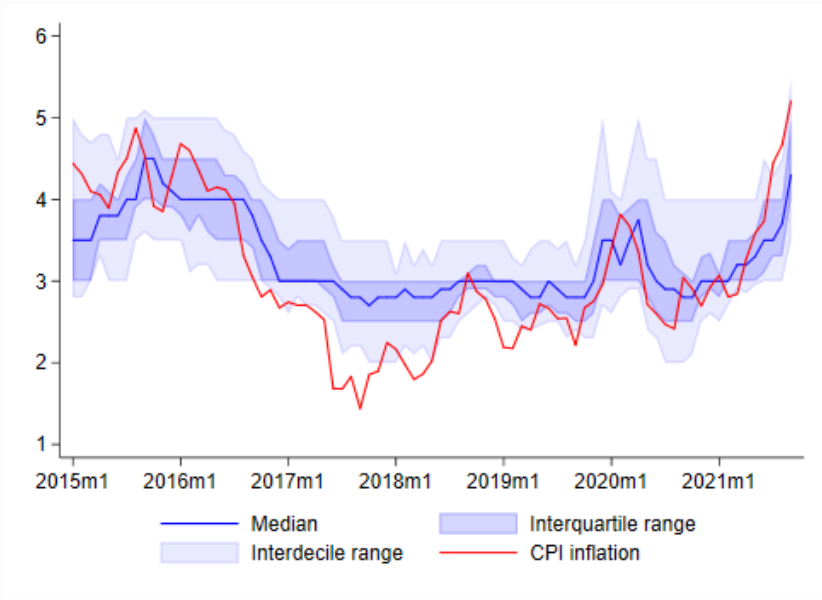
Unique data

- Chile during Jan 2015–Sep 2021
  - Great setting → CPI inflation moved between 1.4% and 5.2%

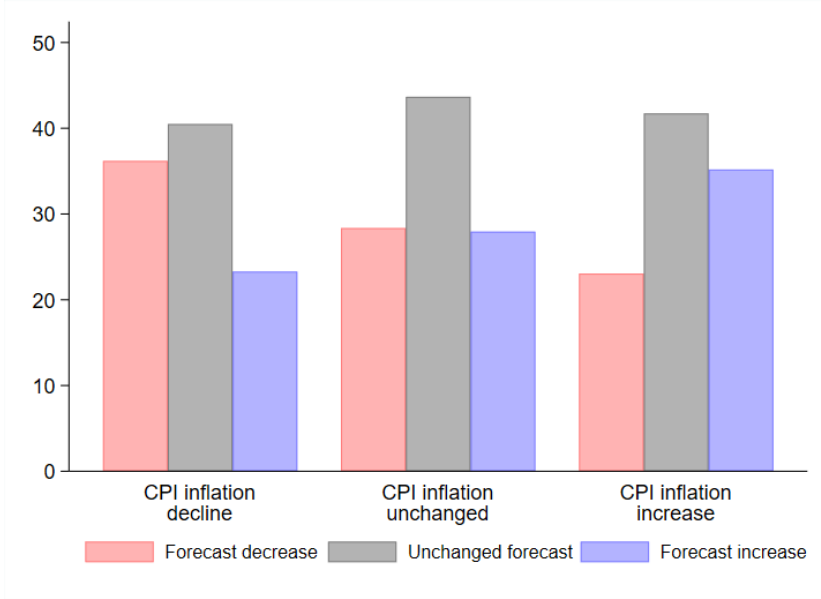
- (Matched) data sources
  1. Expectation survey
     - Monthly, since December 2004
     - Key question: *"What do you think inflation will be in the next 12 months (measured by the Consumer Price Index CPI)?"*
  2. VAT registry
     - B2B transaction data since 2014 to identify supply chain
     - p and q for all products purchased and sold
  3. Customs
     - p and q for all products imported and exported
  4. Income tax form
     - Monthly revenue and purchases of materials
  5. Social Security Treasury
     - Firms' monthly wage bill

Firms' disagreement and inattention

(a) Dispersion in inflation expectations



(b) Share of firm-month observations responding to changes in CPI inflation



- Firms have different views about inflation
  - But tend to correlate with inflation outcome
- Almost $1/2$ of firms do not change forecasts, $1/5$ change them in wrong direction
  - Firms appear to attribute changes in activity to supply shocks

Reconciliating supply chain, disagreement, and inattention

- In Lucas (1972), firms are located on islands and learn from a subset of islands they trade with
  - Signal extraction problem: firms need to forecast aggregate inflation to take production decisions Signal extraction problem

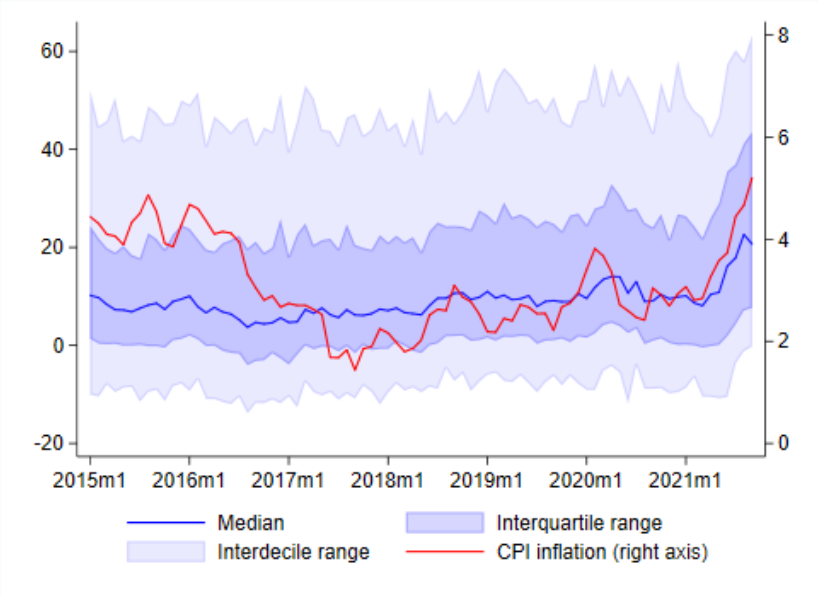
- Disagreement can arise if firms rely on dispersed supply chain conditions to form aggregate beliefs

- Firms may be inattentive to macro developments if these are less relevant than supply chain inflation for their business

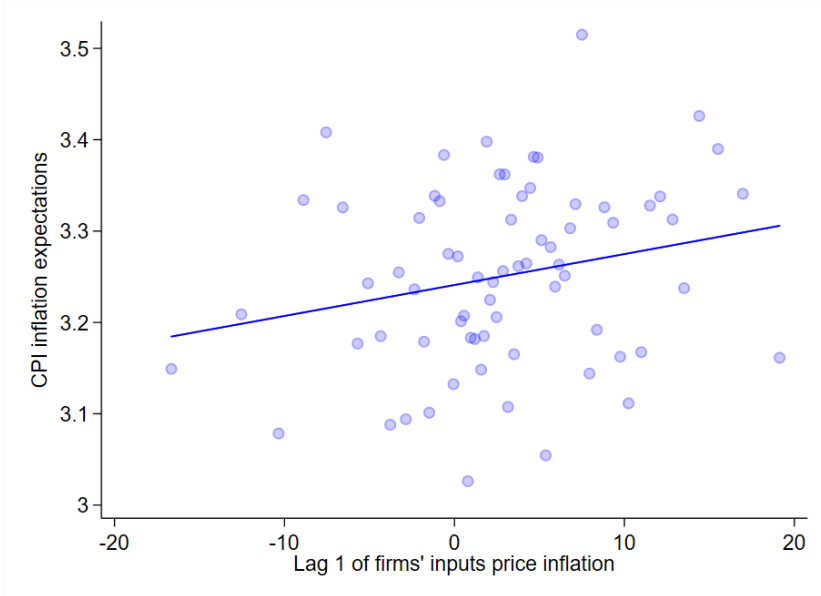
Supply chain inflation and firms' inflation expectations

Series construction

(a) Input price inflation



(b) Input price inflation and firms' expectations



- Dispersion of input price inflation reflecting heterogeneity along supply chain, with longer right tail
- Significant volatility over time compared to actual inflation
- Yet, inflation expectations correlated with supply chain inflation

Responses of firms' aggregate inflation expectations

$$E_{i,t+h}\pi_{t+h+12} - E_{i,t-1}\pi_{t-1+12} =$$
$$\alpha_i^h + \sum_{p=1}^{P} \beta_p^h \pi_{t-p} + \sum_{p=1}^{P} \gamma_p^h \pi_{i,t-p} + \sum_{p=1}^{P} \theta_p^h X_{i,t-p} + \varepsilon_{i,t+h}$$

- Sample
  - After cleaning, 340 firms for over 7,800 observations
- Orthogonality
  - Controlling for aggregate inflation isolates changes in supply chain prices that do not have implications for inflation
  - Inherent, sharp, FIRE test: $\gamma_p^h = 0$

Responses of firms' aggregate inflation expectations

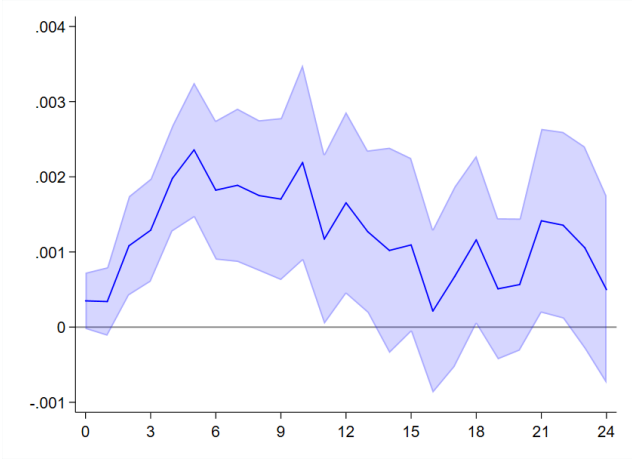
$$E_{i,t+h}\pi_{t+h+12} - E_{i,t-1}\pi_{t-1+12} =$$
$$\alpha_i^h + \sum_{p=1}^{P} \beta_p^h \pi_{t-p} + \sum_{p=1}^{P} \gamma_p^h \pi_{i,t-p} + \sum_{p=1}^{P} \theta_p^h X_{i,t-p} + \varepsilon_{i,t+h}$$

- Sample
  - After cleaning, 340 firms for over 7,800 observations
- Orthogonality
  - Controlling for aggregate inflation isolates changes in supply chain prices that do not have implications for inflation
  - Inherent, sharp, FIRE test: $\gamma_p^h = 0$
- Identification
  - Input prices exogenously determined wrt firms' inflation expectations
  - Direct measure of prices observed by firms ($\neq$ sector inflation)
  - Expectations elicited at 1-year horizon, closer to MP horizon
  - Survey's higher frequency reduces chances of confounding factors

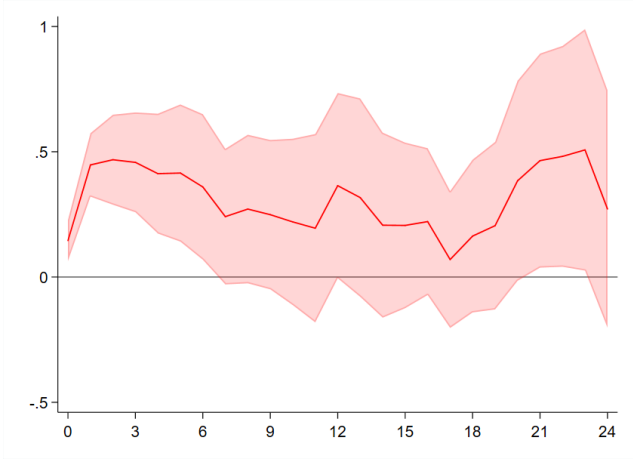
Responses of firms' aggregate inflation expectations

Robustness

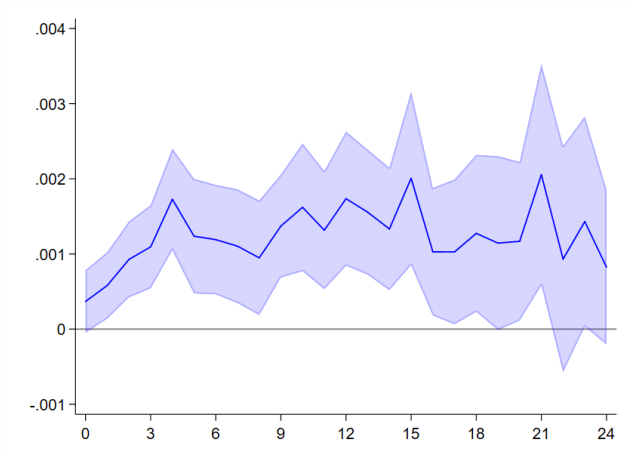
(a) 1pp increase in input price inflation



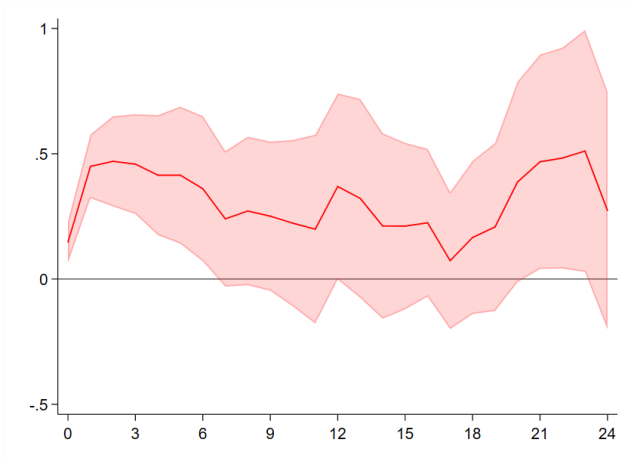
(b) 1pp increase in CPI inflation



(c) 1pp increase in domestic and imported input price inflation



(d) 1pp increase in CPI inflation (regression with domestic and imported input price inflation)



- Effect of 1SD ↑ at peak: input price inflation → 0.1pp; CPI inflation → 0.4pp

Imposing orthogonality at all horizons

- Results reject FIRE, yet firms may be anticipating that a surge in input prices will lead to higher inflation in the *future*

Imposing orthogonality at all horizons

- Results reject FIRE, yet firms may be anticipating that a surge in input prices will lead to higher inflation in the *future*

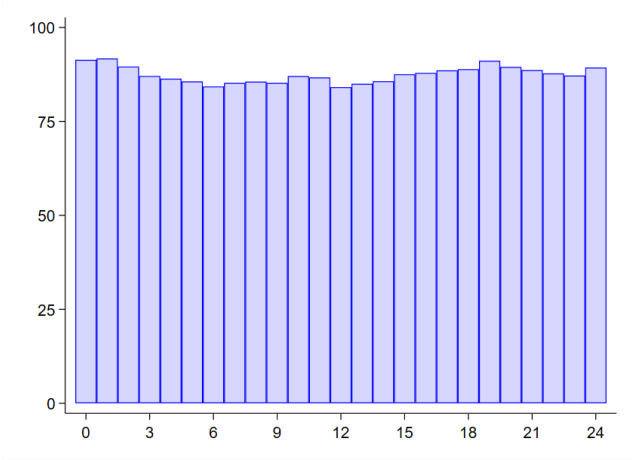
- Test robustness to future orthogonality
  1. Firm-by-firm regressions to assess non-predictability (i.e., $\gamma_p^{i,h}$ not significant)

$$\pi_{t+h} = \iota^i + \sum_{p=1}^{P} \beta_p^{i,h} \pi_{t-p} + \sum_{p=1}^{P} \gamma_p^{i,h} \pi_{i,t-p} + \nu_{i,t+h}$$

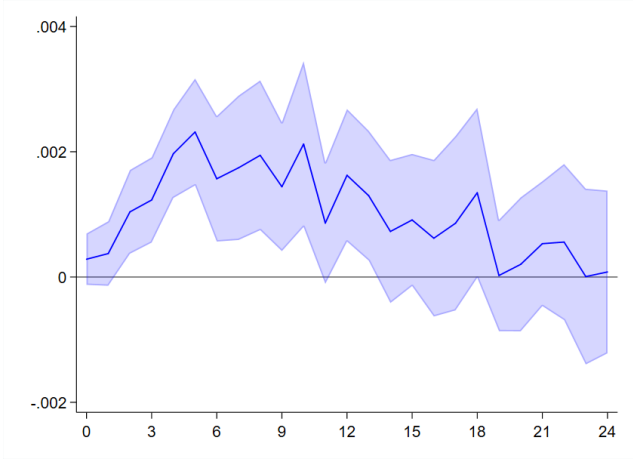
  2. Compute share of firms at any h for which supply chain prices cannot predict aggregate inflation
  3. Re-estimate baseline with firms/horizons for which we ensure non-predictability

Imposing orthogonality at all horizons

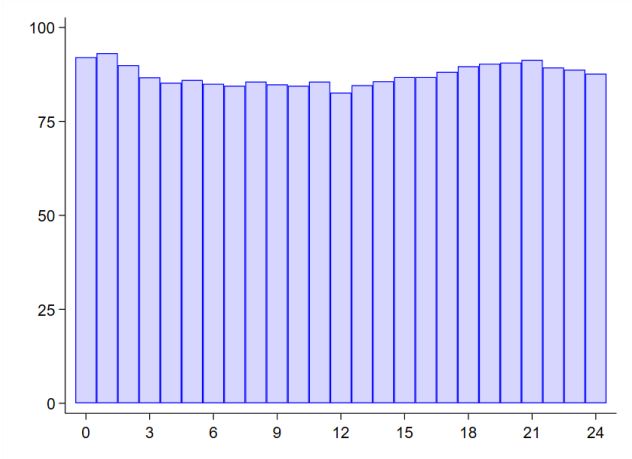
(a) Share of firms with input price inflation unrelated to future CPI inflation



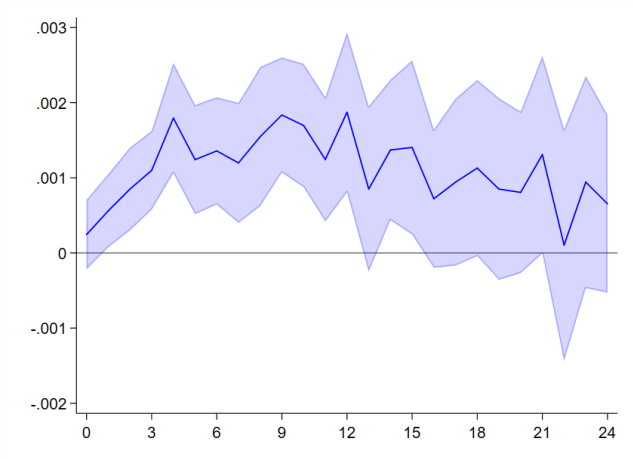
(b) 1pp increase in input price inflation



(c) Share of firms with domestic and imported input price inflation unrelated to future CPI inflation



(d) 1pp increase in domestic and imported input price inflation



A placebo test

- For each firm i, consider all other firms $J \neq i$ and regress one-by-one all J's supply chain inflation on firm i's supply chain inflation

$$\pi_{j,t} = a^j + b^j \pi_{i,t} + e_{j,t} \quad \forall j \in J$$

- Then add supply chain inflation of firm j that produced the smallest coefficient $|b^{j*}|$ to baseline specification to test that $|b^{j*}| = 0$

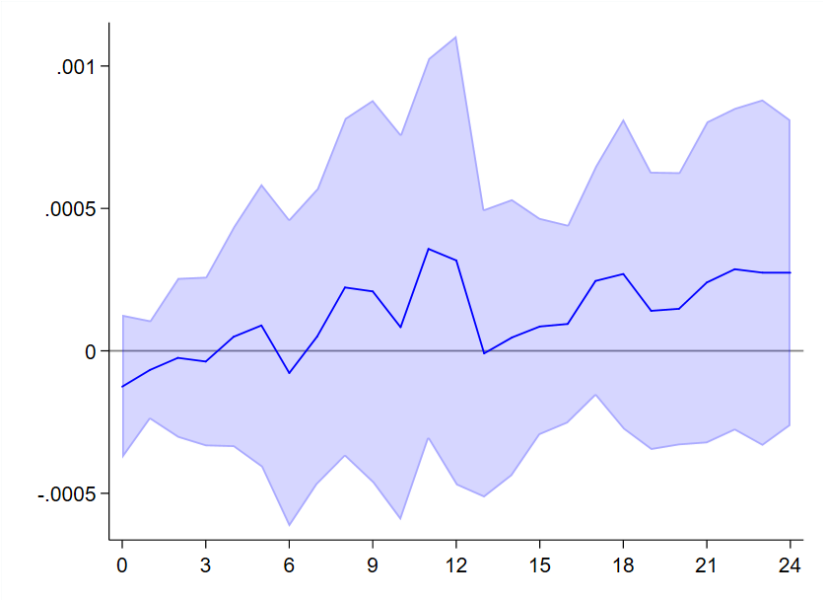
A placebo test

- For each firm i, consider all other firms $J \neq i$ and regress one-by-one all J's supply chain inflation on firm i's supply chain inflation

$$\pi_{j,t} = a^j + b^j \pi_{i,t} + e_{j,t} \quad \forall j \in J$$

- Then add supply chain inflation of firm j that produced the smallest coefficient $|b^{j*}|$ to baseline specification to test that $|b^{j*}| = 0$

(a) Placebo test for input price inflation



Firms' price setting behavior

- Virtually no empirical evidence on PC estimations with micro data

Firms' price setting behavior

- Virtually no empirical evidence on PC estimations with micro data

- We derive and estimate the NKPC at the firm level
  - Price adjustment costs as in Rotemberg (1982) to avoid symmetric equilibrium

$$\pi_{i,t} = \beta E_{i,t}\pi_{i,t+1} + \frac{\theta\psi}{\gamma}\widetilde{\psi}_{i,t}$$

Firms' price setting behavior

- Virtually no empirical evidence on PC estimations with micro data

- We derive and estimate the NKPC at the firm level
  - Price adjustment costs as in Rotemberg (1982) to avoid symmetric equilibrium

$$\pi_{i,t} = \beta E_{i,t}\pi_{i,t+1} + \frac{\theta\psi}{\gamma}\widetilde{\psi}_{i,t}$$

- Caveat: we have to assume that firms expect their relative prices to remain constant over time

$$E_{i,t}\pi_{i,t+1} = E_{i,t}\pi_{t+1} + \omega_{i,t}$$

so that we can estimate a pseudo NKPC

$$\pi_{i,t} = \beta E_{i,t}\pi_{t+1} + \frac{\theta\psi}{\gamma}\widetilde{\psi}_{i,t} + \beta\omega_{i,t}$$

(Pseudo) NKPC estimation

	Input price inflation		Weighted avg of input and import price inflation	
	(1)	(2)	(3)	(4)
Lagged inflation expectations	1.353***	0.992*	1.371***	1.204**
	(0.386)	(0.528)	(0.365)	(0.480)
Real marginal costs	0.053	0.046	0.055	0.084
	(0.041)	(0.065)	(0.042)	(0.060)
F-test lagged inflation expectations $= 1$	0.830	0.000	1.030	0.180
Sample	Full	LP sample	Full	LP sample
Firms	411	269	423	102
Observations	11,131	5,649	11,567	5,820
R-squared	0.196	0.233	0.193	0.243

Notes: All regressions include firm fixed effects. Clustered standard errors at the firm and time level in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

- Firms set prices according to their expectations of future aggregate inflation, which depend on supply chain inflation dynamics
- Coefficient on expected inflation not statistically different from 1
- Real marginal costs borderline insignificant

Hybrid (pseudo) PC estimation

	Input price inflation		Weighted avg of input and import price inflation	
	(1)	(2)	(3)	(4)
Lagged inflation expectations	1.293***	0.935*	1.290***	0.947*
	(0.378)	(0.520)	(0.354)	(0.541)
Real marginal costs	0.051	0.048	0.053	-0.001
	(0.041)	(0.062)	(0.041)	(0.076)
Lagged dependent variable	0.045***	0.039***	0.046***	0.048***
	(0.009)	(0.013)	(0.009)	(0.016)
F-test lagged inflation expectations $= 1$	0.600	0.020	0.670	0.010
Sample	Full	LP sample	Full	LP sample
Firms	409	269	418	175
Observations	11,007	5,649	11,392	3,140
R-squared	0.214	0.247	0.211	0.302

Notes: All regressions include firm fixed effects. Clustered standard errors at the firm and time level in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

- A naive inclusion of the lagged dependent variable does not change the results
- Firms very much forward looking

Conclusions and implications

- Main results
  - Supply chain inflation informs firms' expectations about aggregate inflation, even if it doesn't have any aggregate effect
  - Firms fully pass-through changes in CPI inflation expectations to sales prices

- Underlying theories
  - Islands model (Lucas, 1972)
  - Information rigidities (Mankiw and Reis, 2002; Sims, 2003)

- Implications
  - The channel we highlight in this paper can lead to dispersion in inflation expectations, which is a metric of anchoring
  - Forecast disagreement can translate into (welfare-costly) price dispersion
  - The information frictions we discuss in this paper weaken the effectiveness of the expectation channel of policies

Firms as islands—setting

Back

- N islands with a firm in each that charges p_i, and aggregate prices $p_t = 1/N \sum_i^N p_{i,t}$
- Firms increase output if own price is higher than aggregate price

$$y_{i,t} = \gamma(p_{i,t} - p_t)$$

- Assumption: imperfect information
  - Firms know their price $p_{i,t}$
  - Firms do not know aggregate price $p_t \rightarrow$ need to guess $E(p_t|I_{i,t-1})$
- Supply curve becomes

$$y_{i,t} = \gamma(p_{i,t} - E(p_t|I_{i,t-1}))$$

- How do firms form $E(p_t|I_{i,t-1})$?
  - RE: $p_t = E(p_t|I_{i,t-1}) + \epsilon$ with $\epsilon_t \sim N(0, \sigma)$
  - Island's prices differ randomly from aggregate: $p_{i,t} = p_t + z_t$ with $z \sim (0, \tau)$
- Firms' production decision:
  - If firm had perfect information, $y_{i,t} = z_t$
  - With imperfect information, $y_{i,t} = z_t + \epsilon_t$

Firms as islands—signal extraction problem

Back

- Firms need to assess how much of the composite shock is due to z_t and to ϵ_t, and change output only in response to z_t
  - Proportion of composite shock coming from z: $\theta = \tau^2/(\sigma^2 + \tau^2)$
  - Infer it from the past
- Since $p_{i,t} = p_t + z_t$, they need to guess aggregate prices to decide production

$$\begin{aligned} E(p_t|I_{i,t-1}, p_{i,t}) &= p_{i,t} - E(z_t|I_{i,t-1}, p_{i,t}) \\ &= p_{i,t} - \theta(p_{i,t} - E(p_t|I_{i,t-1})) \\ &= (1-\theta)p_{i,t} + \theta E(p_t|I_{i,t-1})) \end{aligned}$$

- In changes

$$E(\pi_t|I_{i,t-1}, p_{i,t-1}) = (1-\theta)\pi_{i,t} + \theta E(\pi_t|I_{i,t-1})$$

Supply chain inflation

Back

- Construction steps
  1. Collect prices and quantities for each product j purchased by firm i during period t, p_{ijt} and q_{ijt}
  2. Some cleaning
     - Drop if identifier of the buyer and the seller is the same
     - Drop if $p_{ijt} \leq 10$
     - Drop if $q_{ijt} \leq 0$.
  3. For each product purchased by each firm, compute the y-o-y log difference of the median price observed in each month, π^{50}_{ijt}
  4. To aggregate at the firm level, compute the average of product inflation weighted by the transaction amount, $\pi_{it} = \sum_j \frac{p_{ijt}q_{ijt}}{p_{it}q_{it}} \pi^{50}_{ijt}$
  5. Trim observations outside of the $[-30, 100]$ percent change band

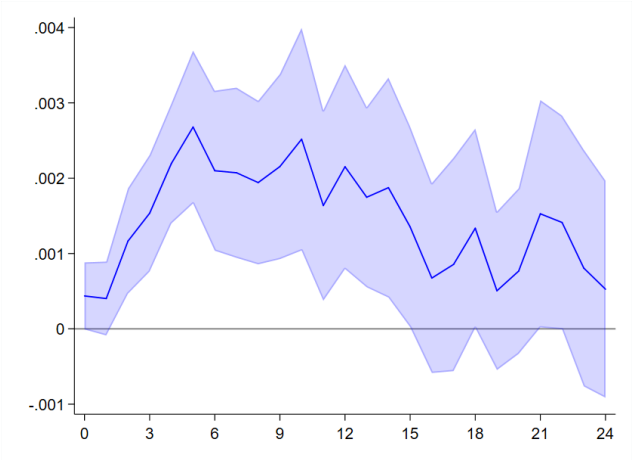
- Firms involved in international trade may experience price changes for inputs sourced *abroad*
  - Most firms answering the survey have zero or small imports
  - Compute weighted average of input and import price inflation

- Do the same for sales and export price inflation

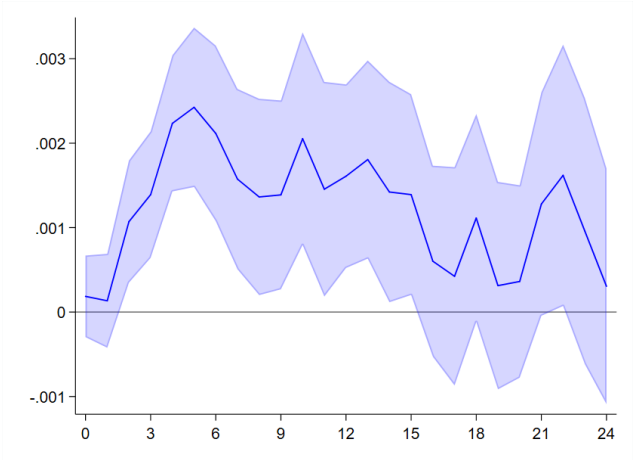
Robustness results

Back

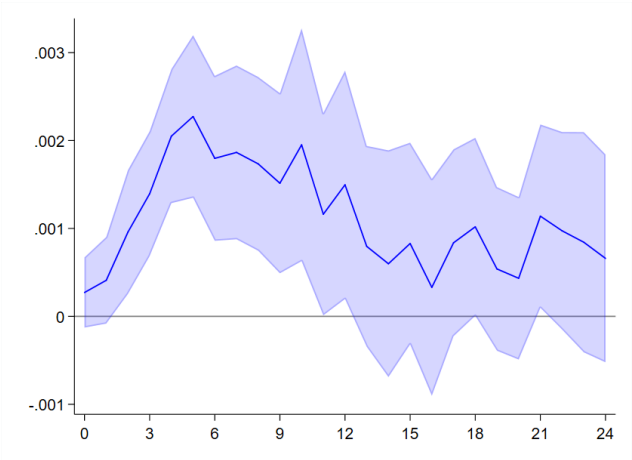
(a) At least 25 suppliers per firm



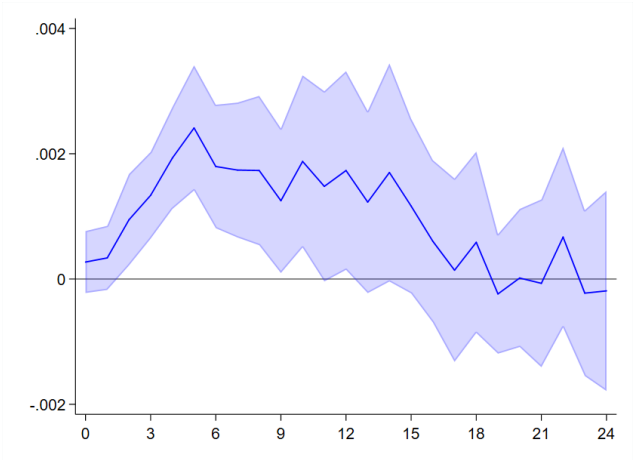
(b) More lags



(c) No lags



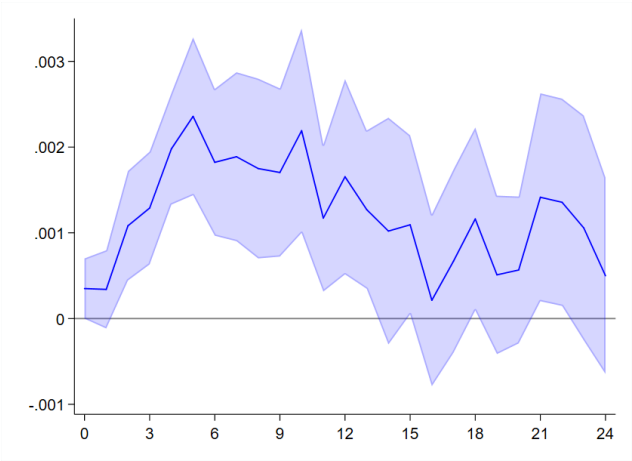
(d) Controlling for input price inflation



Robustness results

Back

(a) Driscoll-Kraay standard errors



(b) Double-clustered standard errors