Beyond Costs: The Dominant Role of Strategic Complementarities in Pricing*

Elias Albagli
Central Bank of Chile

Francesco Grigoli
IMF

Emiliano Luttini
World Bank

Dagoberto Quevedo
Central Bank of Chile

Marco Rojas
Central Bank of Chile

February 3, 2025

Abstract

This paper establishes five facts about the role of strategic complementarities for firms' price setting using administrative data for Chilean firms. (1) Strategic complementarities are overwhelmingly important for firms' price setting, relatively more than changes in marginal costs. (2) The strength of strategic complementarities varies significantly across sectors, but remains dominant with respect to changes in marginal costs. (3) When inflation runs high firms not only become more wary of changes in their costs, but also more sensitive to what their competitors' actions. (4) Firms' prices react more strongly when competitors' raise prices than when they cut them, akin to the 'rockets and feathers' phenomenon of costs. (5) Firms exhibit stronger strategic complementarities when they face lower competition, market shares are higher, and their customer bases are larger. These results suggest that real rigidities are substantial, but also state-dependent, asymmetric, and depend on the market structure, with implications for monetary policy effectiveness.

Keywords: Pass-through, price setting, strategic complementarities, state dependency, asymmetry, market structure
JEL Codes: D22, E31

*Elias Albagli, ealbagli@bcentral.cl; Francesco Grigoli, fgrigoli@imf.org; Emiliano Luttini, eluttini@worldbank.org; Marco Rojas, mrojaso@bcentral.cl. The views expressed in this paper are those of the authors and do not necessarily represent those of the Central Bank of Chile, the IMF, the World Bank, their Executive Boards, or their management. This study is part of the research agenda of the Central Bank of Chile in economics and finance, which relies on anonymized data provided by several public and private entities to which the Central Bank of Chile has access within the collaboration agreements signed with these entities. We thank Damiano Sandri for comments and suggestions. No conflict of interest to declare.

1 Introduction

A central tenet of New-Keynesian macroeconomic models is that prices adjust sluggishly to changes in marginal costs. This in turn delivers some degree of monetary non-neutrality and is reflected in a flatter Phillips curve. If instead prices are flexible, the sacrifice ratio increases and monetary policy effectiveness gets impaired or even neutral (Golosov and Lucas, 2007). However, price rigidity is not only about the pass-through of marginal costs. A firm's pricing strategy may also depend positively upon other firms' strategies (Cooper and John, 1988), and these strategic complementarities have a direct effect on the slope of the Phillips curve (Gopinath and Itskhoki, 2011; Gagliardone et al., 2023). In fact, some studies argue that monetary non-neutrality arises only when real rigidities are coupled with nominal rigidities (Klenow and Willis, 2016).

But where do strategic complementarities come from? When a firm considers raising its price in response to an increase in marginal costs, it also considers how competitors would react. If strategic complementarities are strong, the pass-through of marginal cost changes is reduced because firms would be concerned about losing market share. And because of that, strategic complementarities can lead to a coordination problem where firms become hesitant to be the first to change prices, which in turn leads to price stickiness. From a theoretical perspective, strategic complementarities arise in oligopolistic settings in which the elasticity of demand and markups are a function of the firms' market shares (Atkeson and Burstein, 2008; Wang and Werning, 2022). In these frameworks an increase in competitors' prices translates into lower relative prices, which boost the firm's demand and its market share, resulting in a market share and markup beyond the optimal level. Thus, the firm reacts by increasing its prices and reducing its market share, bringing markups back to their optimal levels. The slim empirical evidence on the importance of strategic pricing suggests interdependence in firms' pricing is important, albeit less than changes in firms' marginal costs (Amiti, Itskhoki and Konings, 2019; Gagliardone et al., 2023).

This paper uses administrative data on purchase and sales prices of Chilean firms to document some key facts about strategic complementarities in price setting. It does so by examining the dynamic responses of firms' prices to changes in their *competitors' prices* and *own marginal costs*, both along the extensive and intensive margin of price adjustments. Identifying firms' competitors is challenging and the literature relies on a fine sector classification. However, firms may not compete with all other firms in the same industry. Leveraging the granularity of the data, we construct a significantly narrower measure of competitors' prices that accounts for the geographical area where firms sell

and the products that they sell. As for marginal costs, we directly measure the prices of intermediate inputs using data from electronic invoices. Our sample period—from January 2014 to December 2023—is characterized by large inflation fluctuations in Chile, which allows exploring whether firms' strategic pricing is state dependent and asymmetric. At the same time, the large cross-sectional dimension of the data—covering the universe of firms in the manufacturing, wholesale, and retail sectors—lets us examine how the intensity of competition, firms' market shares, and their customer bases shape strategic behavior in pricing.

The first fact we document is that strategic complementarities are overwhelmingly important for firms' price setting, relatively more than changes in marginal costs. We estimate that firms pass-through 55 percent of the changes in competitors' prices to their own sales prices within the same month and about two-thirds of the initial price increase over the one-year horizon. In response to changes in marginal costs firms slowly and moderately adjust their sales prices, with the degree of pass-through lingering below 10 percent one year after the shock. That is, the pass-through of changes in competitors' prices is about 9 times larger than the pass-through of changes in their own costs. Compared to recent studies estimating these elasticities, we find a much more prominent role of strategic complementarities relative to changes in marginal costs for firms' pricing, and more generally evidence of stronger nominal and real rigidities.[1]

Moreover, we find that the price adjustments to competitors' prices happen both on the intensive and the extensive margin. One year after a 10 percentage point increase in competitors' prices, the frequency of price changes is 24 percentage points higher, which is 7 times the response to a same-size increase in marginal costs. This implies that a 25 percent increase in competitors' prices is sufficient for the average firm to change the prices of all its products. Comparatively, marginal costs would have to almost triple to get the average firm to change all the prices of all its products. As for the intensive margin, firms respond by quickly reflecting a large share of these price changes in their own prices. By the end of a year, they passed on four-fifths of the changes in competitors' prices. In contrast, the adjustment to changes in marginal costs is gradual and only 12 percent of the initial increase is reflected in sales prices.

The second fact is that the strength of strategic complementarities varies across sectors, but remains of first-order importance. We show that manufacturing firms pass through 35 percent of the changes in competitors' prices. This is considerably less than

[1] Using data on Belgian manufacturing firms, Amiti et al. (2022) and Gagliardone et al. (2023) find an elasticity of about 0.4 in response to its competitors' price changes and with an elasticity of about 0.6 in response to its own cost shocks.

for wholesale and retail firms, whose pass-through is about 70 percent.[2] However, it is still 4 times larger than the cost pass-through, confirming that strategic complementarities are of first-order importance even for firms that typically operate in oligopolistic settings. Turning to the magnitude of price adjustments, we find that retailers pass on a much larger share of the changes in competitors' prices within the first couple of months since the shock, while it takes the entire year for manufacturers to pass on the same share. The frequency of price adjustment is also significantly higher for retailers than manufacturers. These results align with the evidence of higher repricing costs for manufacturers, which face longer production cycles and less frequent sales (Goldberg and Hellerstein, 2007).

The third fact we document is that strategic pricing is state dependent. When inflation runs high, consumers' purchasing power shrinks and demand falls, hence sales decline and firms get closer to their breakeven. As profit margins get squeezed, they find it more difficult not to pass-through changes in their own costs, hence nominal rigidities are less binding (Blanco et al., 2024). From a policy perspective, this implies that monetary policy potency may be diminished right when it is needed the most. However, when inflation is high and profit margins are reduced, firms may become more willing to pass-through more of the increase in competitors' prices to recover their profit margins, generating stronger real rigidities. Our results lend support to this hypothesis. Focusing on manufacturing firms, we find that not only they become more wary of changes in their own costs, but are also twice as likely to react to changes in competitors' prices. While firms are more likely to respond to changes in costs by adjusting prices more frequently, changes in competitors' prices trigger both more frequent and larger price adjustments.[3]

The fourth fact is that firms' prices react more strongly when competitors' raise prices than when they cut them, like 'rockets and feathers'. The literature has shown that firms are more sensitive to cost increases than cost decreases (Bacon, 1991; Peltzman, 2000). Yet, it is unclear whether strategic pricing is also asymmetric. When a firm raises its prices, competitors may quickly follow suit to avoid being perceived as lower quality. And when a firm lowers its prices, competitors may be slower to match the decrease to avoid triggering a price war. At the same time, firms may react by cutting their prices quickly if they are concerned about losing market shares. Expectations can amplify asymmetries: if firms anticipate that competitors will quickly match price increases but slowly match price decreases, they will be more inclined to raise prices

[2] For simplicity, we will be referring to firms in the wholesale and retail sectors as retail firms or retailers.

[3] An exercise based on the 2021–2022 inflation surge reveal that deviations of inflation from its mean are largely driven by changes in the frequency of price adjustments.

rapidly and lower them gradually (and vice versa). Explicit or tacit collusion to maintain higher prices can also lead to faster price increases and slower decreases. Beyond confirming that the pass-through is higher for cost increases and lower for cost decreases, we show that this difference narrows over time and becomes statistical insignificant after one year. On the other hand, we find evidence indicating that the pass-through is larger for competitors' price increases than decreases, and that the difference between the two is more persistent than for the cost pass-through. That is, we also observe a 'rockets and feathers' phenomenon for strategic pricing, which is indicative of upward real rigidities. The larger pass-through of competitors' price increases reflects both a larger increase in the frequency and the magnitude of price adjustments.

The fifth fact is that firms exhibit stronger strategic complementarities when they face lower competition, market shares are higher, and when they have larger customer bases. Firms are more willing to engage in strategic pricing when they operate in concentrated markets (Atkeson and Burstein, 2008). In such settings, firms with market power can influence prices more effectively to maximize their profits. Also, concentrated markets often have higher barriers to entry, allow existing firms to engage in strategic pricing without the immediate risk of losing market share to new competitors; and with fewer competitors, firms can more easily coordinate their pricing strategies. Slicing the data for the manufacturing sector either by the number of competing firms, the firms' market shares, or the number of buyers—all measures proxying market concentration—we find that firms in more concentrated markets engage more aggressively in strategic pricing.

We consider a variety of robustness checks for the facts presented in the paper. Our results are virtually unchanged when controlling for sector-time fixed effects to capture sectoral shocks or coordinate wage adjustments. Also, taking advantage of the data granularity, we construct instrumental variables to deal with the potential reverse causality of marginal costs due to the potential monopsonic power of some firms, as well as the simultaneity in price setting between firms and their competitors. For changes in marginal costs, we exclude purchases of firms from suppliers that have only a few buyers; while for changes in competitors' prices we rely on the changes in input costs of the competitors' suppliers of each firm, excluding the set of inputs that are purchased from suppliers selling to both the firm itself and its competitors. We show that the instrumental variable (IV) results are consistent with the OLS ones. Using available information for labor costs, we provide evidence that they do not alter the conclusions of our findings. Additional tests show that our findings are robust to extending the horizon of the estimated responses or using alternative estimation approaches.

Our results speak to the importance of featuring real price rigidities in macroeco-

nomic models. By showing that real rigidities are stronger than previously thought, our findings generally imply that monetary policy can have relatively larger effects on real variables. However, these conclusions are subject to other macroeconomic conditions, the direction of changes in costs and competitors' prices, and the characteristics of the markets in which firms operate. By precisely estimating the competitors' price elasticity of firms' sales prices and the firms' own costs pass-through and how these elasticities vary in different conditions, our findings open up avenues for future research aimed at assessing the effectiveness of monetary policy when nominal rigidities are paired with real ones.

Literature Our paper is primarily related to the studies quantifying the strength of strategic complementarities. The two key studies in this area are Amiti, Itskhoki and Konings (2019) and Gagliardone et al. (2023), who use Belgian micro data for manufacturing firms showing that the prices of the competitors matter when firms decide how to adjust their own prices. We contribute to the evidence in these papers by shifting the focus to an emerging market with larger inflation swings, broadening the sample of firms to those in the retail and wholesale sectors, narrowing the identification of competitors' by introducing the geographical and product dimensions, exploring firms' price adjustments along the extensive and the intensive margin, and examining pass-through dynamics.[4]

The paper is also more generally related to the literature on cost pass-through. Data limitations forced much of the work in this area using micro data to focus on a few small sectors, such as cars, beer, and coffee (Feenstra, Gagnon and Knetter, 1996; Nakamura and Zerom, 2010; Goldberg and Hellerstein, 2013). Moreover, as it is challenging to come by information about the cost of firms' intermediate inputs, many studies solely consider selected products like energy (Fontagné, Martin and Orefice, 2018; Ganapati, Shapiro and Walker, 2020; Lafrogne-Joussier, Martin and Mejean, 2023) or rely on movements in the exchange rate (Auer and Schoenle, 2016; Pennings, 2017; Gopinath and Itskhoki, 2010) to identify exogenous variation in costs. Even when the data is available, its coverage is typically limited, making it difficult to identify firms' competitors and assess the role of strategic complementarities in price setting. With respect to these studies, we leverage the price information from the VAT registry of bilateral transactions, departing from admittedly noisy accounting measures of firms' average variable costs and measuring directly the price changes of intermediate inputs.

[4]Pass-through dynamics to changes in competitors' prices received little attention. Gagliardone et al. (2023) characterize the dynamic pass-through via an error-correction equation, nesting the static pass-through approach of Amiti et al. (2022).

Our analysis of the state dependency in strategic pricing is related to the growing evidence on firms' optimizing behavior. Earlier contributions showed that pricing is indeed state dependent, both in advanced economies (Klenow and Kryvtsov, 2008; Nakamura and Steinsson, 2008; Eichenbaum, Jaimovich and Rebelo, 2011; Campbell and Eden, 2014; Lafrogne-Joussier, Martin and Mejean, 2023) and emerging markets (Gagnon, 2009; Alvarez et al., 2019). We extend these findings that largely focus on firms' own costs by examining whether the scope to engage in strategic pricing is also state dependent. Similarly, we contribute to the literature on asymmetric pricing (Bacon, 1991; Peltzman, 2000), extending it to strategic pricing. Studies in this area are typically limited to firms' own costs and specific markets, such as fuel, food, and retail goods (Karrenbrock et al., 1991; Neumark and Sharpe, 1992). We broaden the focus to the universe of firms in the manufacturing and retail sectors and examine both the asymmetric price response of firms to changes in marginal costs and competitors' prices.

Finally, our study contributes to the literature on how market concentration shapes firms' pricing behavior. In the model of Atkeson and Burstein (2008), strategic complementarities are stronger among firms facing lower competition and holding higher market shares. Amiti, Itskhoki and Konings (2019) document that strategic complementarities differ between large and small firms, as well as between firms with high and low market shares. Consistent with these findings, we show that firms with higher market shares exhibit stronger strategic complementarities—particularly when they face less competition and maintain a larger customer base. Our results can inform quantitative models, such as Wang and Werning (2022), that rely on estimates of strategic complementarities to gauge the effects of monetary policy under varying degrees of market concentration.

The rest of the paper is organized as follows. In section 2, we describe the sources of our data and the cleaning procedure, and provide a descriptive analysis of price adjustments along the extensive and the intensive margins. We then discuss the empirical framework in section 3. In section 4, we document five key facts about firms' price setting. We present the results of a series of robustness tests in section 5. Concluding remarks are in section 6.

2 Data

Our empirical setting is Chile from January 2014 to December 2023. Compared to advanced economies in which inflation was low and stable until the pandemic, Chile experienced some large inflation fluctuations throughout the sample period. On a year-on-year basis, CPI inflation fell to 1.4 percent in late 2017 after reaching 5.9 percent at the end

of 2014 and remaining above the central bank target of 3 percent during the so-called 'commodity supercycle'. After a period of stability around the central bank target, inflation started to climb in mid-2020 and reached 13.2 percent in August 2022. Since then, it progressively declined to 3.8 percent by the end of the sample period. PPI inflation followed the same dynamics, but its volatility was significantly higher. Over the sample period, it fell into negative territory in 2016, 2019, and 2023, reaching a trough of -8.7 percent in July 2023; and it was just shy of 10 percent in 2014 and spiked to 27.9 percent in July 2022. These large fluctuations provide an appropriate testing ground to study price-setting behavior.

To construct our dataset, we leverage price information from the administrative records of the VAT registry maintained by Chile's Internal Revenue Service. Since 2014 Chilean firms have been mandated to use electronic invoices, which report prices and quantities for each product variety sold. From these records, we extract information about the buyer, the seller, their economic sectors, the varieties sold (identified by text descriptors), and the prices at which transactions were settled for the universe of bilateral domestic transactions.[5]

We finally aggregate the transaction-level data at the selling firm-product variety-month level by taking the median (or alternatively the average) price at which each product variety was sold during the month. We drop erroneous or invalid records, which we identify according to the following rules. If the change in price from one month to the next is smaller than 10 Chilean pesos (less than 2 USD cents), we replace the observation with the last month's price. We also use the last month's price if the change observed in any given month is fully reverted in the following month. Finally, we drop records for which the price change lies outside the bottom and top 5th percentile interval of the distribution, corresponding to instances in which prices decline by more than half or increase by more than double. Also, to ensure that we capture actual firms rather than entities created for mere tax avoidance, we filter out some observations based on the following criteria. First, we drop firms with less than five employees on average during the year.[6] Second, we only keep firms that appear in the National Accounts registry of Chilean firms. Third, we remove all transactions among firms that are part of the same

[5] Eichenbaum et al. (2014) shows that unit value based pricing induces a leftward shift in the distribution of price changes, leading to infer that there are many more small price changes and fewer large price changes than exist and that the median size of price changes is smaller than in reality. As we directly observe the prices, this issue of apparent small price changes arising from unit value index calculations is not present in our data.

[6] Chilean employers are required to submit information about their employees' wages to calculate the social security contributions and related withholding taxes. From these records, we retrieve the number of employees as well as their wages.

business entities, as these may not be settled at market prices. And fourth, we also drop transactions that suffered invoice corrections via credit notes.

In subsequent steps of the analysis, we want to map product varieties to CPI or PPI categories and identify firms' competitors as those selling similar products. However, the text descriptors identifying product varieties in our data do not necessarily match the product categories of standardized classifiers. Thus, we rely on the work of Acevedo et al. (2025), who use natural language processing (NLP) techniques to classify the product varieties into product categories—or simply products—consistent with the Central Product Classification (CPC) and (an adapted version of) the Classification of Individual Consumption by Purpose (COICoP).[7]

2.1 CPI and PPI prices

We first provide some descriptive evidence about price rigidity based on product varieties that enter the CPI and PPI baskets, and compare it with that available for other countries.[8] Working with observed prices can be problematic for at least two reasons. The first is related to temporary sales and stockouts. The idea is that price variations associated with these events have little to do with the price changes analyzed in price-setting models and are unlikely to be related to macroeconomic conditions. The second issue is product substitution. A price change associated with the end of a product's life cycle and the introduction of a new one is motivated by factors unrelated to the firm's desire to change the product's price. Hence, including price changes motivated by product substitution may bias the calculations of both the frequency and the size of price adjustments.

To deal with temporary sales, we follow Nakamura and Steinsson (2008) and compute regular prices from observed prices. This methodology assumes that the regular price is usually the same after sales and stockouts as before, which indicates that the old regular price should be viewed as a latent state variable in the firm's pricing problem. Specifically, we employ a filter that removes asymmetric V-shaped sales, where a sale is followed by a change in the regular price, and uses a window for return of 5 months.[9] As for product substitution, we get around the issue by working with data at the product variety level. In the Chilean system, whenever a firm introduces a new product substituting an old

[7] See Appendix A for the description of the algoritm used for the mapping.

[8] For the period January 2018–December 2023, we can easily map product varieties to CPI and PPI categories using the CPC and COICoP classifiers as per the National Statistics Institute classification. Yet, for the period before January 2018, the mapping information is not available and we assume that the first available mapping holds backwards.

[9] Appendix B summarizes the methodology to obtain regular prices.

one, the new product gets assigned a different text descriptor corresponding to a unique variety. Thus, any product substitution gets classified as a new product variety.

We examine price rigidity by decomposing the inflation rate as the product of the extensive margin—the frequency of price changes, f_t—and the intensive margin—the size of non-zero price changes, s_t—as in Klenow and Kryvtsov (2008)

$$\Delta p_t = f_t s_t \tag{1}$$

where Δp_t is either the CPI or the PPI monthly inflation rate.

The frequency of price changes is simply the number of price changes per unit of time. Thus, for each product variety v entering the CPI or PPI category c sold in month t, $p_{v,c,t}$, we compute the frequency of price changes at the CPI or PPI category level, $f_{c,t}$, and aggregate at the economy level using the expenditure weights

$$f_t = \sum_c \omega_c f_{c,t} = \sum_c \omega_c \frac{\sum_{v \in c} D_{v,c,t}}{\sum_{v \in c} O_{v,c,t}} \tag{2}$$

where ω_c denotes the CPI and the PPI weights from the National Statistics Institute, $D_{j,c,t}$ is a dummy variable that takes value one when the product variety changes price, and $O_{j,c,t}$ is a dummy variable that takes value one when the price of the product variety is observed; so that $D_{j,c,t} \leq O_{j,c,t}$. From the frequency of price changes, we infer the price price duration as $-1/\ln(1-f_t)$.

The size of price changes (i.e., the magnitude of price changes conditional on the prices changing from $t-1$ to t) is similarly computed by aggregating the magnitude of non-zero price changes at the CPI and PPI category level $s_{c,t}$ weighted by expenditure

$$s_t = \sum_c \omega_c s_{c,t} = \sum_c \omega_c \frac{\Delta p^{\neq 0}_{v,c,t}}{O^{\neq 0}_{v,c,t}} \tag{3}$$

where $\Delta p^{\neq 0}_{v,c,t} = p_{v,c,t} - p_{v,c,t-1} \neq 0$ and $O^{\neq 0}_{j,c,t}$ is a dummy variable that takes value one when the price differs from the one of the previous month.

To understand whether price increases or decreases are more frequent, we also compute the frequency of price changes separately for positive and negative price changes, f_t^+ and f_t^- respectively. Analogously, we repeat the size calculations for price increases and decreases, s_t^+ and s_t^-, such that

$$\Delta p_t = f_t^+ s_t^+ + f_t^- s_t^- \tag{4}$$

The upper panel of Table 1 reports the time average of the frequency measure, as defined in equation (2). The frequency based on the weighted changes of median prices is 30.3 and 30.9 percent for CPI and PPI products, respectively. This implies that after the price of a product changes, it takes almost three months to change again. The frequency computed out of median prices is significantly smaller than that obtained from average prices, suggesting that a few CPI and PPI product categories have relatively higher frequencies.

The analog calculations for regular prices indicate that, as expected, the frequency estimate is smaller than for observed prices. For regular prices of CPI and PPI products, we find frequency estimates of 25.6 and 25.2 percent respectively, indicating a longer duration of about 3 months and a half. These results suggest that temporary sales are a feature of the data, both for products sold to final consumers and intermediate inputs. Another finding is that price increases are considerably more frequent than decreases, pointing to downward nominal rigidities. The frequency of observed price increases is about 5 percentage points higher than for price declines. The same is true for regular prices.

It is difficult to compare estimates across studies as methodologies, sample periods, and data sources vary considerably. However, the evidence on emerging markets suggests that our estimates of the frequency of price adjustment are broadly in the range of those of other countries. For example, Gouvea (2007) and Barros et al. (2009) use prices of CPI products and find an average frequency of 37.2 and 37 percent, respectively. Julio, Zárate and Hernández (2009) estimate the average frequency at 21.1 percent using CPI data for Colombia, while the median frequency is 11.9 percent. Gagnon (2009) uses price information of Mexican CPI products and finds that the average frequency changes substantially when inflation is low and high, from 22.1 percent to 61.9 percent. Creamer and Rankin (2008) examine both CPI and PPI products in South Africa and find that the frequency is 16 percent for the former and 19.5 percent for the latter. Earlier evidence on Chile by Medina, Rappoport and Soto (2007) is limited to CPI products in the pre-2005 period and reports an average frequency of 44.7 percent and a median frequency of 28.9 percent.

The lower panel of Table 1 reports the time average of the size of price changes of CPI and PPI products, as defined in equation (3). Using median prices, the average size of price changes of CPI and PPI products over the full sample period is 1.3 percent. Also, differences are small when the size of price changes is computed starting from average prices instead of median prices.

We find that removing instances of temporary sales does not significantly alter the

size of price adjustments. The size of regular price changes is in fact only two-tenths of a percentage point smaller than that of observed price changes. When we separate price increases and price decreases, however, we find that the size of regular price changes is smaller after excluding temporary sales. This suggests that price changes associated with temporary sales tend to be larger than other price adjustments.

Interestingly, while price decreases occur less frequently than price increases, they tend to be larger. For observed median prices, the size of price decreases is 15 percent for CPI products over the full sample, 2.3 percentage points larger than for price increases. In the case of PPI products, price decreases are 1.7 percentage points larger than price increases. These differentials are of similar magnitude for regular prices.[10]

Figure 1 shows the density distribution of the frequency and size of observed and regular price changes $f_{c,t}$ and $s_{c,t}$, separately for products entering the CPI and the PPI baskets. As shown in the top panels, regular prices have relatively fatter left tails than observed prices, indicating a lower frequency of adjustments as expected. The mode of the distribution for regular prices is about 0.25, meaning that one-fourth of the products change prices in a typical CPI/PPI category and month. Also, the right tails of the distributions are long, indicating a few instances in which a significantly larger share of products changed prices. The bottom panels show that, after excluding instances in which prices did not change, regular prices display smaller price changes than observed prices, with the mode of the distribution at around 1.5 percent both in the case of CPI and PPI product categories. The distributions in the two panels display relatively fatter right tails, indicating that price increases are more frequent than price declines.[11]

2.2 Firms' prices

We now move to firms' prices, the object of interest of this paper. We compute a measure of firm-level inflation by first broadening the sample to all products sold by firms of the manufacturing and retail sectors—including the ones that do not have a mapping into the CPI or the PPI indexes. Then, we obtain the median (or alternatively the average) price for each product sold by the firm during each month. Finally, for each firm i selling product v at time t, we construct its inflation rate as the sales-weighted average of product-level price changes

$$\Delta p_{i,t} = \sum_{v \in i} \omega_{i,v,t} \Delta p_{i,v,t} \tag{5}$$

[10] The results for the post-January 2018 period—for which the mapping between product and CPI and PPI categories is available—are remarkably similar to those for the entire sample period.

[11] Appendix B reports the frequency and size of price changes across CPI and PPI product categories.

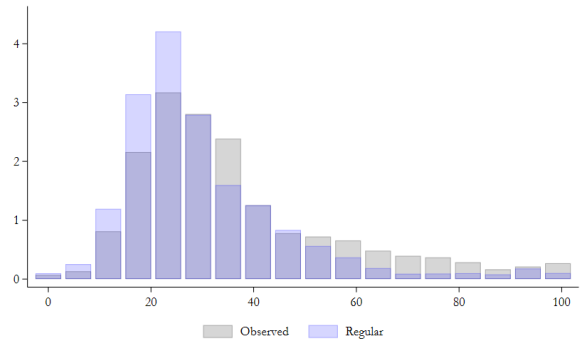
Table 1: Frequency and size of price changes of CPI and PPI products (Percent)

	CPI		PPI	
	Median prices	Average prices	Median prices	Average prices
Frequency				
Observed prices				
All changes	30.3	36.4	30.9	37.7
Duration (months)	2.8	2.2	2.7	2.1
Increases	17.3	21.2	16.6	22.0
Decreases	11.5	15.1	11.6	15.8
Regular prices				
All changes	25.6	30.0	25.2	28.9
Duration (months)	3.4	2.9	3.5	3.0
Increases	14.7	17.6	13.7	16.7
Decreases	9.5	12.1	9.1	12.2
Size				
Observed prices				
All changes	1.3	1.3	1.3	1.3
Increases	12.7	13.7	10.5	11.1
Decreases	-15.0	-15.8	-12.2	-12.6
Regular prices				
All changes	1.2	1.1	1.5	1.4
Increases	11.8	12.6	10.1	10.8
Decreases	-14.2	-15.0	-11.7	-12.3

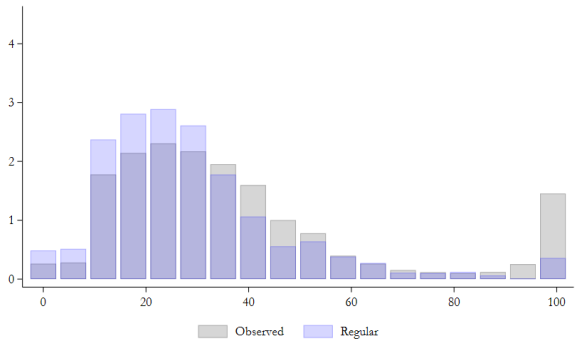
Notes: The table reports the frequency and size of price changes of CPI and PPI product varieties. Starting in January 2018, we can map product varieties to CPI and PPI categories using the COICOP and CPC classifications; before that, we assume the same mapping. Regular prices (i.e., excluding sales) are obtained by applying the filter of Nakamura and Steinsson (2008) which removes asymmetric V-shaped sales, where a sale is followed by a change in the regular price and uses a window for return of 5 months. Implied duration is expressed in months.

Figure 1: Distribution of frequency and size of price changes

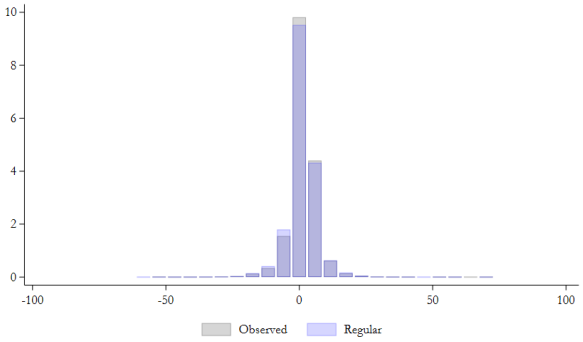
(a) Frequency, CPI products



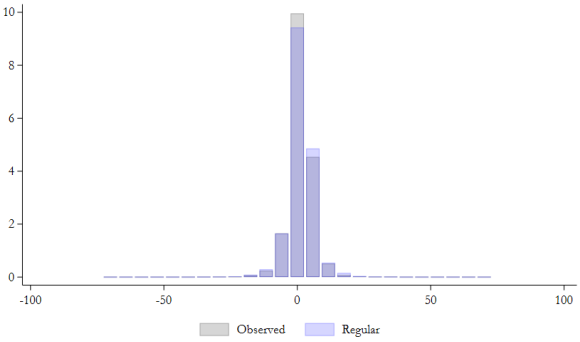
(b) Frequency, PPI products



(c) Size, CPI products



(d) Size, PPI products



Notes: The figure shows the density distribution of the frequency and size of (median) price changes for CPI and PPI product categories. Regular prices (i.e., excluding sales) are obtained by applying the filter of Nakamura and Steinsson (2008) which removes removes asymmetric V-shaped sales, where a sale is followed by a change in the regular price, and uses a window for return of 5 months.

where the weights are the one-year rolling average of the products' sales shares.[12] We end up with a sample of 21,722 firms.

To explore how firms set prices along the extensive and intensive margins, we construct a firm-level measure of the frequency of price changes as the share of products sold by the firm that changed prices per unit of time

$$f_{i,t} = \frac{\sum_{j \in i} D_{v,i,t}}{\sum_{v \in i} O_{v,i,t}} \tag{6}$$

while the firm-level measure of the average size of price changes conditional on observing

[12] As alternative weighting schemes, we employ simple averages and the contemporaneous sales shares.

a price change is

$$s_{i,t} = \sum_{v \in i} \omega_{i,v,t}^{\neq 0} \frac{\sum_{v \in i} \Delta p_{v,i,t}^{\neq 0}}{\sum_{v \in i} O_{v,i,t}^{\neq 0}} \tag{7}$$

As we also want to examine whether price increases or decreases are more frequent and different in size, we repeat the frequency and size calculations separately for price increases and decreases such that

$$\Delta p_{i,t} = f_{i,t} s_{i,t} = f_{i,t}^{+} s_{i,t}^{+} + f_{i,t}^{-} s_{i,t}^{-} \tag{8}$$

where superscripts + and − denote positive and negative price changes, respectively. To avoid large fluctuations potentially due to the entry and exit of products, we drop observations outside of the bottom and top 5 percentile interval of the distribution, which corresponds to monthly price declines and increases of over 20 percent.

Table 2 reports the frequency and size of price changes at the firm level, as described in equations (6) and (7). To aggregate across firms we alternatively use sales or employment-based weights, and then we report the time average. When we use sales-based weights, the weighted median of the frequency of observed price changes is 40.5 percent. Using employment weights delivers a lower estimate of 37.3 percent. Both these estimates, however, imply that firms change prices about every other month. In the case of regular prices, the weighted median frequency drops to 31.6 percent using sales weights and 27.7 percent using employment weights. That is, regular prices last almost 2 weeks longer than observed prices.

Like CPI and PPI products, price increases are more frequent than price decreases, suggesting that downward rigidities are evident also at the firm level. In the case of observed prices, the difference is about 6 percentage points. For regular prices, the difference is smaller at about 4 percentage points. Comparing observed to regular prices also reveals that the reduction in frequency is mainly attributable to price increases, consistent with the idea that regular prices smooth out price declines associated with temporary sales. Finally, weighted averages are higher than weighted medians, suggesting the presence of some products for which price changes happen more frequently.

We now turn to the intensive margin of firms' price changes. Over the sample period, firms recorded price changes between 0.7 and 0.8 percent, depending on whether we use median or average prices. Price increases are as large as 11.1 to 13.4 percent, depending on the weighting variable and whether we consider medians or average prices. However, price declines tend to be tend to be even larger, by about 2.5 percentage points. That is, while firms reduce prices less frequently, they tend to do so by a larger magnitude

relative to price increases. Comparing regular prices to observed prices, we find that the magnitude of price changes is similar. However, we also find relatively smaller regular price increases and decreases than for observed prices, suggesting that price adjustments associated with temporary sales tend to be larger in magnitude.

Table 2: Frequency and size of price changes of firms
(Percent)

	Sales weighting		Empl. weighting	
	Median prices	Average prices	Median prices	Average prices
Frequency				
Observed prices				
All changes	40.5	45.7	37.3	43.5
Duration (months)	2.0	1.6	2.2	1.8
Increases	20.2	25.9	17.0	24.4
Decreases	14.8	19.9	11.8	19.1
Regular prices				
All changes	31.6	34.8	27.7	33.3
Duration (months)	2.7	2.4	3.1	2.5
Increases	15.7	19.1	13.4	18.3
Decreases	11.5	15.6	8.9	15.0
Size				
Observed prices				
All changes	0.8	0.7	0.8	0.7
Increases	11.1	12.3	12.0	13.4
Decreases	-13.4	-14.6	-14.4	-15.9
Regular prices				
All changes	0.7	0.6	0.9	0.7
Increases	10.4	11.6	11.1	12.6
Decreases	-12.5	-13.8	-13.5	-15.0

Notes: The table reports the frequency and size of price changes of firms. Regular prices (i.e., excluding sales) are obtained by applying the filter of Nakamura and Steinsson (2008) which removes asymmetric V-shaped sales, where a sale is followed by a change in the regular price and uses a window for return of 5 months. Implied duration is expressed in months.

3 Empirical framework

Strategic complementarities arise in models where the elasticity of demand and markups are a function of the firms' market shares (Atkeson and Burstein, 2008). If a firm's market

share depends inversely on its relative price, then its price should react positively to increasing competitors' prices. For instance, an increase in the competitors' price translates into a firm's lower relative price, increasing its demand and market share, which results in a market share and markup beyond its optimal level. Because of that, the firm reacts by increasing its prices and reducing its market share, bringing markups to their optimal levels.

This strategic motive in pricing dampens the response of firms' prices to changes in their marginal costs. To see this, suppose that a firm suffers a cost shock holding constant competitors' prices. The firm can then aim at maintaining its markup by increasing its price and losing market share, or lower its markup by maintaining its price and market share. However, when a firm considers raising its price in response to an increase in marginal costs, it also considers how competitors would react. If strategic complementarities are strong, the pass-through of marginal cost changes is reduced because firms would be concerned about losing market share. Hence, strategic complementarities can lead to a coordination problem where firms become hesitant to be the first to change prices, which in turn leads to price stickiness.

To examine the strength of strategic complementarities with respect to firms' own cost pass-through, we borrow the theoretical framework from Amiti, Itskhoki and Konings (2019), in which firms maximize profit by setting prices according to

$$p_{i,t} = mc_{i,t} + \mathcal{M}_i(p_{i,t}, \boldsymbol{p_{-i,t}}, \boldsymbol{\xi_t}) \tag{9}$$

where $mc_{i,t}$ denotes firm i's (log of) marginal cost at time t and $\mathcal{M}$ is the (log of the) markup function, with its arguments being the firms' own prices, a vector of its competitors' prices $\boldsymbol{p_{-i,t}}$, and a vector of demand shifters $\boldsymbol{\xi_t}$.

The markup is defined as

$$\mathcal{M}_i(p_{i,t}, \boldsymbol{p_{-i,t}}, \boldsymbol{\xi_t}) = \log\left(\frac{\epsilon\left(p_{i,t} - p_{-i,t}, \boldsymbol{\xi_t}\right)}{\epsilon\left(p_{i,t} - p_{-i,t}, \boldsymbol{\xi_t}\right) - 1}\right) \tag{10}$$

where ϵ is the elasticity of demand. The intuition behind this characterization of the markup function that includes the firms' own prices is that a change in any firm's prices affects the demand of other firms in the same industry, which in turn alters their demand elasticities such that the optimal markups change for all firms. A key advantage of this framework is its generality. Specifically, the markup function holds for any invertible demand system and competition structure, and any vector $p_{-i,t}$, such that $p_{i,t}$ is the firm's best reaction function.

After some algebraic manipulations, the following estimating equation can be derived

$$\Delta p_{i,t} = \alpha_i + \tau_t + \sum_{r=0}^{R} \beta^r \Delta mc_{i,t-r} + \sum_{r=0}^{R} \gamma^r \Delta p_{-i,t-r} + \varepsilon_{i,t} \tag{11}$$

which is the distributed lag version of the generalized accounting framework of price changes of Gopinath, Itskhoki and Rigobon (2010) and Burstein and Gopinath (2014). The equation indicates that firms adjust prices according to the degree of pass-through of changes in their own marginal cost β^r and the strength of strategic complementarities γ^r, with the two coefficients being functions of the underlying own and competitor markup elasticities. The distributed lag specification allows us to retrieve the dynamics in response to changes in marginal costs and competitors' prices—to our understanding, this is the first paper to do that.[13]

We also examine the responses of the extensive and intensive margins of price adjustments. To do that, we replace the dependent variable with the frequency of price changes and the magnitude of price changes as defined in equations (6) and (7), respectively. One should note that the pass-through is not simply the product of the change in frequency and the change in size of price changes, rather it is equal to $\Delta_R p_{i,t} = f_{t-R}\Delta_R s_t + s_{t-R}\Delta_R f_t + \Delta_R s_t \Delta_R f_t$, where Δ_R is the difference operator and we omit the subscript i for simplicity. More specifically, let $\beta^{f,r}$ and $\beta^{s,r}$ be the estimated coefficients on the changes in the marginal costs from replacing the dependent variable in equation (11) with the frequency of price changes and the magnitude of price changes. Then, the relationship between these coefficients and the effect of a change in marginal costs on firms' prices over the projection horizon is $\frac{\partial \Delta_R p_t}{\partial \Delta mc_t} = \sum_{r=0}^{R} \beta^r = f_{t-1} \sum_{r=0}^{R} \beta^{s,r} + s_{t-1} \sum_{r=0}^{R} \beta^{f,r} + \sum_{r=0}^{R} \beta^{s,r} \sum_{r=0}^{R} \beta^{f,r}$, with f_{t-1} and s_{t-1} evaluated at their sample mean.

3.1 Marginal costs

To measure firms' marginal costs, we leverage the granularity and the comprehensiveness of the price information in the VAT registry. For each intermediate input k purchased by firm i in month t, we obtain the changes in k's within-month median prices, $\Delta ip_{k,i,t}$,

[13] One could alternatively obtain the dynamics by estimating local projections. However, there are two downsides to this approach. First, the first year of data would be lost because the independent variables have 12 lags, and this is particularly costly with already short series (moreover, specifications for farther horizons would be estimated on fewer observations because of the long difference in the dependent variable). Second, local projections are computationally more intensive as they require the estimation of one regression per horizon compared to a single regression in the distributed lag framework. In the robustness section of the paper, we present results using local projections.

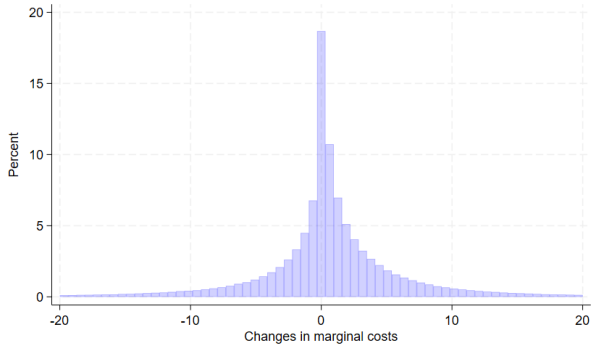
weighted by the firm's expenditure share $\omega_{i,k,t}$

$$\Delta mc_{i,t} = \sum_{k} \omega_{k,i,t} \Delta ip_{k,i,t} \tag{12}$$

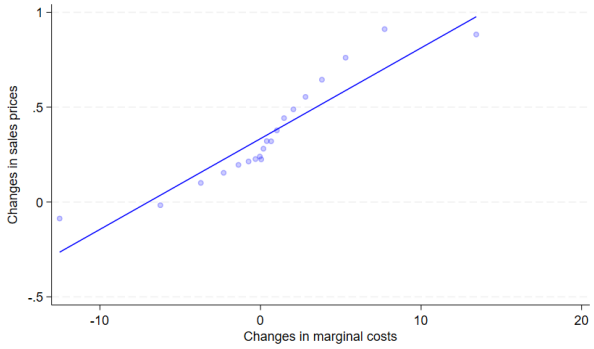
where the expenditure shares are computed as one-year rolling averages.[14] The left panel of Figure 2 shows the distribution of changes in marginal costs, which resembles a normal one with a fatter right tail, indicating that cost increases are more frequent than decreases. The right panel displays the unconditional relationship between changes in marginal costs and changes in sales price. The slope of the regression line is 0.05 and statistically significant at the 1 percent significance level, which points to a weak positive correlation between the two variables.

Figure 2: Changes in marginal costs
(Percent)

(a) Distribution



(b) Relationship with sales prices



Notes: The figure shows the distribution of the changes in marginal costs and the relationship of changes in marginal costs with changes in sales prices.

Compared to Amiti, Itskhoki and Konings (2019) and Gagliardone et al. (2023), who proxy marginal costs with the admittedly noisy accounting measures of the firms' average variable costs and instrument them with the price of imported intermediate inputs, we make progress by precisely tracking all price changes of the intermediates purchased by the firm. That is, we replace the variation in some commodity prices with all actual intermediate input costs that firms bear. One should note, however, that our measure neglects changes in prices of imported intermediate inputs, which we do not directly observe. In the Chilean context, this is less concerning as the share of firms that source all their intermediate inputs domestically is about 70 percent.We also do not have a precise measure

[14]To rule out potential recording mistakes, we restrict the universe of a firm's intermediate inputs to those that the firm should buy according to the input-output matrix.

of variable labor costs. In fact, from the Social Security accounts we only observe workers' total wages over the months they worked in the year, from which we can compute workers' average wages and then aggregate them at the firm level to obtain a measure of total labor costs. Luckily, total labor costs on average account only for 23 percent of the sum of intermediate inputs and total labor costs. In a set of robustness tests, however, we provide evidence that changes in total labor costs do not have any significant relationship with firms' pricing.

3.2 Competitors' prices

It is difficult to identify firms' competitors and, therefore, construct the relevant measure of competitors' prices. The literature typically assumes that competitors are all the other firms operating in the same sector.[15] Rossi-Hansberg, Sarte and Trachter (2021) stress that product markets are generally local because transportation of goods and people is expensive, so firms set up production plants, distribution centers, and stores close to buyers. In turn, customers locate in areas where they can obtain the goods they desire. In addition to the geographical dimension, the product dimension is also critical. Firms may sell and compete with different sets of firms depending on what product they sell, even if they are assigned to the same sector and sell in the same geographical area.

We depart from the literature and leverage the granularity of our data to construct a significantly narrower measure of competitors' prices. That is, for each firm in the sample we define its competitors' price inflation as the sales-weighted average of the price changes of the same products sold in the same municipality by other firms of the same sector as follows

$$\Delta p_{-i,t} = \sum_{r}^{R_i} \omega_{j,s,r,t} \sum_{d}^{D_i} \sum_{j \neq i}^{J_{s,d,r}} \omega_{j,s,d,r,t} \Delta p_{j,s,d,r,t} \tag{13}$$

where R_i denotes the set of municipalities in which firm i sells, D_i the set of products sold by firm i, and $J_{s,d,r}$ is the set of firms selling product d in municipality r operating in the same sector s as firm i (i.e. i's competitors).[16] And the firm-municipality-product

[15] See Amiti, Itskhoki and Konings (2019) and Gagliardone et al. (2023) for empirical examples and Wang and Werning (2022) for a theoretical model.

[16] According to the 3-digit ISIC rev. 4 classification, firms are sorted into 54 manufacturing sectors, 5 wholesale sectors, and 11 retail sectors. As for the other dimensions, there are 345 municipalities and about 1,700 products.

level inflation rate is defined as

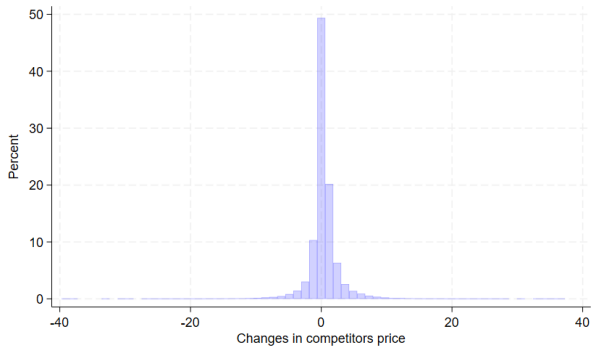
$$\Delta p_{j,s,d,r,t} = \sum_{v}^{V_{j,s,d,r,t}} \omega_{j,v,t} \Delta p_{j,v,t} \tag{14}$$

where $V_{j,s,d,r,t}$ is the set of varieties of product d that firm j sells in municipality r at time t. This measure builds on the details of the electronic invoices. In particular, the municipality is the one in which the buyer is located, consistent with the idea that product markets are local; and the product corresponds to the one obtained by mapping product varieties to standardized product categories via NLP techniques, as described in section 2.

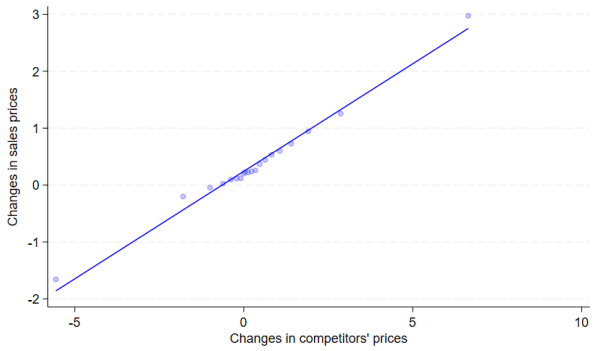
The distribution of changes in competitors' prices in Figure 3 appears leptokurtic, with a larger mass on the positive side of the distribution. In almost half of the firm-time observations, competitors' prices do not change, and when they do they are more likely to increase.[17] The unconditional correlation with the changes in firms' sales price is about 0.38, which is suggestive of sizable strategic complementarities. Importantly, the correlation between changes in marginal costs and changes in competitors' prices is low at 0.16, allowing us to identify the β^r and γ^r coefficients in equation (11).

Figure 3: Competitors' price inflation
(Percent)

(a) Distribution



(b) Relationship with sales prices



Notes: The figure shows the distribution of the changes in competitors' prices and the relationship of changes in competitors' prices with changes in sales prices.

[17] Competitors' price changes range from -40 to 40 percent as its construction is based on the changes in prices of product varieties, which are bounded between -50 and 200 percent. Trimming the distribution of competitors' prices between -20 and 20 percent produces virtually the same results.

3.3 Identification threats

Estimating equation (11) presents three key identification challenges. First, sectoral demand shocks or wage adjustments may lead to changes in sales prices, leading to an omitted variable bias. To address this, we re-estimate equation (11) replacing time fixed effects with sector-time fixed effects. These purge our baseline estimates from factors that vary at the sector level and over time, potentially correlated with either the marginal costs and the competitors' prices.

The second challenge is that, while the prices of intermediate inputs are likely exogenously determined for most of the firms in the sample, firms with monopsony power may impose prices on their suppliers. For these firms, reverse causality is a meaningful concern. We then leverage the granularity of the data to construct an instrument for our measure of changes in marginal costs that excludes purchases of firms whose suppliers have only a few buyers

$$\Delta mc^{*}_{i,t} = \sum_{k} \omega_{k,i,t} \Delta ip^{90}_{k,i,t} \tag{15}$$

where $\Delta ip^{90}_{k,i,t}$ refers to changes in the costs of intermediates sold by suppliers that have a number of clients higher than the 90th percentile of the distribution. The idea is that, by excluding these transactions, we mitigate the risk that firms' monopsonic position may determine their purchase prices.

The third identification challenge is that there may be simultaneity in price setting for the firms and their competitors. We therefore construct an instrument for competitors' by bringing in the geographical and product dimensions that we exploited for calculating competitors' prices in equation (13). Specifically, for each firm i we first identify the subset of suppliers $\mathcal{S}$ that sell both to i and its competitors. Then, we compute the sales-weighted changes in the costs of inputs K that competitors J operating in sector s use to produce product d sold in municipality r in month t.[18] However, we exclude from the set of inputs K those that are purchased from suppliers $\mathcal{S}$ that sell to both firm i and its competitors.

$$\Delta mc^{*}_{-i,t} = \sum_{r}^{R_i} \omega_{j,s,r,t} \sum_{d}^{D_i} \sum_{j \neq i}^{J_{s,d,r}} \omega_{j,s,d,r,t} \sum_{k \notin K_{\mathcal{S}}} \omega_{k,j,t} \Delta ip_{k,j,t} \tag{16}$$

Thus, the identifying assumption is that, by excluding inputs of firms selling both to the firm and its competitors, the possible simultaneity in price setting is broken. All the regression results are reported in the robustness section.

[18] Note that input k is defined at the same level of a product variety v.

4 Five facts about firms' price setting

In this section we document some key facts about firms' pricing behavior.

4.1 Fact 1: strategic complementarities are overwhelmingly important

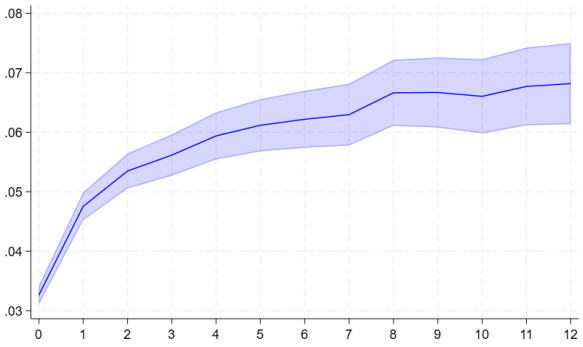
Our first key result is that strategic complementarities are overwhelmingly important for firms' price setting, relatively more than changes in marginal costs. Figure 4 presents the results from estimating equation (11) with standard errors clustered at the firm and month level. We find that firms react quickly and sizably to changes in competitors' prices. Firms pass through 55 percent of the changes in competitors' prices to their own sales prices within the same month. Over the one-year horizon, the pass-through estimate reaches 66 percent. This is significantly larger than the pass-through estimate of marginal costs. On impact, less than 4 percent of the increase in marginal costs is passed through to sales prices and this estimate remains below 7 percent one year after the shock. That is, the pass-through of changes in competitors' prices is about 9 times larger than the pass-through of changes in their own costs.

Overall, the results suggest that firms' pricing decisions are heavily influenced by the prices set by competitors. This interdependence makes firms less responsive to changes in their own marginal costs and more focused on maintaining relative price stability with their competitors, pointing to substantial real rigidities. These findings stand in contrast with the predictions of complete pass-through and no strategic complementarities of canonical models featuring constant markups with CES demand functions and monopolistic competition. Instead, they lend support to models allowing for strategic complementarities, such as Atkeson and Burstein (2008) and Amiti et al. (2022).

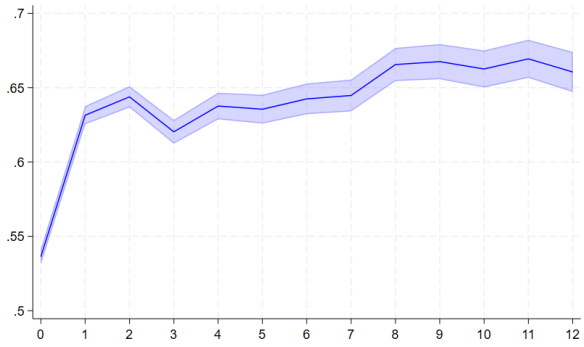
Compared to the results of Amiti et al. (2022) and Gagliardone et al. (2023) for Belgium, our estimates of the pass-through of firms' own costs are lower and the ones of the pass-through of competitors' prices are higher. That is, we find evidence of stronger nominal and real rigidities. This is an important finding because, as noted by Ball and Romer (1990) and Klenow and Willis (2016), monetary non-neutrality arises when nominal rigidities are coupled with real rigidities. Finally, compared to studies that do not account for strategic complementarities, our estimates for the pass-through of changes in marginal costs are lower. However, to the extent that changes in marginal costs and competitors' prices are not orthogonal, omitting the latter would bias downward the coefficient on the changes in marginal costs. As a benchmark, estimating equation (11) without competitors' prices delivers a cost pass-through of about 20 percent, closer to the ones in the literature.

Figure 4: Cost pass-through and strategic complementarities
(Percent)

(a) Change in marginal costs



(b) Change in competitors' prices



Notes: The figure shows the percent change in firms' sales prices in response to a one percentage point change in their marginal costs and a one percentage point change in competitors' prices, along with the 90 percent confidence interval. The specification includes firm and time fixed effects. Standard errors are clustered at the firm and time level.

One aspect we stressed in section 2 is that the geographical and product dimensions are important to appropriately identify firms' competitors. We provide evidence of how neglecting these dimensions can affect the elasticities of interest. To do that, we replace competitors' prices as defined in equation (13) with the measure typically used in the literature, which identifies competitors solely based on the industry in which the firm operates. The results in Figure 5 confirm that excluding the geographical and product dimensions imparts a significant bias on the estimated elasticities. The estimate of the marginal cost pass-through would be 38 percent higher and the competitors' prices pass-through would be 23 percent lower.

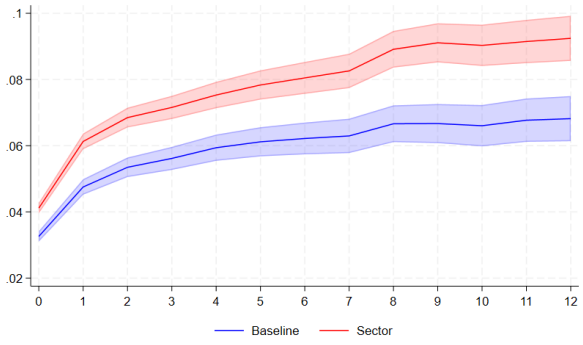
4.1.1 Extensive and intensive margins of price adjustments

We first examine the response of prices along their extensive margin. That is, how many of the firms' product varieties change prices per month in response to a change in marginal costs or a change in competitors' prices? The top left panel of Figure 6 shows that a 10 percentage point increase in the firms' marginal costs is associated with an increase in the share of products changing prices by 3.4 percentage points over a 12-month period. Based on the results in Table 2 for the sales-weighted median prices, this implies that the share of products that change price every month would reach almost 44 percent for the average firm in the sample.

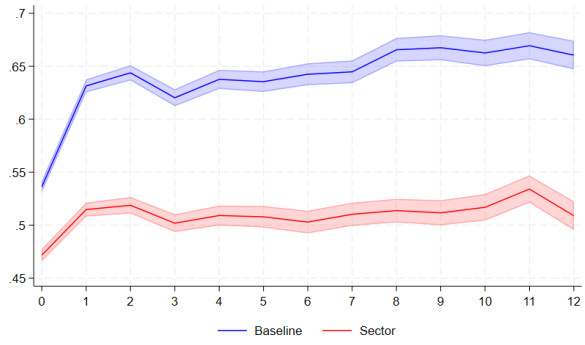
Interestingly, the top right panel indicates that the frequency of price changes reacts

Figure 5: Pass-through estimates with alternative measures of competitors' prices (Percent)

(a) Change in marginal costs



(b) Change in competitors' prices



Notes: The figure shows the percent change in firms' sales prices in response to a one percentage point change in their marginal costs and a one percentage point change in competitors' prices, along with the 90 percent confidence interval. The figure compares the pass-through estimates when competitors are identified as in the baseline (i.e., firms in the same sector, selling in the same municipality, and selling the same product) to the estimates when competitors are identified using only the sector in which they operate. The specification includes firm and time fixed effects. Standard errors are clustered at the firm and time level.

more vigorously to changes in competitors' prices. In response to a 10 percentage point increase in competitors' prices, the share of products changing prices is 24 percentage points higher one year after the shock. Our findings imply that for the average firm to change prices of all its product varieties, marginal costs would have to surge by 2.7 times; however, it would take only a 25 percent increase in competitors' prices to get the same effect.

We complete the characterization of firms' price adjustments by showing the results of the impact of changes in marginal costs and competitors' prices on the intensive margin of price changes. In other words, we quantify by how much firms change their prices when they decide to adjust them (i.e., excluding zero price changes). On impact, about 5 percent of changes in marginal costs is reflected in firms' own prices. Firms, however, continue to adjust prices over time and about 12 percent of the initial cost increase is reflected in sales prices one year after the shock.

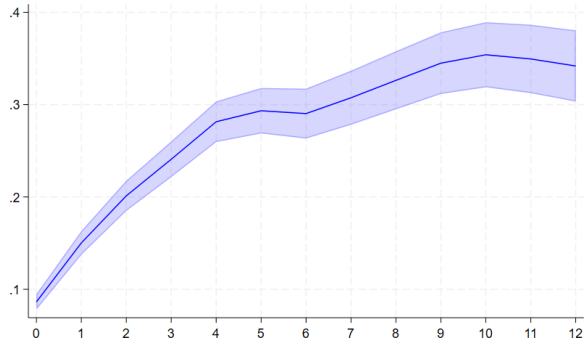
Changes in competitors' prices produce different estimates and dynamics compared to changes in marginal costs. When competitors raise prices, firms respond by reflecting a much larger share of such increase in their own prices. On impact, 64 percent of the increase in competitors' prices is passed through to firms' own prices. This estimate reaches 77 percent within the quarter, but then declines to about 70 percent over the

following months.

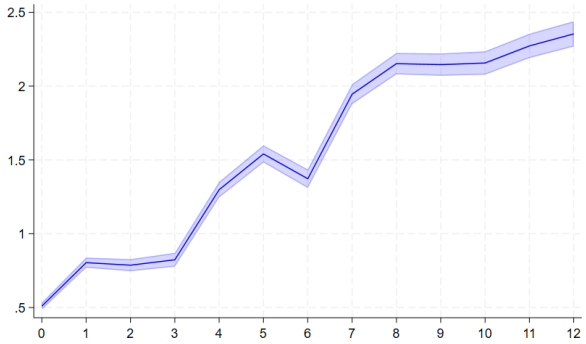
All in all, the large competitors' prices pass-through reflects both adjustments on the extensive and the intensive margins. And the broadly monotonically increasing dynamics of the competitors' prices pass-through reflect a short-run increase in the size of price adjustments and a longer-run decline in the size of price adjustments, opposed by a steady increase in the frequency of price adjustments.

Figure 6: Frequency and size of price adjustments
(Percent)

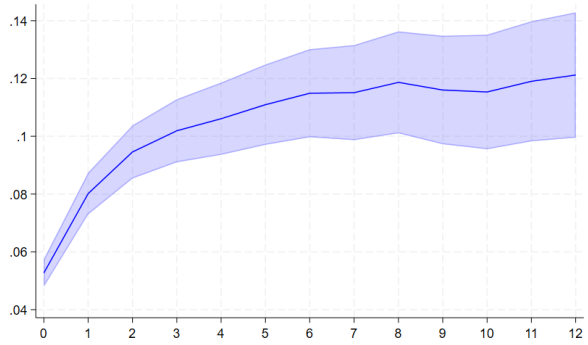
(a) Frequency, change in marginal costs



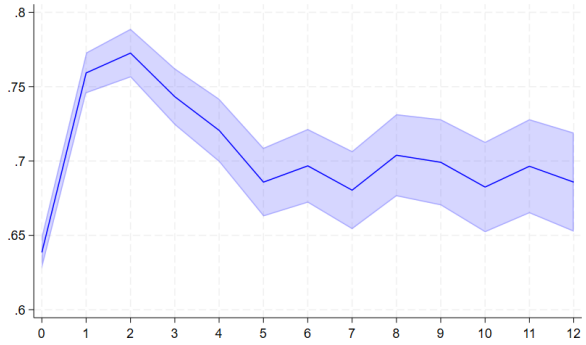
(b) Frequency, change in competitors' prices



(c) Size, change in marginal costs



(d) Size, change in competitors' prices



Notes: The figure shows the change in firms' frequency of sales price adjustments and the percent change in firms' size of non-zero sales price adjustments, in response to a one percentage point change in their marginal costs and a one percentage point change in competitors' prices, along with the 90 percent confidence interval. The specification includes firm and time fixed effects. Standard errors are clustered at the firm and time level.

4.2 Fact 2: strategic complementarities are dominant across sectors

The second fact is that the strength of strategic complementarities varies across sectors, but remains of first-order importance even in oligopolistic settings. As noted in section 2,

our sample covers the universe of both manufacturing and retail firms, with the latter representing about two-thirds of the total number of firms. Hence, the results presented in subsection 4.1 reflect a sample composition skewed towards the retail sector. We have assumed so far that firms internalize the effect of their pricing decisions on the market in which they compete and react strategically to their competitors, while this is not the case for the industry to which they are assigned. This appears a fair assumption for our setup, because large firms have relatively large market shares in the narrowly defined markets in which they compete (i.e., 3-digit ISIC sector-municipality-product), and small ones in their sector industries (i.e., 3-digit ISIC sectors) or macro sectors (i.e., 1-digit ISIC sectors, which correspond to manufacturing and retail). The average within sector-municipality-product market share is 7.1 percent, while it is only 1.7 within the sector industry and 0.5 within the macro sector.

One concern with this assumption is that retail firms may act as price takers that prioritize undercutting competitors to attract price-sensitive customers rather than favoring the coordinated pricing strategies, which are our object of interest. This is because retailers usually operate in perfectly competitive markets, selling similar products and with little power to influence competitors' prices. This risk that the regressions pick up a pure price-taking behavior, however, is somewhat mitigated by our narrow definition of the market in which firms operate. As shown in Figure 7, market shares are significantly larger when we define the markets at the sector-municipality-product level. As a reference, for such level of disaggregation the average market share of retail firms is high at 6.1 percent for retail firms, compared to an average market share of 8.9 percent for manufacturing firms. Thus, we argue that sectoral differences are more likely to reflect sector idiosyncratic aspects (Goldberg and Hellerstein, 2007).

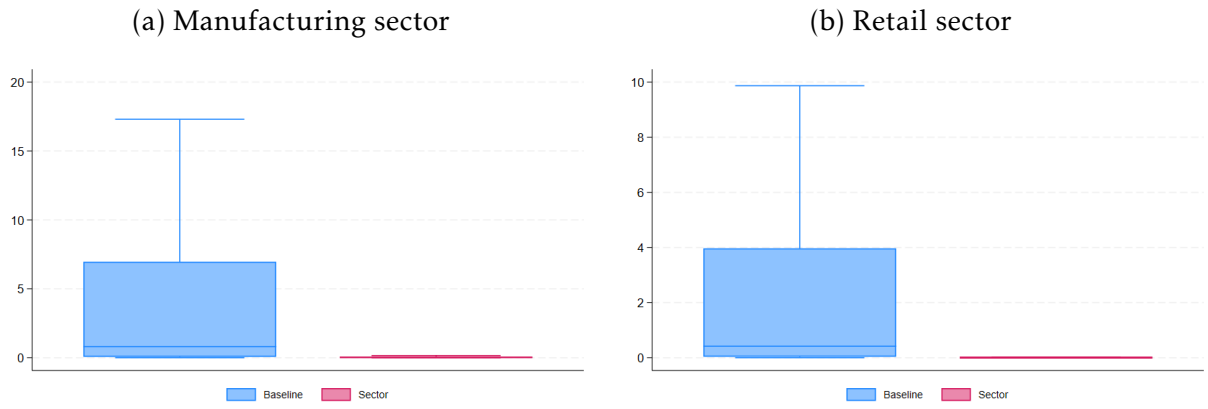
To examine the strength of strategic complementarities in more typical oligopolistic settings, we estimate a variation of equation (11) that allows the coefficients to vary for the manufacturing and the retail sector

$$\Delta p_{i,t} = \alpha_i + \tau_t + \sum_{r=0}^{R} \Delta mc_{i,t-r}(\beta^r + \delta^r M_{i,t-r}) + \sum_{r=0}^{R} \Delta p_{-i,t-r}(\gamma^r + \xi^r M_{i,t-r}) + \varepsilon_{i,t} \qquad (17)$$

where $M_{i,t-r}$ is a dummy taking value one if firm i is assigned to the manufacturing sector, and zero otherwise.

Figure 8 shows that the pass-through of changes in marginal costs is similar on impact for manufacturing firms (4 percent) compared to retail firms (3 percent). Yet, a wedge opens up over time and the pass-through estimate of manufacturing firms reaches

Figure 7: Market shares distributions
(Percent)



Notes: The figure shows the distributions of firms' market shares when markets are defined as in the baseline (i.e., firms in the same sector, selling in the same municipality, and selling the same product) to the market shares when markets are defined using only the sector in which firms operate.

13 percent one year after the cost increase, which is more than double that of retail firms. Sector heterogeneity is more marked for changes in competitors' prices. For manufacturing firms, we find that less than one-fifth of the competitors' price changes gets passed through to sales prices on impact. On the other hand, retail firms selling to end-consumers pass through about 65 percent of the competitors' price changes. Over time firms continue to adjust prices and by the end of the year manufacturing firms passed through about 40 percent of competitors' price changes, compared to retail firms that passed through about three-fourths of them. [19]

These results suggest that, even after excluding possible price takers of the retail sector and focusing exclusively on the manufacturing firms more likely to operate in oligopolistic settings, strategic complementarities are still a key determinant of the price-setting behavior. And while pass-through estimates of the competitors' prices are now smaller than those in Amiti, Itskhoki and Konings (2019) and Gagliardone et al. (2023), in contrast with the results in these studies we find that they are about 4 times larger than those of marginal cost pass-through.

We now turn to the sectoral differences in the extensive and intensive margins of price adjustments. Our results indicate that in response to a marginal cost increase, firms in the manufacturing sector adjust prices more frequently and by a larger magnitude than firms

[19] Appendix Table D.1 reports the cumulated coefficients on the interaction terms along with their statistical significance, both for the interactions with changes in marginal costs and with changes in competitors' prices.

in the retail sector. A 10 percentage point increase in marginal costs leads manufacturing firms to change prices of a number of product varieties that is 7 percentage points higher at the end of the year, compared to about 2 percentage points for retail firms. Similarly, our results for the size of price changes indicate that manufacturing firms pass through 23 percent of the increase in marginal costs to sales prices, compared to 8 percent for retail firms.

The story is different for changes in competitors' prices. A 10 percentage point surge in competitors' prices is associated with an increase in the share of product varieties changing prices of about 5 percentage points on impact for both manufacturing and retail firms. However, by the end of the year manufacturing firms have increased the share of product varieties changing prices by 15 percentage points and retail firms by 26 percentage points. Interestingly, while the path of the frequency response of retail firms is still increasing 12 months after the shock, the one of manufacturing firms reaches its peak at 18 percentage points 6 months after the shock and then marginally declines.

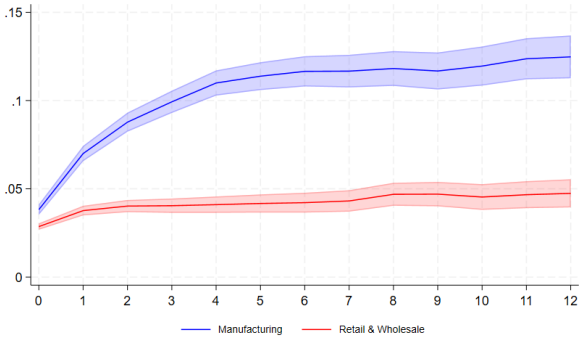
The response of the size of price adjustments also show different dynamics for manufacturing and retail firms. The size of price adjustments for manufacturing firms is 28 percent on impact and it then rises steadily reaching 63 percent 12 months after the shock. Retail firms, on the other hand, pass on three-fourths of the changes in competitors' prices on impact, with the peak effect occurring just two months after the shock at 82 percent. That is, retail firms are quicker than manufacturing ones to react to changes in competitors' prices, likely reflecting the high degree of competition of the market in which they operate. After that, however, there is some retrenchment and the effect one year after the shock is not statistically different.

4.3 Fact 3: state-dependent strategic pricing

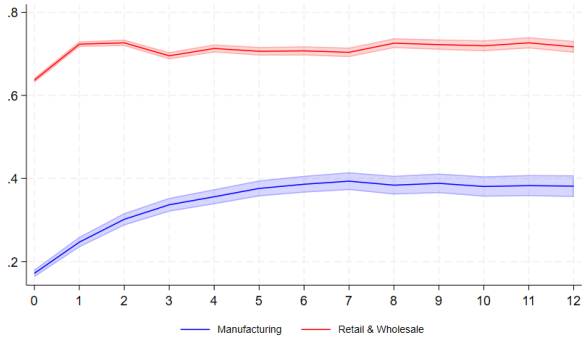
The third fact is that when inflation runs high, firms become more sensitive to the actions of their competitors. In a high inflation environment, consumers' purchasing power shrinks and demand falls, hence sales decline and firms get closer to their breakeven. Thus, as their margins get squeezed, they find it more difficult not to pass through changes in their own costs, hence nominal rigidities are less binding. The literature pointed out that when pricing is state-dependent, monetary policy becomes approximately neutral (Golosov and Lucas, 2007) and the Phillips curve is nonlinear, increasing the sacrifice ratio (Karadi et al., 2024). At the same time, when inflation runs high and profit margins are reduced, firms may take any opportunity to recover by passing through more of the increase in competitors' prices.

Figure 8: Manufacturing versus retail firms
(Percent)

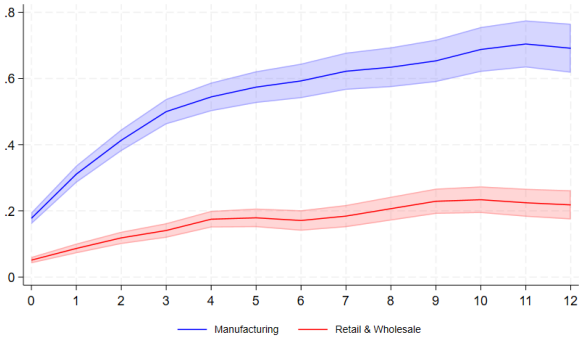
(a) Pass-through, change in marginal costs



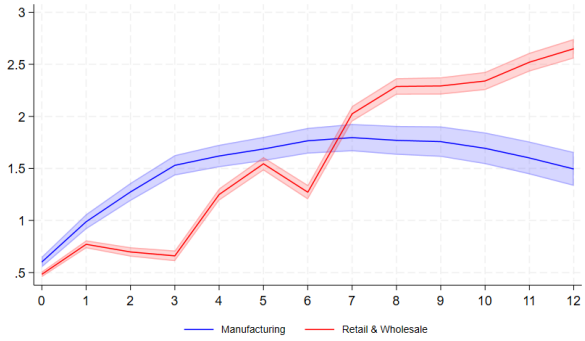
(b) Pass-through, change in competitors' prices



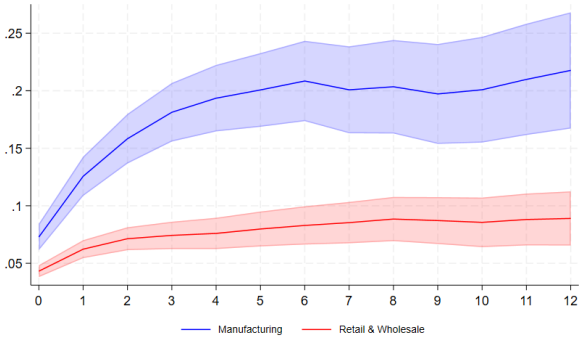
(c) Frequency, change in marginal costs



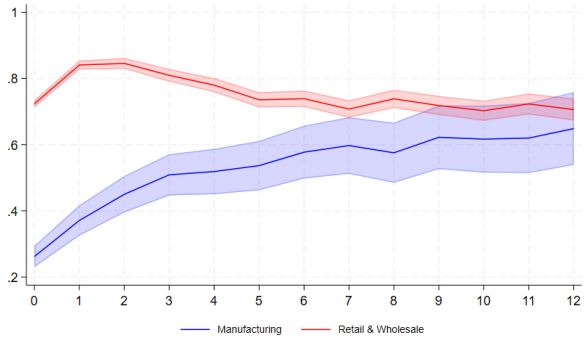
(d) Frequency, change in competitors' prices



(e) Size, change in marginal costs



(f) Size, change in competitors' prices



Notes: The figure shows the percent change in firms' sales prices, the change in firms' frequency of sales price adjustments, and the percent change in firms' size of non-zero sales price adjustments in response to a one percentage point change in their marginal costs and a one percentage point change in competitors' prices, along with the 90 percent confidence interval. The figure compares the responses of manufacturing firms and retail firms. The specification includes firm and time fixed effects. Standard errors are clustered at the firm and time level.

We study whether firms' pricing behavior changes in a high inflation environment by conditioning the responses to changes in marginal costs and competitors' prices on the inflation level

$$\Delta p_{i,t} = \alpha_i + \tau_t + \sum_{r=0}^{R} \Delta mc_{i,t-r}(\beta^r + \delta^r \pi_{t-r}) + \sum_{r=0}^{R} \Delta p_{-i,t-r}(\gamma^r + \xi^r \pi_{t-r}) + \varepsilon_{i,t} \tag{18}$$

where π_{t-r} is a dummy variable taking value one when (monthly) inflation is above the median plus one standard deviation.[20] To rule out potential price-taking behaviors takers discussed in subsection 4.2, we focus exclusively on manufacturing firms and report the results for retail firms in Appendix E. In this conditional specification, coefficients β^r and γ^r describe the responses to changes in marginal costs and competitors' prices in a low inflation environment, while coefficients δ^r and ξ^r quantify the corresponding differential effects in a high inflation environment.

Figure 9 shows the marginal cost and competitors' prices pass-through estimates comparing periods in which inflation runs low to periods in which it runs high. We find that in a high inflation environment firms become more wary of their own costs, passing through a larger portion of them to sales prices. On impact, manufacturing firms pass through about 5 percent of the change in marginal costs when inflation is high, compared to 3 percent when inflation is low. Over time this gap widens considerably, with firms passing through almost 13 percent of cost changes in a high inflation environment and only 7 percent in a low inflation environment.

The wedge in the cost pass-through between periods of low and high inflation is accounted for by more frequent price adjustments when inflation is high. A 10 percent surge in marginal costs is associated with a 9 percentage point increase in the frequency of price adjustments when inflation is high, compared to a 2 percentage point increase when inflation is low. The response of the size of price adjustment, instead, is broadly the same. The fact that firms adjust a significantly larger share of their products per unit of time when aggregate inflation runs high is consistent with the evidence in the literature (Nakamura et al., 2018; Alvarez et al., 2019; Karadi and Reiff, 2019; Blanco et al., 2024).

We now turn to whether inflation alters the scope for strategic behavior in price setting. We find that firms also become more sensitive to how competitors set prices when inflation runs high. Specifically, a one percentage point increase in competitors' prices is associated with a 0.5 percent increase in sales prices when inflation is high and only 0.2

[20] Mean and standard deviation are computed using the calendar months. We obtain similar results when we alternatively construct the dummy using monthly inflation irrespective of the calendar month or annual inflation, as shown in Appendix C.

percent when inflation is low.

In the case of changes in competitors' prices, however, firms react both on the extensive and the intensive margin. A 10 percentage point increase in prices of the competitors is associated with a 22 percentage point increase in the frequency of price adjustment a year after the shock when inflation is high. On the other hand, the frequency increases only temporally and marginally when inflation is low, reaching a peak of 9 percent 3 months after the shock and with no statistically significant effect one year after. In addition, when inflation is high firms fully reflect the changes in competitors' prices on the prices that they decide to change, while the size effect is only 0.3 percent when inflation runs low.[21] In sum, we find that a high inflation environment triggers weaker nominal rigidities but stronger real rigidities.

4.3.1 The 2021–2022 inflation surge

We established that when inflation runs high, firms respond to changes in their own marginal costs mostly by increasing the frequency of price adjustments, and by increasing both the frequency and the magnitude of the price changes when competitors raise their prices. An interesting question is what margin of price adjustments was the largest contributor to the 2021–2022 inflation surge.

Let us define CPI inflation as $\pi_t = \dot{\pi} + \tilde{\pi}_t$, where $\dot{\pi}$ denotes its time series average and $\tilde{\pi}_t$ denotes deviations of CPI inflation from its average. The deviations from the average can then be decomposed into contributions of changes in the frequency of price adjustment, changes in the size of price adjustment, and a residual term

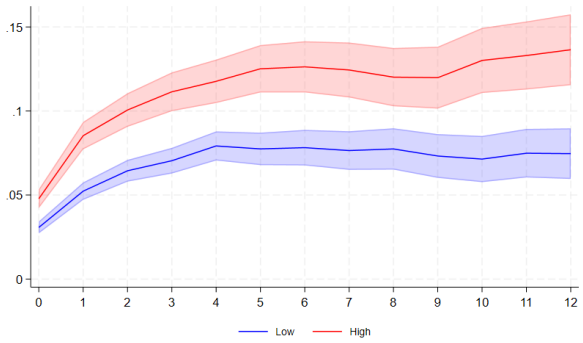
$$\tilde{\pi}_t = \underbrace{\left(\tilde{f}_t^{+}\,\dot{s}_t^{+} + \tilde{f}_t^{-}\,\dot{s}_t^{-}\right)}_{\text{Frequency}} + \underbrace{\left(\dot{f}^{+}\,\tilde{s}_t^{+} + \dot{f}^{-}\,\tilde{s}_t^{-}\right)}_{\text{Size}} + \underbrace{\left(\tilde{f}_t^{+}\,\tilde{s}_t^{+} + \tilde{f}_t^{-}\,\tilde{s}_t^{-}\right)}_{\text{Residual}} \tag{19}$$

Figure 10 plots the contribution of each margin to the deviation of aggregate inflation from its average. The results unambiguously point to the fact that the frequency of price adjustment was the largest contributor to the inflation surge that started in 2021 and the normalization that began in 2023.

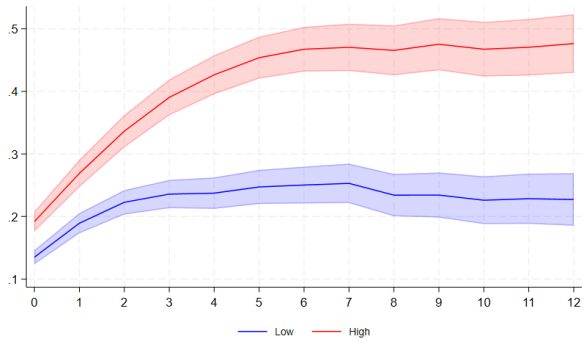
[21] Appendix Figure E.1 reports the results for retail firms. In this case, the results are more mixed, but similar to manufacturing firms we find that firms in the retail sector react to changes in their costs and competitors' prices by disproportionately changing the prices of a higher share of product varieties.

Figure 9: Firms' pricing during high vs low inflation
(Percent)

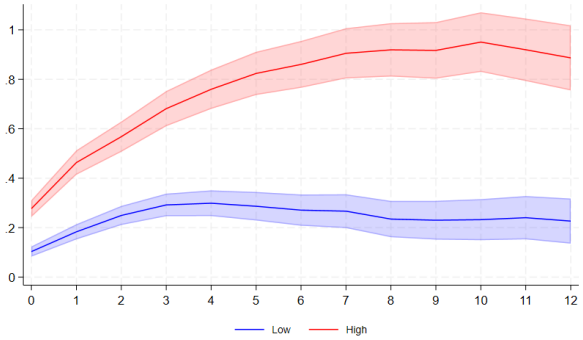
(a) Change in marginal costs



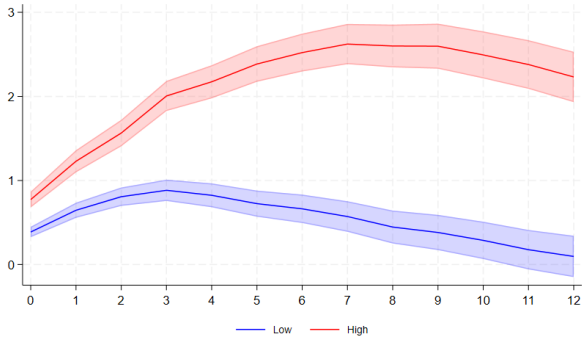
(b) Change in competitors' prices



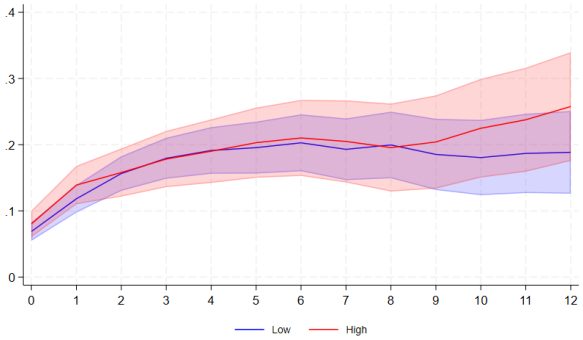
(c) Frequency, change in marginal costs



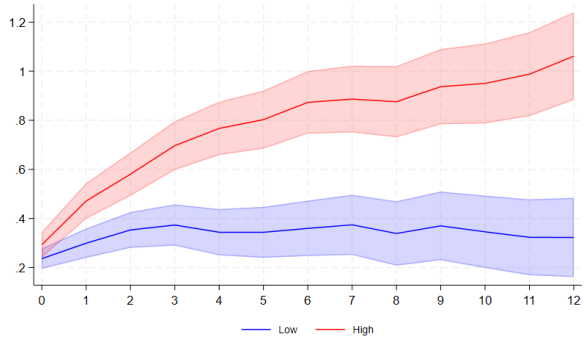
(d) Frequency, change in competitors' prices



(e) Size, change in marginal costs

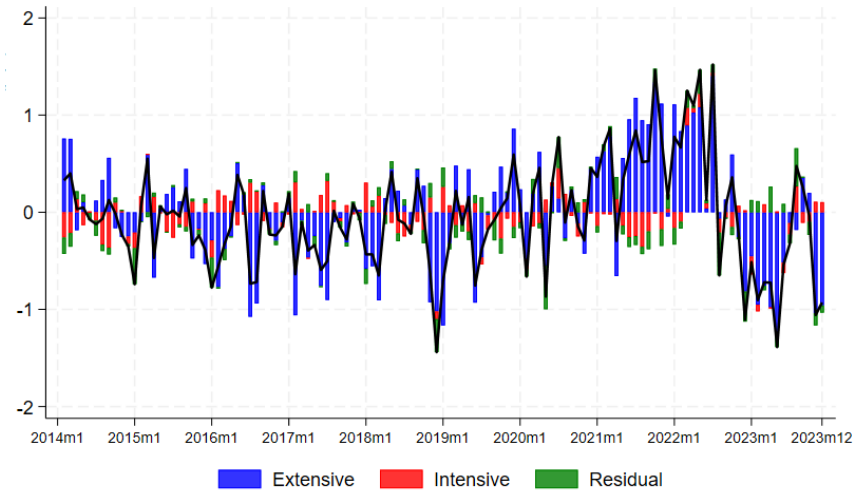


(f) Size, change in competitors' prices



Notes: The figure shows the percent change in firms' sales prices, the change in firms' frequency of sales price adjustments, and the percent change in firms' size of non-zero sales price adjustments in response to a one percentage point change in their marginal costs and a one percentage point change in competitors' prices, along with the 90 percent confidence interval. The figures compare the responses of manufacturing firms in a high inflation environment to those in a low inflation environment. The specification includes firm and time fixed effects. Standard errors are clustered at the firm and time level.

Figure 10: Contributions of margins of price adjustments to aggregate inflation
(Percentage points)



Notes: The figure shows the contributions of the extensive and intensive margins of price adjustments to firms' inflation deviations from the time average.

4.4 Fact 4: strategic complementarities as 'rockets and feathers'

The fourth fact is that firms' prices react more strongly when competitors raise prices (like rockets) than when they cut them (like feathers). Earlier work on cost pass-through has shown that firms are more sensitive to cost increases than cost decreases (Bacon, 1991; Peltzman, 2000). The underlying mechanism is that when costs rise, firms increase prices to maintain profit margins and avoid losses, generating a high pass-through of cost increases. However, when costs fall, firms that enjoy favorable demand have an incentive to keep prices constant to avoid buyers re-optimizing their purchase decisions. There is also a behavioral argument: buyers may not immediately realize that prices fell due to cognitive costs, reducing the incentive for firms to cut prices as they continue to enjoy higher-than-rationally optimal demand (Rebelo, Santana and Teles, 2024).

Yet, little is known about whether the incentives to engage in strategic pricing vary when competitors raise or cut prices. The theoretical effect is ambiguous. When a firm raises its prices, competitors may quickly follow suit to avoid being perceived as lower quality. And when a firm lowers its prices, competitors may be slower to match the decrease to avoid triggering a price war. Price wars can erode profit margins for all firms involved, so there is a strategic incentive to delay matching price cuts. On the other hand, firms may also react by cutting their prices quickly if they are concerned about losing market shares. The way firms form their expectations can also lead to asymmetric price adjustments: if firms anticipate that competitors will quickly match price increases

but slowly match price decreases, they will be more inclined to raise prices rapidly and lower them gradually (and vice versa). In some markets, firms might engage in explicit or tacit collusion, where they implicitly agree to maintain higher prices. This coordination can also lead to faster price increases and slower decreases, as firms collectively avoid aggressive price competition.[22]

To examine asymmetric pricing both in response to changes in competitors' prices (as well as changes in marginal costs), we estimate the following specification

$$\Delta p_{i,t} = \alpha_i + \tau_t + \sum_{r=0}^{R} \Delta mc_{i,t-r}(\beta^r + \delta^r I_{i,t-r}^{\Delta mc,+}) + \sum_{r=0}^{R} \Delta p_{-i,t-r}(\gamma^r + \xi^r I_{i,t-r}^{\Delta p_{-i},+}) + \varepsilon_{i,t} \tag{20}$$

where $I_{i,t-r}^{\Delta mc,+}$ and $I_{i,t-r}^{\Delta p_{-i},+}$ denote positive changes in marginal costs and competitors' prices, respectively.

In Figure 11 we present the results for manufacturing firms. Our results for the marginal cost pass-through confirm earlier findings in the literature: the pass-through is higher for cost increases and lower for cost decreases. This is particularly visible right after the cost change, when the gap is as large as 4 percentage points. However, the gap narrows over time and the difference is not statistically significant by the end of the year. In terms of the margins of price adjustment, we find that firms catch up with cost increases by adjusting sales prices more frequently compared to when marginal costs decline. One year after a 1 percentage point increase in marginal costs, the share of products changing prices is 7 percentage points higher compared to a statistically non-significant effect when marginal costs fall at the same rate.[23] This is consistent with the notion that firms delay price adjustments to avoid buyers paying cognitive costs and re-optimizing their decisions. We also find that firms initially adjust prices by a larger extent in response to cost increases than cost decreases, but this difference quickly fades away and the adjustment is roughly equal a quarter after the change in costs.

The evidence of asymmetric pricing points to a 'rockets and feathers' phenomenon also for competitors' prices, but dynamics are different. That is, the pass-through estimate is larger for competitors' price increases than decreases, and the gap is more persistent. On impact, the pass-through estimate is 9 percentage points higher for price hikes

[22] To the best of our knowledge, the only study looking at asymmetric responses to changes in competitors' prices is Koga, Yoshino and Sakata (2019), which is based on survey data of Japanese firms. They find, however, that firms' price adjustments are larger when competitors reduce prices and they ascribe that to quasi-kinked demand curves.

[23] Note that by construction the regression estimates depict the responses of the frequency of price adjustments to increases in marginal costs or competitors' prices. Hence, in the case of declines in marginal costs or competitors' prices, negative estimates should be interpreted as a positive change in the frequency.

than price cuts (19 percent against 10 percent). The gap then widens and by the end of the year firms have passed through 35 percent of the increases in competitors' prices and only 21 percent of their price cuts.

These dynamics reflect a larger increase in both the frequency and magnitude of price adjustments in response to competitors increasing their prices. A 10 percentage point hike in competitors' prices leads to a gradual increase in the share of products changing prices, which is 28 percentage points higher by the end of the year. When competitors cut prices, the frequency of price adjustment also increases, but to a smaller extent. By the end of the year, the frequency is 15 percentage points higher. The size of price changes in response to changes in competitors' prices is statistically the same for price increases and price cuts. Overall, we interpret the evidence on competitors' prices as indicative of upward real rigidities.[24]

4.5 Fact 5: market structure shapes firms' strategic pricing responses

The fifth fact is that firms exhibit stronger strategic complementarities when they face lower competition, they enjoy higher market shares, and have larger customer bases. In models of oligopolistic competition, firms operating in less competitive sectors exhibit stronger strategic complementarities compared to those in more competitive markets. For example, in the Atkeson and Burstein (2008) framework a larger number of competing firms implies a lower degree of strategic complementarities. As competition intensifies, firms' market shares shrink and demand elasticity increases, reducing the scope for strategic complementarities. Other studies focusing on firms' own costs, including Genesove and Mullin (1998), Campbell and Hopenhayn (2005), and Genakos and Pagliero (2022) lend support to this view, finding that markups are inversely related to the number of competitors, which in turn raises the pass-through of firms' own cost changes into prices.

We empirically test these predictions. To do that, we first construct a proxy for the degree of competition as the sales-weighted sum of the number of firms operating in the same markets of firm i

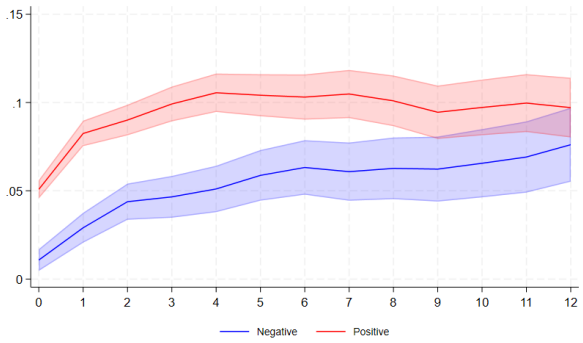
$$C_{i,t} = \sum_{r} \sum_{p} \omega_{f,r,p,t} \#F_{p(i),s(i),r,t} \tag{21}$$

where $\omega_{i,r,p,t}$ is the share of firm i's sales in product-municipality r,p, and $\#F_{p(i),s(i),r,t}$ denotes the number of firms selling product p within sector s and municipality r as firm i.

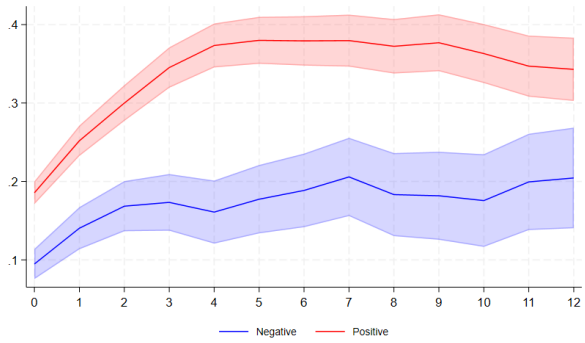
[24] We report the results for retail firms in Appendix Figure E.2. In this case, the results still point to considerably larger effects of increases in competitors' prices on the frequency of price adjustments compared to price decreases, but the effect on magnitudes and pass-through elasticities are more mixed.

Figure 11: Asymmetric pricing
(Percent)

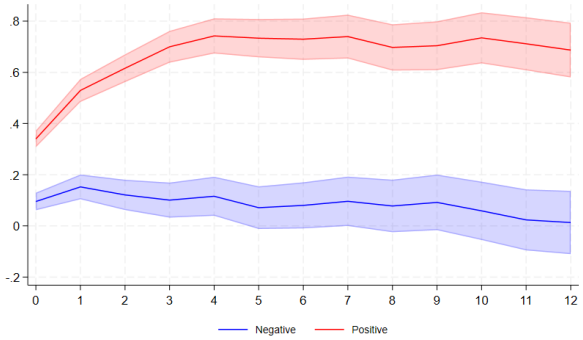
(a) Pass-through, change in marginal costs



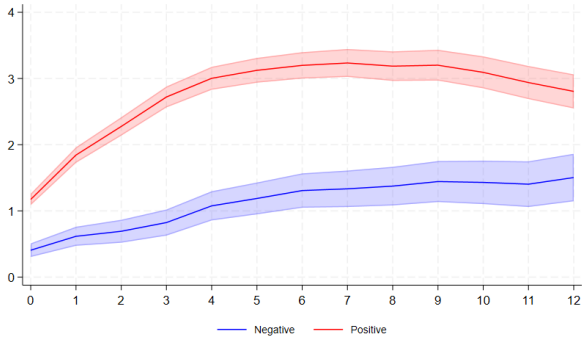
(b) Pass-through, change in competitors' prices



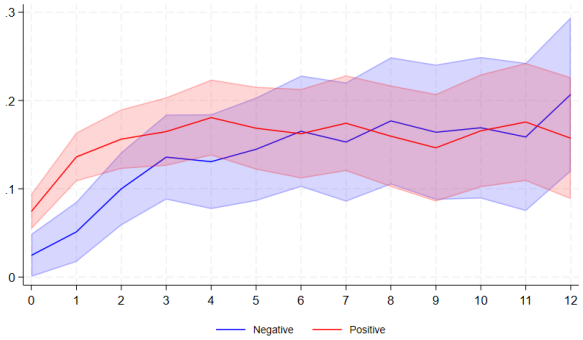
(c) Frequency, change in marginal costs



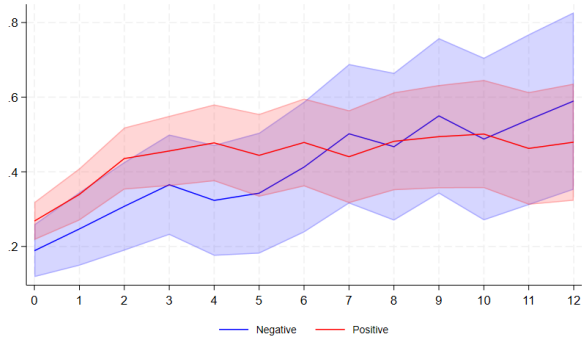
(d) Frequency, change in competitors' prices



(e) Size, change in marginal costs



(f) Size, change in competitors' prices



Notes: The figure shows the percent change in firms' sales prices, the change in firms' frequency of sales price adjustments, and the percent change in firms' size of non-zero sales price adjustments in response to a one percentage point change in their marginal costs and a one percentage point change in competitors' prices, along with the 90 percent confidence interval. The figures compare the responses of manufacturing firms to positive and negative changes in marginal costs and competitors' prices. The specification includes firm and time fixed effects. Standard errors are clustered at the firm and time level.

Then, we examine if firms respond differently to changes in their own costs and competitors' prices by estimating the following specification for manufacturing firms

$$\Delta p_{i,t} = \alpha_i + \tau_t + \sum_{r=0}^{R} \Delta mc_{i,t-r}(\beta^r + \beta^r_{z,mc} z_{i,t-r}) + \sum_{r=0}^{R} \Delta p_{-i,t-r}(\gamma^r + \beta^r_{z,p} z_{i,t-r}) + \sum_{r=0}^{R} \beta^r_z z_{i,t-r} + \varepsilon_{i,t}. \tag{22}$$

where $z_{i,t-r}$ is a dummy taking value one if $C_{i,t}$ is above the cross-sectional median at any given point in time, and zero otherwise.

Figure 12 shows the pass-through estimates of changes in input costs and competitors' prices when the numbers of competitors is high versus when it is low. Since in this case we are after differences in the long-run effect, we focus on the impact after one year. We find that firms facing lower competition (i.e., with a lower number of competitors) respond more aggressively to changes in their competitors' prices. A one percentage point increase in competitors' prices is associated with a 0.4 percentage point increase in prices for firms facing low competition one year after the shock, compared to a 0.3 percentage point increase for firms in more competitive markets. Consistent with this, firms in less competitive markets exhibit a lower pass-through of their own cost changes than firms operating in more competitive markets.

We further explore the role of competition by replacing variable $z_{i,t-r}$ in equation 22 with a dummy variable that takes value one when firm i's market share is above the cross-sectional median. As discussed above, we measure the firm's market shares at the sector-municipality-product level and then aggregate them according to the firm's weights in each market

$$\text{market share}_{i,t} = \sum_r \sum_p \omega_{i,r,p,t} \frac{\text{sales}_{i,p,r,t}}{\text{sales}_{r,p,t}} \tag{23}$$

where $\text{sales}_{r,p,t} = \sum_f^{\#F_{p(i),s(i),r,t}} \text{sales}_{f,r,p,t}$

Our results suggest that firms with higher market shares respond more strongly to changes in competitors' prices than those with lower market shares. This aligns with the intuition that strategic complementarities become larger as market shares increase, given that larger firms face greater sensitivity in markups to competitors' price changes (Atkeson and Burstein, 2008; Burstein and Gopinath, 2014). The magnitudes of these effects are similar to those observed when using the number of competing firms as a metric. The evidence is less conclusive when considering the pass-through of marginal costs, with no statistically significant differences one year after the shock.

Since a higher market share is associated with firms facing a larger residual demand, a

relationship between the number of buyers and the strength of strategic complementarities should arise. This is because firms with a large customer base would be more focused on maintaining the market share, leading them to pass through a smaller portion of the marginal cost increases to avoid losing customers. Conversely, when competitors raise prices, these firms can increase demand and market share by increasing their own prices to reach optimal markup levels. As before, we test if this is born out in the data by using a dummy that takes value one when the number of buyers is above the cross-sectional median, and zero otherwise.

We find that firms with larger customer bases react strongly to their competitors' prices and less to their marginal costs relative to firms with fewer buyers, although the differences related to marginal costs are not statistically significant. A one percentage point increase in competitors' prices is associated with a 0.4 percentage point increase in prices for firms with a large customer base, compared to a 0.2 percentage point increase for firms with a small one.[25]

To conclude, our findings indicate that the market structure shapes firms' pricing behavior, with strategic complementarities being stronger when the degree of competition in a given market is lower, market shares are higher, or the size of a firm's customer base is larger. These findings underscore the role of market structure in shaping the firms' pricing behavior.

5 Robustness

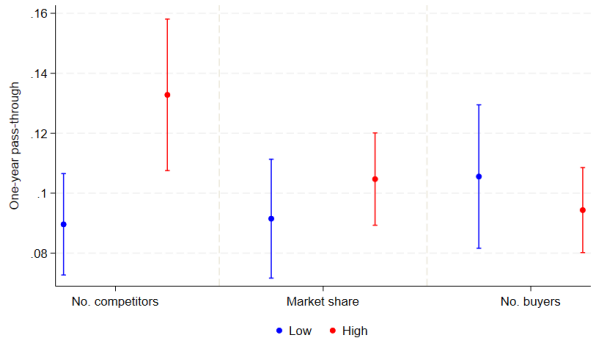
In this section, we summarize the results of a series of robustness tests. As we acknowledged in section 3, there are threats to our identification approach. One is that there may be factors common to the sector that cause firms' prices to change. For instance, prices may react to sectoral demand shocks or coordinated wage adjustments resulting from collective bargaining. We test the robustness of our baseline results by amending the specification in equation Equation 11 to include sector-time fixed effects, which soak up these time-varying sectoral factors. The responses in Figure 13 are remarkably similar to our baseline results.

Another issue is related to the possible reverse causality of marginal costs. That is, if firms face little competition from other buyers for the goods they produce, they may be able to set prices for those goods. Thus, we instrument marginal costs with a measure

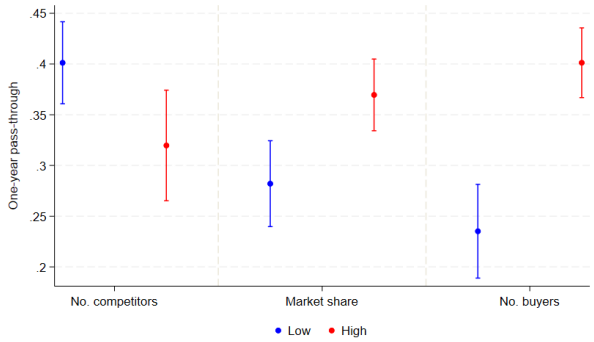
[25] We report the evidence for retailers in Appendix Figure E.3. We find that the results on strategic complementarities are consistent with the ones of the manufacturing sector. In contrast, there are no statistically significant differences in terms of cost pass-through between firms with high and low number of competitors and market shares, while there are in the regressions conditioning on the number of buyers.

Figure 12: The role of market structure
(Percent)

(a) Change in marginal costs



(b) Change in competitors' prices



Notes: The figure shows the percent change in firms' sales prices one year after a change in their marginal costs and competitors' prices, conditional on the firm's number of competitors, market share, and number of buyers, along with the 90 percent confidence interval. The specification includes firm and time fixed effects. Standard errors are clustered at the firm and time level.

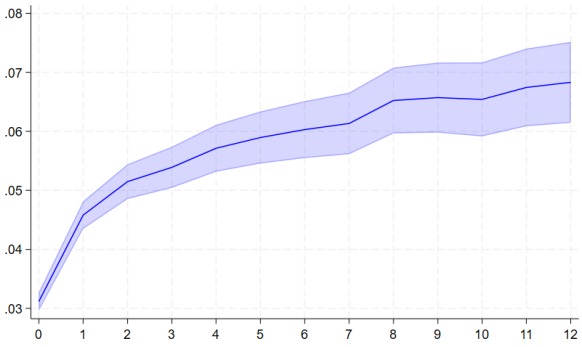
that excludes purchases of firms from suppliers that have only a few buyers, as described in equation (15). The first-stage Kleibergen-Paap Wald F-statistic is always above 900, confirming the relevance of the instrument. And the results from the IV estimations in Figure 14 are virtually identical to the baseline ones.

Competitors' prices can also be potentially endogenous because of the simultaneity in price setting between firms and their competitors. Thus, besides instrumenting changes in marginal costs, we also instrument changes in competitors' prices with the measure described in equation Equation 16. This is constructed using the changes in the costs of inputs of the competitors' suppliers of each firm, excluding the set of inputs that are purchased from suppliers selling to both the firm itself and its competitors. To be completed

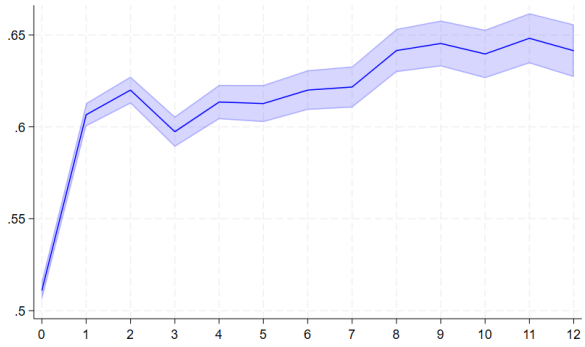
One limitation of our proxy of changes in marginal costs is that it abstracts from labor costs. This is because we do not have an accurate measure of *variable* labor costs, rather we observe *total* wages earned by workers during the months of the year they worked. We then construct a proxy for changes in variable labor costs by first computing workers' monthly average wages, then aggregating at the firm level, and finally computing changes in total labor costs. Since each worker's average wages only change at the end of the year or when she/he transitions to another firm or unemployment, at the firm level within-year monthly variation in labor costs reflects changes in employment, while end-year monthly variation can reflect both changes in employment and changes in wages of individual workers. Using this suboptimal variable, we perform some robustness tests.

Figure 13: Sector-time fixed effects
(Percent)

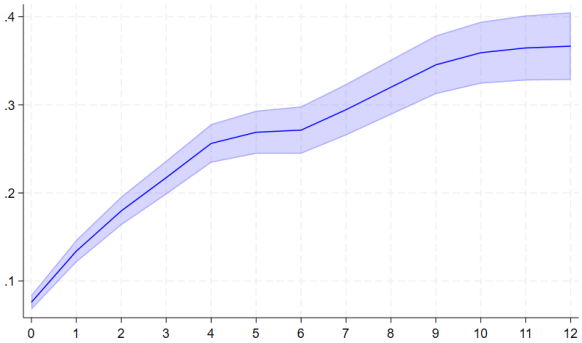
(a) Pass-through, change in marginal costs



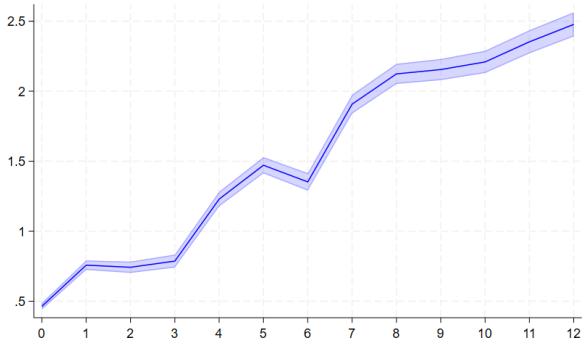
(b) Pass-through, change in competitors' prices



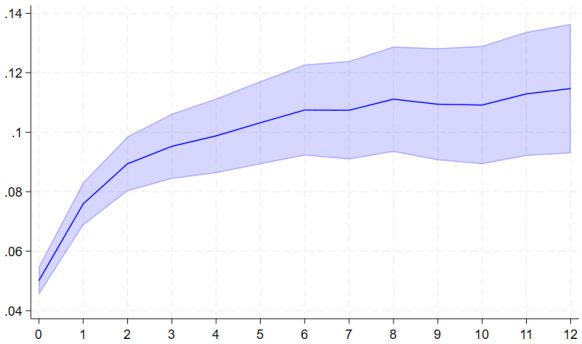
(c) Frequency, change in marginal costs



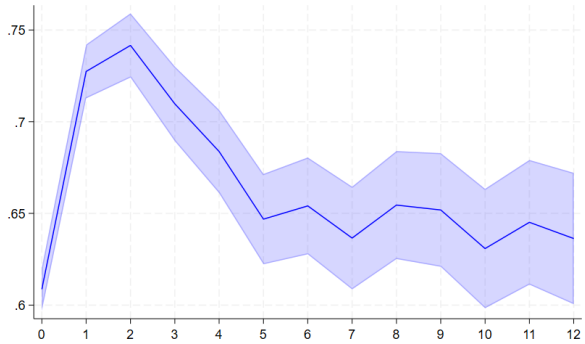
(d) Frequency, change in competitors' prices



(e) Size, change in marginal costs



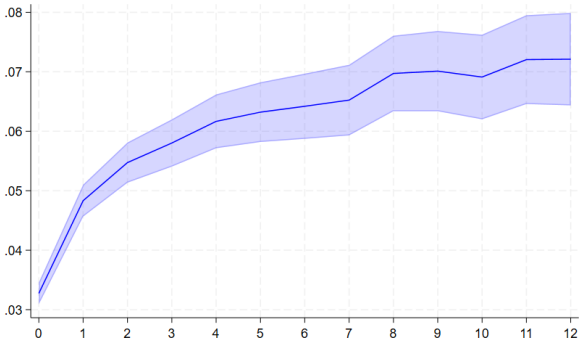
(f) Size, change in competitors' prices



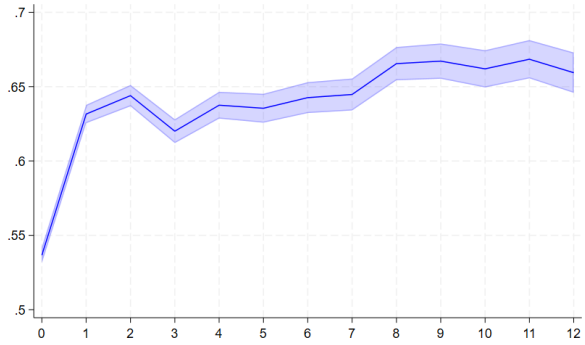
Notes: The figure shows the percent change in firms' sales prices, the change in firms' frequency of sales price adjustments, and the percent change in firms' size of non-zero sales price adjustments in response to a one percentage point change in their marginal costs and a one percentage point change in competitors' prices, along with the 90 percent confidence interval. The specification includes firm and sector-time fixed effects. Standard errors are clustered at the firm and time level.

Figure 14: IV regressions instrumenting marginal costs
(Percent)

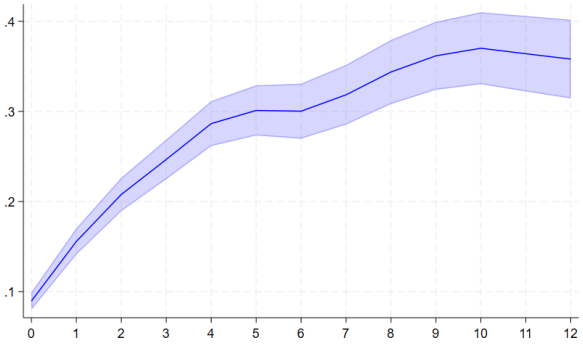
(a) Pass-through, change in marginal costs



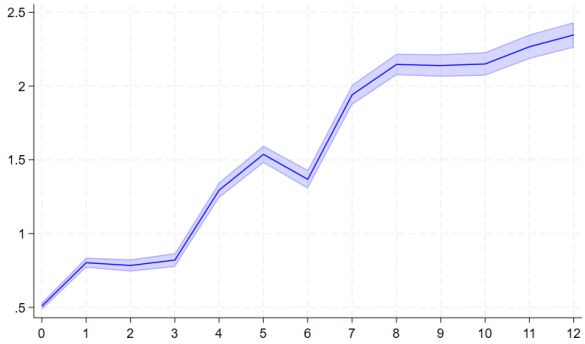
(b) Pass-through, change in competitors' prices



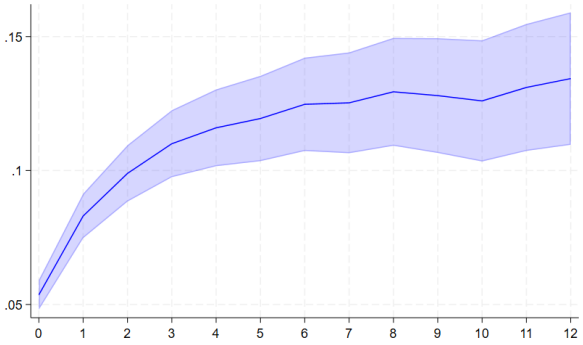
(c) Frequency, change in marginal costs



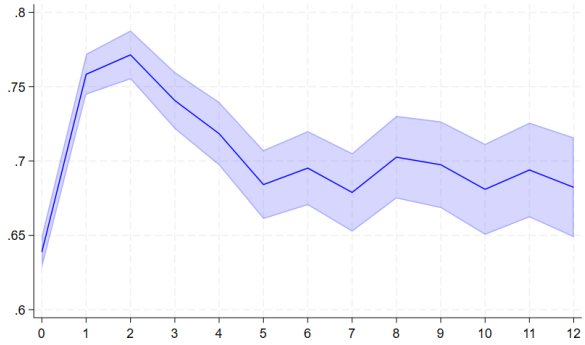
(d) Frequency, change in competitors' prices



(e) Size, change in marginal costs



(f) Size, change in competitors' prices



Notes: The figure shows the percent change in firms' sales prices, the change in firms' frequency of sales price adjustments, and the percent change in firms' size of non-zero sales price adjustments in response to a one percentage point change in their marginal costs and a one percentage point change in competitors' prices, along with the 90 percent confidence interval. The figure reports the results from IV regressions, in which changes in marginal costs are instrumented. The specification includes firm and time fixed effects. Standard errors are clustered at the firm and time level.

Figure 15: To be completed Robustness to instrumenting marginal costs and competitors' prices

(Percent)

Notes: The figure shows the percent change in firms' sales prices, the change in firms' frequency of sales price adjustments, and the percent change in firms' size of non-zero sales price adjustments in response to a one percentage point change in their marginal costs and a one percentage point change in competitors' prices, along with the 90 percent confidence interval. The figure reports the results from IV regressions, in which both changes in marginal costs and competitors' prices are instrumented. The specification includes firm and time fixed effects. Standard errors are clustered at the firm and time level.

We first estimate equation (11) replacing the changes in marginal costs with the changes in total labor costs. Second, we use the weighted average of the changes in intermediate inputs and total labor costs. The results in Figure 16 show that changes in total labor costs have no effect on sales prices. The estimates are close to and statistically indistinguishable from zero. One could conjecture that changes in labor costs may still lead to some effect on the two margins of price adjustments. However, this is not the case as the coefficients are again close to zero and not statistically significant. In light of these results, we unsurprisingly find comparable estimates to our baseline one when we use the weighted average of the changes in intermediate inputs and wages as a measure of marginal costs.

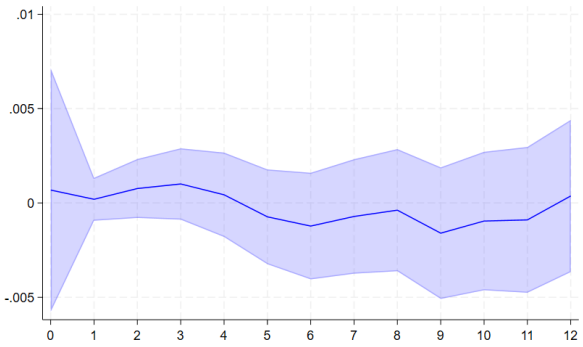
Another issue is that the longitudinal dimension of our data is limited to the period from January 2014 to December 2023. This constraints the length of the horizon over which we can study the elasticities of interest. In the distributed lag model, the trade-off is that a longer horizon requires more lags of the changes in marginal costs and competitors' prices, which would come at the cost of even shorter series for the changes in sales prices. In our baseline regression, we assumed that all the effects take place within 12 months. We then test if this is the case by re-estimating the baseline specification over a two-year horizon.

Figure 17 reports the results. The responses to changes in marginal costs confirm that most of the action ends 12 months after the shock. If anything, the size of price adjustments gets smaller during the second year, but the estimates are also less precise. In the case of changes in competitors' prices, we find that the pass-through elasticity after 24 months is 55 percent, about 10 percentage points below our baseline ones, but still considerably larger than the one of changes in marginal costs. This is explained by a continued reduction in the size of price adjustments during the second year after the shock, partially offset by a somewhat larger effect on the frequency of price adjustments.

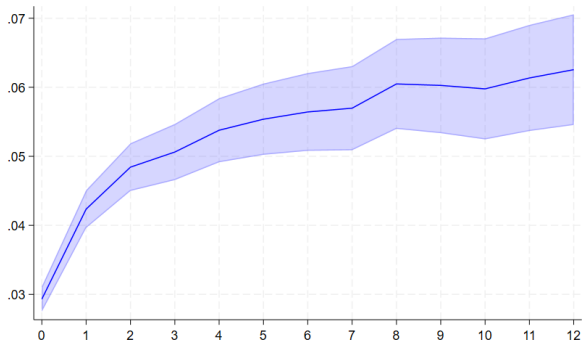
Our preferred estimation approach is the distributed lag model because it allows the

Figure 16: Measures of marginal costs accounting for labor costs
(Percent)

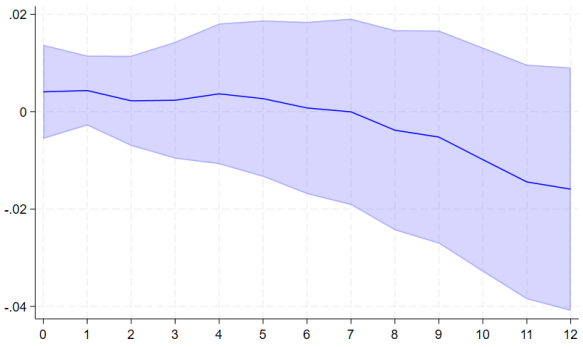
(a) Pass-through, changes in total labor costs



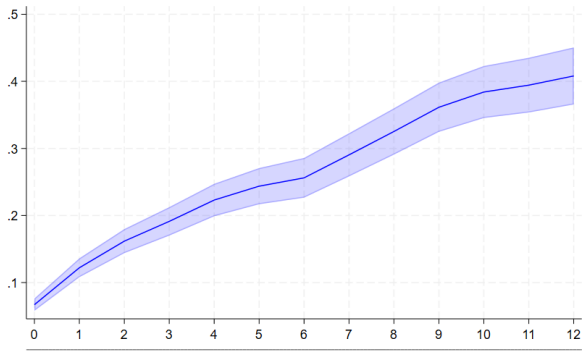
(b) Pass-through, changes in intermediate input costs and total labor costs



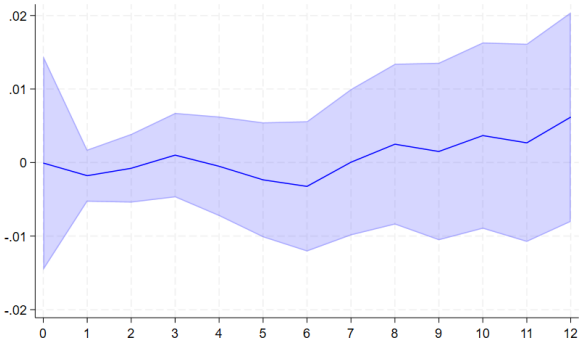
(c) Frequency, change in total labor costs



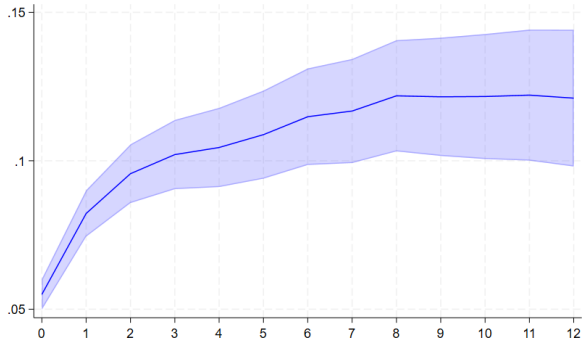
(d) Frequency, change in intermediate input costs and total labor costs



(e) Size, change in total labor costs



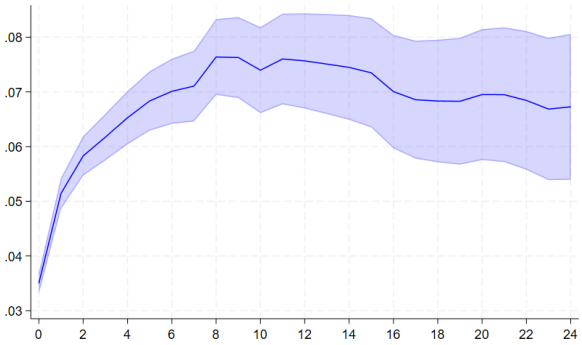
(f) Size, change in intermediate input costs and total labor costs



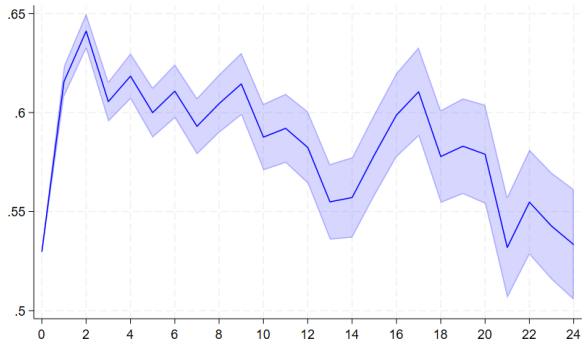
Notes: The figure shows the percent change in firms' sales prices, the change in firms' frequency of sales price adjustments, and the percent change in firms' size of non-zero sales price adjustments in response to a one percentage point change in their marginal costs and a one percentage point change in competitors' prices, along with the 90 percent confidence interval. Marginal costs are either defined as changes in total labor costs or as the weighted average of the changes in intermediate input costs and total labor costs. The specification includes firm and time fixed effects. Standard errors are clustered at the firm and time level.

Figure 17: Longer horizon
(Percent)

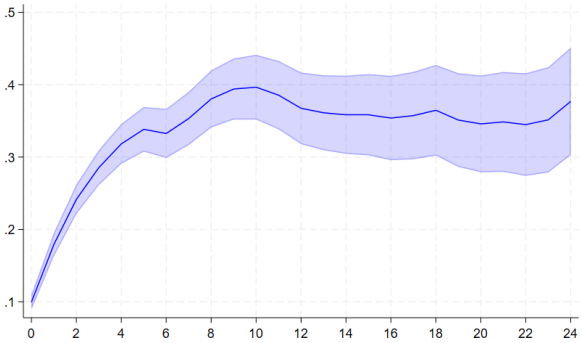
(a) Pass-through, change in marginal costs



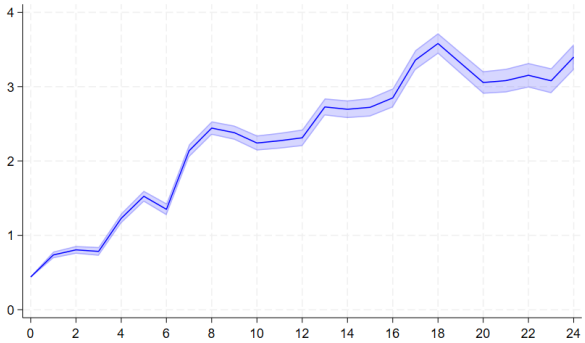
(b) Pass-through, change in competitors' prices



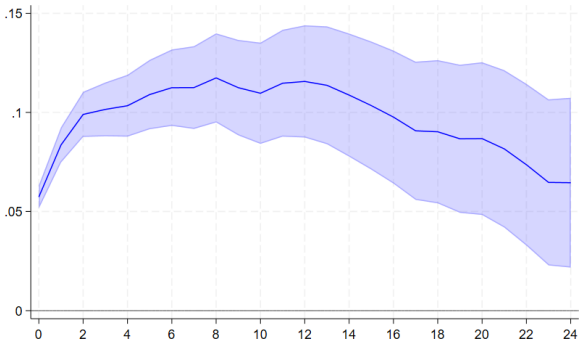
(c) Frequency, change in marginal costs



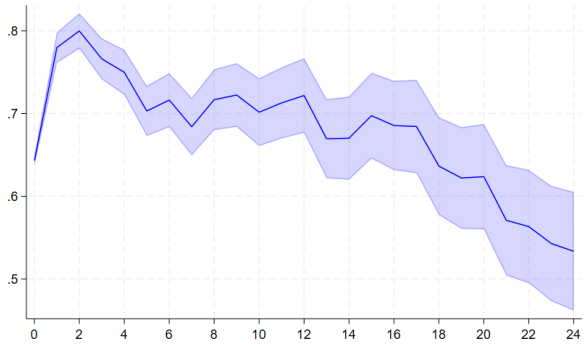
(d) Frequency, change in competitors' prices



(e) Size, change in marginal costs



(f) Size, change in competitors' prices



Notes: The figure shows the percent change in firms' sales prices, the change in firms' frequency of sales price adjustments, and the percent change in firms' size of non-zero sales price adjustments in response to a one percentage point change in their marginal costs and a one percentage point change in competitors' prices, along with the 90 percent confidence interval. The specification includes firm and time fixed effects. Standard errors are clustered at the firm and time level.

use of the entire time series. However, we test the robustness of the results by estimating the elasticities of interest using local projections, which lead to the loss of the first year of data due to the lags of the independent variables. In particular, we estimate horizon-specific elasticities as follows[26]

$$p_{i,t+h} - p_{i,t-1} = \alpha_i + \tau_t + \beta^h \left(mc_{i,t+h} - mc_{i,t-1} \right) + \gamma^h \Delta \left(p_{-i,t+h} - p_{-i,t-1} \right) + \varepsilon^h_{i,t} \tag{24}$$

where the changes in marginal costs and competitors' prices are cumulated over the same horizon at which the dependent variables are evaluated.

This approach takes into account the fact that changes in marginal costs and competitors' prices may be autocorrelated, such that the initial changes are followed by other changes during the next h periods. If that is the case, running conventional local projections may overestimate the elasticities over periods $h > 0$ as they would not take into account the changes in marginal costs and competitors' prices that took place after the initial ones. If these changes were instead mean-reverting, then conventional local projections would underestimate the elasticities of interest.

We report the results of horizon-specific local projections in Figure 18. The results are consistent with the baseline ones. However, the estimates are marginally smaller: the one-year ahead marginal cost pass-through is 5.5 percent compared to 6.9 percent, and the one-year ahead competitors' prices pass-through is 59 percent compared to 66 percent. The results on the margins of price adjustments are also in line with our baseline ones, with some differences in terms of point estimates. The surge in frequency of price adjustments in response to an increase in marginal costs is higher than in our baseline estimates (0.59 percent versus 0.35 percent), while the size effect is smaller (0.10 percent versus 0.12 percent). The frequency increase of price adjustments in response to a change in competitors' prices is also higher than in our baseline estimates (2.8 percent versus 2.4 percent), while the size effect is similar (0.7 percent).

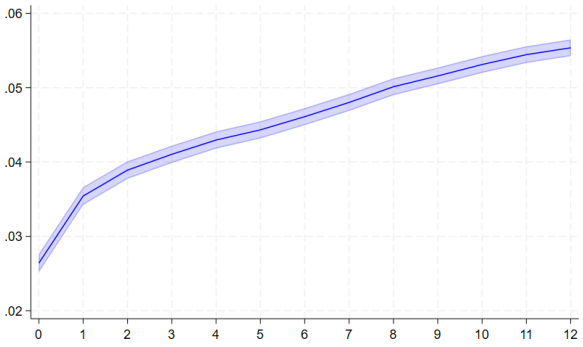
6 Conclusions

In this paper, we examine the role of strategic complementarities in firms' price setting. Using granular administrative data on Chilean firms, we make progress on measuring changes in marginal costs and competitors' prices, and document five key facts. First, we find that firms set their prices strategically and that the pass-through from competitors'

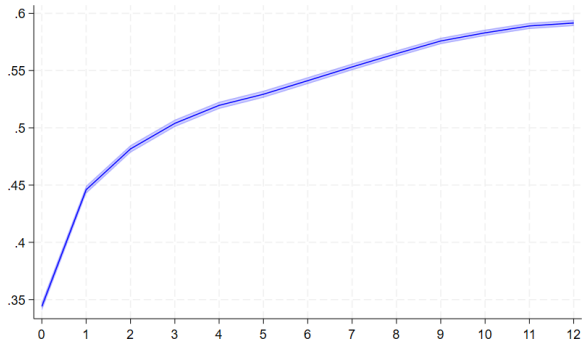
[26] Amiti, Itskhoki and Konings (2022) and Boehm, Levchenko and Pandalai-Nayar (2023) employ the same method to estimate exchange rate pass-through and trade elasticities, respectively.

Figure 18: Horizon-specific elasticities
(Percent)

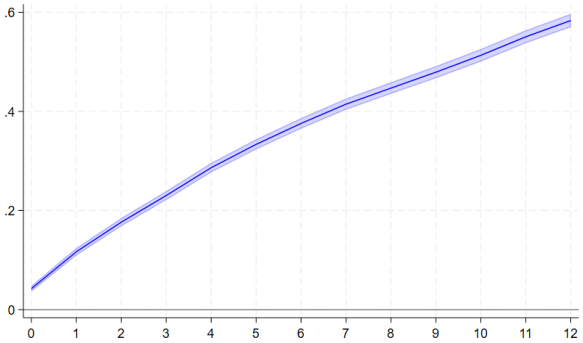
(a) Pass-through, change in marginal costs



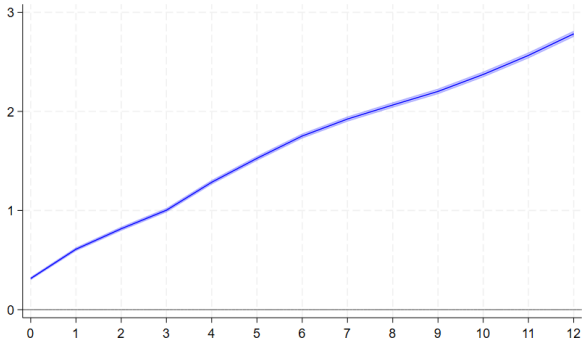
(b) Pass-through, change in competitors' prices



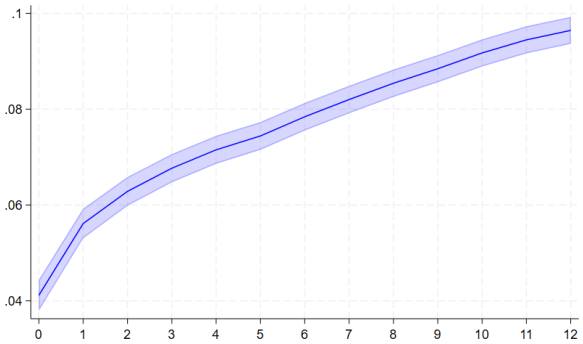
(c) Frequency, change in marginal costs



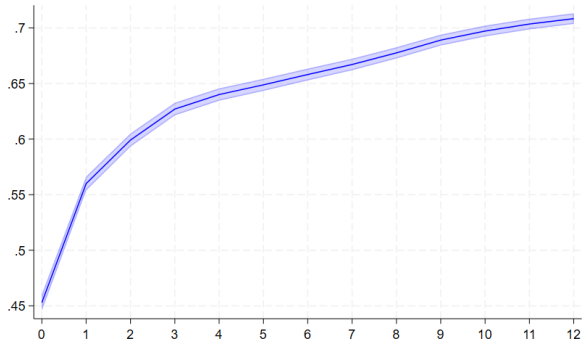
(d) Frequency, change in competitors' prices



(e) Size, change in marginal costs



(f) Size, change in competitors' prices



Notes: The figure shows the percent change in firms' sales prices, the change in firms' frequency of sales price adjustments, and the percent change in firms' size of non-zero sales price adjustments in response to a one percentage point change in their marginal costs and a one percentage point change in competitors' prices, along with the 90 percent confidence interval. The specification includes firm and time fixed effects. Standard errors are clustered at the firm and time level.

prices is abundantly larger than the cost pass-through. Our estimates indicate that firms pass through two-thirds of the changes in competitors' prices, which is about 9 times larger than the pass-through of changes in their own costs. The second fact is that the strength of strategic complementarities varies across sectors, but remains of first-order importance even in oligopolistic settings typical of the manufacturing sector. For manufacturing firms, we estimate the pass-through of changes in competitors' prices at 35 percent. This is considerably less than for retail firms, whose pass-through is about 70 percent. However, it is still 4 times larger than the cost pass-through, confirming that strategic complementarities are of first-order importance.

The willingness of firms to engage in strategic pricing, however, changes depending on a number of factors. As the third fact, we find that strategic complementarities are state dependent. Focusing on manufacturing firms, we find that when inflation runs high not only they become more wary of changes in their own costs, but they are also twice as likely to react to changes in competitors' prices, thereby weakening nominal rigidities and strengthening real ones. The fourth fact is that the pass-through is larger for competitors' price increases than decreases. That is, we also observe a 'rockets and feathers' phenomenon for strategic pricing, which is indicative of upward real rigidities. Finally, the fifth fact is that firms exhibit stronger strategic complementarities when they face lower competition, markets shares are higher, and when they have larger customer bases.

References

Acevedo, Pablo, Emiliano Luttini, Matías Pizarro, Dagoberto Quevedo, and Marco Rojas. 2025. "Invoices rather than surveys: Using ML to monitor the economy." mimeo.

Alvarez, Fernando, Martin Beraja, Martin Gonzalez-Rozada, and Pablo Andrés Neumeyer. 2019. "From hyperinflation to stable prices: Argentina's evidence on menu cost models." *Quarterly Journal of Economics*, 134(1): 451–505.

Amiti, Mary, Oleg Itskhoki, and Jozef Konings. 2019. "International shocks, variable markups, and domestic prices." *Review of Economic Studies*, 86(6): 2356–2402.

Amiti, Mary, Oleg Itskhoki, and Jozef Konings. 2022. "Dominant currencies: How firms choose currency invoicing and why it matters." *Quarterly Journal of Economics*, 137(3): 1435–1493.

Amiti, Mary, Sebastian Heise, Fatih Karahan, and Aysegul Sahin. 2022. "Pass-through of wages and import prices has increased in the post-COVID period." Federal Reserve Bank of New York Liberty Street Economics.

Atkeson, Andrew, and Ariel Burstein. 2008. "Pricing-to-market, trade costs, and international relative prices." *American Economic Review*, 98(5): 1998–2031.

Auer, Raphael A, and Raphael S Schoenle. 2016. "Market structure and exchange rate pass-through." *Journal of International Economics*, 98: 60–77.

Bacon, Robert W. 1991. "Rockets and feathers: The asymmetric speed of adjustment of UK retail gasoline prices to cost changes." *Energy Economics*, 13(3): 211–218.

Ball, Laurence, and David Romer. 1990. "Real rigidities and the non-neutrality of money." *Review of Economic Studies*, 57(2): 183–203.

Barros, Rebecca, Marco Bonomo, Carlos Carvalho, and Silvia Matos. 2009. "Price setting in a variable macroeconomic environment: Evidence from Brazilian CPI." unpublished paper.

Blanco, Andres, Corina Boar, Callum J Jones, and Virgiliu Midrigan. 2024. "Non-linear inflation dynamics in menu cost economies." NBER Working Paper No. 32094.

Boehm, Christoph E, Andrei A Levchenko, and Nitya Pandalai-Nayar. 2023. "The long and short (run) of trade elasticities." *American Economic Review*, 113(4): 861–905.

Burstein, Ariel, and Gita Gopinath. 2014. "International prices and exchange rates." In *Handbook of international economics*. Vol. 4, 391–451. Elsevier.

Campbell, Jeffrey R, and Benjamin Eden. 2014. "Rigid prices: Evidence from us scanner data." *International Economic Review*, 55(2): 423–442.

Campbell, Jeffrey R., and Hugo A. Hopenhayn. 2005. "Market size matters." *Journal of Industrial Economics*, 53(1): 1–25.

Cooper, Russell, and Andrew John. 1988. "Coordinating coordination failures in Keynesian models." *Quarterly Journal of Economics*, 103(3): 441–463.

Creamer, Kenneth, and Neil Rankin. 2008. "Price setting in South Africa 2001 to 2007 stylised facts using consumer price micro data." *Journal of Development Perspectives*, 4(1): 93–118.

Eichenbaum, Martin, Nir Jaimovich, and Sergio Rebelo. 2011. "Reference prices, costs, and nominal rigidities." *American Economic Review*, 101(1): 234–262.

Eichenbaum, Martin, Nir Jaimovich, Sergio Rebelo, and Josephine Smith. 2014. "How frequent are small price changes?" *American Economic Journal: Macroeconomics*, 6(2): 137–155.

Feenstra, Robert C, Joseph E Gagnon, and Michael M Knetter. 1996. "Market share and exchange rate pass-through in world automobile trade." *Journal of International Economics*, 40(1-2): 187–207.

Fontagné, Lionel, Philippe Martin, and Gianluca Orefice. 2018. "The international elasticity puzzle is worse than you think." *Journal of International Economics*, 115: 115–129.

Gagliardone, Luca, Mark Gertler, Simone Lenzu, and Joris Tielens. 2023. "Anatomy of the Phillips curve: Micro evidence and macro implications." NBER Working Paper No. 31382.

Gagnon, Etienne. 2009. "Price setting during low and high inflation: Evidence from Mexico." *Quarterly Journal of Economics*, 124(3): 1221–1263.

Ganapati, Sharat, Joseph S Shapiro, and Reed Walker. 2020. "Energy cost pass-through in US manufacturing: Estimates and implications for carbon taxes." *American Economic Journal: Applied Economics*, 12(2): 303–342.

Genakos, Christos, and Mario Pagliero. 2022. "Competition and pass-through: Evidence from isolated markets." *American Economic Journal: Applied Economics*, 14(4): 35–57.

Genesove, David, and Wallace P. Mullin. 1998. "Testing static oligopoly models: Conduct and cost in the sugar industry, 1890–1914." *The RAND Journal of Economics*, 29(2): 355–377.

Gentzkow, Matthew, Bryan Kelly, and Matt Taddy. 2019. "Text as data." *Journal of Economic Literature*, 57(3): 535–574.

Goldberg, Pinelopi, and Rebecca Hellerstein. 2007. "A Structural approach to identifying the sources of local currency price stability." Federal Reserve Bank of New York, Staff Report no. 287.

Goldberg, Pinelopi, and Rebecca Hellerstein. 2013. "A structural approach to identifying the sources of local currency price stability." *Review of Economic Studies*, 80(1): 175–210.

Golosov, Mikhail, and Robert E Lucas. 2007. "Menu costs and Phillips curves." *Journal of Political Economy*, 115(2): 171–199.

Gopinath, Gita, and Oleg Itskhoki. 2010. "Frequency of price adjustment and pass-through." *Quarterly Journal of Economics*, 125(2): 675–727.

Gopinath, Gita, and Oleg Itskhoki. 2011. "In search of real rigidities." *NBER Macroeconomics Annual*, 25(1): 261–310.

Gopinath, Gita, Oleg Itskhoki, and Roberto Rigobon. 2010. "Currency choice and exchange rate pass-through." *American Economic Review*, 100(1): 304–336.

Gouvea, Solange. 2007. "Price rigidity in Brazil: Evidence from CPI micro data." Banco Central do Brasil, Working Paper N. 143.

Joulin, Armand, Edouard Grave, Piotr Bojanowski, and Tomas Mikolov. 2016. "Bag of tricks for efficient text classification." *arXiv preprint arXiv:1607.01759*.

Julio, Juan Manuel, Héctor Manuel Zárate, and Manuel Dario Hernández. 2009. "The stickiness of Colombian consumer prices." Borradores de Economía, Banco de la Republica N. 578.

Karadi, Peter, and Adam Reiff. 2019. "Menu costs, aggregate fluctuations, and large shocks." *American Economic Journal: Macroeconomics*, 11(3): 111–146.

Karadi, Peter, Anton Nakov, Galo Nuno, Ernesto Pastén, and Dominik Thaler. 2024. "Strike while the iron is hot: Optimal monetary policy with a nonlinear Phillips curve." BIS Working Paper No. 1203.

Karrenbrock, Jeffrey D, et al. 1991. "The behavior of retail gasoline prices: symmetric or not?" Federal Reserve Bank of St. Louis Review Vol. 73(4): 19–29.

Klenow, Peter J, and Jonathan L Willis. 2016. "Real rigidities and nominal price changes." *Economica*, 83(331): 443–472.

Klenow, Peter J, and Oleksiy Kryvtsov. 2008. "State-dependent or time-dependent pricing: Does it matter for recent US inflation?" *Quarterly Journal of Economics*, 123(3): 863–904.

Koga, Maiko, Koichi Yoshino, and Tomoya Sakata. 2019. "Strategic complementarity and asymmetric price setting among firms." Bank of Japan Working Paper Series(19-E-5).

Lafrogne-Joussier, Raphaël, Julien Martin, and Isabelle Mejean. 2023. "Cost pass-through and the rise of inflation." Institut national de la statistique et des études économiques No. 94.

Medina, Juan, David Rappoport, and Claudio Soto. 2007. "Dynamics of price adjustments: Evidence from micro level data for Chile." Central Bank of Chile, Working Paper N. 432.

Nakamura, Emi, and Dawit Zerom. 2010. "Accounting for incomplete pass-through." *Review of Economic Studies*, 77(3): 1192–1230.

Nakamura, Emi, and Jón Steinsson. 2008. "Five facts about prices: A reevaluation of menu cost models." *Quarterly Journal of Economics*, 123(4): 1415–1464.

Nakamura, Emi, Jón Steinsson, Patrick Sun, and Daniel Villar. 2018. "The elusive costs of inflation: Price dispersion during the US great inflation." *Quarterly Journal of Economics*, 133(4): 1933–1980.

Neumark, David, and Steven A Sharpe. 1992. "Market structure and the nature of price rigidity: evidence from the market for consumer deposits." *Quarterly Journal of Economics*, 107(2): 657–680.

Peltzman, Sam. 2000. "Prices rise faster than they fall." *Journal of Political Economy*, 108(3): 466–502.

Pennings, Steven. 2017. "Pass-through of competitors' exchange rates to US import and producer prices." *Journal of International Economics*, 105: 41–56.

Rebelo, Sergio, Miguel Santana, and Pedro Teles. 2024. "Behavioral Sticky Prices." NBER Working Paper No. 32214.

Rossi-Hansberg, Esteban, Pierre-Daniel Sarte, and Nicholas Trachter. 2021. "Diverging trends in national and local concentration." *NBER Macroeconomics Annual*, 35(1): 115–150.

Wang, Olivier, and Iván Werning. 2022. "Dynamic oligopoly and price stickiness." *American Economic Review*, 112(8): 2815–2849.

Appendix

A Classification of product varieties into product categories

We follow the work of Acevedo et al. (2025) to classify the product varieties into product categories consistent with the CPC and (an adapted version of) the COICoP. In a nutshell, the algorithm is as follows

1. It builds a sample of text descriptors associated with each product category.
2. It then computes a score for each text descriptor within each economic sector of the seller based on the sales amount.
3. For each product category, it selects up to 2,000 text descriptors with the highest score and manually classifies them into product categories.
4. It cleans the text descriptors following Gentzkow, Kelly and Taddy (2019), as free text descriptors are unstructured and might contain uninformative parts.
5. It employs the FastText classification algorithm proposed in Joulin et al. (2016) to predict the product category using the text of the training sample.[27]
6. It finally uses the trained model on the untrained sample and obtains the mapping between product varieties and product categories.

B Regular prices

B.1 Algorithm to compute regular prices

For any product, we compute the regular prices r_t from observed prices p_t following the procedure of Nakamura and Steinsson (2008). This essentially filters out changes in observed prices due to sales and stockouts by assuming that the regular price of the product comes back to its level after sales and stockouts events. Specifically, the algorithm consists of the following steps

[27] The algorithm also uses information about the economic sector of the selling firm and the price range of the product to improve the fit of the model, which can help distinguish between product categories. For example, the sale of a computer and its repair/maintenance may be described very similarly. However, if the trained model knows the sector and price range associated with a text descriptor, it can better distinguish between them.

1. If $p_t = r_{t-1}$, then $r_t = r_{t-1}$
2. If $p_t > r_{t-1}$, then $r_t = p_t$
3. If $r_{t-1} \in \{p_{t+1}, \ldots, p_{t+J}\}$ and $p_t \leq r_{t-1}$ before returning to r_{t-1}, then $r_t = r_{t-1}$
4. If $\{p_t, p_{t+1}, \ldots, p_{t+L}\}$ has K or more different elements, then $r_t = p_t$
5. Define $p_{max} = \max\{p_{t+1}, \ldots, p_{t+L}\}$ and $t_{max} =$ first-time $\max\{p_{t+1}, \ldots, p_{t+L}\}$; if $p_{max} \in \{p_{t_{max}+1}, \ldots, p_{t_{max}+L}\}$, then $r_t = p_{max}$
6. $r_t = p_t$

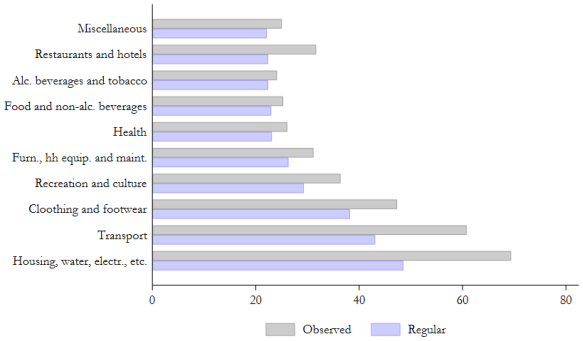
In our calculations, we parametrize the filter with $L = 3$, $K = 3$, and $J = 5$.

B.2 Frequency and size of price changes across CPI and PPI categories

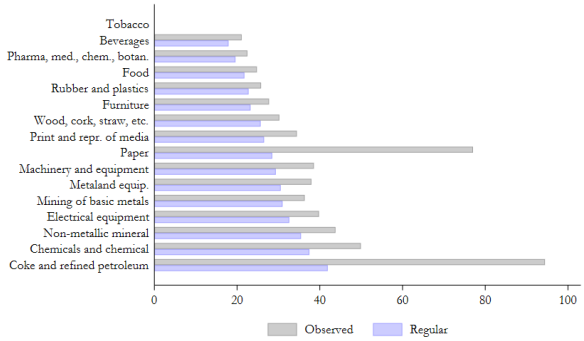
The top panels of Figure B.1 illustrate the median frequency of price changes by CPI and PPI categories. Across categories, regular prices adjusted 5 to 15 percentage points less frequently than observed prices. However, there is substantial heterogeneity across categories. In the case of the CPI, 'restaurants and hotels' (along with 'miscellaneous') display the lowest frequency at 22 percent for regular prices, while 'housing, water, electricity, etc.' prices show the highest at 48 percent. For PPI, the category with the lowest frequency is 'tobacco', for which the median frequency is zero as most of the tobacco products did not change prices over the sample period, while about half of the products in the category 'coke and refined petroleum' changed prices. The bottom panels report the median size of price changes for CPI and PPI categories. Across CPI categories, the largest regular price adjustments take place in 'food and non-alcoholic beverages' with a median size of 1.7 percent, while the smallest price changes (about 0.2 percent) are in the 'clothing and footwear' category. With respect to PPI, the largest price changes happened in the 'tobacco' category (about 4.5 percent), while the smallest took place in the 'non-metallic minerals' group.

Figure B.1: Frequency and size of price changes by product category (Percent)

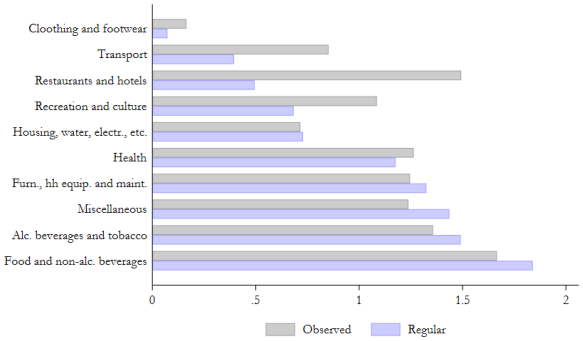
(a) Frequency, CPI products



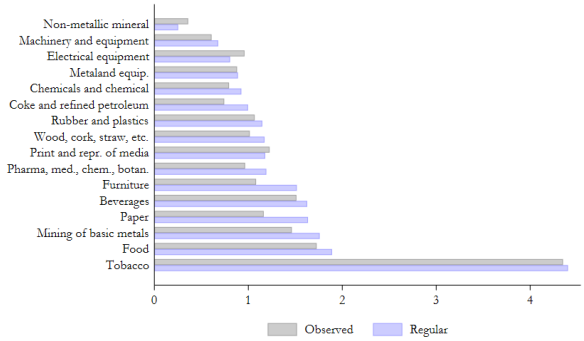
(b) Frequency, PPI products



(c) Size, CPI products



(d) Size, PPI products

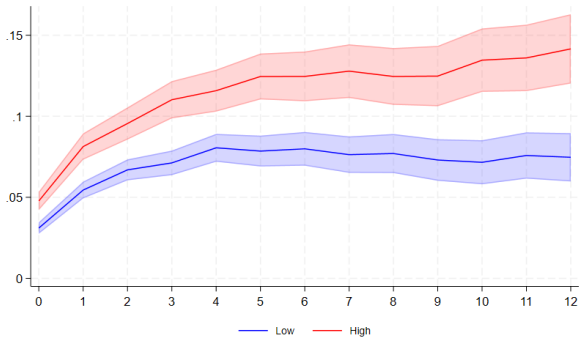


Notes: The figure shows the frequency and size of (median) price changes for CPI and PPI product categories. Regular prices (i.e., excluding sales) are obtained by applying the filter of Nakamura and Steinsson (2008) which removes removes asymmetric V-shaped sales, where a sale is followed by a change in the regular price, and uses a window for return of 5 months.

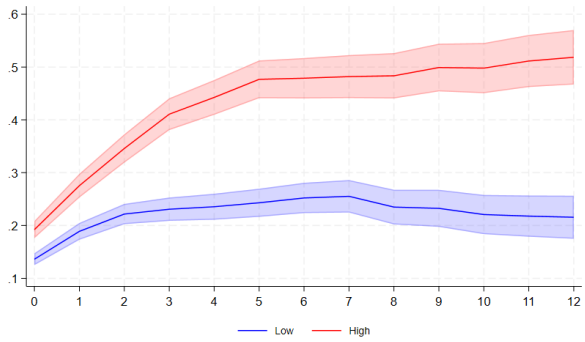
C Alternative measures of high and low inflation

Figure C.1: Pass-through estimates in high and low inflation periods
(Percent)

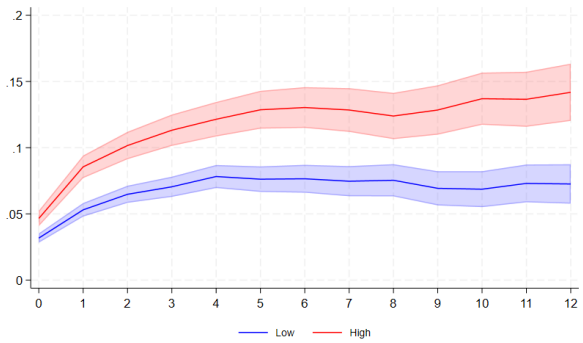
(a) Change in marginal costs, monthly inflation



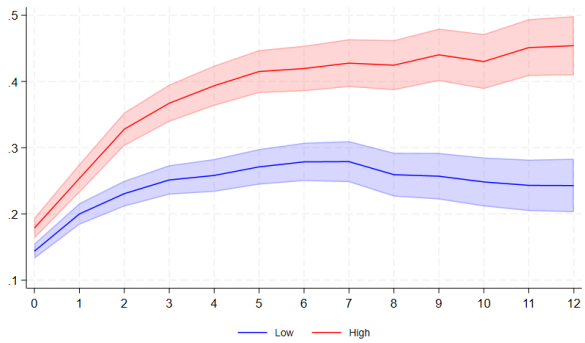
(b) Change in competitors' prices, monthly inflation



(c) Change in marginal costs, annual inflation



(d) Change in competitors' prices, annual inflation



Notes: The figure shows the percent change in firms' sales prices in response to a change in their marginal costs and competitors' prices differentiating between periods of low and high inflation, along with the 90 percent confidence interval. In panels (a) and (b), high inflation periods are identified using the mean and standard deviation of monthly inflation; while in panels (c) and (d) using the mean and standard deviation of annual inflation. The specifications include firm and time fixed effects. Standard errors are clustered at the firm and time level.

D Statistical differences

Table D.1: Differences in coefficients

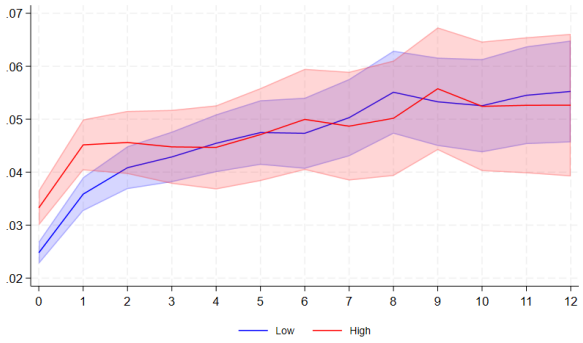
	Changes in marginal costs	Changes in competitors' prices
Manufacturing firms - retail firms		
Pass-through	0.077***	-0.335***
Frequency	0.473***	-1.155***
Size	0.155***	-0.038
High inflation - low inflation		
Pass-through	0.062***	0.249***
Frequency	0.660***	2.134***
Size	0.069	0.739***
Positive changes - negative changes		
Pass-through	0.021	0.138**
Frequency	0.674***	1.301***
Size	-0.050	-0.110
Many competitors - few competitors		
Pass-through	-0.043***	0.082**
Large mkt share - small mkt share		
Pass-through	-0.013	-0.088***
Many buyers - few buyers		
Pass-through	0.011	-0.166***

Notes: The table reports the one-year cumulated coefficients on the interaction terms with changes in marginal costs in column (1) and the interaction terms with changes in competitors' prices in column (2), for the regressions of pass-through, frequency of price adjustments, and size of price adjustments. All specifications include firm and time fixed effects. Standard errors are clustered at the firm and time level. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

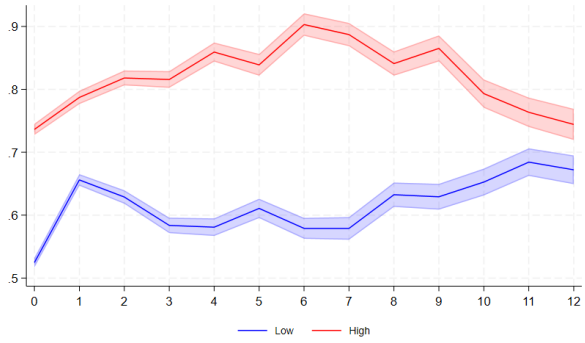
E Evidence on retail firms

Figure E.1: Retail firms' pricing during high vs low inflation
(Percent)

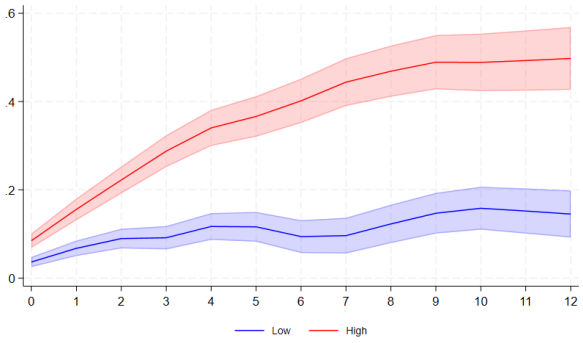
(a) Change in marginal costs



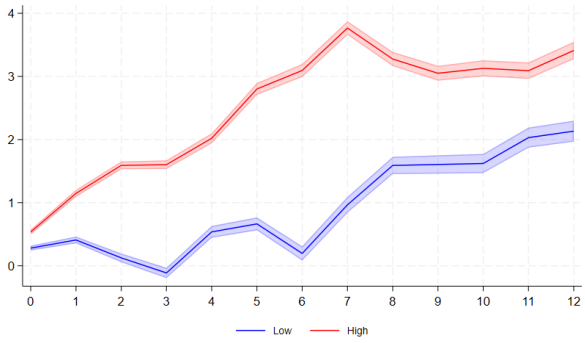
(b) Change in competitors' prices



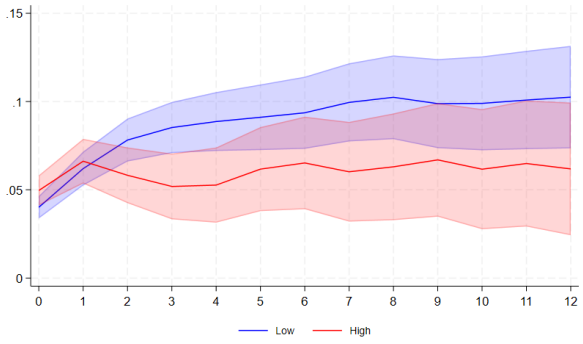
(c) Frequency, change in marginal costs



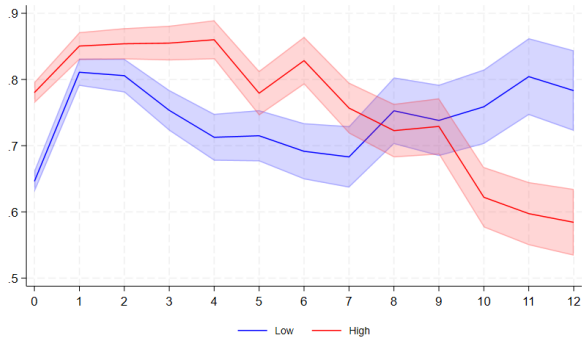
(d) Frequency, change in competitors' prices



(e) Size, change in marginal costs



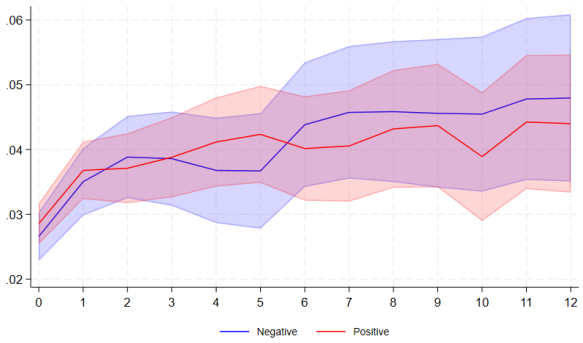
(f) Size, change in competitors' prices



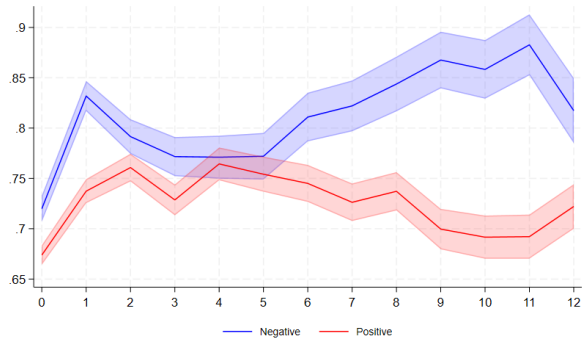
Notes: The figure shows the percent change in firms' sales prices, the change in firms' frequency of sales price adjustments, and the percent change in firms' size of non-zero sales price adjustments in response to a one percentage point change in their marginal costs and a one percentage point change in competitors' prices, along with the 90 percent confidence interval. The figures compare the responses of retail firms in a high inflation environment to those in a low inflation environment. The specification includes firm and time fixed effects. Standard errors are clustered at the firm and time level.

Figure E.2: Asymmetric pricing of retail firms
(Percent)

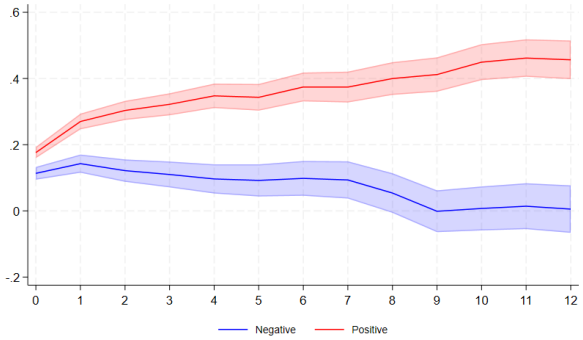
(a) Pass-through, change in marginal costs



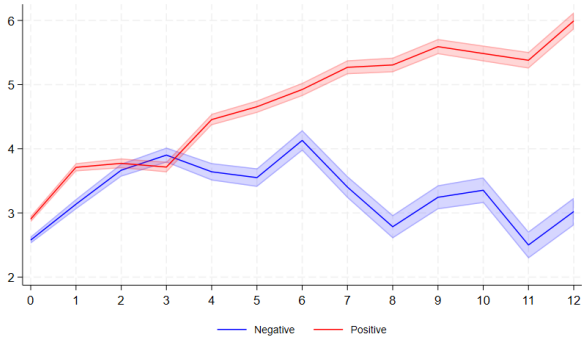
(b) Pass-through, change in competitors' prices



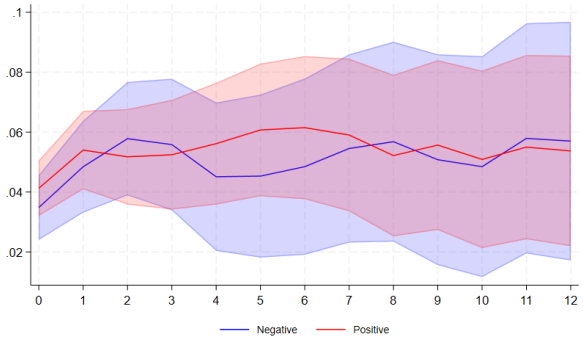
(c) Frequency, change in marginal costs



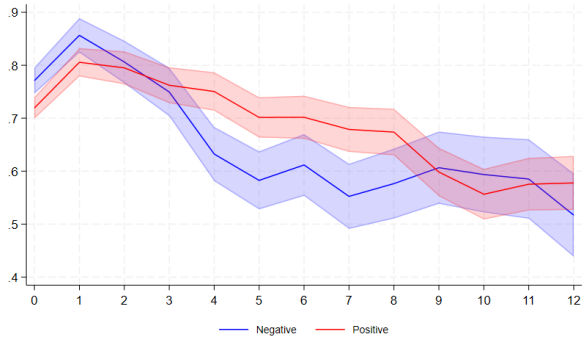
(d) Frequency, change in competitors' prices



(e) Size, change in marginal costs



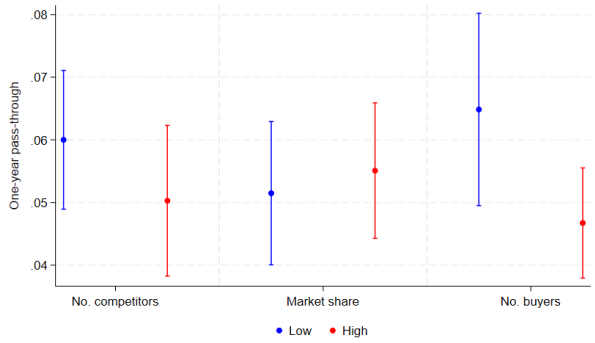
(f) Size, change in competitors' prices



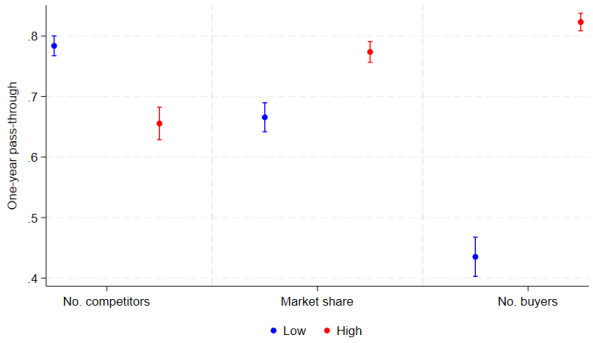
Notes: The figure shows the percent change in firms' sales prices, the change in firms' frequency of sales price adjustments, and the percent change in firms' size of non-zero sales price adjustments in response to a one percentage point change in their marginal costs and a one percentage point change in competitors' prices, along with the 90 percent confidence interval. The figures compare the responses of retail firms to positive and negative marginal cost and competitors' price changes. The specification includes firm and time fixed effects. Standard errors are clustered at the firm and time level.

Figure E.3: Market structure of retail firms
(Percent)

(a) Change in marginal costs



(b) Change in competitors' prices



Notes: The figure shows the percent change in retail firms' sales prices one year after a change in their marginal costs and competitors' prices, conditional on the firm's number of competitors, market share, and number of buyers, along with the 90 percent confidence interval. The specification includes firm and time fixed effects. Standard errors are clustered at the firm and time level.