Inflation Expectations and the Supply Chain

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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
  - Very relevant to current macroeconomic juncture

- Bernanke (2007): "Information on the price expectations of businesses who are, after all, the price setters (...) is particularly scarce"

- Firms look at same easy-to-consult aggregates, yet information rigidity results in forecast disagreement and inattention

- Firms may learn from their surroundings/network and assign an "aggregate value" to local signal (Lucas, 1972)

- **Research questions**→ Do firms' supply chains play a role in the inflation expectation formation mechanism? Do these beliefs affect firms' sales pricing decisions?

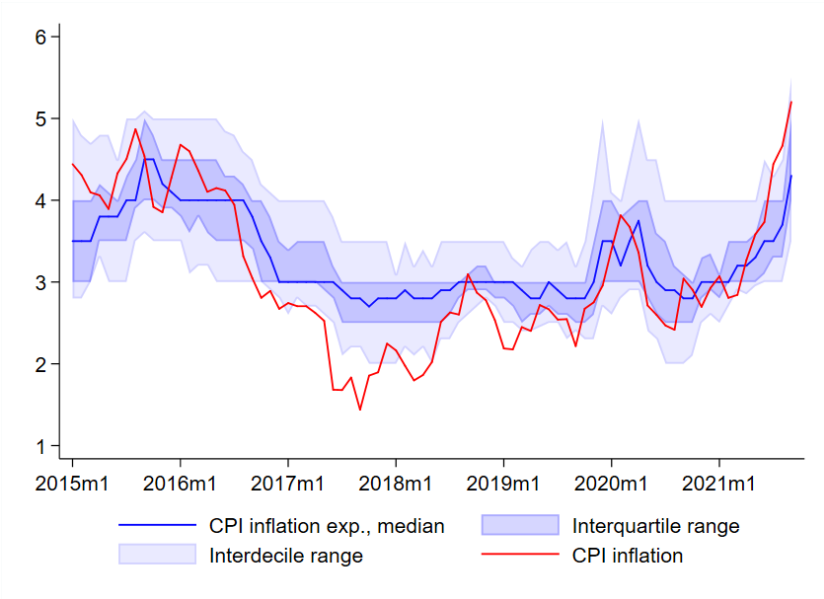
Unique data

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

- 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 by Chilean firms
  3. Customs
     - p and q for all products imported and exported by Chilean firms
  4. Income tax form
     - Monthly revenue and purchases of materials
  5. Social Security Treasury
     - Firms' monthly wage bill

Firms' disagreement

(a) Inflation expectation dispersion

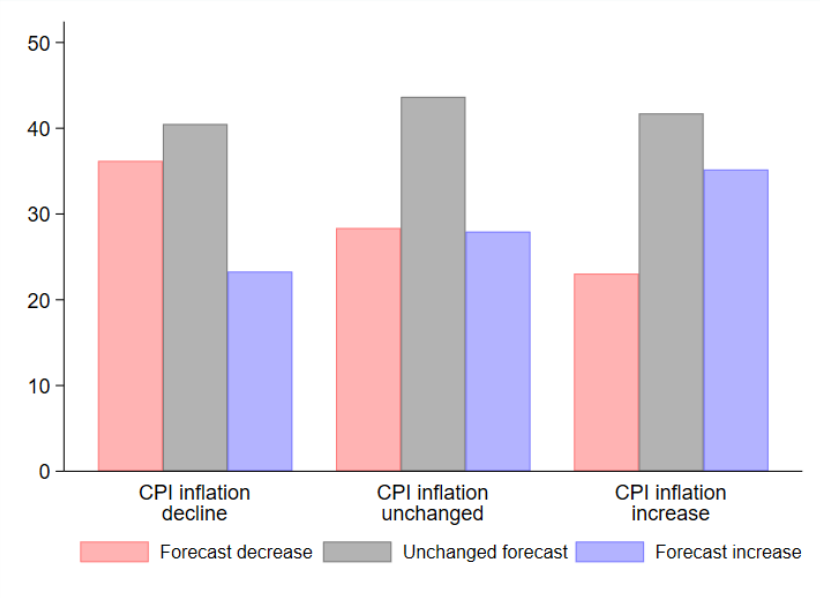


(b) Inflation and firms' expectations

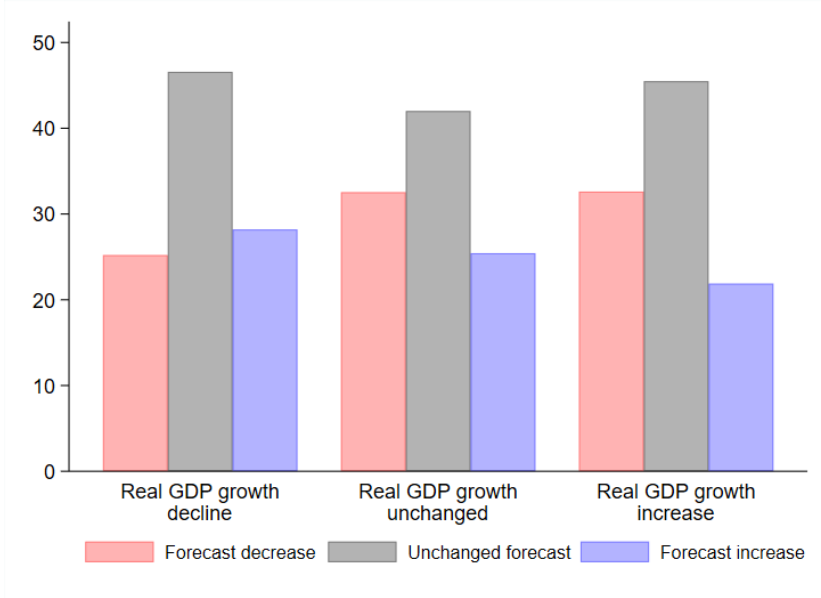
- Firms have different views about inflation
- But tend to correlate with inflation outcome

Inattention to macroeconomic developments

(a) Changes in CPI inflation



(b) Changes in real GDP growth



- 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 decision 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

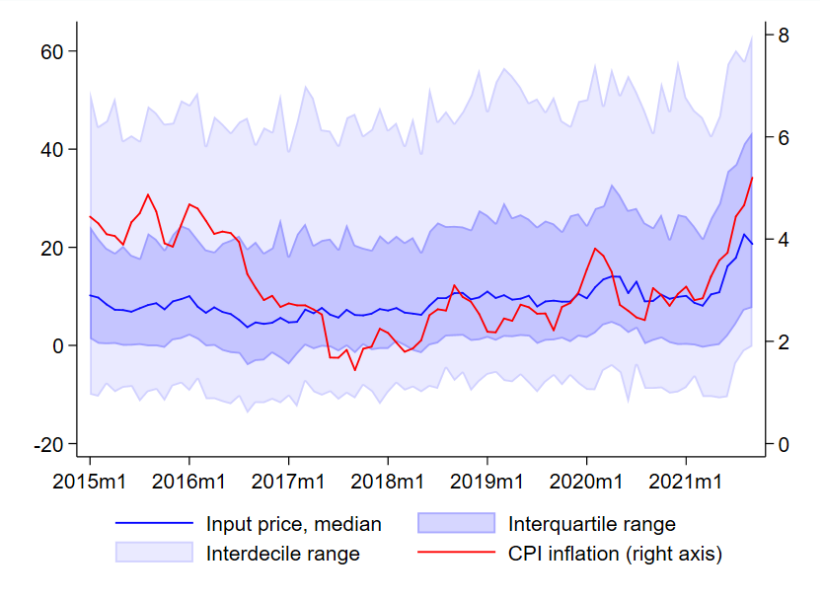
- Construction steps
  1. Collect prices and quantities for each product j purchased by firm i during period t, p_{ijt} and q_{ijt}
  2. Some cleaning
     - Drop if identifier of the buyer and the seller is the same
     - Drop if $p_{ijt} \leq 10$
     - Drop if $q_{ijt} \leq 0$.
  3. For each product 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

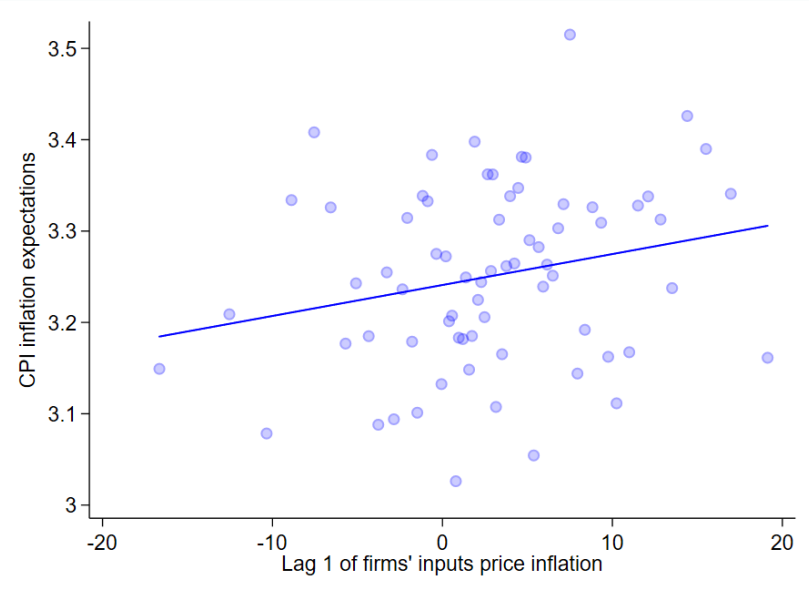
- Do the same for sales and export price inflation

Supply chain inflation and firms' inflation expectations

(a) Input price inflation



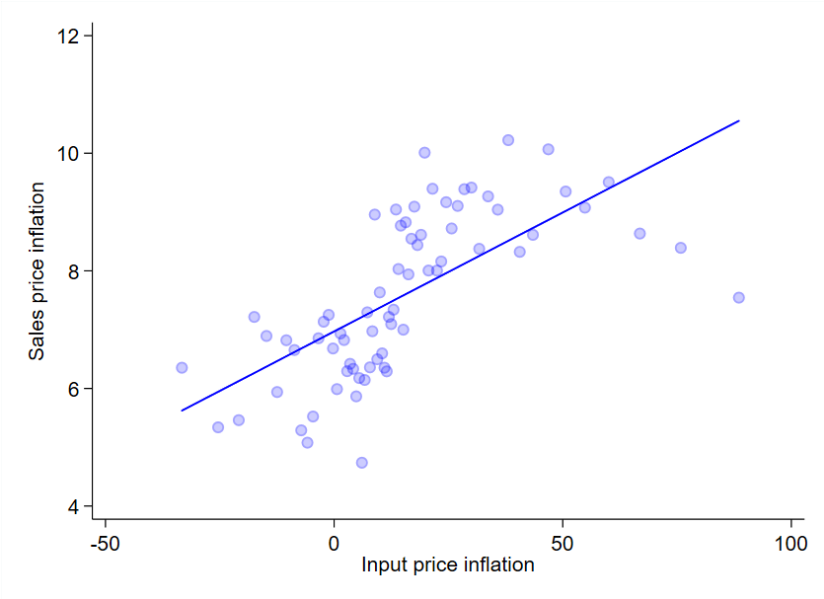
(b) Input price inflation and firms' expectations



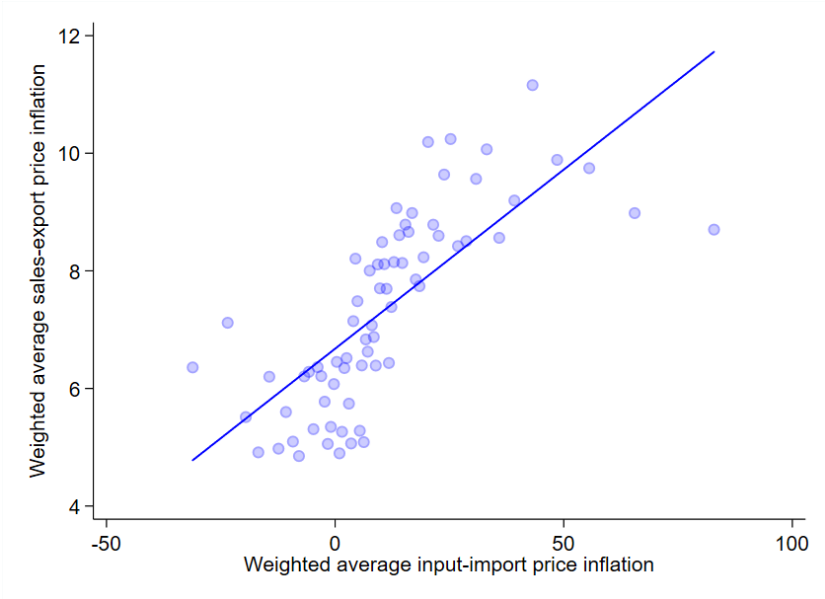
- Dispersion of input price inflation reflecting heterogeneity along supply chain, with longer right tail
- Significant volatility over time compared to actual inflation
- Yet, inflation expectations correlated with supply chain inflation

Correlation between input and sales price inflation

(a) Domestic measures



(b) Measures including international trade



- Input and sales price inflation positively correlated, albeit weakly
- Heterogeneous pass through likely reflecting firms' strategic considerations

Responses of firms' aggregate inflation expectations

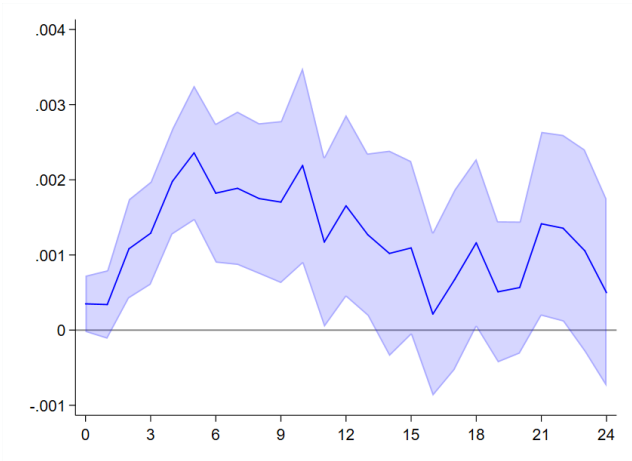
$$E_{i,t+h}\pi_{t+h+12} - E_{i,t-1}\pi_{i,t-1+12} =$$
$$\alpha_i^h + \sum_{p=1}^{P} \beta_p^h \pi_{t-p} + \sum_{p=1}^{P} \gamma_p^h \pi_{i,t-p} + \sum_{p=1}^{P} \theta_p^h X_{i,t-p} + \varepsilon_{i,t+h}$$

- Sample
  - After cleaning, 340 firms for over 7,800 observations
- Identification
  - Input prices exogenously determined wrt firms' inflation expectations
    - Robustness excluding firms with less than 25 suppliers
  - Granular data allows constructing direct measure of what prices firms observe and addresses issue of firms operating in multiple sectors
  - Survey's higher frequency reduces chances of confounding factors
- Orthogonality
  - Controlling for aggregate inflation isolates changes in supply chain prices that do not have implications for inflation
  - Inherent FIRE test (under FIRE $\beta_p^h > 0$ and $\gamma_p^h = 0$)

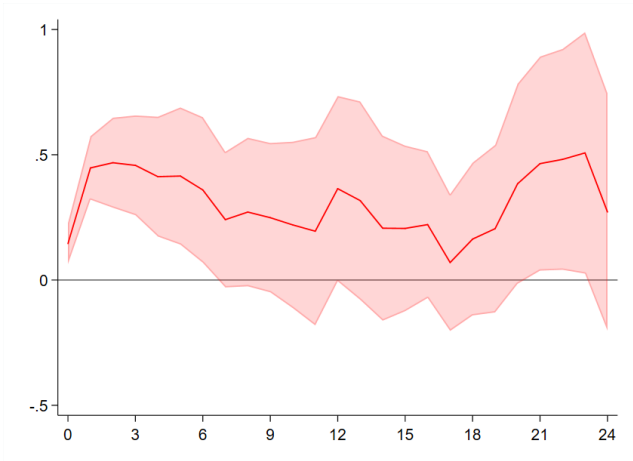
Responses of firms' aggregate inflation expectations

Robustness

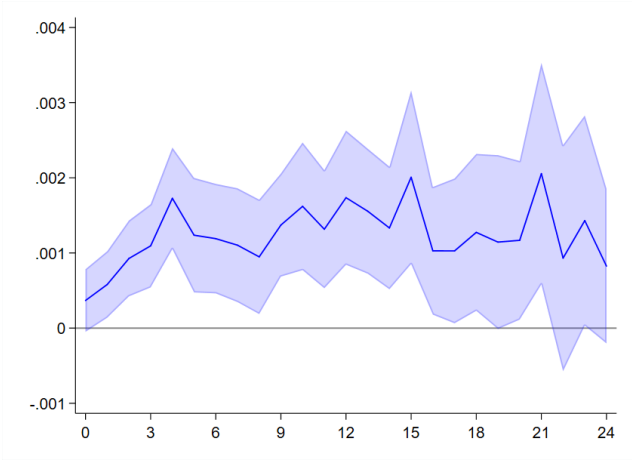
(a) 1pp increase in firms' input price inflation



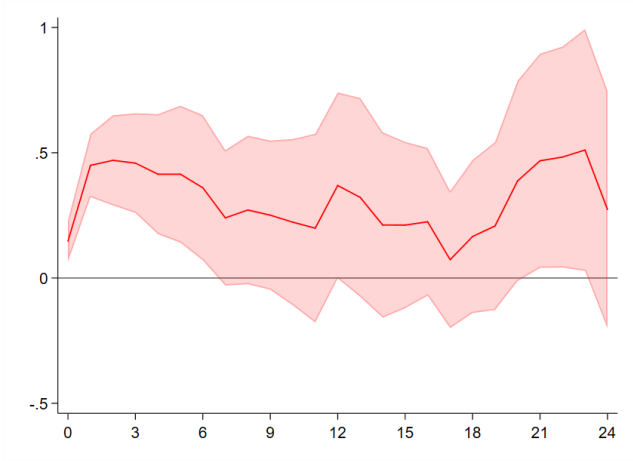
(b) 1pp increase in CPI inflation



(c) 1pp increase in the weighted average of input and import price inflation



(d) 1pp increase in CPI inflation (regression with w. avg. of input and import price inflation)



- Effect of 1SD ↑ at peak: input price inflation → 0.5pp; CPI inflation → 0.4pp

Placebo

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*

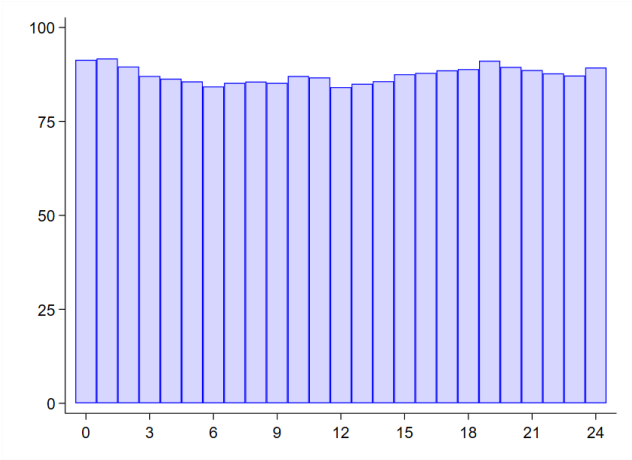
- Test robustness to future orthogonality
  1. Firm-by-firm regressions to assess non-predictability (i.e., $\gamma_p^{i,h}$ not significant)

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

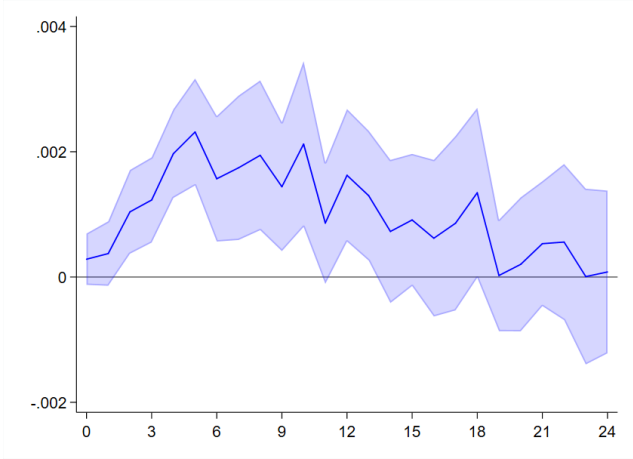
  2. Compute share of firms at any h for which supply chain prices cannot predict aggregate inflation
  3. Re-estimate baseline with firms/horizons for which we ensure non-predictability

Imposing orthogonality at all horizons

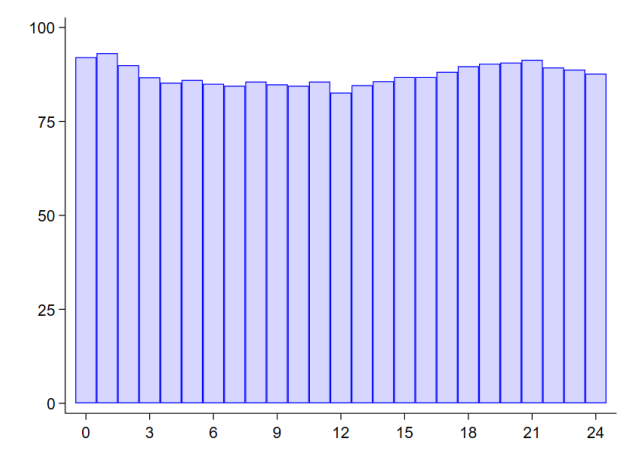
(a) Share of firms with input price inflation unrelated to future CPI inflation



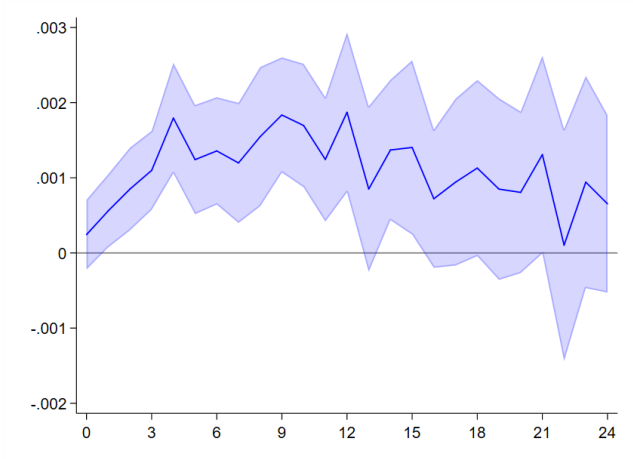
(b) 1pp increase in input price inflation



(c) Share of firms with the w. avg. of input and import price inflation unrelated to future CPI inflation



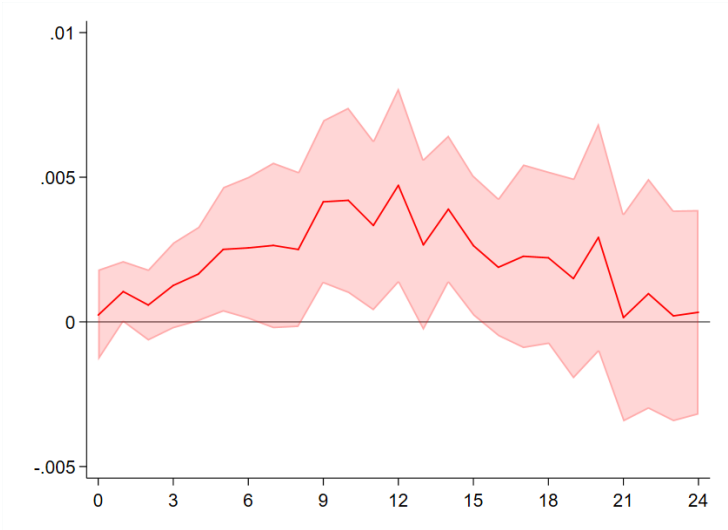
(d) 1pp increase in the weighted average of input and import price inflation



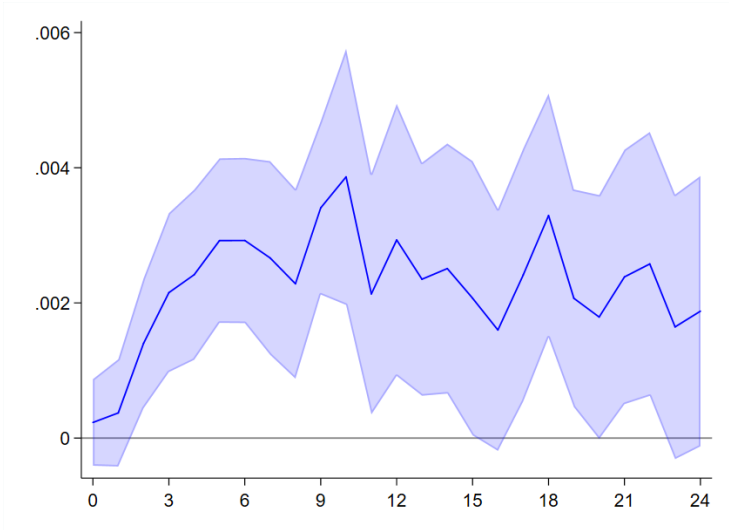
Industry inflation

- Do firms learn from the inflation of the sector they belong to?

(a) 1 pp increase in industry inflation



(b) 1pp increase in firms' input price inflation



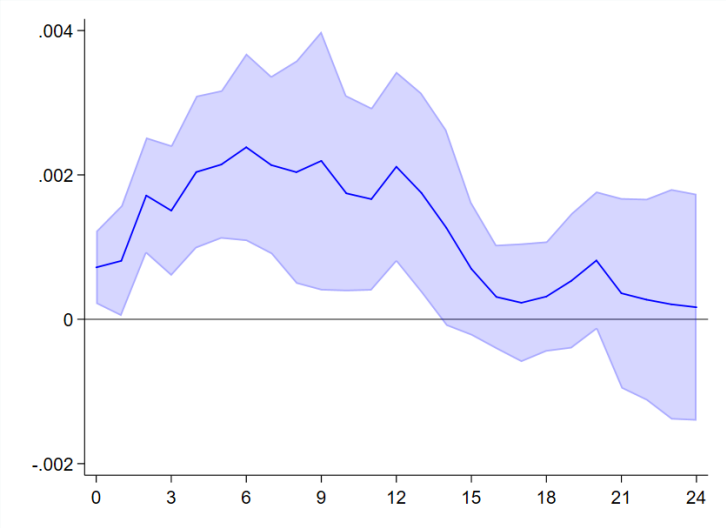
- Controlling for industry inflation does not explain away the results
- Firms' do not observe prices of the sector, rather they observe prices at which they source their inputs from suppliers
- Industry inflation may be an imprecise proxy for firms operating at the intersection of more than one sector

FIRE test

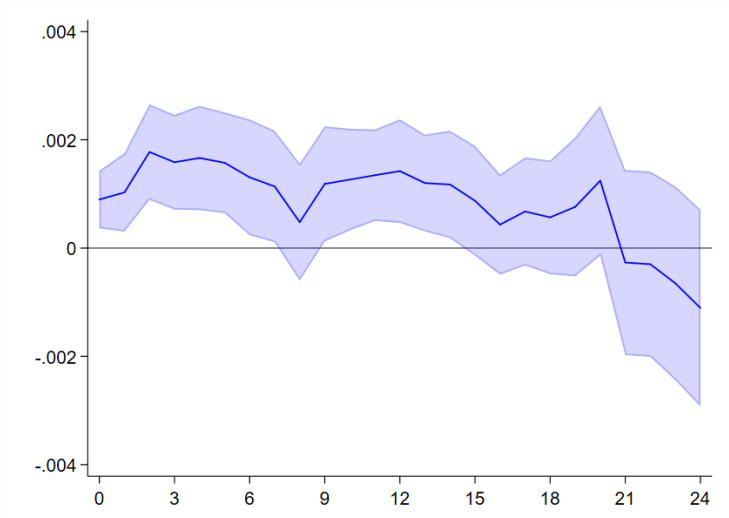
- We directly test FIRE hypothesis by looking at the impact of supply chain inflation on firms' inflation forecast error

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

(a) 1pp increase in input price inflation



(b) 1pp increase in the weighted average of input and import price inflation



- Firms systematically underpredict inflation

Firms' price setting behavior

- Virtually no empirical evidence on PC estimations with micro data (Cloyne et al, 2016 notable exception)
- We derive and estimate the NKPC at the firm level
  - Price adjustment costs as in Rotemberg (1982) to avoid symmetric equilibrium

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

- We leverage information on sales price inflation at firm level, but 2 key caveats
  - No data on expectations of firms' price changes, so we approximate $E_{i,t}\pi_{i,t+1}$ with $E_{i,t}\pi_{t+1}$, which we know is driven by supply chain inflation
  - Temporal aggregation requires summing 12 NKPS equations to express the relationship in y-o-y terms

$$\pi^{12}_{i,t} = \alpha_i + \beta E_{i,t-11}\pi^{12}_{t+1} + \frac{\theta\psi}{\gamma}\widetilde{\psi}^{12}_{i,t} + u_{i,t}$$

(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
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 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
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
  - Inflation along the supply chain informs firms' expectations about aggregate inflation, even if it doesn't have any aggregate effect
  - Firms set sales prices according to aggregate beliefs

- Underlying theories
  - Islands model (Lucas, 1972)
  - Noisy and sticky information (Sims, 2003; Mankiw and Reis, 2002)
  - Granularity (Gabaix, 2011)

- Implications
  - MP can be thrown off its optimal path when changes in expectations do not lead to changes in inflation
  - Disagreement can lead to de-anchoring
  - Potential for welfare-costly price dispersion

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

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

A placebo test

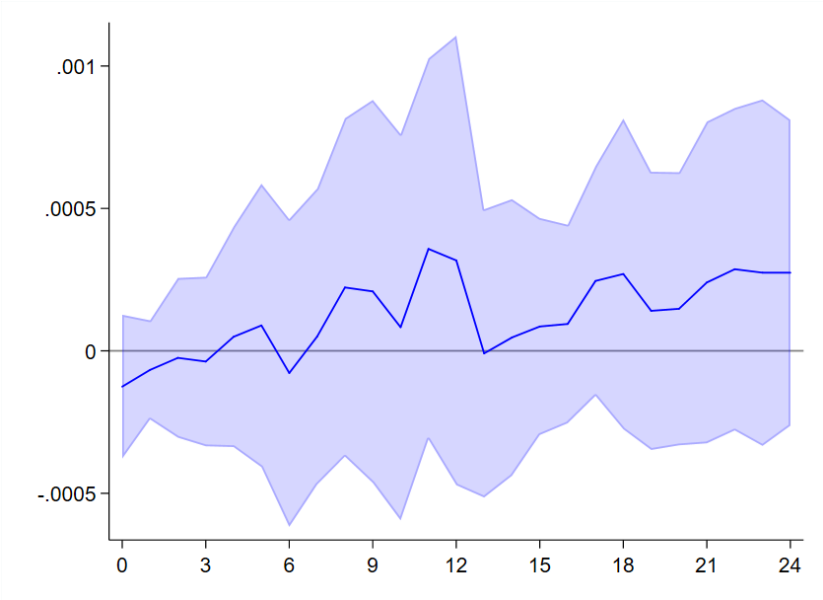
Back

- 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 $|b^{j*}| = 0$

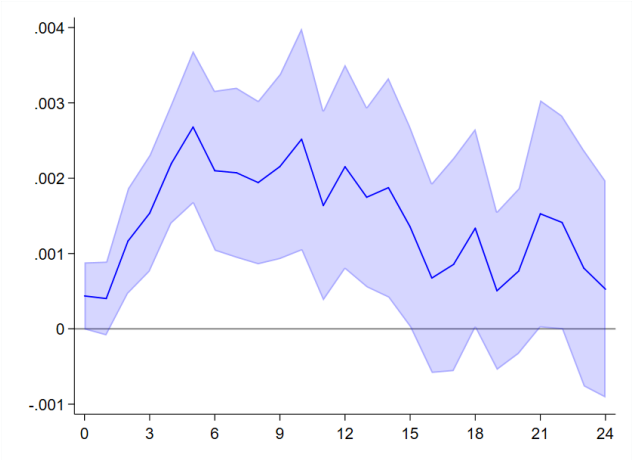
(a) Placebo test for input price inflation



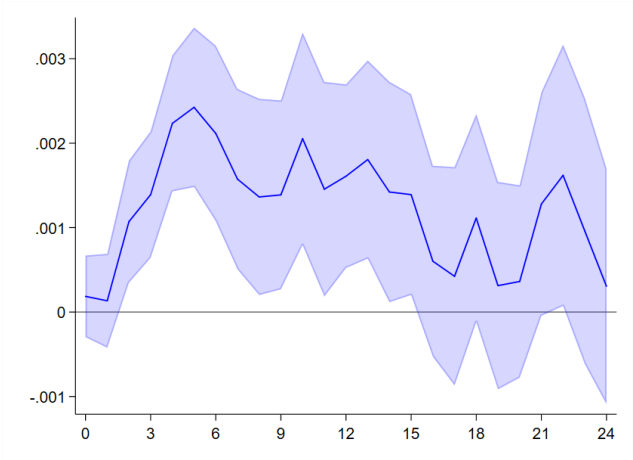
Robustness results

Back

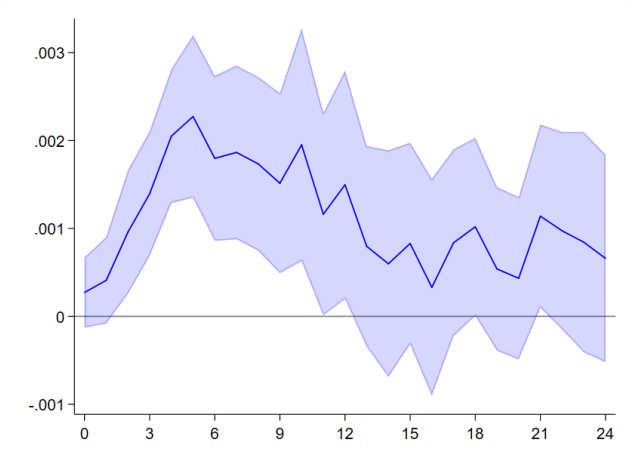
(a) At least 25 suppliers per firm



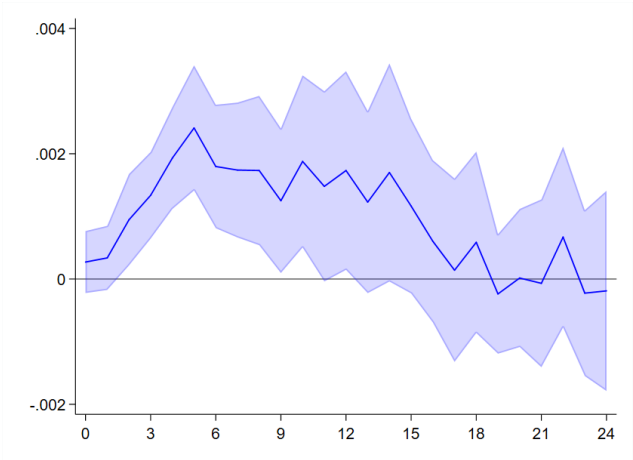
(b) More lags



(c) No lags



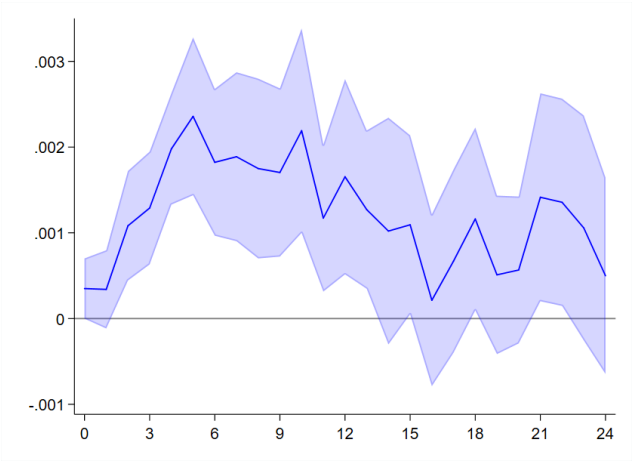
(d) Controlling for input price inflation



Robustness results

Back

(a) Driscoll-Kraay standard errors



(b) Double-clustered standard errors