Price Rigidity within Firm-to-firm Relationships

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The views expressed are those of the author and do not necessarily represent the views of the International Monetary Fund, the Central Bank of Chile or its board members

Motivation

- Sectoral heterogeneity in price stickiness: crucial in **amplifying** the degree of monetary non-neutrality (Basu, 1995, Nakamura and Steinsson 2010)
- Relevance of the interplay between price stickiness' heterogeneity and:
  1. Structure intersectoral linkages (Pasten et al., 2020, Rubbo, 2023)
  2. Within-sector market structure (Mongey, 2021)
- **Question**: What is their joint role in determining price-setting behavior within firm-to-firm relationships?
  - Provide a better understanding of the micro origins of price rigidity within supply chains
  - Discipline and assess structural models of price rigidities

This paper

- Study the sources of price-rigidity within firm-to-firm relationships
  - Use transaction level data from Chile: prices at the supplier-client-variety level
  - Decompose the sources of price adjustment variability attributed to supplier, buyer, product-time, and supplier-buyer-product-time characteristics
  - Assess the role that bilateral market shares play in price-adjustment decisions
- Use oil price shocks as a laboratory to study the probability of price adjustment and pass-through to other firms as a function of seller-buyer characteristics
  - Estimate how bilateral market share affects price-adjustment decisions: extensive and intensive margin
- Discuss theoretical implications

Takeaways

- Large share of variance ($\approx 40\%$) of adjustment frequencies given by supplier-client characteristics
- Supplier bilateral market share is an important determinant of how frequently prices are adjusted, especially during COVID-19 when the frequency increased significantly
- In the face of an oil price shock,
  - Suppliers with more market share are more likely to adjust prices to buyers
  - Higher pass-through of cost-shocks (oil price) to buyers as a function of suppliers' bilateral market shares
- Towards a theory
  - State-dependent pricing: menu costs, non-constant demand elasticity, and market power (Gopinath and Itskhoki, 2010) within firm-to-firm relationships
  - Implication within New Keynesian production network models (e.g., Rubbo, 2023)

Related literature

1. Micro origins of price stickiness
   - Bils and Klenow (2004), Nakamura and Steinsson (2008), Goldberg and Hellerstein (2011), Bhattara and Schoenle (2014), Midrigan, (2011); Eichenbaum, Jaimovich, and Rebelo, (2011); Alvarez and Lippi (2014), Turen (2023), Afrouzi (2023)

   Contribution: document the relevance of bilateral market structure

2. Monetary non-neutrality in multisector models with sticky prices
   - Nakamura and Steinsson (2010), Pasten et al. (2020), Rubbo (2023), Alvarez and Lippi (2014), Blanco et al. (2022), Mongey (2022), Ghassibe (2022), Minton and Wheaton (2023)

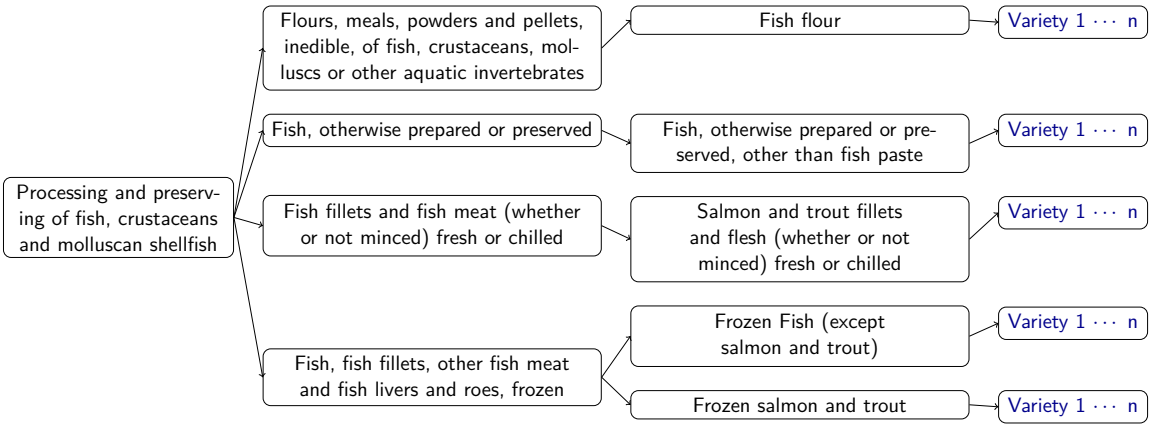
   Contribution: highlight the role of market power in bilateral firm-to-firm relationships as a determinant of price rigidity and, therefore, shaping the amplification of cost-push shocks and monetary policy shocks

The data

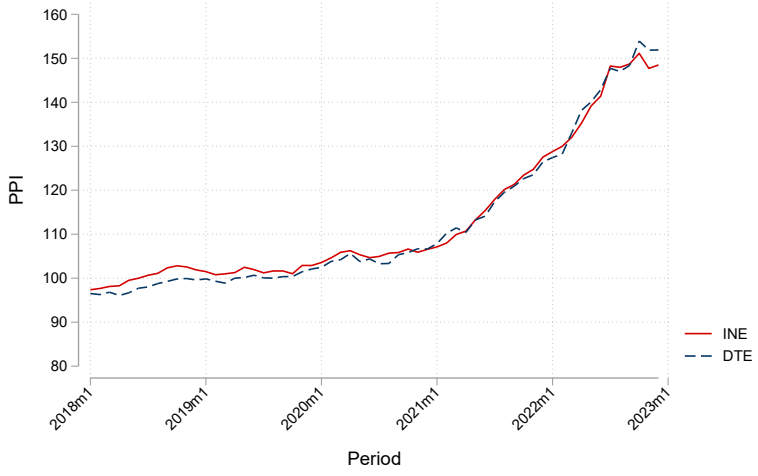
The data

- Universe of **daily firm-to-firm** (seller-customer) transactions in Chile, 2018-2023.
  - Access to firms' unique tax identification numbers of both the supplier and the buyer
  - Information: Date of transaction, value, price per-unit, type of product and location
  - Use Machine Learning tools to identify prices at the variety level, [Acevedo et.al. (2022)]
- Generate price "triplet" p_{ijv}, i:*seller*, j:*buyer* and v:*variety*
  - Restrict varieties to be associated with products in the official CPI and PPI baskets.
  - Each variety must appear at least 24 times (for any supplier)
- Merged with Balance Sheet information about **both** seller and client
  - Total Sales, employment, industries, input purchases

Example: Classes, Subclasses, Products, and varieties (INE-PPI)



Representativeness of the data (PPI)



Note: The sum of weights is 0.97 of 100, and there are 165 of 173 products

Consistent with Acevedo et al. (2022) ▸ Additional validation

Descriptive statistics: supplier characteristics

	Mean	Std. Dev.	p10	p25	p50	p75	p90	Obs.
Average sales (CLP millions)	7,050	133,640	35.19	87.13	250.45	882.1	3,657	15,568
Number of customers	45.5	966.7	1.0	1.3	3.3	11.4	35.5	15,568
Number of products sold	2.4	3.2	1.0	1.0	1.3	2.5	4.8	15,568

By sector

- We have 15,568 firms and a total of 10,348,986 supplier-client-variety triplets.
- Average annual sales are 7050 million pesos ($\approx$ 7.5 million USD), median sales 250 million pesos (0.21 million USD)

▸ Size and subclasses ▸ Size and customers ▸ Firms Linkages

Frequency price change

Aggregate descriptive statistics

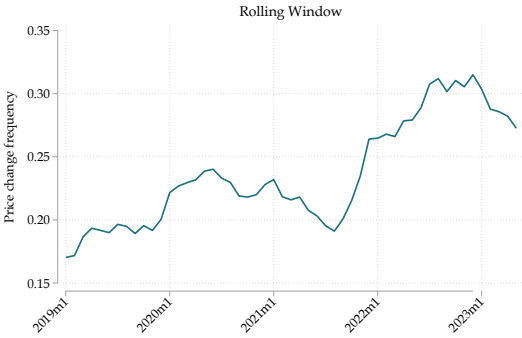
Frequency of price adjustment at supplier-client-variety level f_{ijv}

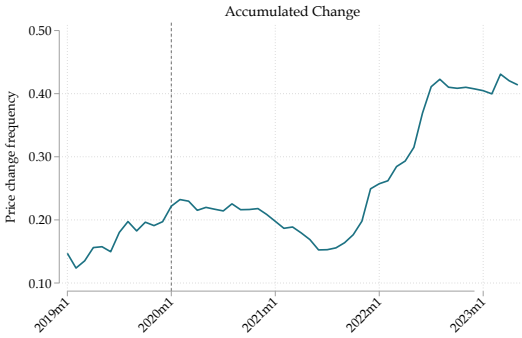
	Mean	SD	P10	P25	P50	P75	P90	N
f_i	0.34	0.28	0.05	0.13	0.25	0.50	0.84	15,568
$dlogP_i$	0.13	0.19	0.05	0.07	0.10	0.14	0.21	15,568
f_{ijv}	0.33	0.29	0.00	0.10	0.25	0.50	0.77	10,348,986
$dlogP_{ijv}$	0.31	0.26	0.00	0.12	0.25	0.45	0.71	8,014,515

Note: We obtain f_{ijv} as follows $f_{ijv} = \frac{\sum_{t=1}^{T_{ijv}} \mathbf{1}(\Delta \log P_{ijvt} > 0.005)}{T_{ijv}}$

- Average price frequency of f_i and f_{ijv} is 0.33 (price duration $\approx$ 3 months)
- Note the skewed distribution

Frequency price change over time





The structure of firm-to-firm relationships

market shares at the supplier-buyer level

Structure of firm-to-firm relationships

1. Bilateral market power of seller i,

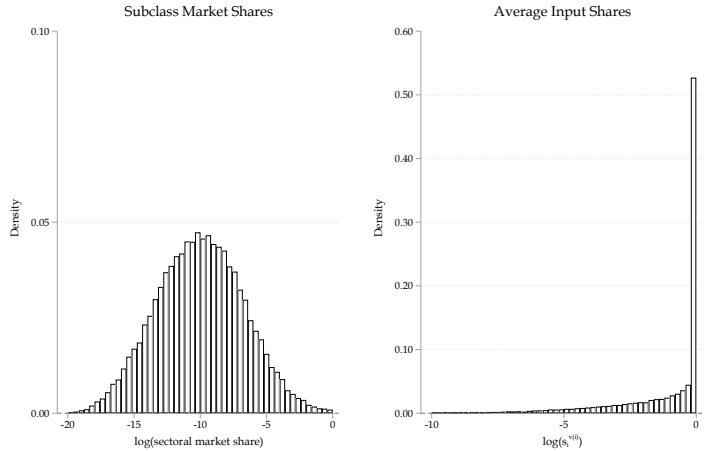
$$s_{ijs} = \frac{p_{ijs} q_{ijs}}{\sum_{k \in Z_j} p_{kjs} q_{kjs}}$$

2. Bilateral market power of buyer j,

$$x_{ijs} = \frac{q_{ijs}}{\sum_{k \in Z_i} q_{iks}}$$

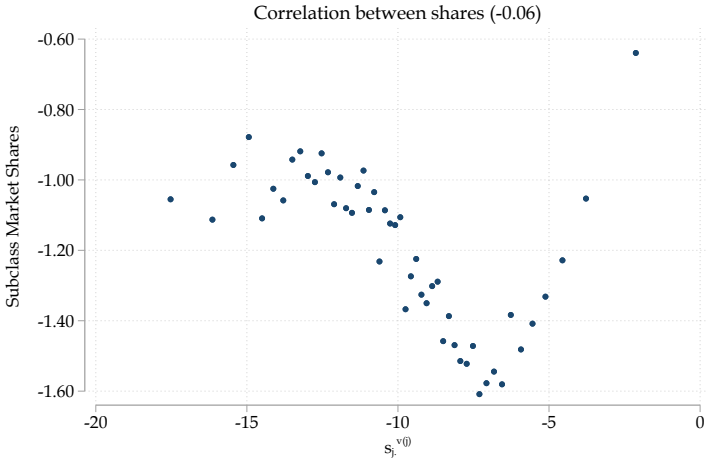
3. # of transactions of v between seller-buyer (log)
4. Duration: length of relationship between ijv (log)

Bilateral market shares s_{ijs}



Product market share of suppliers (left) vs average suppliers' market share in their buyers (right)

Supplier bilateral market shares



A supplier can be large in the market but with a small share of each buyer's purchases

The origins of price rigidity

at the supplier-client-product level

(unconditional moments)

Decomposing the sources price rigidity

- Study the supplier, buyer, product, or match specific characteristics

$$y_{ijvt} = \alpha + \beta X_{ijvt} + FE_i + FE_j + FE_{vt} + \epsilon_{ijvt}$$

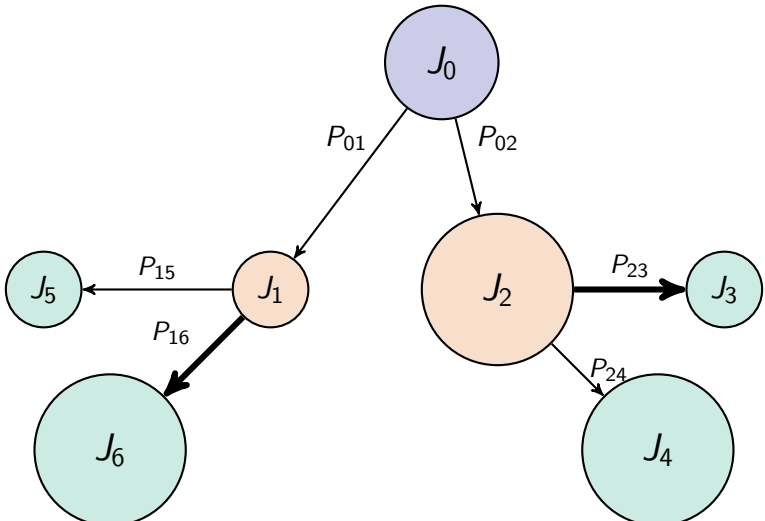
- y_{ijv} is log P_{ijv} or a dummy of price adjustment ($|\Delta \log P_{ijvt}| > \epsilon$)
- X_{ijvt} seller-buyer-variety/subclass match specific controls:
  1. Bilateral market power of seller i, $s_{ijs} = \frac{p_{ijs} q_{ijs}}{\sum_{k \in Z_j} p_{kjs} q_{kjs}}$
  2. Bilateral market power of buyer j, $x_{ijs} = \frac{q_{ijs}}{\sum_{k \in Z_i} q_{iks}}$
  3. # of transactions of v between seller-buyer (log)
  4. Duration: length of relationship between ijv (log)
- Decompose the variance of each component to assess the role of unobserved matches.

Determinants of price rigidity

	(1) $\ln P$	(2) f_{ijvt}	(3) $f_{ijvt} > 0$	(4) $f_{ijvt} < 0$
s_{ijst}	0.016***	0.028***	0.025***	0.003***
	(0.001)	(0.001)	(0.001)	(0.001)
x_{ijst}	-0.062***	-0.024***	-0.028***	0.004
	(0.005)	(0.004)	(0.003)	(0.003)
Panel A. Overall price dispersion				
FE_i	0.4956	0.1762	0.0689	0.1091
FE_j	0.0300	0.0096	0.004	0.0081
FE_{vt}	0.4455	0.3860	0.469	0.2242
E_{ijvt}	0.0289	0.4272	0.4573	0.6583
Panel B. Within seller-product dispersion				
FE_j	0.2583	0.0224	0.0091	0.0127
E_{ijvt}	0.7381	0.9755	0.9895	0.9869

Pricing effects of an oil price shock

The network in an oil importing country



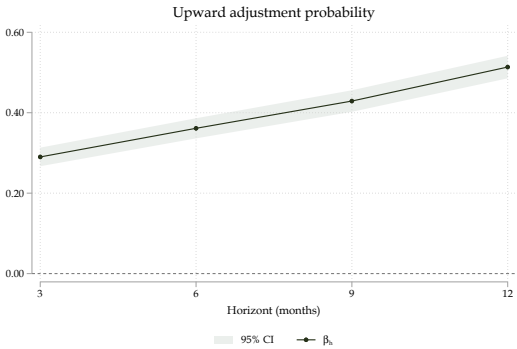
Adjustment probability

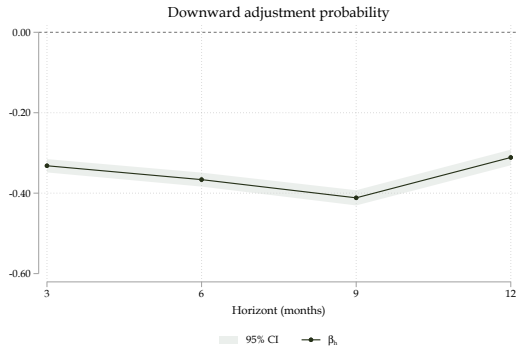
- Study the extensive margin of prices **conditioning** on changes in oil prices.
- The specification builds on Karadi et al.(2022):

$$I^{+,-}_{ijs,t+h} = \alpha_i + \alpha_j + \alpha_s + \beta_h \Delta P^{oil}_t + \phi_h(\Delta P^{oil}_t \times Z_{ij}) + \gamma_h X_{ij} + \psi w_t + \epsilon_{ijs},$$

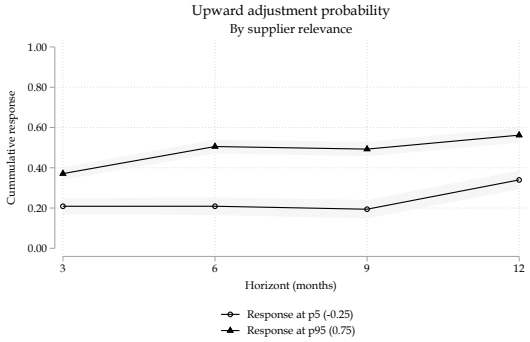
- $I^{+,-}_{ijs,t+h}$: 1 if seller i changes price to buyer j of subclass s between month t and t + h
- ΔP^{oil}_t change in the oil price, instrumented with Oil supply series, Baumeister and Hamilton (2019)
- Z_{ij}, X_{ij} are supplier, client, or supplier-client characteristics
- Add subclass, month, supplier-industry, and customer-industry FE.
- Estimate at $h = 3, 6, 9, 12$

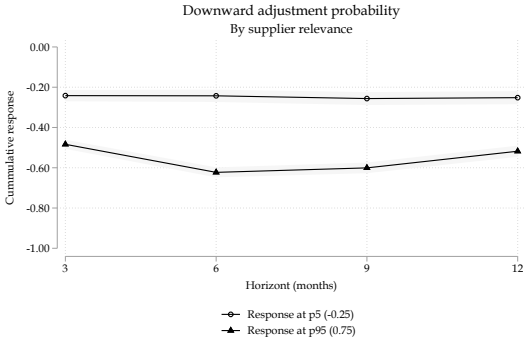
Average probability of price adjustment (firms in J_1 and J_2)





Heterogeneous adjustment probability: seller bilateral market share s_{ijs}





Probability of adjusting prices increases with supplier's bilateral market share s_{ijs}

▸ Large Customers ▸ Small Customers

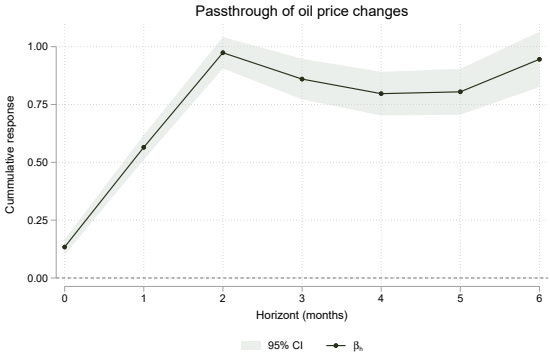
Cumulative price pass-through (intensive margin)

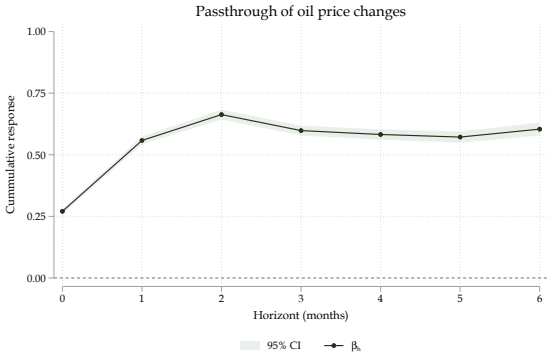
- We estimate the following Local Projection-IV regression

$$\pi^{K,ijv}_{t-1,t+h} = \alpha + \beta^K_h(\Delta \ln P_{c,t}) + \phi^K_h(\Delta \ln P_{c,t} \cdot Z_{ijt}) + \sum_{j=1}^{12} \delta^j \pi_{t-j} + \sum_{j=1}^{12} \gamma^j \Delta P_{c,t-j} + \psi X_t + \varepsilon_t,$$

- where $\pi^{K,ijv}_{t-1,t+h}$ is the log change in $P^{K,ijv}$ between $t+h$ and $t-1$.
- Again, we rely on Oil shock surprises as instruments for the first stage.

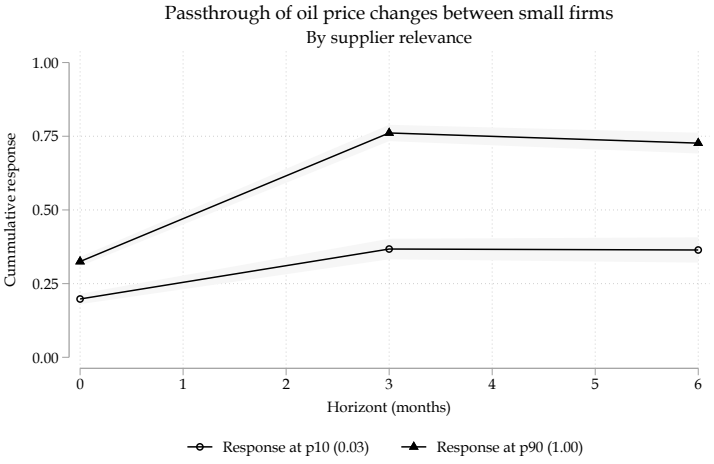
Pass-through at node 0 (oil extraction) and 1 (refinery industries)





- Full pass-through, after two months, to firms in node 0.
- Partial pass-through to firms in node 1.

Pass-through to different customers (supplier importance)



Price passthrough increases with bilateral market share s_{ijs}

▸ Supplier and customer size

Taking stock

- Higher bilateral market share increases the probability of price adjustments and the implied price change
- Price adjustment probability is asymmetric, especially for:
  - Suppliers with high bilateral market share
  - Big supplier selling to small clients (not shown)
- Economies with different market structures within domestic supply chain relationships:
  - Different inflation dynamics in response to the same shock
  - Different degree of monetary non-neutrality

Towards a theory (ongoing)

- Develop a theory of firm-to-firm relationships, menu costs, and non-constant demand elasticity.
- Extension of Gopinath and Itskhoki (2010) to firm-to-firm networks.
- Higher supplier bilateral market share implies lower demand elasticity and smaller losses from adjusting (increasing) prices
  - Bilateral market shares and demand elasticity are endogenous
  - Depend on productivity and import price shocks
  - Large shocks can shape price rigidity depending on the existing network structure
  - But also via changing bilateral relationships: During COVID-19, for example, we observe more concentrated relationships

Implications within current frameworks (e.g., Rubbo, 2023) in Appendix

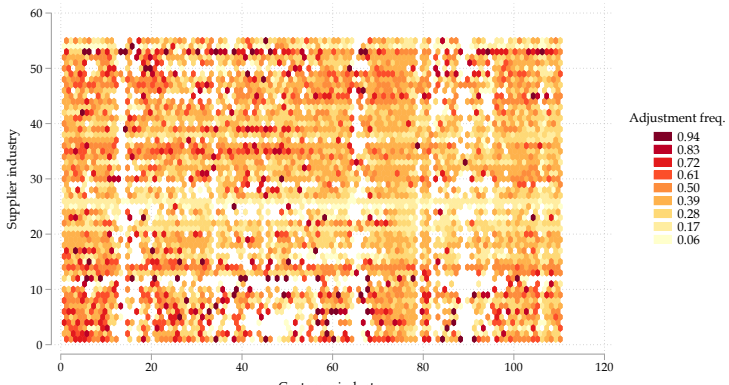
Conclusions

- We documented the granular sources of price rigidity within firm-to-firm relationships
  - $\approx 40\%$ of total variation accounted by supplier-buyer characteristics rice stickiness varies considerably
  - $\approx 98\%$ of within supplier-product price variation accounted by supplier-buyer characteristics
- Heterogeneous price adjustment rates and pass-through to oil shocks as a function of suppliers' bilateral market share.
- **Ongoing:** Theoretical and quantitative implications of our mechanisms for inflation dynamics and monetary non-neutrality

Appendix

Implication within current frameworks

- What are the implications of sectoral-to-sectoral price rigidity to shock propagation?



Implication within current frameworks

- Building on Pasten et al. (2023) and Rubbo (20023), we derive an analytical (first-order approximation) solution for the pricing decision with sectoral price-stickiness.
- All prices are flexible. With probability $\lambda_{kk'}$, a firm in sector k' sets its price to sector k before observing a productivity shock.
- Sectoral intermediate input bundle price and the marginal cost of a sector:

$$p_t^k = \sum \omega_{kk'} p_{kk't},$$

$$mc_{kt} = \delta p_t^k - a_{kt}$$

- With $\omega_{kk'}$ aggregator weights, a_{kt} sectoral productivity shock, $E[a_{kt}] = 0$, $Var(a_{kt}) = v^2$
- Price setting becomes sector-sector specific:

$$p_{k'kt} = (1 - \lambda_{k'k}) mc_{kt}$$

Towards a theory

- Price setting becomes sector-sector specific:

$$p_{k'kt} = \delta(1 - \lambda_{k'k}) \sum_{k'=1}^{K} \omega_{kk'} p_{kk't} - a_{kt}.$$

- Aggregating:

$$\begin{aligned} \tilde{\mathbf{p}} &= \delta(I - \mathbf{\Lambda})\tilde{\mathbf{\Omega}}\tilde{\mathbf{p}} - (I - \mathbf{\Lambda})\tilde{\mathbf{a}} \\ &= -[I - \delta(I - \mathbf{\Lambda})\tilde{\mathbf{\Omega}}]^{-1}(I - \mathbf{\Lambda})\tilde{\mathbf{a}} \end{aligned}$$

- Where $\tilde{\mathbf{p}}$ is a N^2 vector of all sector-to-sector prices and $\tilde{\mathbf{\Omega}}$ an extension of the input-output matrix $\mathbf{\Omega}$ to the N^2 dimension.
- The vector of sectoral prices paid by the households $\mathbf{p}^{\mathbf{sec}}$:

$$\begin{aligned} \mathbf{p}^{\mathbf{sec}} &= \hat{\Omega}\tilde{\mathbf{p}} \\ &= -\hat{\Omega}[I - \delta(I - \mathbf{\Lambda})\tilde{\mathbf{\Omega}}]^{-1}(I - \mathbf{\Lambda})\tilde{\mathbf{a}} \end{aligned}$$

Towards a theory

- Sectoral prices:

$$\mathbf{p^{sec}} = -\hat{\Omega}[I - \delta(I - \mathbf{\Lambda})\tilde{\mathbf{\Omega}}]^{-1}(I - \mathbf{\Lambda})\tilde{\mathbf{a}}$$

- If $\lambda_{kj} = \lambda ij$ this reduces to Pasten et.al.(2023):

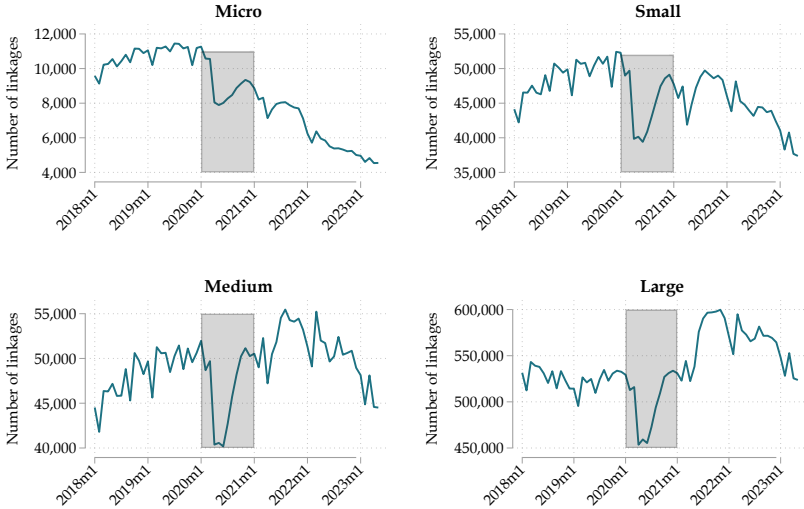
$$\mathbf{p} = [I - \delta(I - \tilde{\mathbf{\Lambda}})\mathbf{\Omega}]^{-1}(I - \tilde{\mathbf{\Lambda}})\mathbf{a}$$

- Where $\tilde{\Lambda}$ matrix with the average price flexibility of each sector on the diagonal and Ω the input-output network.

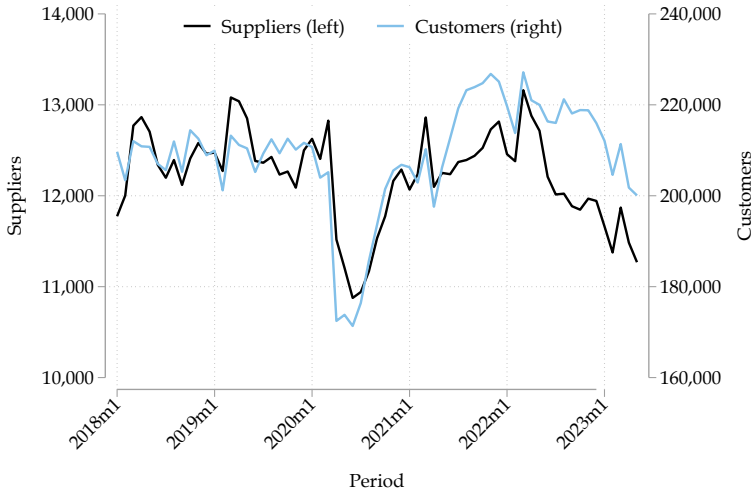
- In our case, $\lambda_{kj} \neq \lambda ij$, $(I - \Lambda)\tilde{\Omega}$ changes the effective linkages (non-linearly), implying $\mathbf{p}^{sec} \neq \mathbf{p}$

- Under a Diagonal Network $\mathbf{p}^{sec} = \mathbf{p}$. However, with a heterogeneous network, the latter does not hold.

Procyclical linkages and composition changes



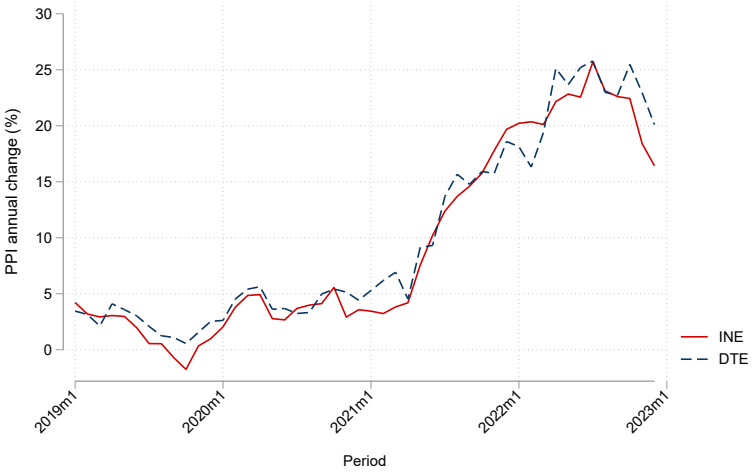
Linkages are procyclical



Across industries

	Agriculture	Mining	Manufactures	Electricity
f_{ijvt}	0.357	0.222	0.237	0.357
	(0.479)	(0.416)	(0.425)	(0.479)
Panel A. Overall price dispersion				
FE_i	0.253	0.367	0.094	0.174
	(0.117)	(0.335)	(0.079)	(0.069)
FE_j	0.098	0.080	0.063	0.151
	(0.050)	(0.033)	(0.043)	(0.071)
FE_{vt}	0.334	0.288	0.453	0.276
	(0.079)	(0.107)	(0.123)	(0.063)
E_{ijvt}	0.394	0.333	0.216	0.400
	(0.070)	(0.195)	(0.079)	(0.047)
Panel B. Within seller-product dispersion				
FE_j	0.394	0.333	0.216	0.508
	(0.092)	(0.105)	(0.148)	(0.244)
E_{ijvt}	0.606	0.667	0.784	0.508
	(0.092)	(0.105)	(0.148)	(0.244)
Obs.	775085	78195	87356832	121724
R^2	0.569	9.672	0.516	0.499

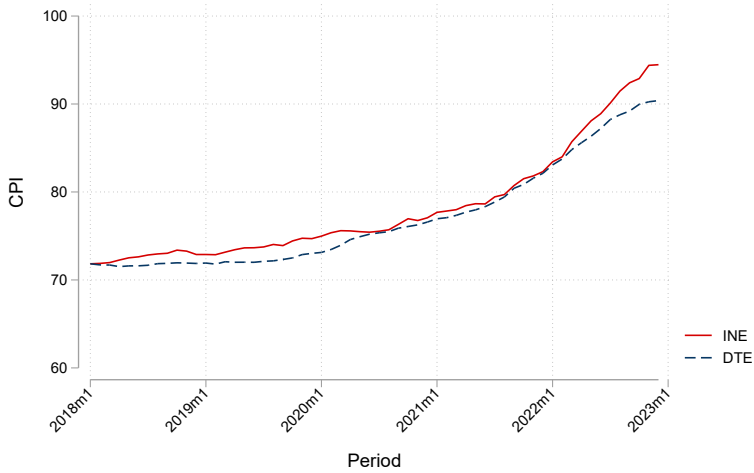
Representativeness of the data (PPI annual change)



Note: The sum of weights is 0.97 of 100, and there are 165 of 173 products

Additional validation

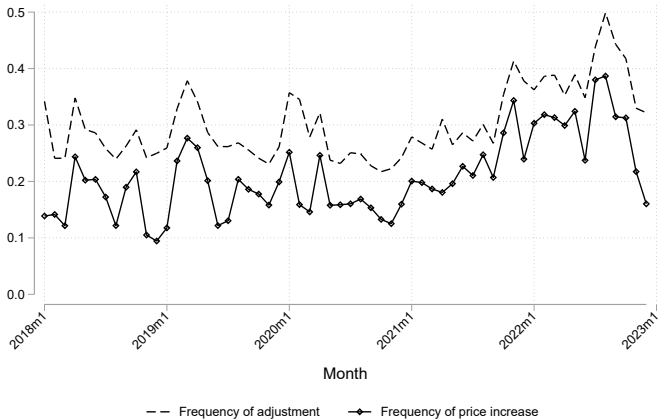
Representativeness of the data (CPI)



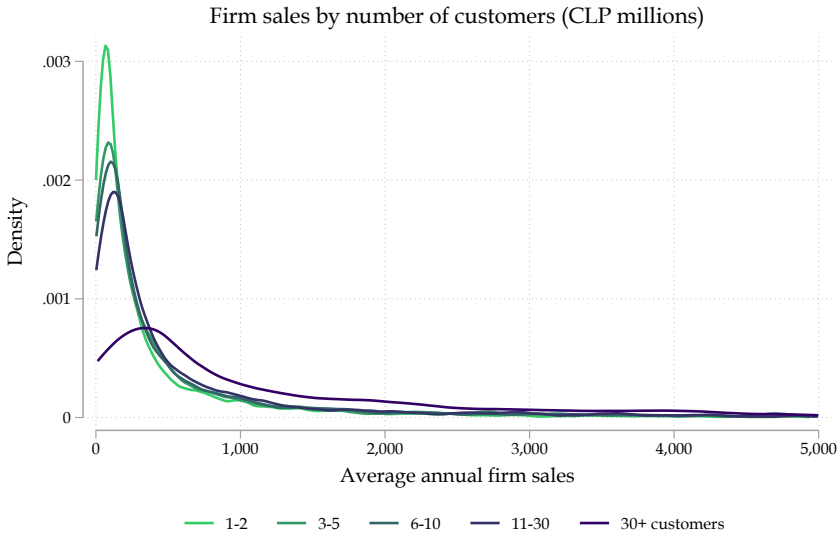
Note: The sum of weights is 71.83 of 100, and there are 254 of 303 products

Evolution frequency price change: CPI

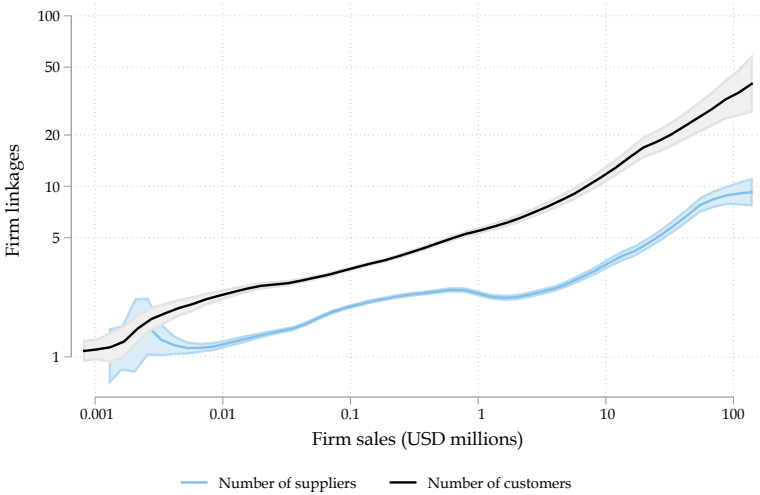
back



Descriptive statistics: size and downstream customers



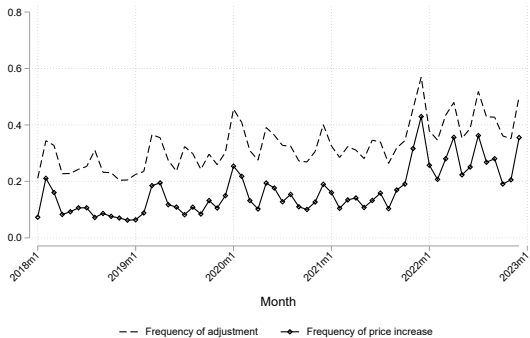
Large firms are more connected: up and downstream

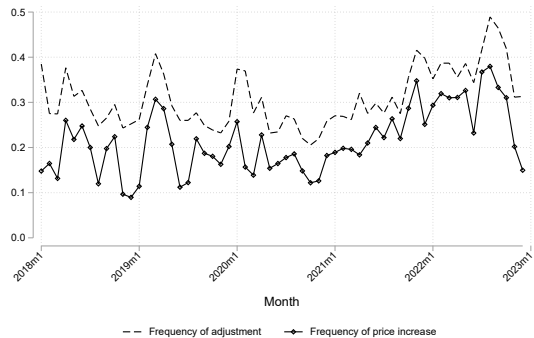


▸ Time-varying links ▸ Back

Evolution frequency price change: PPI and CPI frequent transactions

Figure: Frequency of price change (left) and CPI (right) frequent transactions





Competitor-price gap (strategic complementarities)

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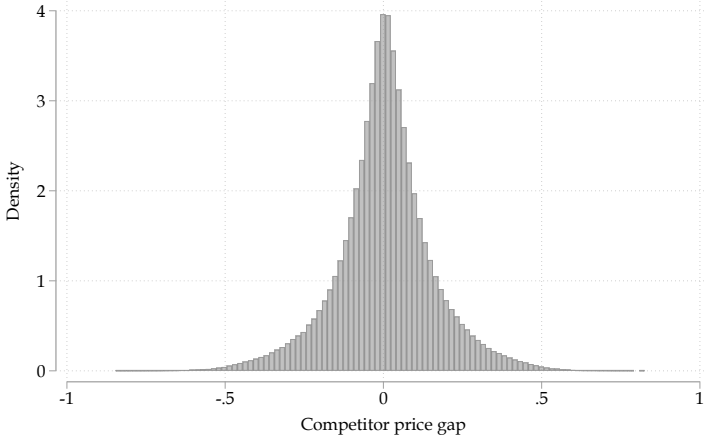
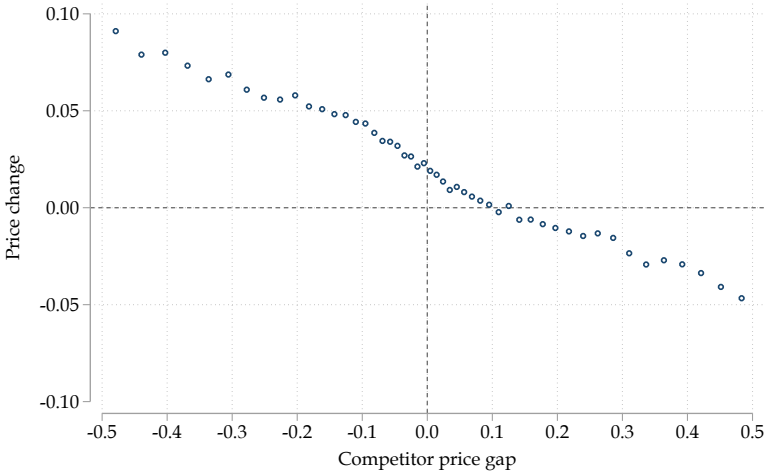


Note: competitor grap truncated at 50 percent

Filtered of supplier-product and month FE, using OLS (Karadi, Schoenle and Wursten (2022)). Using subclasses (bundling varieties, keeping constant number of varieties)

Magnitude of adjustment as function of competitor price gap

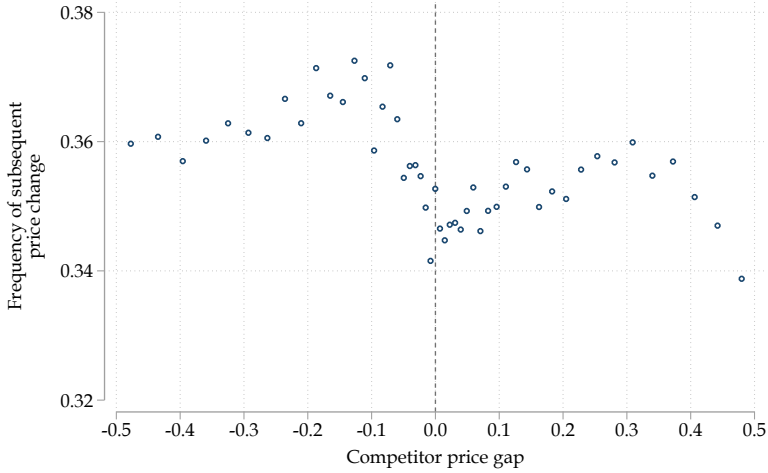
Figure: Magnitude of adjustment (t+1) as function of the gap



Note: competitor grap truncated at 50 percent

Frequency of adjustment (t+1) as function of competitor price gap

Figure: Magnitude of adjustment as function of the gap



Note: competitor grap truncated at 50 percent

Descriptive statistics (freq. price increases)

Table: Frequency of price increases

	Mean	SD	P10	P25	P50	P75	P90	N
CPI product	0.24	0.21	0.00	0.06	0.20	0.38	0.56	12,947,624
PPI product	0.17	0.17	0.00	0.00	0.13	0.27	0.42	10,007,004
Total	0.21	0.20	0.00	0.00	0.17	0.33	0.50	22,954,628

Descriptive statistics (share of price increases)

Table: Share of price increases

	Mean	SD	P10	P25	P50	P75	P90	N
CPI product	0.72	0.29	0.33	0.50	0.75	1.00	1.00	10,486,557
PPI product	0.83	0.26	0.50	0.67	1.00	1.00	1.00	7,121,443
Total	0.77	0.28	0.40	0.57	0.86	1.00	1.00	17,608,000

Descriptive statistics (supplier characteristics)

	Mean	Std. Dev.	p10	p25	p50	p75	p90	Obs.
Average sales (CLP millions)	3,903	92,937	8	23	92	381	1,714	25,078
Number of customers	24.6	699.6	1.0	1.1	1.8	5.2	17.2	25,078
Number of subclasses sold	1.6	1.9	1.0	1.0	1.0	1.5	2.7	25,078

By sector

We have 25,078 firms and a total of 22,954,628 supplier-client-variety triplets

Frequency/magnitude price change

1. Multi-product Evidence
   - **Positive** correlation between number of products sold (subclass-level) and frequency of price changes.
   - Negative correlation between the size of changes and the number of products sold.
   - Consistent with Bhattarai and Schoenle (2014) → Economies of scope in menu-costs.
2. Size Evidence
   - **Large** firms adjust more frequently and in smaller magnitudes
   - In line with Goldberg and Hellerstein (2011) and Zbaracki et al. (2004)→ returns to scale in price setting or better information
   - Similar when considering industry/product market share
   - Size matters beyond its association with multiproduct firms Evidence

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Descriptive statistics (supplier characteristics by sector)

Table 2: Supplier characteristics by economic sector

	Mean	Std. Dev.	p10	p25	p50	p75	p90	Obs.
1								
Average sales (CLP millions)	951	14,948	7	20	85	335	1,247	7,454
Number of customers	3.1	11.5	1.0	1.0	1.1	2.1	5.1	7,454
Number of subclasses sold	1.3	1.3	1.0	1.0	1.0	1.0	1.8	7,454
2								
Average sales (CLP millions)	95,645	805,937	43	125	372	1,329	5,040	234
Number of customers	5.6	26.5	1.0	1.0	1.4	2.6	6.8	234
Number of subclasses sold	1.2	0.6	1.0	1.0	1.0	1.0	1.6	234
3								
Average sales (CLP millions)	3,926	60,147	8	25	96	402	2,013	16,864
Number of customers	34.9	852.9	1.0	1.3	2.5	7.5	23.9	16,864
Number of subclasses sold	1.8	2.1	1.0	1.0	1.0	1.7	3.1	16,864
4								
Average sales (CLP millions)	4,157	32,407	3	7	25	120	1,164	526
Number of customers	8.7	42.1	1.0	1.2	2.1	5.2	12.9	526
Number of subclasses sold	1.2	0.8	1.0	1.0	1.0	1.0	1.4	526
Total								
Average sales (CLP millions)	3902.6	92937.2	7.6	22.8	92.0	381.4	1714.4	25,078
Number of customers	24.6	699.6	1.0	1.1	1.8	5.2	17.2	25,078
Number of subclasses sold	1.6	1.9	1.0	1.0	1.0	1.5	2.7	25,078

Note: 1 “Agriculture” 2 “Minning” 3 “Manufacture” 4 “Utilities”

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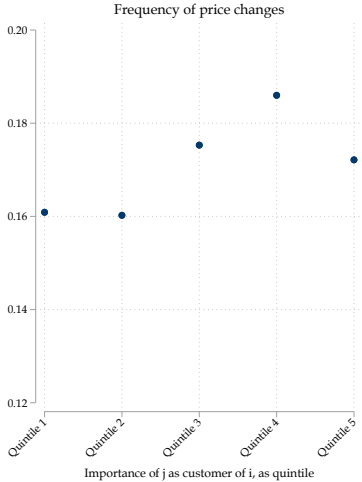
Descriptive statistics (supplier characteristics, subsample)

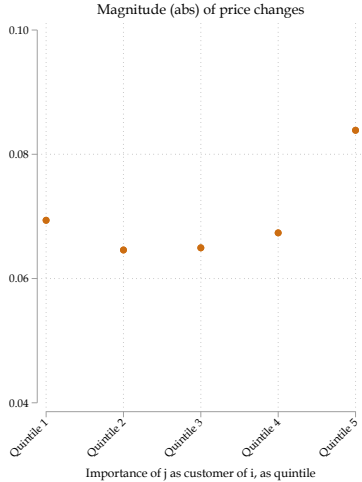
Table: Supplier characteristics - Subsample

	Mean	Std. Dev.	p10	p25	p50	p75	p90	Obs.
Average sales (CLP millions)	13,134	118,547	24	90	404	2,088	12,585	4,109
Number of customers	123.9	1724.5	1.5	3.1	8.4	25.0	75.1	4,109
Number of subclasses sold	4.3	3.6	2.1	2.4	3.1	4.7	7.7	4,109

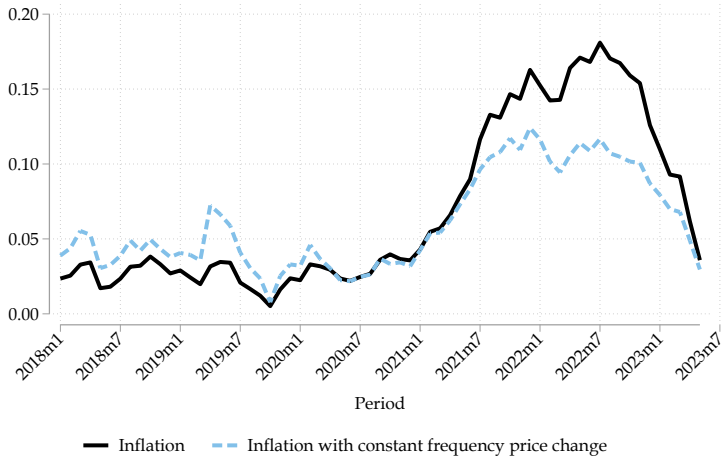
Firms selling more than one subclass

Frequency/magnitude price adj. and customer market share product level





Decomposing inflation: intensive vs extensive margin



Economy-wide frequency of price adjustment increased during COVID-19

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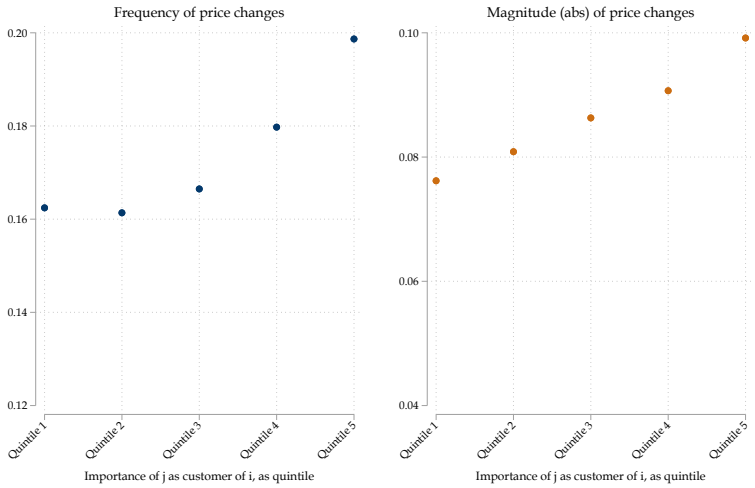
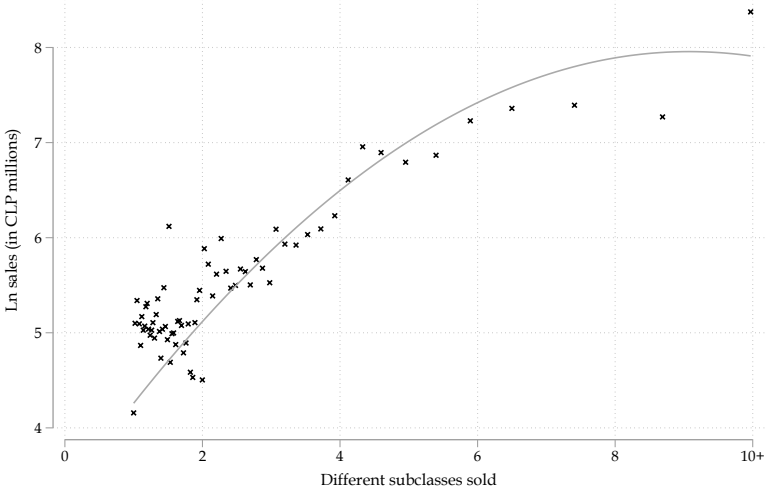
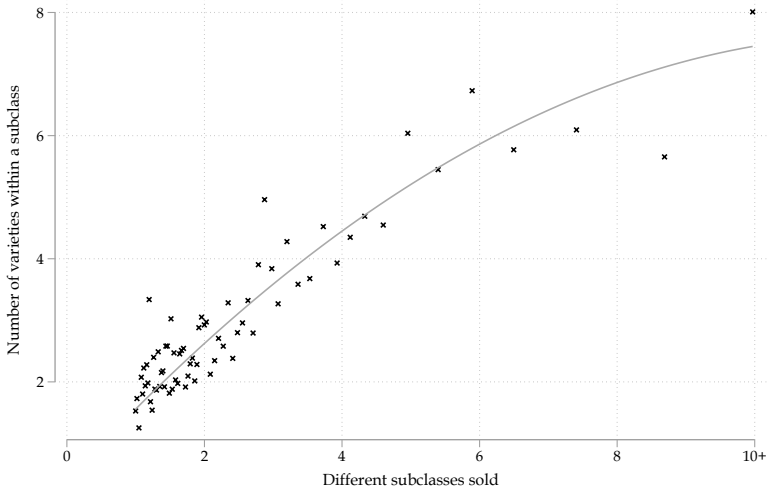
Frequency/magnitude price adj. and customer market share (product truncated)



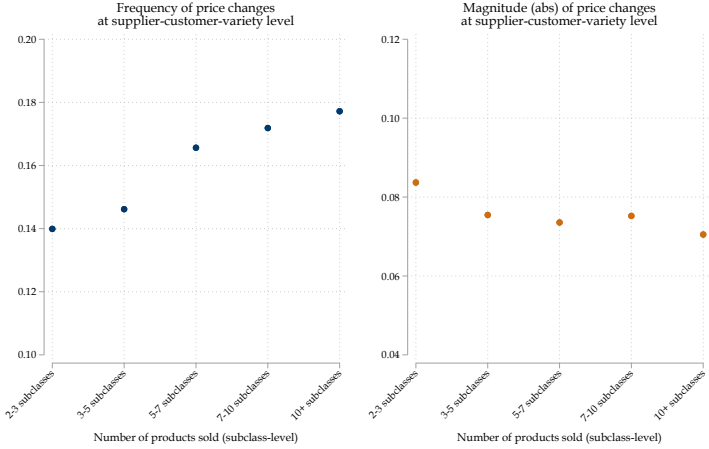
Size and subclasses



Variety and subclasses



Frequency/magnitude price adj. and # of products sold



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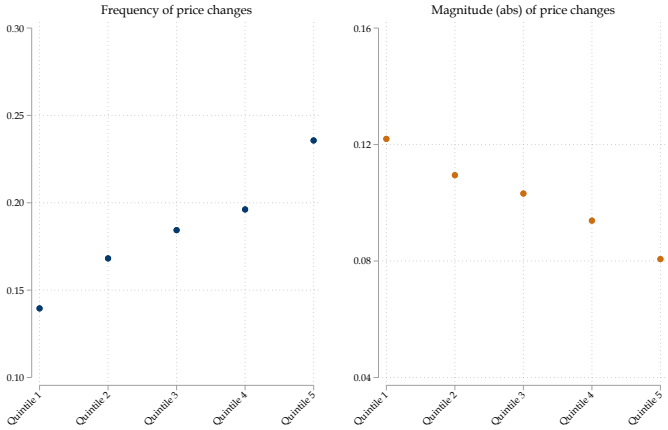
Frequency/magnitude price adj. and total sales



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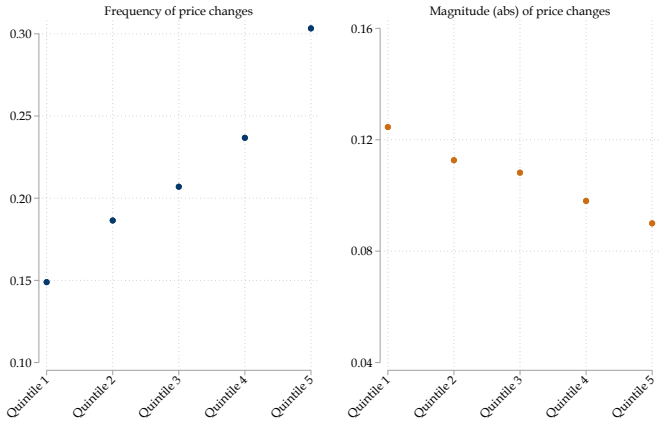
Frequency/magnitude price adj. and sales (one-product firms)



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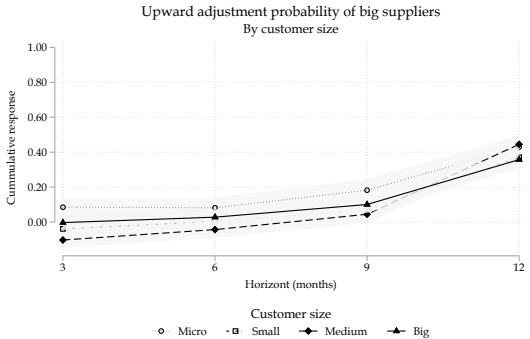
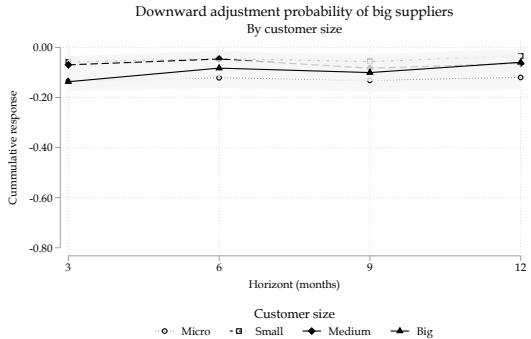
Adjustment probability cond. **size**

Figure: Heterogeneity in the Extensive of Price Adjustment: Big suppliers and customer size





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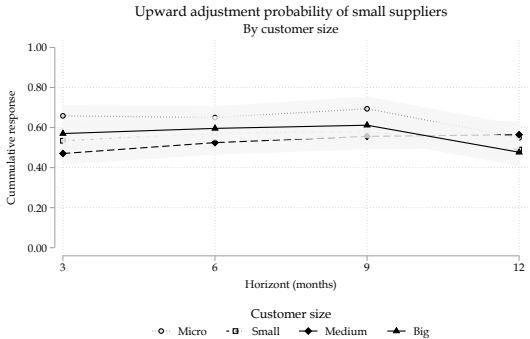
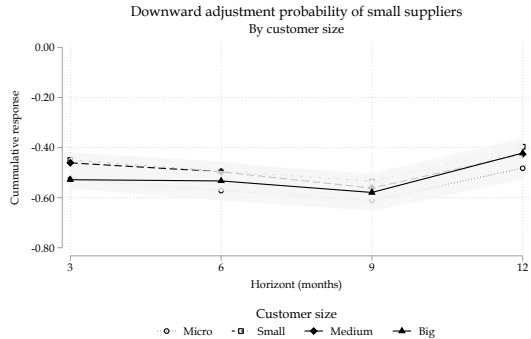
Adjustment probability cond. **size**

Figure: Heterogeneity in the Extensive of Price Adjustment: Small suppliers and customer size





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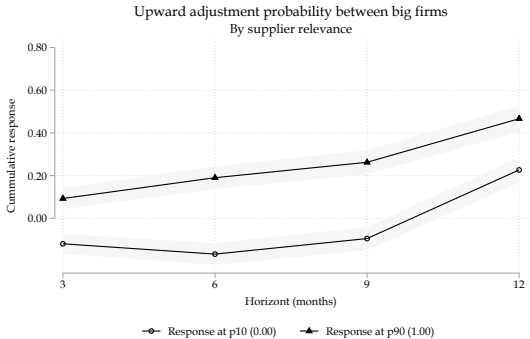
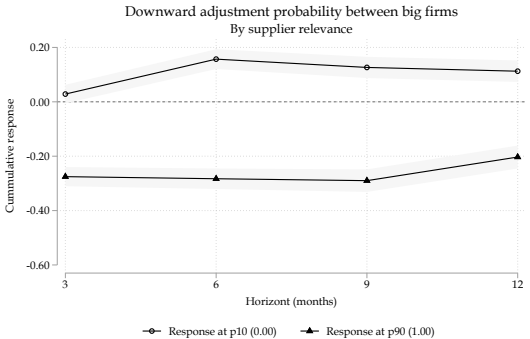
Supplier Relevance between large firms

Figure: Heterogeneity in the Extensive of Price Adjustment: Supplier Relevance between Large Firms





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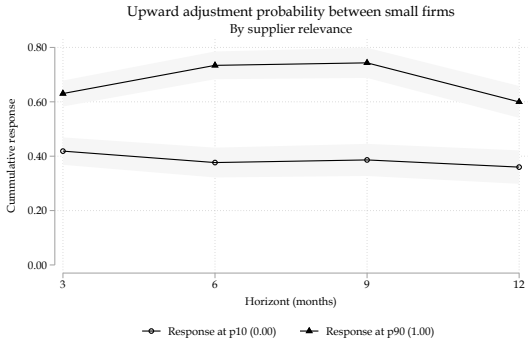
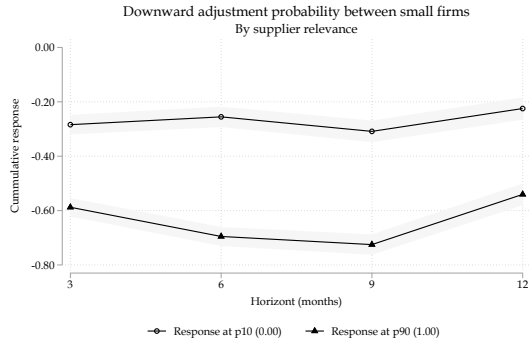
Supplier Relevance between small firms

Figure: Heterogeneity in the Extensive of Price Adjustment: Supplier Relevance between Small Firms





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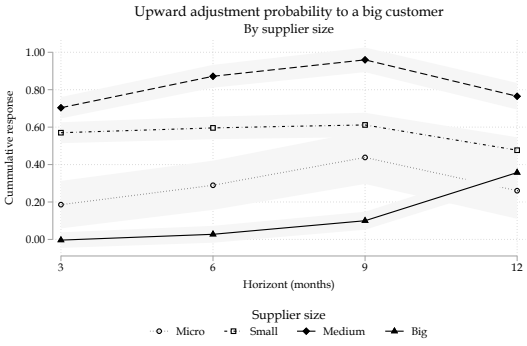
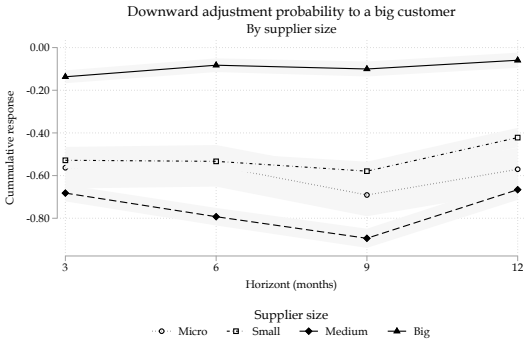
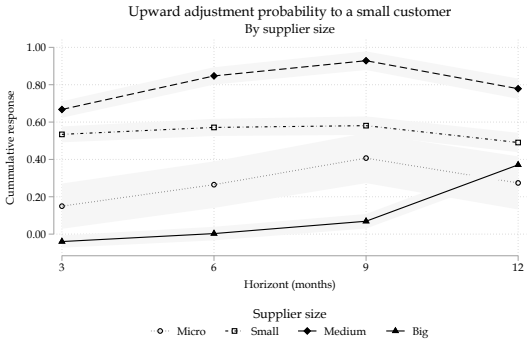
Price adjustment probability: supplier size for big customers

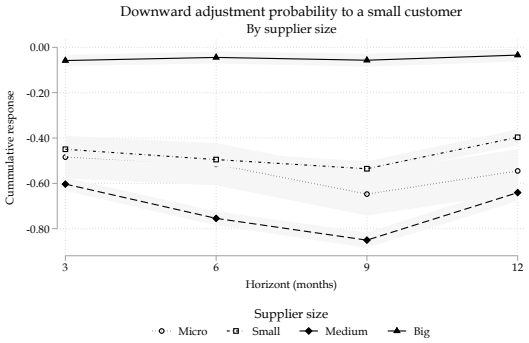




Upward adjustment probability increases in firm size, except for big firms. Mild asymmetry $Pr(I^{+}_{ijv,t+h}) > Pr(I^{-}_{ijv,t+h})$, except for micro firms. ▸ Back

Price adjustment probability: supplier size for small customers





Upward adjustment probability increases in firm size, except for big firms. Significant asymmetry $Pr(I^{+}_{ijv,t+h}) > Pr(I^{-}_{ijv,t+h})$ for big firms.

▸ Customer size ▸ Back