Inflation Expectations and the Supply Chain*

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Abstract

We show that firms rely on price changes observed along their supply chain to form expectations about aggregate inflation, and that these expectations have a complete pass-through to sales prices. Leveraging a unique dataset on Chilean firms merging expectation surveys and records from the VAT and customs registries, we document that changes in prices at which firms purchase inputs inform their forecasts of the economy's inflation. This is the case even if changes in input costs do not determine the inflation outcome. These findings reject the full-information rational-expectations hypothesis and are consistent with firms' disagreement about future inflation and inattention to macroeconomic news, which we document for Chile. Our results from a firm-level Phillips' curve estimation suggest that firms' beliefs about inflation are a key determinant for their price-setting decisions. Therefore, we argue that the channel we highlight in this paper has the potential to lead to dispersion in inflation expectations, price dispersion, and weaken the expectation channel of policies.

Keywords: Forecast disagreement, inflation expectations, information frictions, Phillips curve, rational inattention, supply chain

JEL Codes: E30, E31

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1 Introduction

How firms form beliefs about future inflation is crucial to many aspects of policymaking. *In primis* it is relevant to monetary policy, as it targets aggregates—prices and employment—that depend on firms' expectations and decisions. Yet, information frictions can hamper firms' ability to collect and process the data to forecast inflation and our understanding of what factors firms rely upon to form their beliefs remains limited. This is, at least in part, because "Information on the price expectations of businesses who are, after all, the price setters (...) is particularly scarce" (Bernanke, 2007). Moreover, the scant evidence from surveys of firms reveals substantially different facts compared to surveys of professional forecasters and households, which makes these poor substitutes for surveys of firms.[1]

In this paper, we explore whether firms use price changes observed along the supply chain to form their views about future inflation, and if these beliefs are reflected in their price-setting decisions. To do that, we leverage a unique dataset merging confidential information from the expectation surveys of Chilean firms with administrative records of prices and quantities purchased from the VAT and customs registries. Our main result—which is new in the literature—is that firms use changes in input prices observed in the transactions with their suppliers (i.e., supply chain inflation) to form expectations about aggregate (i.e., CPI) inflation, even if they are contemporaneously unrelated. We estimate that a 1 standard deviation increase in supply chain inflation that is orthogonal to movements in CPI inflation leads firms to revise upward their inflation expectations by 0.1 percentage points.

Our findings provide empirical support for macroeconomic models incorporating nominal frictions á la Lucas (1972). In Lucas' "island model", firms do not observe all prices in the economy. Instead, they operate as if they were located on different islands and learn from a subset of islands they trade with. Consistent with this, we find that firms extrapolate an *aggregate* value for future inflation from a *local* signal obtained from their purchasing prices orthogonal to current inflation. We conclude that our results reject the full-information rational-expectations hypothesis, and are supportive of the imperfect information benchmark.

These results are consistent with a series of well-known empirical facts such as firms' disagreement about future inflation and inattention to macroeconomic news (Coibion, Gorodnichenko and Kumar, 2018; Candia, Coibion and Gorodnichenko, 2022). We show

[1] Using surveys of different countries, Candia, Coibion and Gorodnichenko (2022) document that mean inflation forecasts of firms deviate significantly from that of professional forecasters and households and present a more pervasive disagreement, among other things.

that supply-chain inflation displays significant dispersion across firms in Chile, which is unsurprising as firms buy different goods and services from different partners. For example, a shortage of a given input that a firm uses to produce its products and services is a bottleneck in the supply chain of that firm, but it does not necessarily affect the rest of the economy nor firms in the same sector that source inputs from other suppliers. However, dispersion in supply chain inflation is consequential because—when firms form their beliefs according to these heterogeneous prices set by their suppliers—it gets reflected in inflation forecast disagreement. Also, we show that supply chain inflation is more volatile than CPI inflation. This, together with the costs associated to process macroeconomic news, can lead to inattention to economy-wide developments as firms would focus their attention on shocks which are more immediately relevant to their businesses and to which they are naturally exposed. Finally, we find that the relationship between input price inflation and CPI inflation expectations does not depend on the frequency of input purchases nor the size of their price changes, providing evidence against perceptual learning of firms and support for the rational inattention framework.

After establishing that the prices at which firms purchase inputs from their suppliers inform their inflation forecasts, we test if they set their prices according to these beliefs. Departing from the vast literature estimating the Phillips curve with aggregate or regional data, we estimate it at the firm level.[2] Relying on direct measures for firms' sales price inflation, inflation expectations, and marginal costs, we find that firms' inflation expectations are a critical factor shaping their pricing decisions. In particular, we document a complete pass-through of changes in inflation expectations to firms' sales prices. Under different specifications, including allowing for sluggish firms' price dynamics, we show that firms' price increases depend on expected future price increases with a coefficient which is not statistically different from one, pointing to a price-setting behavior as predicted by forward-looking New Keynesian models.

Combining the results suggesting that inflation expectations are a function of supply chain inflation with the ones pointing to a full pass-through of inflation expectations to firms' sales prices offers a number of policy insights. If firms form their inflation beliefs according to price changes observed along the supply chain and these are heterogeneous across firms, the channel we highlight in this paper can lead to dispersion in inflation expectations, which is one metric of inflation expectations' anchoring.[3] This is particularly

[2] Coibion, Gorodnichenko and Ulate (2019) use expectations of firms and households to estimate a Phillips curve, but their setting is still at the country level.

[3] The literature defines inflation expectation anchoring in a number of ways. These include the deviation of long-term mean inflation forecasts from target, the variability of mean inflation forecast, the sensitivity of long-term inflation forecasts to inflation surprises, as well as the dispersion of inflation forecasts (Capistrán

relevant in the post-COVID-19 recovery, in which the mix of a gradual—and at times reversed—re-opening and strong demand generated bottlenecks in the supply chains. Also, as firms act on the basis of their beliefs by setting prices for their goods and services accordingly, forecast disagreement can translate into welfare-costly price dispersion. Finally, our results imply a weaker effectiveness of the expectation channel of policies. Improvements in central bank communication aimed at reducing firms' inattention have the potential to dampen the effects of the information frictions highlighted in this paper. In this regard, experimental studies examining the effects of the type, amount, and the way in which information is communicated can be informative.[4]

This paper contributes to the literature documenting information frictions in the inflation expectation formation mechanism. The closest paper to ours is Andrade et al. (2022), which shows that French firms learn from inflation observed in their industry. Compared to this paper, we shift the focus from industry inflation to supply chain inflation, which better aligns with Lucas (1972)'s framework for which firms observe prices at which they settle transactions with their suppliers rather than industry inflation. It also squares with the fact that firms may operate at the intersection of different industries, a reason for which industry inflation may turn out to be an imprecise proxy of the price changes that matter for these firms. By relying on firm-level indices of changes in input prices, we are also able to improve on the identification and estimate causal effects of supply chain inflation on CPI inflation expectations.

The literature on learning from observed prices is heavily concentrated on studies at the individual level. For example, Kumar et al. (2015) provides some evidence that in New Zealand firm managers form expectations about aggregate inflation based on the prices observed when they go on personal shopping. Cavallo, Cruces and Perez-Truglia (2017) and D'Acunto et al. (2021) find that shopping prices lead to changes in consumers' inflation expectations in the United States and Argentina. Also, Coibion and Gorodnichenko (2015*b*) show that gasoline prices have an impact for inflation expectations of households in the United States. Kuchler and Zafar (2019) document that individuals extrapolate from counties' house-price changes to expectations about the real estate sector in the United States economy. Compared to this literature, our results have a more direct relationship with monetary policy as, in the end, firms are the actual price setters in the economy.

and Ramos-Francia, 2010; Dovern, Fritsche and Slacalek, 2012; Demertzis, Marcellino and Viegi, 2012).

[4]See, for example, Coibion, Gorodnichenko and Weber (2022) who study how communicating different messages to individuals can affect their inflation expectations (as well as their spending decisions). Relatedly, Salle (2022) stresses the importance of experimental studies on firms to mitigate the distortions due to information rigidity.

In addition, while most survey-based studies use data on advanced economies, we focus on Chile, an emerging market that experienced significant swings in inflation over the sample period. As argued by Cavallo, Cruces and Perez-Truglia (2017), Candia, Coibion and Gorodnichenko (2021), Candia, Coibion and Gorodnichenko (2022), and Fuster and Zafar (2022), advanced economies have a history of low and stable inflation, which makes economic agents inattentive to inflation and other macroeconomic events (Kumar et al., 2015). Emerging markets, on the other hand, traditionally recorded higher and more volatile inflation and have the potential to enrich our understanding the inflation expectation formation mechanism.

The paper is also related to other strands of literature. In showing that firms respond to a local signal that is unrelated to the aggregate value they are forecasting, it contributes to the literature documenting violations of the full-information rational-expectations hypothesis (Coibion and Gorodnichenko, 2012, 2015*a*; Bordalo et al., 2020; Born et al., 2021). Also, it directly relates to the literature on rational inattention, which shows that firms devote resources to process volatile information that is more relevant for them (Mackowiak and Wiederholt, 2009; Pasten and Schoenle, 2016).

The rest of the paper is organized as follows. Section 2 describes the data used in the analysis and how we construct measures of supply chain inflation. Section 3 presents some key stylized facts about firms' inflation expectations and discusses their relationship with supply chain inflation. Section 4 presents the empirical results about the impact of supply chain inflation on firms' inflation expectations. Section 5 shows the results of the firm-level Phillips curve estimations. Section 6 concludes.

2 Data

Our empirical setting is Chile during January 2015—September 2021. Consumer prices experienced significant swings during this period. Amid the end of the commodity supercycle and weak aggregate demand, inflation fell from an average of 4.3 percent in 2015 to less than 2 percent in 2017. As economic activity bounced back, inflation converged towards the central bank target of 3 percent in late 2018 and hovered within the target band of 2–4 percent up to the onset of the COVID-19 pandemic. A mix of lockdown policies aimed at containing the spread of the virus and expansionary fiscal measures resulted in supply bottlenecks, which led inflation to spike in the last months of 2020 and in early 2021 to over 5 percent. This variation in the inflation rate provides an ideal setting to study the expectation formation mechanism of firms.

For the purpose of the analysis we combine confidential datasets from different sources.

The first dataset draws from the expectation survey (*Índice Mensual de Confianza Empresarial*) run by the Central Bank of Chile. The survey is sent to an average of about 600 firms each month, of which about two thirds submit their answers. It targets all large firms and randomly selected smaller ones, which on average account for 35.5 percent of total sales during the sample period. The expectation survey asks a total of 18 questions to firms operating in four broad sectors: manufacturing, retail, construction, and mining. The question we focus on in this paper elicits firms' expectations about CPI inflation expectations by asking: "What do you think inflation will be in the next 12 months (measured by the Consumer Price Index CPI)?". This question targets only firms in the manufacturing and retail sectors, which represent 35 percent and 23 percent of each sector's sales respectively.

The second dataset consists of the administrative records from the VAT registry maintained by the Internal Revenue Service.[5] From this, we extract all the invoices in which firms answering the expectation survey are either purchasing or selling, and we retrieve information about what goods and services are sold, in what quantities, and at what prices. It should be noted that one product may have different varieties and that we actually obtain the information at the variety level (rather than the product level), making our dataset even more granular.[6] In what follows, we use the term product when we refer to a variety. We convert sales in Chilean Pesos into real values called *Unidad de Fomento*, a CPI inflation-indexed unit of account calculated and published by the Central Bank of Chile.[7]

The third dataset includes information on firms' imports (cost, insurance, and freight) and exports (free on board) at the transaction level from the National Customs Service. Each transaction record reports an identifier for the product being imported or exported, the amount transacted, as well as the quantities.[8]

The fourth dataset consists of firm-level information collected from the income tax form that firms submit to the Internal Revenue Service.[9] Specifically, we obtain monthly data on sales revenue and expenditures related to the purchase of materials. In addition,

[5]Chile was a pioneer in introducing electronic invoicing, leading the way for other countries in Latin America as Brazil and Mexico. The use of electronic invoices started in 2003, but it was made mandatory for all firms in 2014.

[6]In the classification used by the Chilean authorities, there are over 16 million varieties purchased and sold by the firms that answer the expectation survey during the sample period.

[7]See https://si3.bcentral.cl/estadisticas/Principal1/metodologias/EC/IND_DIA/ficha_tecnica_UF_EN.pdf.

[8]The product classification follows the Harmonized System Codes, which is different from the classification used for domestic transactions.

[9]The income tax form we work with is form F29 (*Declaración Mensual y Pago Simultáneo de Impuestos*).

we retrieve the wage bill from the administrative records of the Social Security Treasury.[10]

2.1 Supply chain inflation

To measure supply chain inflation, we construct a firm-level index of input price inflation as follows. Let p_{ijt} and q_{ijt} be the prices and quantities for each product j purchased by firm i during period t, where i is a firm answering the expectation survey. We reduce the probability of erroneous records by dropping observations for which (a) the identifier of the buyer and the seller is the same; (b) the price is less than 10 Chilean pesos, $p_{ijt} \leq 10$; and (c) the purchased quantity is zero or negative, $q_{ijt} \leq 0$. For each product purchased by each firm, we then compute the year-on-year log difference of the median price observed in each month, π^{50}_{ijt}. To aggregate this at the firm level, we compute the average of product inflation weighted by the transaction amount, $\pi_{it} = \sum_j \frac{p_{ijt}q_{ijt}}{p_{it}q_{it}} \pi^{50}_{ijt}$. We finally limit extreme volatility in the indicator by trimming observations that lie outside of the $[-30, 100]$ percent change band.[11] To summarize, our indicator of supply chain inflation consists of the percent change in input costs that firms observe when they purchase from their suppliers.

Similarly, we construct a firm-level index of sales price inflation following the same methodology. This corresponds to the percent change in sales prices that firms charge to their customers. While input price inflation is by construction based only on 'business-to-business' transactions, sales price inflation uses both 'business-to-business' and 'business-to-consumer' transactions.

Figure 1 shows the cross-firm distribution over time of input and sales price inflation. A few facts stand out. First, both input and sales price inflation display significant cross-firm dispersion. The average cross-sectional standard deviation over the sample period is 23.6 percent for the former and 16.7 percent for the latter, suggesting that firms observe markedly different conditions along the supply chain. This is unsurprising, as firms buy and sell different—and possibly unrelated—products and services, but it is consequential if firms use conditions observed along the supply chain to form their beliefs about aggregate variables. For example, if firms were to form their CPI inflation expectations according to heterogeneous prices changes, disagreement would arise. It is also striking how cross-firm heterogeneity differs between the two indicators. The maximum and the minimum of the interdecile range of input price inflation over the sample period are

[10] Employers are mandated to submit information about their employees' wages to calculate the social security contributions and related withholding taxes.

[11] Widening the size of the band does not significantly affect the results, but introduces more volatility in the estimated impulse responses.

-17 and 62 percent, respectively, while they are -10 and 50 percent for sales price inflation. Excluding the post-COVID-19 period when inflation increased even at the bottom of the firm distribution, the difference becomes even more evident: the interdecile range of input price inflation before 2020 is as large as 75 percentage points compared to 46 percentage points for sales price inflation.

Second, at any given point in time the distributions of input and sales price inflation are right skewed. In the case of input price inflation about 3/4 of the data points are within the 0–20 percent range, however risks of large deviations from the median are more on the upside than on the downside. Despite the much smaller dispersion of sales price inflation, larger upside deviations remain visible.

Third, both input and sales price inflation display significant volatility over time compared to CPI inflation. Input price inflation for the median firm hovered between 3.7 and 22.6 percent during 2015–2021 with a standard deviation of 23.8 percent. Sales price inflation fluctuated slightly less, between 1.4 and 9.5 percent with a standard deviation of 17.5 percent. As a benchmark, CPI inflation moved between 1.4 and 5.2 percent and the standard deviation was only 0.9 percent.

Fourth, despite the cross-firm heterogeneity and time volatility, the medians of both indicators track the evolution in CPI inflation. The correlation coefficient for input price inflation is 35 percent and the one for sales price inflation is 69 percent, both significant at five percent significance level. This suggests that movements in input and sales price inflation tend to happen in the same direction of CPI inflation, yet movements uncorrelated with CPI inflation are not infrequent, especially for input price inflation.[12]

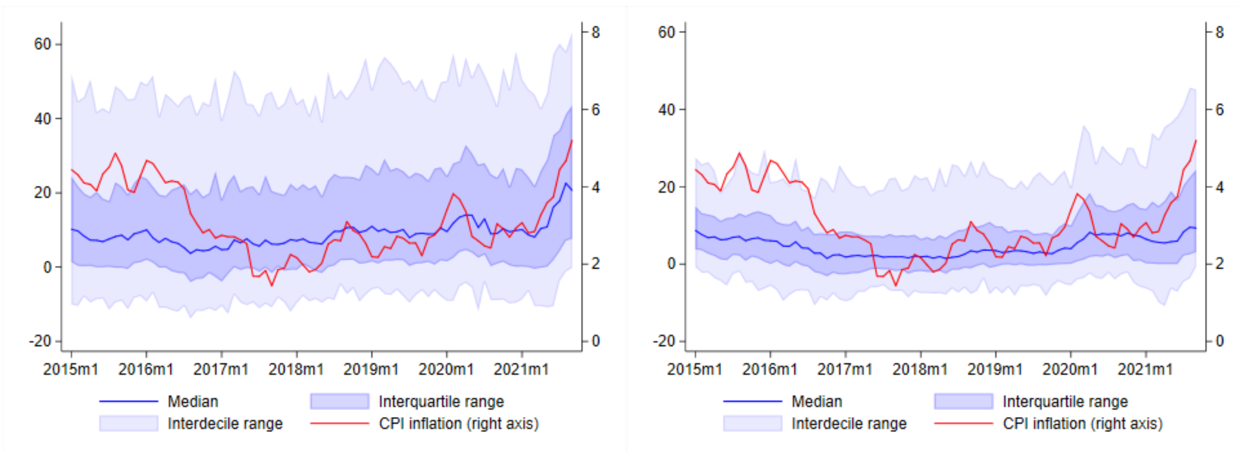
Our indicator of input price inflation is a measure of the *domestic* price pressures that firms observe along the supply chain. However, firms trading internationally may also experience price changes for inputs purchased from *abroad* and change their domestic sales prices and/or export prices accordingly. While most firms that answer the expectation survey only purchase domestically or import a small share of their purchases, we test the robustness of our results by constructing firm-level measures of import and export price inflation.[13] To do that, for each firm i and product j^*—where * is a superscript

[12] Figure A.1 in Appendix A provides some further illustrations of the distribution of supply chain inflation as well as CPI inflation. The histograms in panels A.1a and A.1b show a larger probability mass for positive price changes, suggesting that price increases are more frequent than price declines. As a reference, a 10 percent increase in input (sales) price inflation is about four (three) times more likely than a 10 percent decline. Panel A.1e shows the probability distribution of CPI inflation, which support is narrower than for supply chain inflation. In this case, the distribution resembles a bimodal one, with a larger mass for the 2 to 3 percent range.

[13] As shown in Figure A.2 of Appendix A, 45 percent of the firms in the sample do not import their inputs from abroad and another large fraction only has a small share of imports in total purchases.

Figure 1: Supply chain inflation
(Percent)

(a) Input price inflation (b) Sales price inflation



Notes: Panel 1a and panel 1b present the cross-firm distribution of input price inflation and sales price inflation, respectively. The blue lines denote the medians of the corresponding variable and the shaded areas denote the cross-firm interquartile ranges (dark blue) and the cross-firm interdecile ranges (light blue). The red lines denote CPI inflation.

for either an imported or an exported product—we obtain the unit price in period t by dividing the amount the firm imported or exported by the quantity during the month, $p^*_{i,j,t} = (p^*_{i,j,t} q^*_{i,j,t})/q^*_{i,j,t}$. Then, we compute the log difference of the median price at the firm-product-month level, $\pi^{*,50}_{i,j,t}$. In the last step, for each firm we compute the average of the product-specific median prices weighted by the transaction amount and obtain an indicator of export price inflation and one of import price inflation, $\pi^*_{it} = \sum_j \frac{p^*_{ijt} q^*_{ijt}}{p^*_{it} q^*_{it}} \pi^{50,*}_{ijt}$. Also in this case, we drop observations outside of the $[-30, 100]$ percent change band.

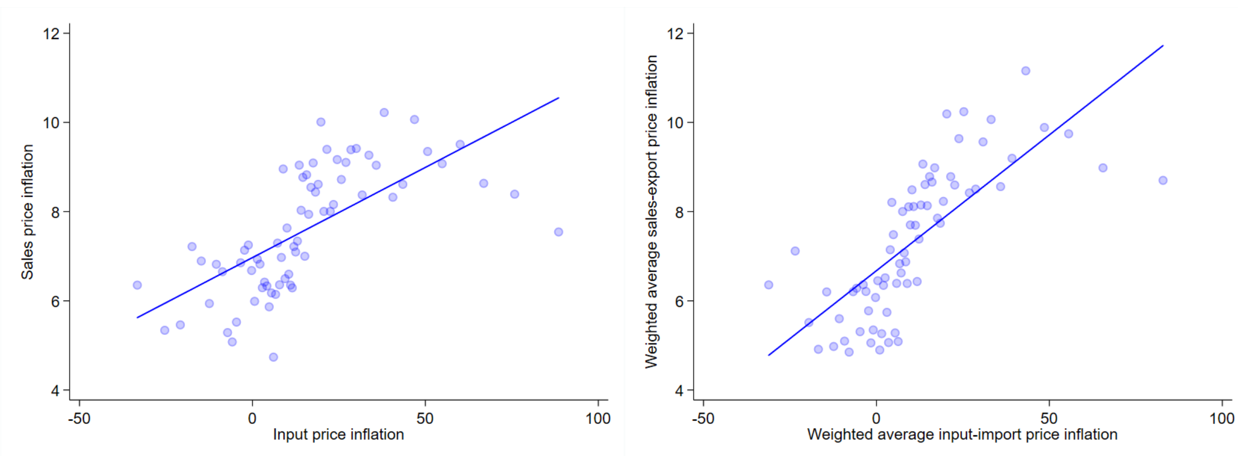
To measure the inflation pressures that the firm observes both domestically and abroad, we produce an indicator of input price inflation that takes into account import price developments. This is constructed as the weighted average of input price inflation and import price inflation—which we call domestic and imported input price inflation—where the weights are simply the share of domestic purchases and imports to total purchases. Analogously, we compute the weighted average of sales price inflation and export price inflation—which we call domestic and export sales price inflation—where the weights are the share of domestic sales and exports to total sales.

Figure 2 reports two binned scatter plots that illustrate the correlation between the domestic measures of supply chain inflation and the correlation between the measures that account for international trade. Panel 2a shows input price inflation and sales price inflation are positively, albeit weakly, correlated. A simple visual inspection suggests that the pass-through to changes in sales prices is higher for small increases of input costs. On the other hand, input price declines tend to be translated into (small) sales price increases. Panel 2b conveys a similar message, with the domestic and imported input price inflation being positively correlated with the domestic and export sales price inflation.

Figure 2: Relationship between input price inflation and sales price inflation
(Percent)

(a) Domestic measures

(b) Measures including international trade



Notes: In panel 2a each dot represents the average of input price inflation and sales price inflation. In panel 2b each dot represents the average of the domestic and imported input price inflation and the domestic and export sales price inflation. The lines denote the linear fit. Data is residualized with respect to firm fixed effects.

In Section 5, we will formally test in a Phillips Curve framework if changes in input prices have an impact on firms' price-setting decisions via the expectation channel. For the estimation of the Phillips curve, we compute a measure of firms' real marginal costs. Under constant return to scales, marginal costs are equal to average costs and we can then compute them as the ratio of firms' costs to quantities sold. By dividing firms' costs by the amount sold, we instead obtain a measure of real marginal costs. Even in this case, we produce two alternative versions of the real marginal costs. The first uses exclusively domestic variables, so that costs include the sum of domestic purchases and the wage bill and sales are domestic sales. The second takes into account international trade by including imports costs and exports in sales.[14]

[14]Table A.1 in Appendix A reports the descriptive statistics for all variables used in the analysis.

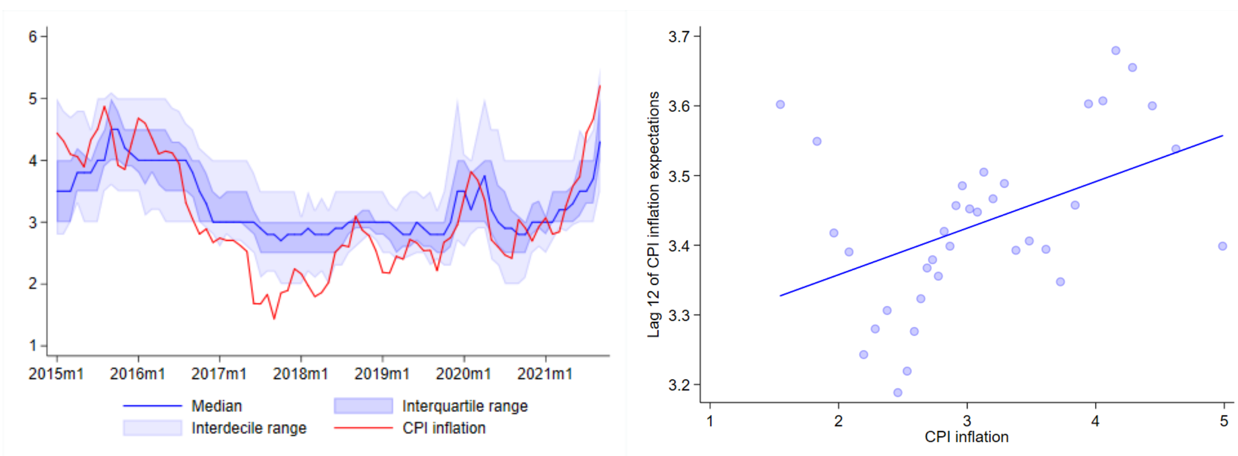
3 Disagreement, inattention, and the supply chain

Firms have substantially different views about next year's CPI inflation. Panel 3a of Figure 3 shows that the cross-sectional dispersion of firms' expectations is generally wide. However, such dispersion varies over time, narrowing when actual CPI inflation converges towards the central bank's target and widening when it deviates from it. During the sample period, the interdecile range is larger than 2 percentage points in a few instances and it collapses to about 0.5 percentage points when inflation approaches the target.

The distribution of inflation expectations appears generally symmetric. When it turns asymmetric, the right tail of becomes longer than the left one, even when inflation is below the target. However, firms do not appear to systematically predict inflation above the inflation outcome.[15] Panel 3b indicates that firms' predictions in fact correlate with the inflation outcome (the correlation coefficient is 11 percent and is significant at 5 percent significance level).

Figure 3: Firms' disagreement about aggregate inflation
(Percent)

(a) Dispersion in firms' inflation expectation (b) Inflation and firms' expectations



Notes: In panel 3a the blue line denotes the median of firms' expectations about CPI inflation, the shaded areas denote the cross-firm interquartile range (dark blue) and the cross-firm interdecile range (light blue), and the red line denotes CPI inflation. In panel 3b, each dot represents the average of the twelfth lag of firms' inflation expectations against CPI inflation, and the line denotes the linear fit. Data is residualized with respect to firm fixed effects.

We then examine whether firms are attentive to macroeconomic developments. To do that, we compute the share of firm-month observations that display a change in expecta-

[15]Coibion, Gorodnichenko and Kumar (2018) find that disagreement is large across firms in New Zealand and that they generally predict a higher level of inflation compared to the observed one.

tions in response to a change in CPI inflation. To avoid that mild variations in inflation affect our calculations, we classify changes smaller than half of its standard deviation as periods of unchanged CPI inflation. Panel 4a of Figure 4 shows that in more than 40 percent of the cases, firms did not change their predictions of inflation when the previous period's CPI inflation changed, regardless of whether it increased, fell, or remained broadly the same, which is suggestive of inattention. This is notable given that Chile is an emerging market that experienced swings in inflation during the sample period.

As expected, when inflation declines, we observe more instances of falling inflation expectations compared to when inflation increases or remains the same; and similarly, when inflation increases, we observe more firms increasing their inflation projections than when inflation stays the same or falls. Yet, more than one-fifth of firms predicts a change in inflation in the opposite direction compared to the direction of the change in actual inflation observed in the previous month, suggesting that other factors could potentially influence the way in which firms form their views.

Panel 4b reports the results of the same experiment replacing changes in CPI inflation with changes in real GDP growth. We find consistent results in terms of the share of firms that do not change their inflation expectations. Interestingly, we also find that in response to a decline in real GDP growth, the number of firms forecasting an increase in CPI inflation is larger than the number of firms forecasting a decline; and that in response to an increase in real GDP growth, the number of firms forecasting an increase in CPI inflation is smaller than the number of firms forecasting a decline. This suggests that firms attribute changes in real GDP growth to supply shocks.[16]

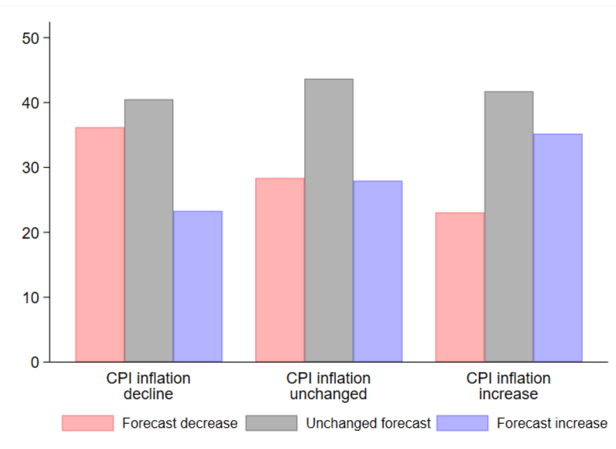
It is well documented that forecast disagreement and inattention are related and can arise both in a noisy information setting (Sims, 2003) and in a sticky information one (Mankiw and Reis, 2002). While we do not point to any specific source of information rigidity, we posit that there exist information frictions such that firms observe price changes along the supply chain and, based on those changes, form their expectations about aggregate inflation. That is, as in Lucas (1972), firms operate as if they were located on different islands and learn from a subset of islands they have relationships with. Thus, firms extract a signal about future aggregate inflation from realized supply chain inflation.[17] If this is true, forecast disagreement may then arise because firms would rely on "local" conditions, which are not necessarily the same across firms and that may not even have an aggregate effect. This, in turn would lead firms to be inattentive to inflation

[16] This is consistent with the evidence in Candia, Coibion and Gorodnichenko (2020) that show that households and firms have a 'stagflationary view of inflation'.

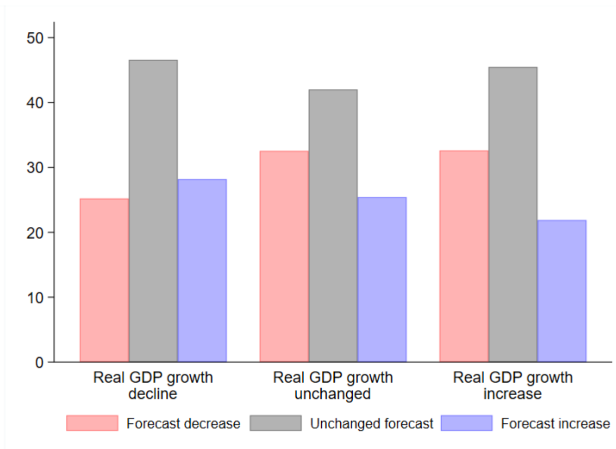
[17] See Appendix B for a formalization of the signal extraction problem.

Figure 4: Inattention to macroeconomic developments
(Percent)

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



(b) Share of firm-month observations responding to changes in real GDP growth



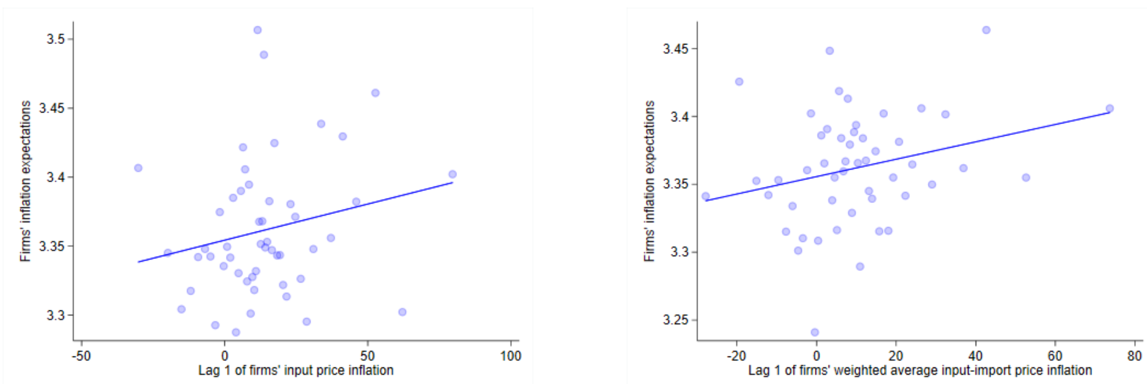
Notes: The red and blue bars denote the shares of firm-month observations that report a decline or an increase in inflation expectations a month after a change in CPI inflation (panel 4a) or a change in real GDP growth (panel 4b), where a change is defined as a variation larger than half of the variable's standard deviation; the gray bars denote the share of firm-month observations that report unchanged inflation expectations.

developments because they would deem aggregate information less relevant than supply chain information for their business.

Figure 5 reports some *prima facie* evidence of the relationship between supply chain inflation and firms' expectations about CPI inflation. The binned scatter plots in panels 5b and 5a depict a positive association between firms' inflation expectations and the previous month value of domestic input price inflation and domestic and imported input price inflation, respectively. In Section 4, we investigate this relationship further.

Figure 5: Supply chain inflation and inflation expectations
(Percent)

(a) Domestic input price inflation   (b) Domestic and imported input price inflation



Notes: In panel 5a each dot represents the average of input price inflation and firms' inflation expectations. In panel 5b each dot represents the average of domestic and imported input price inflation and firms' inflation expectations. The lines denote the linear fit. Data is residualized with respect to firm fixed effects.

4 Supply chain inflation and firms' inflation expectations

In this section, we empirically uncover the role of the supply chain in the inflation expectation formation mechanism of firms. First, we document that firms use changes in their input costs to forecast aggregate inflation. Second, we show that this is the case even when these price changes are unrelated to aggregate inflation, violating the full-information rational-expectation hypothesis. Third, we explore the heterogeneity of this channel in terms of frequency, sign, and size of price changes, and relate it to underlying theories of information rigidity. And fourth, we ensure that our results are robust to a number of tests.

4.1 The role of supply chain inflation

We estimate a reduced-form specification in the spirit of Andrade et al. (2022) using local projections (Jordà, 2005)

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

where the dependent variable is the cumulative change in firm's i beliefs about next year's CPI inflation in month $t+h$, with $h = [0,\ldots,24]$, with respect to its views as of the last month. The independent variables include two lags of the supply chain inflation measure, $\pi_{i,t-p}$, which is either domestic input price inflation or domestic and imported input price inflation; two lags of CPI inflation, π_{t-p}; and a set of controls, $X_{i,t-p}$, which consists of two lags of the dependent variable to account for persistence in firms' inflation expectations, one lag of aggregate activity (i.e., the latest reading of the quarterly real GDP growth), and two lags of firms' sales in real terms.[18] Finally, the specification includes firm fixed effects α_i^h. We do not include time fixed effects as they are collinear with CPI inflation, which is a variable we want to condition on and retrieve a coefficient for, and aggregate activity. Standard errors are clustered at the firm and time level.[19]

The coefficient of interest γ_p^h traces the cumulative response in firms' inflation expectations due to innovations in prices that firms observe along the supply chain. As the specification includes CPI inflation, it reveals the effect of supply chain shocks that are orthogonal to changes in aggregate inflation. If firms were behaving as in the full-information rational-expectations benchmark, they would discard the information coming from shocks that do not have aggregate effects when forecasting CPI inflation, and the coefficient should be statistically insignificant. Yet, in presence of information rigidities, firms may not be able to distinguish between shocks that have aggregate effects and those that do not; or it may be too costly for them to process aggregate information as they deem it irrelevant for their businesses. As a result, firms would end up assigning some weight to shocks in supply chain inflation when forecasting CPI inflation. The other coefficient

[18] Since real GDP growth is observed at the quarterly frequency, we repeat the observation for three consecutive months. This is in line with the idea that firms observe the latest available real GDP growth number. Replacing the lag of real GDP growth with the monthly indicator of economic activity published by the Central Bank of Chile does not alter the results (for more information about this indicator see `https://www.bcentral.cl/en/web/banco-central/area/statistics/imacec`).

[19] The literature suggests that production networks are characterized by large firms with a lot of connections (Bernanke, 2007; Alfaro-Urena et al., 2018; Cardoza et al., 2020), including in Chile (Grigoli, Luttini and Sandri, 2021). In presence of suppliers that sell to many firms, time fixed effects would absorb the variation we are interested in.

of interest is β_p^h, which describes the effect of changes in CPI inflation on firms' forecasts of CPI inflation. The expected sign in this case is positive as aggregate shocks should lead to changes in inflation expectations, unless inattention is so pervasive that firms become unresponsive to aggregate signals.

We argue that the coefficient associated to supply chain inflation can be interpreted in a causal sense. The identification assumption is that input and import prices are generally exogenously determined with respect to firms' expectations of CPI inflation. There is, however, the possibility that some firms answering the survey have monopsony power and influence prices at which they buy their inputs according to their inflation expectations. In the robustness section we further mitigate this concern by excluding firms that source inputs from suppliers that have on average less than 25 buyers.

While the specification is in line with the one used by Andrade et al. (2022), our study differs from theirs in a number of aspects. First, rather than using inflation indices at the industry level, we rely on supply chain inflation indices at the firm level. This higher degree of data granularity brings about some key advantages. Our measures of supply chain inflation better align with Lucas (1972)'s notion of "islands" as they directly quantify the price changes that firms observe in their transactions. Also, they minimize the risk of mismeasuring the signal that firms receive. For example, for firms buying from more than one sector (especially when sectors are finely defined and/or firms have different businesses), industry-level indices would incorrectly measure the firm-level price changes.

Second, the survey question about inflation expectations is quantitative instead of qualitative, which allows us to obtain an estimate for the impact of a shock in supply chain inflation on firms' expectations for CPI inflation. Third, inflation expectations are measured over a 1-year horizon, compared to 3 months. This allows to examine the expectation formation process over a horizon that is closer to the one relevant to monetary policy. And fourth, the survey is sent to firms each month rather than each quarter. The higher frequency reduces the time span between the moment in which firms observe price changes and the moment in which they submit the answers to the survey. This helps mitigating the concerns that confounding factors may be biasing the estimates.

Figure 6 shows the results of the estimations.[20] Panel 6a reports the response of firms' expectations of CPI inflation to a shock in input price inflation, conditional on CPI inflation. The plot indicates that firms are indeed responsive to conditions observed along the supply chain even when these have no effect on CPI inflation: a 10 percentage point increase in input price inflation leads to a 0.02 percentage point increase in inflation ex-

[20]Tables C.1 and C.2 of Appendix C report the results of the baseline regressions.

pectations five months after the shock. In terms of a 1 standard deviation shock, this effect corresponds to an increase in firms' inflation expectations of about 0.1 percentage point. The effect dies out over a 14-month period, likely reflecting the time needed for firms to realize that changes in input prices do not determine CPI inflation.

In panel 6b we report the response of firms' inflation expectations to a change in CPI inflation. A one percentage point increase in CPI inflation leads firm to increase their expectations for next year's inflation by almost 0.5 percentage point a month after the shock. Translating this in terms of a 1 standard deviation shock, the size of estimated increase in inflation expectations at the peak reaches 0.4 percentage points. This coefficient is larger than the one on supply chain inflation, but this is unsurprising. The response to a shock in input price inflation and to a shock in CPI inflation, in fact, are not strictly comparable. This is because our specification isolates changes in input prices that are orthogonal to CPI inflation. In other words, we are purging movements in supply chain inflation that are correlated to the evolution of CPI inflation; this is obviously not the case for movements in CPI inflation. Our results are remarkable also because firms are forecasting CPI inflation, but supply chain inflation is more closely related to producer price inflation.[21]

The timing of the response is somewhat different. While both responses display either an immediate effect or an effect that takes one or two months to materialize, the impact coming from a change in CPI inflation is shorter-lived, dying within 6 months. One way to rationalize such short duration is to relate it the credibility that the Central Bank of Chile gained over the past few decades (Albagli et al., 2020).[22]

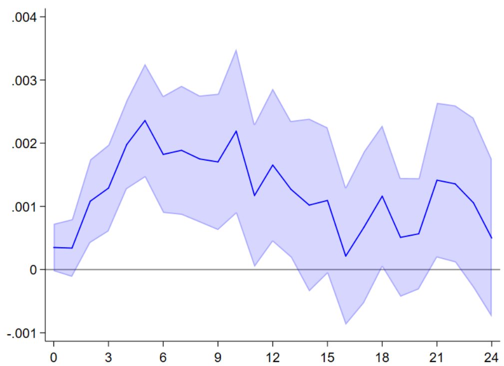
To test if import prices have the potential to alter these conclusions, we estimate the same specification replacing domestic input price inflation with domestic and imported input price inflation. The results in panels 6b and 6d resemble the ones of the domestic counterparts. We conclude that our results hold even for firms that rely on international trade to source their inputs. Taken together, we interpret these results as evidence of firms extracting aggregate signals from price variation along the supply chain, even when this is irrelevant for aggregate price dynamics.

[21] Andrade et al. (2022) do not quantify the effects of the shocks on inflation expectations, however the magnitude of the response to industry inflation is about one fourth of the response to aggregate inflation (which in their case is the change in prices of industrial products). After normalizing the responses to innovations equal to 1 standard deviation, the ratio becomes one eight.

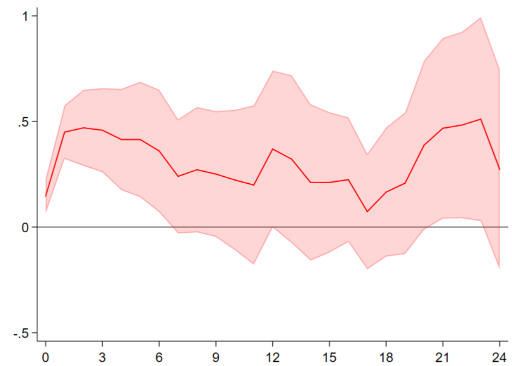
[22] Bems et al. (2021) provide cross-country evidence on the degree of anchoring of inflation expectations of professional forecasters. Chile features as the top emerging market, with a score in line with that of the best performing advanced economies.

Figure 6: Response of firms' inflation expectations to shocks in input price inflation (Percentage points)

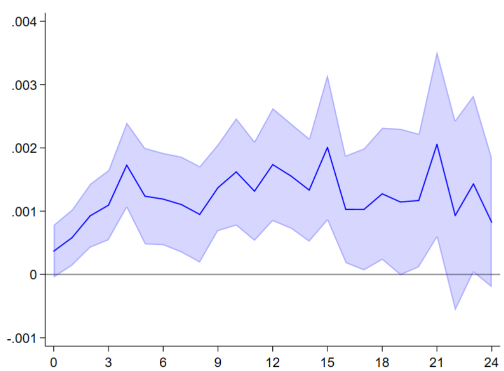
(a) 1pp increase in input price inflation



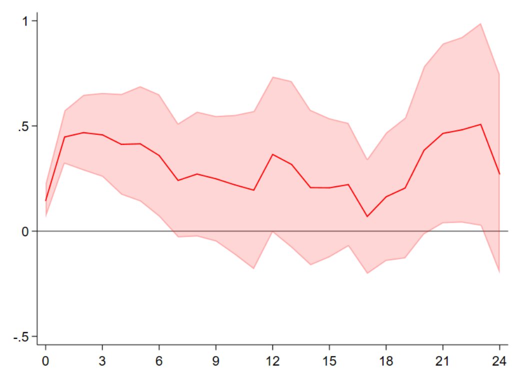
(b) 1pp increase in CPI inflation (regression with input price inflation)



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



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



Notes: The horizontal axes represent the number of months after the shock, the lines denote the point estimates, and the shaded areas correspond to 90 percent confidence intervals computed with standard errors clustered at the firm and time level.

4.1.1 Industry-level inflation

To relate our results to the ones of Andrade et al. (2022)—where firms learn from inflation observed in the industry to which they belong—we estimate a specification that includes industry-specific inflation

$$E_{i,t+h}\pi_{t+h+12} - E_{i,t-1}\pi_{t-1+12} = \alpha_i^h + \sum_{p=1}^{P}\gamma_p^h \pi_{i,t-p} + \sum_{p=1}^{P}\beta_p^h \pi_{t-p} + \sum_{p=1}^{P}\psi_p^h \pi_{s,t-p} + \sum_{p=1}^{P}\theta_p^h X_{i,t-p} + \varepsilon_{i,t+h} \tag{2}$$

where $\pi_{s,t-p}$ is inflation in industry s, which is the sector to which firm i is assigned.[23]

Panel 7a of Figure 7 shows that an innovation in industry inflation leads firms to forecast higher CPI inflation, but the effect is significant only at some horizons. Panel 7b reports the response of inflation expectations to a shock in input price inflation controlling for industry inflation. Despite the inclusion of industry inflation in the specification, the effect remains generally significant, albeit the response becomes more volatile. The magnitude of the effect is somewhat larger: a 10 percentage point increase in input price inflation results in 0.04 percentage point higher in inflation expectations 10 months after the shock, which is about a third larger than the response estimated without controlling for industry inflation.

These results are consistent with the notion that firms do not directly observe the prices of the sector, rather they observe the prices at which they source inputs from their suppliers. They are also in line with the fact that there are firms operating at the intersection of different industries, for which inflation of a specific industry may be an imprecise proxy of what prices they observe.

4.2 Testing the full-information rational-expectations hypothesis

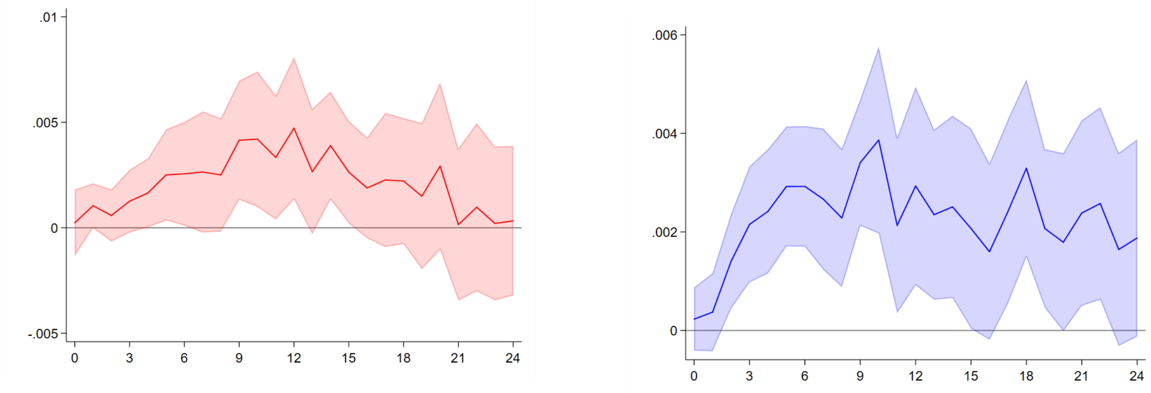
The full-information rational-expectations hypothesis posits that shocks without aggregate consequences should leave firms' expectations about aggregates unaffected. In contrast with that, we find that changes in prices along the supply chain that have no impact on CPI inflation lead to changes in firms' inflation expectations. Our results, however, originate from a specification that assumes only *contemporaneous* orthogonality of supply chain inflation to CPI inflation. Thus, there is the possibility that changes in firms' supply chain inflation have predicting power with respect to *future* CPI inflation. In other

[23] We rely on industry-level inflation indexes from the Central Bank of Chile. Industries are defined according to the *Clasificador Chileno de Actividades Económicas*, which is an adaptation of CIIU Revision 4. This consists of 170 different industries, most of which are part of the broader manufacturing sector. The results are virtually unchanged when we use a less detailed classification with 42 industries.

Figure 7: Response of firms' inflation expectations to shocks in industry inflation
(Percentage points)

(a) 1 pp increase in industry inflation

(b) 1pp increase in input price inflation controlling for industry inflation



Notes: The horizontal axes represent the number of months after the shock, the lines denote the point estimates, and the shaded areas correspond to 90 percent confidence intervals computed with standard errors clustered at the firm and time level.

words, it can be the case that firms are anticipating that a surge in supply chain prices will lead to higher CPI inflation in the future.

To interpret our results as a rejection of the full-information rational-expectation hypothesis, we need to ensure orthogonality with respect to future CPI inflation. We do that by first running a battery of firm-by-firm regressions for all firms i to assess the non-predictability of future CPI inflation with respect to current input inflation after accounting for current CPI inflation[24]

$$\pi_{t+h} = \iota^i + \sum_{p=1}^{P} \gamma_p^{i,h} \pi_{i,t-p} + \sum_{p=1}^{P} \beta_p^{i,h} \pi_{t-p} + \nu_{i,t+h} \tag{3}$$

where non-predictability of future CPI inflation would deliver a statistically insignificant $\gamma^{i,h}$ coefficient, with $h = [0, \ldots, 24]$. Then, for each horizon we compute the share of firms for which supply chain inflation cannot predict CPI inflation. Finally, we re-estimate our baseline specification in equation (1) excluding firms which supply chain inflation predicts future CPI inflation.[25]

Figure 8a reports the results. At any given horizon, only a small share of firms presents

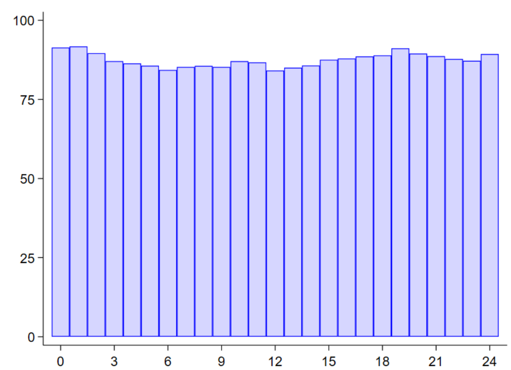
[24]We exclude firms with time series of less than 30 observations.

[25]We assess statistical significance of the $\gamma^{i,h}$ coefficient using a 95 percent significance level, but results are similar when setting the significance threshold to 90 percent, which would result in more firms being dropped from the sample.

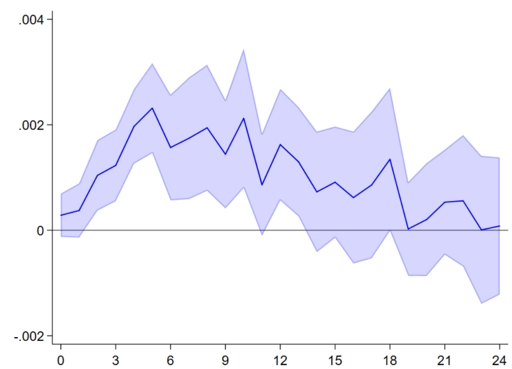
a statistically significant estimate of $\gamma^{i,h}$. Panels 8a and 8c indicate that at least 80 percent of firms' supply chain inflation does not have any predictive power with respect to future CPI inflation once current CPI inflation is controlled for. Panels 8b and 8d report the results of the specification in equation (1) only including firms for which the two measures of supply chain inflation are orthogonal to future CPI inflation. The estimated responses are similar to the ones obtained in our baseline set of results in Figure 6. We conclude that our results represent a violation of the full-information rational-expectation benchmark.

Figure 8: Orthogonality with respect to future CPI inflation
(Percentage points, unless otherwise specified)

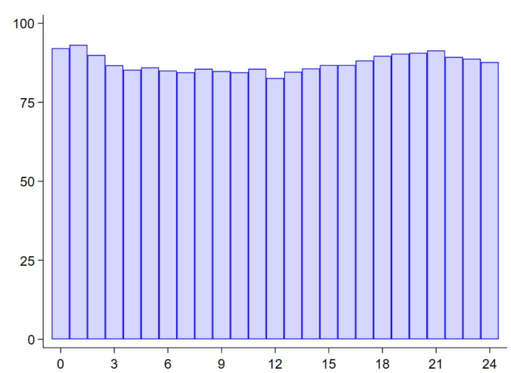
(a) Share of firms with input price inflation unrelated to future CPI inflation, percent



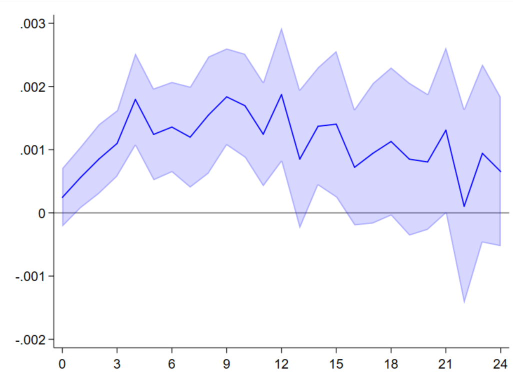
(b) 1pp increase in input price inflation



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



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



Notes: The horizontal axes represent the number of months after the shock. In panels 8a and 8c the bars denote the share of firms for which γ^h in equation (3) is statistically insignificant at the 95 percent confidence level. In panels 8b and 8d the lines denote the point estimates and the shaded areas correspond to 90 percent confidence intervals computed with standard errors clustered at the firm and time level.

4.3 Heterogeneity

We now propose some heterogeneity tests that help to shed light on the expectation formation of firms. The caveat is that our sample is relatively small, both along the within-firm and between-firm dimensions, and consists only of firms in the manufacturing and retail sectors. Yet, we can still explore some aspects that drive the association between supply chain inflation and inflation expectations.

In an experimental study, Georganas, Healy and Li (2014) show that individuals weigh more frequent signals when forming inflation expectations, consistent with the insights from the literature on perceptual learning (Watanabe, Nanez and Sasaki, 2001). At the household level, D'Acunto et al. (2021) find that price changes of more frequently purchased goods lead to changes in CPI inflation expectations. Also, they show that larger price movements have a larger impact on expectations, which implies that infrequent shoppers who tend to observe larger changes across shopping trips respond more to the grocery price changes to which they are exposed.

In principle, one would expect firms to be less sensitive than households to the frequency at which they observe price changes. This is because firms are more likely to have access to the relevant information and be able to process it. In other words, they should equally weight price changes regardless of the frequency at which they are exposed to them. We test if this is the case by constructing a frequency-based indicator of input price inflation, which overweights price changes of products that are purchased more frequently. That is, instead of weighting input price inflation by the value of the transactions, we construct weights using the number of transactions n, $\pi_{it}^{freq} = \sum_j \frac{n_{ijt}}{n_{it}} \pi_{ijt}^{50}$.

Columns (1) to (3) of Table 1 report the results of the regressions in which we replace (the value-weighted) input price inflation with the frequency-based version of it and test its effect 4 to 6 months after the shock, which is when the peak of the effect is observed in our baseline results. In columns (4) to (6), we include both the value-weighted measure of input price inflation and the frequency-based one. The results do not show any significant effect from the frequency-based measure, while the coefficient on the value-weighted measure of input price inflation remains significant and virtually identical in magnitude to the one of the baseline regression, providing evidence against perceptual learning in the case of firms.[26]

We now turn to examine heterogeneity in terms of sign and size of input price infla-

[26] Alternatively, using the distribution of the average (of the log) number of transactions of each firm over the sample period, we classify firms into three groups which correspond to the distribution terciles and therefore to how frequently they make purchases of inputs. We then include interaction of input price inflation with dummies for these groups. Again, we do not find evidence of an effect from the frequency at which firms observe input price changes.

Table 1: Frequency of input price changes

	Frequency-based input price inflation			Frequency-based and value-weighted input price inflation		
	(1) $h=4$	(2) $h=5$	(3) $h=6$	(4) $h=4$	(5) $h=5$	(6) $h=6$
Lag of freq.-based input price infl.	0.000	-0.000	-0.000	-0.000	-0.001*	-0.001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Lag of input price inflation				0.002***	0.003***	0.002***
				(0.000)	(0.001)	(0.001)
Firms	312	314	312	312	314	312
Observations	7,383	7,323	7,133	7,383	7,323	7,133
R-squared	0.350	0.363	0.327	0.355	0.367	0.331

Notes: This table reports the results for 4 to 6 months after the shock, which is around peak of the effect of input price inflation on inflation expectations in the baseline regressions. All regressions include all baseline regressors and firm fixed effects. Clustered standard errors at the firm and time level in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

tion. First, we test if firms react asymmetrically to input price inflation and input price deflation. We replace input price inflation with its interaction with a dummy that takes value one when input prices increase and its interaction with a dummy that takes value one when input prices decline.

Column (1) to (3) of Table 2 show that firms forecast higher CPI inflation in response to positive changes in input prices, however they do not change their inflation expectations when input price decline. This implies some downward rigidity in firms' inflation expectations. One prediction of the rational inattention literature is that firms should not react differently to input price changes of different magnitude. On the other hand, if salience of input prices is relevant, we should find a stronger effect for large changes of input price inflation (D'Acunto et al., 2021). To test this, we include in the specification the squared term of input price inflation. Column (4) to (6) show that the squared term is not statistically significant for horizons 4 and 6, while for horizon 5 is only significant at the 10 percent significance level and is negative, giving support to the rational inattention framework.

4.4 Robustness

To ensure the robustness of our findings, we run a set of tests.[27] First, to show that our results are not an artifact of the empirical approach, we perform a placebo test. The

[27] We only report the results of the robustness tests for the domestic measure of supply chain inflation. However, results using the measure that includes the price changes of imported inputs convey the same messages and are available upon request.

Table 2: Sign and size of input price changes

	Sign			Size		
	(1)	(2)	(3)	(4)	(5)	(6)
	$h = 4$	$h = 5$	$h = 6$	$h = 4$	$h = 5$	$h = 6$
Lag of positive input price inflation	0.002***	0.002***	0.002**			
	(0.001)	(0.001)	(0.001)			
Lag of negative input price inflation	-0.001	-0.002	-0.002			
	(0.002)	(0.003)	(0.003)			
Lag of input price inflation				0.002***	0.004***	0.003***
				(0.001)	(0.001)	(0.001)
Lag of input price inflation squared				-0.000	-0.000*	-0.000
Firms	312	314	312	312	314	312
Observations	7,383	7,323	7,133	7,383	7,323	7,133
R-squared	0.355	0.367	0.331	0.354	0.367	0.330

Notes: This table reports the results for 4 to 6 months after the shock, which is around peak of the effect of input price inflation on inflation expectations in the baseline regressions. All regressions include all baseline regressors and firm fixed effects. Clustered standard errors at the firm and time level in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

test consists of constructing a placebo series for supply chain inflation and examine its relevance for firms' inflation expectations compared to the actual supply chain inflation series.

Specifically, for each firm i we consider all other firms $j \in J \neq i$ and regress one-by-one all J's supply chain inflation on firm i's supply chain inflation

$$\pi_{j,t} = a^j + b^j \pi_{i,t} + e_{j,t} \quad \forall j \in J \tag{4}$$

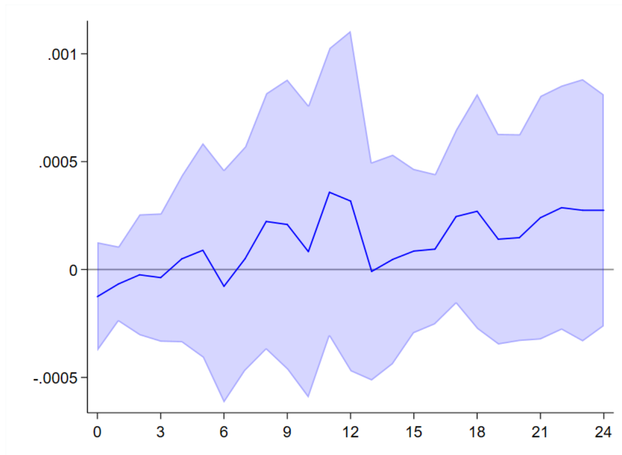
We then take the supply chain inflation series of firm j that produces the smallest coefficient in absolute terms, $|b^{j*}|$ (i.e., the firm with the least predictive power), and call it placebo supply chain inflation series, $\pi^{placebo}_{j,t-1}$. Finally, we re-estimate the baseline specification with the inclusion of the placebo series

$$E_{i,t+h}\pi_{i,t+h+12} - E_{i,t-1}\pi_{i,t-1+12} = \alpha_i^h + \sum_{p=1}^{P} \gamma_p^h \pi_{i,t-1} + \sum_{p=1}^{P} \beta_p^h \pi_{t-p} + \sum_{p=1}^{P} \theta_p^h \pi^{placebo}_{j,t-1} \sum_{p=1}^{P} \theta_p^h X_{i,t-p} + \varepsilon_{i,t+h} \tag{5}$$

If our results are not an artifact of the empirical procedure, we should find non-significant coefficients on the placebo series, indicating absence of predictive power with respect to the firms' inflation expectations. Figure 9 shows that the point estimates cannot be distinguished from zero at any horizons.

One argument jeopardizing the exogeneity of input price inflation with respect to firms' inflation expectations is that firms may have monopsony power to impose purchase prices on their suppliers based on their expectations for future inflation. We mit-

Figure 9: Placebo test
(Response of firms' inflation expectations to a 1pp increase in placebo input price inflation, percentage points)



Notes: The horizontal axis represents the number of months after the shock, the line denotes the point estimates, and the shaded area corresponds to 90 percent confidence interval computed with standard errors clustered at the firm and time level.

igate this concern by running our baseline specification in equation (1) after excluding firms that buy their inputs from suppliers that have only a few buyers. Specifically, for each firm in the sample we first compute the median number of buyers of its suppliers in any given month. Then, we drop all firm-month observations for which the median number of buyers of the suppliers is below the 25th percentile of the sample distribution (which corresponds to 230 buyers). The assumption is that firms with suppliers that have relatively more buyers are less likely to be able to set their purchase prices. As shown in panel 10a, the results are similar to the baseline ones.

Another concern is that variables are highly autocorrelated and that we cannot interpret our shocks as exogenous shocks. Thus, we change the lag structure in equation (1) to include up to four lags of all independent variables as well as the dependent one. The results in panel 10b confirm that adding lags to our baseline specification does not affect the estimates. On the other hand, it could be argued that we are over-controlling by adding too many lags. Hence, we run the opposite experiment of removing the second lag of the independent variables and of the dependent variable from the baseline specification. Again, the results shown in panel 10c are consistent with the baseline ones.

Our indicator of input price inflation may actually capture some of the price pressures that come from abroad, given that they are correlated. To isolate the impact of domestic price pressures observed along the supply chain, we control for import price inflation. The results in panel 10d corroborate our baseline findings, showing that input price inflation remains significant even after controlling for import price inflation.

Finally, while our standard errors are robust to autocorrelation, it can be the case that they are also correlated across firms. Thus, we correct the standard errors following the procedure proposed by Driscoll and Kraay (1998) which accounts for cross-sectional dependence. As shown in panel 10e, results are again in line with the baseline ones. Also, to ensure that we are not over-clustering, we recompute the standard errors clustering them only at the firm level. Even in this case, results are robust as shown in panel 10f.

5 Price-setting behavior of firms

After establishing that firms use price changes observed along the supply chain to form their beliefs about future CPI inflation, we now turn to examine whether firms' price-setting decisions reflect their expectations about aggregate inflation.

5.1 A firm-level Phillips curve

To study the pricing decisions of firms, we derive the New Keynesian Phillips curve (NKPC) at the firm level. We assume that firms face nominal rigidities consisting of price adjustment costs à la Rotemberg (1982) and produce under constant returns to scale.[28]

Firms maximize expected profits

$$E_{i,o}\sum_{t=0}^{\infty}\beta^t\Big[p_{i,t}y_{i,t}-mc_{i,t}y_{i,t}-\frac{\gamma}{2}\Big(\frac{p_{i,t}}{p_{i,t-1}}-1\Big)^2P_ty_t\Big]/P_t \tag{6}$$

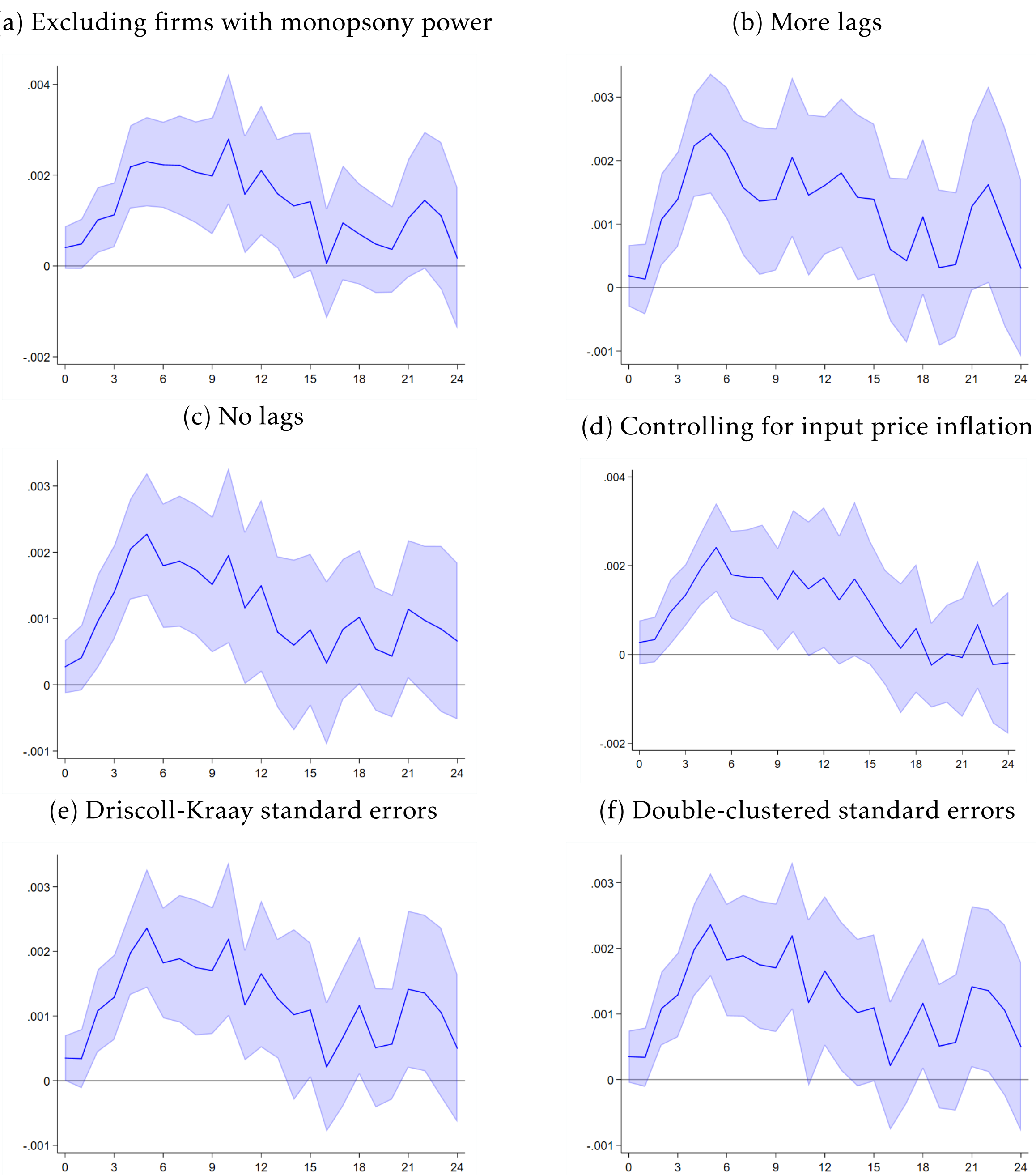
subject to a demand function as in the Dixit-Stiglitz model of imperfect competition

$$y_{i,t}(d)=(P_{i,t}/P_t)^{-\theta}Y_t \tag{7}$$

where $p_{i,t}$, $y_{i,t}$, and $mc_{i,t}$ denote sales price, quantities, and marginal costs of firm i at time t, respectively; and P_t is the CPI.

[28]Calvo staggered prices would not allow to obtain a firm-level Phillips curve as imposing a symmetric equilibrium would translate in a linearized pricing relationship at the aggregate level. Yet, Rotemberg pricing and Calvo pricing are identical to first order.

Figure 10: Robustness tests
(Response of firms' inflation expectations to shocks in input price inflation, percentage points)



(a) Excluding firms with monopsony power

(b) More lags

(c) No lags

(d) Controlling for input price inflation

(e) Driscoll-Kraay standard errors

(f) Double-clustered standard errors

Notes: The horizontal axes represent the number of months after the shock, the lines denote the point estimates, and the shaded areas correspond to 90 percent confidence intervals computed with standard errors clustered at the firm and time level.

We can then derive the first order condition

$$y_{i,t}(1-\theta)+\psi_{i,t}\theta y_{i,t}\frac{P_t}{p_{i,t}}-\gamma\Big(\frac{p_{i,t}}{p_{i,t-1}}-1\Big)\frac{P_t}{p_{i,t-1}}y_t+\beta E_{i,t}\Big[\frac{\lambda_{t+1}}{\lambda_t}\gamma\Big(\frac{p_{i,t+1}}{p_{i,t}}-1\Big)\pi_{i,t+1}\tilde{p}_{i,t+1|t}y_{t+1}\Big]=0 \tag{8}$$

where $\psi_{i,t}=\frac{mc_{i,t}y_{i,t}}{p_{i,t}y_{i,t}}$ is the firm-specific real marginal cost, and linearize it to obtain the NKFP relationship

$$\pi_{i,t}=\beta E_{i,t}\pi_{i,t+1}+\frac{\theta\psi}{\gamma}\widetilde{\psi}_{i,t} \tag{9}$$

where $\widetilde{\psi}_{i,t}=ln(\psi_{i,t})$.

We also assume that firms expect their relative prices to remain constant over time

$$E_{i,t}\pi_{i,t+1}=E_{i,t}\pi_{t+1}+\omega_{i,t} \tag{10}$$

where $\omega_{i,t}$ is a white noise forecast error. This allows us to rewrite equation (9) as

$$\pi_{i,t}=\beta E_{i,t}\pi_{t+1}+\frac{\theta\psi}{\gamma}\widetilde{\psi}_{i,t}+\beta\omega_{i,t} \tag{11}$$

5.2 Estimation

To the best of our knowledge, estimations of the Phillips curve at the firm level are virtually non-existent in the literature.[29] This is largely because micro data on inflation expectations and sales prices are either confidential or not available. In this section, we leverage the information on sales price inflation at the firm level and inflation expectations from the expectation survey and estimate the following specification of the NKPC

$$\pi_{i,t}=\alpha_i+\beta E_{i,t}\pi_{t+1}+\delta\widetilde{\psi}_{i,t}+u_{i,t} \tag{12}$$

where α_i are firm fixed effect that control for the unobserved cross-firm heterogeneity that is constant over time, $\delta=\frac{\theta\psi}{\gamma}$, and $u_{i,t}=\beta\omega_{i,t}$.

Table 3 reports the results of the estimations. Column (1) presents the estimates of the NKPC based on the full sample, while column (2) restricts the sample to the one used in the estimation of the impact of input price inflation on inflation expectations (i.e., the sample for which input price inflation is available). Columns (3) and (4) use the same sample as column (1) and (2), but the dependent variable is now domestic and export sales price inflation and the real marginal cost measure includes the cost of imports and

[29] Cloyne et al. (2016) is a notable exception. Their study estimates the New Keynesian Phillips curve using micro data for firms in the manufacturing sector in the UK.

the receipts from exports. The results suggest that firms do set prices according to their expectations of future CPI inflation.

Depending on the sample and the inclusion of exports and imports, the estimated coefficient indicates that a 1 percentage point increase in expected inflation is associated with firms' raising their sales prices between 1 and 1.4 percentage points. In all specifications we cannot reject that the estimated coefficient on expected inflation is different from one, suggesting a full pass-through of changes in expectations to sales prices. Our measure of marginal costs is borderline insignificant in all specifications.

Table 3: New Keynesian Phillips Curve Estimation Results

	Sales price inflation		Weighted avg of sales and export price inflation	
	(1)	(2)	(3)	(4)
Lag of inflation expectations	1.353***	0.992*	1.371***	1.204**
	(0.386)	(0.528)	(0.365)	(0.480)
Real marginal costs	0.053	0.046	0.055	0.084
	(0.041)	(0.065)	(0.042)	(0.060)
Wald test lag of inflation exp. = 1 (F-test)	0.830	0.000	1.030	0.180
Firms	411	269	423	102
Observations	11,131	5,649	11,567	5,820
R-squared	0.196	0.233	0.193	0.243

Notes: Columns (1) and (2) use sales price inflation as dependent variable, columns (3) and (4) use the weighted average of domestic sales and export sales as dependent variable. Columns (1) and (3) are based on the full sample, columns (2) and (4) use the sample of the baseline regressions underlying Figure 6. All regressions include firm fixed effects. Clustered standard errors at the firm and time level in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

The large body of evidence estimating the Phillips curve using aggregate data point to the fact that prices are also set in light of what happened in the past, resulting in some persistent inflation dynamics (Galı and Gertler, 1999). To capture this backward-looking aspect of the firms' price-setting behavior, the literature estimates a 'hybrid Phillips curve' which includes a lag of the dependent variable. As noted by Cloyne et al. (2016), however, this specification is not micro-founded. Since the objective function of the firm includes an inflation index, it would lead to a formulation of equation (9) featuring both firm-specific and CPI inflation expectations.[30] In our estimations, we naively include the lag of sales prices as a control to account for sluggish firms' price dynamics.

The results in Table 4 corroborate the evidence obtained so far. The coefficient on lagged sales price inflation is positive and significant, but rather small. A 1 percentage point increase in sales price inflation in the previous period is associated with higher

[30]This is not an issue at the aggregate level, as imposing symmetry in equilibrium would make the distinction about firm-specific and CPI inflation irrelevant.

Table 4: Hybrid Phillips Curve Estimation Results

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

Notes: Columns (1) and (2) use sales price inflation as dependent variable, columns (3) and (4) use the weighted average of domestic sales and export sales as dependent variable. Columns (1) and (3) are based on the full sample, columns (2) and (4) use the sample of the baseline regressions underlying Figure 6. All regressions include firm fixed effects. Clustered standard errors at the firm and time level in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

sales price inflation by 0.04 to 0.07 percentage points in the current period, depending on the specification. Nonetheless, the coefficient on lagged inflation expectations remains positive and significant, ranging between 0.9 and 1.3. Even in this case, the coefficient is not statistically different from one, confirming the complete pass-through of changes in inflation expectations to sales prices.

6 Conclusions

We show that firms rely on observed price changes along the supply chain to predict aggregate inflation, even when these changes are contemporaneously unrelated to inflation. We also show that firms act on the basis of such expectations by setting prices accordingly. We find that they fully pass-through changes in CPI inflation expectations to sales prices.

Our results are supportive of the island model of Lucas (1972), in which firms extrapolate an aggregate value for aggregate inflation from a local signal observed along the supply chain. Our findings are consistent with empirical facts at the core of models with different types of information rigidities, such as a high dispersion in inflation expectations and inattention to macroeconomic developments. Since firms do not necessarily observe the same conditions along their supply chains, using input price inflation to forecast CPI inflation can result in more dispersed expectations. At the same time, given that supply chain inflation is volatile, firms may just allocate most of their attention to analyze the idiosyncratic shocks which are more immediately relevant to their businesses.

Combining these results with the ones showing that firms set sales prices consistent with their expectations of CPI inflation allow us to draw some key insights. Since firms set their inflation expectations according to price changes observed along the supply chain and these differ across firms, the channel we highlight in this paper can lead to dispersion in inflation expectations, which is a metric of anchoring of inflation expectations. In turn, forecast disagreement can translate into welfare-costly price dispersion. Finally, the sort of information frictions we highlight in this paper weaken the effectiveness of the expectation channel of policies. In this sense, improvements in central bank communication aimed at reducing firms' inattention are key to dampen the undesirable effects of information frictions and preserve the transmission of policies via the expectation channel.

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Appendix

A Descriptive statistics

Table A.1 reports the descriptive statistics for all variables used in the analysis. Figure A.1 shows the distribution for our measures of supply chain inflation, inflation expectations, and CPI inflation. Figure A.2 reports the distribution of the ratio of imports to total purchases, computed as the sum of imports and domestic purchases.

Table A.1: Descriptive statistics

	Obs	Mean	St. dev.	Min	Max
Firm-level variables					
Inflation expectations	19,163	3.4	0.9	-5.8	15.0
Input price inflation	48,349	14.1	23.8	-30.0	100.0
Sales price inflation	37,540	7.8	17.5	-30.0	100.0
Import price inflation	25,187	6.8	20.1	-30.0	100.0
Export price inflation	10,638	6.5	19.7	-30.0	100.0
Weighted avg. input-import price inflation	50,244	10.7	20.9	-30.0	100.0
Weighted avg. sales-export price inflation	37,780	7.5	17.3	-30.0	100.0
Real marginal cost	41,335	0.2	2.3	-18.8	23.3
Real marginal cost including trade	43,274	0.4	2.1	-16.8	20.0
Sales growth	44,825	5.6	26.5	-50.0	100.0
Country-level variables					
CPI inflation	81	3.1	0.9	1.4	5.2
GDP growth	81	1.8	5.8	-15.4	16.6

B Signal extraction problem

Assume that there are N islands with a firm in each of them that charges p_i, so that aggregate prices would then be $p_t = 1/N \sum_i^N p_{i,t}$. Firms are willing to increase output if their own price is higher than aggregate price

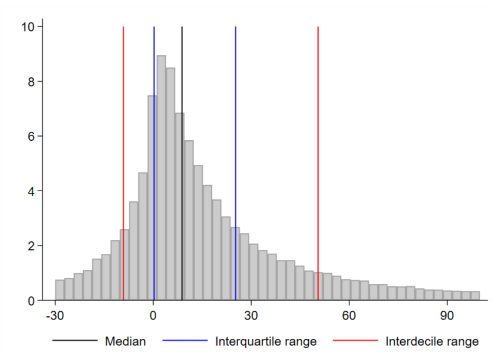
$$y_{i,t} = \gamma(p_{i,t} - p_t)$$

Under imperfect information firms know their price $p_{i,t}$, but they do not know the aggregate price p_t, so they need to make a guess $E(p_t|I_{i,t-1})$. In these conditions, the supply curve becomes

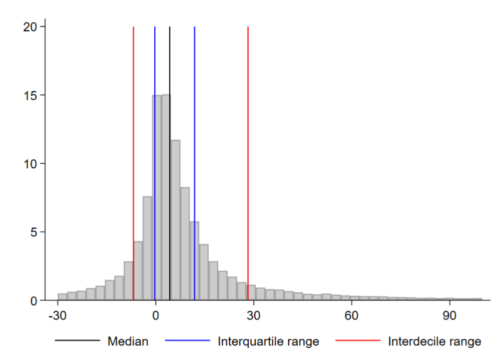
$$y_{i,t} = \gamma(p_{i,t} - E(p_t|I_{i,t-1}))$$

Figure A.1: Distribution of key variables
(Percent)

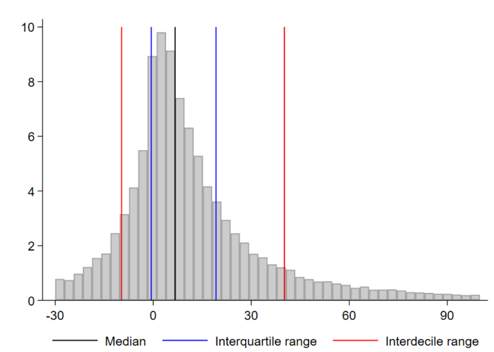
(a) Input price inflation



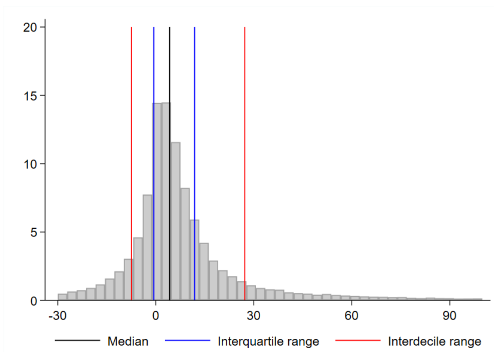
(b) Sales price inflation



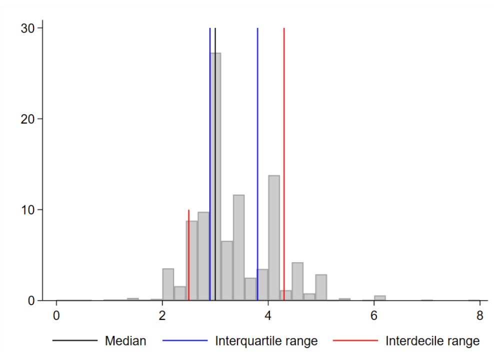
(c) Domestic and imported input price inflation



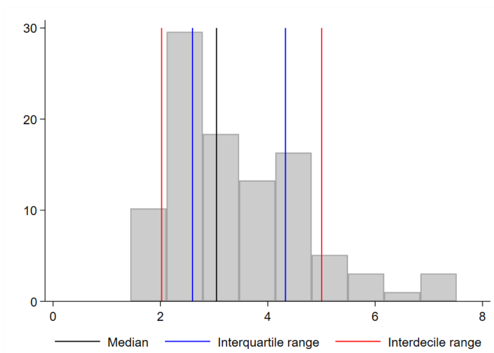
(d) Domestic and export sales price inflation



(e) Inflation expectations

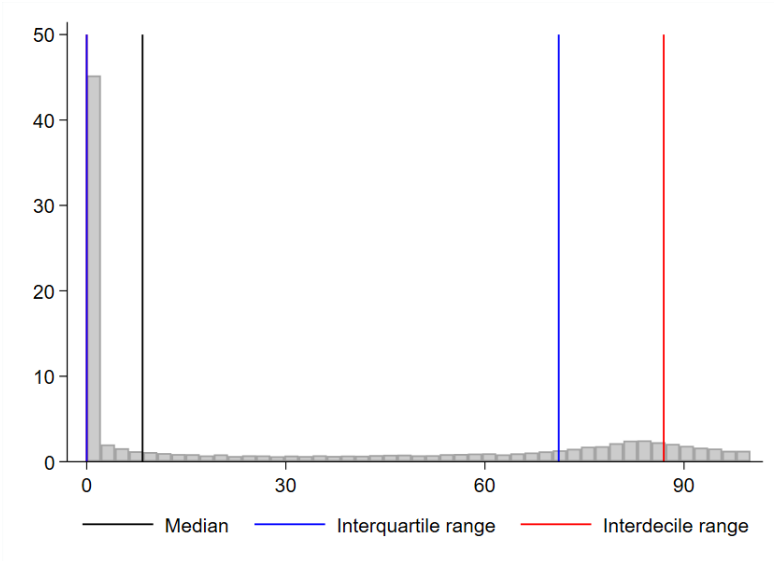


(f) CPI inflation



Notes: The histograms in panels A.1a to A.1e use data at the firm-month level. The histogram for CPI inflation in panel A.1f uses data at the month level.

Figure A.2: Distribution of import share in total purchases
(Percent)



Notes: The share of imports is computed as the ratio of imports to the sum of imports and domestic purchases.

How do firms form their beliefs about aggregate inflation? Under rational expectations $p_t = E(p_t|I_{i,t-1}) + \epsilon$ with $\epsilon_t \sim N(0,\sigma)$ and the islands' prices would differ randomly from aggregate $p_{i,t} = p_t + z_t$ with $z \sim (0,\tau)$. Thus, if firms had perfect information, their production decision would simply be $y_{i,t} = z_t$; with imperfect information, this would change to $y_{i,t} = z_t + \epsilon_t$. Firms then need to assess how much of the composite shock is due to z_t and to ϵ_t, and change output only in response to z_t. As a proportion of composite shock is coming from z, $\theta = \tau^2/(\sigma^2 + \tau^2)$, they can infer it from the past.

Since $p_{i,t} = p_t + z_t$, they need to guess aggregate prices to decide production

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

which in first differences delivers the following expression

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

Thus, firms use the prices they observe in the trade with other islands to form their views about future aggregate inflation.

C Regression results

Table C.1 reports the results for the baseline specification in equation (1), where supply chain inflation is measured with input price inflation. Table C.2 replaces input price inflation with domestic and imported input price inflation. All other results are available upon request.

Table C.1: Baseline results for input price inflation

	(1) $h=0$	(2) $h=4$	(3) $h=8$	(4) $h=12$	(5) $h=16$	(6) $h=20$	(7) $h=24$
Lag of change in inflation expectations	-0.468***	-0.524***	-0.512***	-0.479***	-0.571***	-0.520***	-0.303***
	(0.038)	(0.036)	(0.057)	(0.082)	(0.063)	(0.052)	(0.068)
Lag 2 of change in inflation expectations	-0.202***	-0.277***	-0.268***	-0.231***	-0.319***	-0.215***	-0.034
	(0.030)	(0.034)	(0.066)	(0.076)	(0.061)	(0.056)	(0.081)
Lag of input price inflation	0.000	0.002***	0.002***	0.002**	0.000	0.001	0.000
	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Lag 2 of input price inflation	0.000	0.002***	0.001*	0.001	0.001	0.001	0.001
	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Lag of CPI inflation	0.147***	0.415***	0.272	0.370	0.225	0.388	0.274
	(0.050)	(0.146)	(0.181)	(0.226)	(0.180)	(0.244)	(0.289)
Lag 2 of CPI inflation	-0.099**	-0.413***	-0.422**	-0.673***	-0.640***	-0.844***	-0.954***
	(0.047)	(0.147)	(0.174)	(0.220)	(0.189)	(0.225)	(0.279)
Lag of sales growth	-0.000	0.001	0.001	0.000	0.001	-0.000	0.000
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Lag 2 of sales growth	0.000*	0.000	-0.000	0.002	-0.001	0.000	-0.000
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Lag of real GDP growth	0.012	0.053***	0.085***	0.042	-0.062***	-0.126***	-0.141
	(0.007)	(0.012)	(0.023)	(0.042)	(0.015)	(0.021)	(0.130)
Lag 2 of real GDP growth	-0.000	0.008	-0.044*	-0.088*	-0.069***	0.001	0.057
	(0.008)	(0.015)	(0.024)	(0.048)	(0.021)	(0.033)	(0.143)
Firms	340	312	305	283	261	241	229
Observations	7,812	7,383	6,775	6,163	5,666	5,163	4,688
R-squared	0.262	0.354	0.272	0.303	0.515	0.440	0.439

Notes: For space reasons, this table reports the results for the contemporaneous effect and the effect at the end of each quarter. All regressions include firm fixed effects. Clustered standard errors at the firm and time level in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table C.2: Baseline results for the weighted average of input and import price inflation

	(1) $h = 0$	(2) $h = 4$	(3) $h = 8$	(4) $h = 12$	(5) $h = 16$	(6) $h = 20$	(7) $h = 24$
Lag of change in inflation expectations	-0.469***	-0.525***	-0.513***	-0.481***	-0.571***	-0.520***	-0.303***
	(0.038)	(0.036)	(0.057)	(0.082)	(0.063)	(0.052)	(0.068)
Lag 2 of change in inflation expectations	-0.202***	-0.276***	-0.268***	-0.231***	-0.320***	-0.215***	-0.033
	(0.030)	(0.035)	(0.067)	(0.076)	(0.061)	(0.056)	(0.081)
Lag of input and import price inflation	0.000	0.002***	0.001**	0.002***	0.001*	0.001*	0.001
	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
Lag 2 of input and import price inflation	0.001**	0.001**	0.001**	0.001**	0.001	0.001	0.000
	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
Lag of CPI inflation	0.146***	0.413***	0.271	0.365	0.221	0.384	0.272
	(0.050)	(0.146)	(0.181)	(0.225)	(0.179)	(0.243)	(0.289)
Lag 2 of CPI inflation	-0.098**	-0.411***	-0.421**	-0.668***	-0.637***	-0.841***	-0.952***
	(0.047)	(0.147)	(0.174)	(0.220)	(0.188)	(0.225)	(0.279)
Lag of sales growth	-0.000	0.001	0.001	0.000	0.001	-0.000	0.000
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Lag 2 of sales growth	0.000*	0.000	-0.000	0.002	-0.001	0.000	-0.000
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Lag of real GDP growth	0.012	0.053***	0.085***	0.042	-0.061***	-0.125***	-0.141
	(0.007)	(0.012)	(0.023)	(0.042)	(0.015)	(0.021)	(0.131)
Lag 2 of real GDP growth	-0.000	0.009	-0.044*	-0.087*	-0.069***	0.001	0.057
	(0.008)	(0.015)	(0.024)	(0.048)	(0.021)	(0.033)	(0.143)
Firms	340	312	305	283	261	241	229
Observations	7,812	7,383	6,775	6,163	5,666	5,163	4,688
R-squared	0.263	0.353	0.271	0.303	0.515	0.441	0.439

Notes: For space reasons, this table reports the results for at horizon zero and at the end of each quarter. Input and import price inflation is computed as the weighted average where the weights are the respective shares in total purchases. All regressions include firm fixed effects. Clustered standard errors at the firm and time level in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.