Inflation Expectations and the Supply Chain*

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This draft: May 2022

Abstract

We show that firms rely on price changes observed along their supply chain to form beliefs about aggregate inflation. Leveraging a unique dataset merging expectation surveys and records from the VAT registry and customs for Chilean firms, we find that prices at which transactions with suppliers are settled are key inputs to predict inflation in the economy, even if they do not determine the inflation outcome. We then show that firms' expectations about inflation inform for their price setting decisions. Our results reject the full-information rational-expectation hypothesis for which firms should ignore shocks with no relevance for aggregate inflation. Instead, they are consistent with some well-known facts such as firm disagreement about future inflation and inattention to macroeconomic news, which we document for Chile. The channel we highlight in this paper can throw monetary policy off its optimal path and cause de-anchoring of expectations and price dispersion.

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

JEL Codes: E30, E31

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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, its Executive Board, or its management. Officials of the Central Bank of Chile processed the disaggregated data from the Internal Revenue Service. We thank Héctor Álvarez for the excellent research assistance. We are also grateful to Olivier Coibion, Gita Gopinath, Jose Mota, Damiano Sandri, and participants to IMF seminars for comments and suggestions.

1 Introduction

How firms form expectations about inflation is crucial to many aspects of policymaking. *In primis*, it is relevant to monetary policy, which targets aggregates—prices and employment—that depend on firms' expectations and decisions. Unfortunately, as Bernanke (2007) puts it: "Information on the price expectations of businesses who are, after all, the price setters (...) is particularly scarce". The scant evidence from surveys of firms reveals substantially different facts compared to surveys of professional forecasters or households, which makes them a poor substitute for surveys of firms.[1] While it is widely acknowledged that information frictions are pervasive and that they hamper firms' ability to collect and process the data to forecast inflation, our understanding of what factors firms rely upon to form their beliefs remains limited.

In this paper, we explore whether firms use price changes observed along the supply chain to form their views about future inflation, and if such beliefs affect their price setting behavior. To do that, we leverage a unique dataset merging confidential information from the expectation survey of Chilean firms and administrative records of prices and quantities transacted from the VAT registry and customs. Our main result—which is new in the literature—is that firms use changes in input prices observed in the transactions with the suppliers to form their expectations about aggregate inflation, even if these do not predict aggregate inflation either contemporaneously nor in the future. We estimate that a one standard deviation increase in supply chain inflation leads firms to revise upward their aggregate inflation expectations by 0.5 percentage point, a magnitude similar to the one estimated for a same-size-shock in aggregate inflation.

After establishing that firms form their expectations about aggregate inflation based on the transactions with their suppliers, we test if in fact they set their prices according to these beliefs. We answer this question by estimating a Phillips Curve at the firm level. To the best of our knowledge, estimations of the Phillips curve at the firm level are virtually non-existent in the literature, in part because of data limitations.[2] Relying on sales price inflation obtained from the VAT registry together with the expectation data and income statement information, we find that firms' inflation expectations are a critical factor shaping their pricing decisions.

[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.

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

We argue that these findings are supportive of the "island model" of Lucas (1972), in which firms operate as if they were located on different islands and learn from a subset of islands they have trade with. That is, firms extrapolate an aggregate value for future inflation from an *unrelated* local signal, and use that to price their products and services. In absence of information frictions firms would disregard shocks with no aggregate relevance, instead our findings indicate that firms do not ignore them. Thus, our results reject the full-information rational-expectation hypothesis, and we corroborate this conclusion showing that firms systematically underpredict aggregate inflation.

Our results are also consistent with a series of well-known facts such as firms' disagreement about next year's inflation and the inattention to macroeconomic news that matter to predict inflation (Coibion, Gorodnichenko and Kumar, 2018; Candia, Coibion and Gorodnichenko, 2022), which we document for Chile.[3] As firms produce and sell different goods and services, input price inflation can vary at different points of the supply chain. 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 their inputs from other suppliers. We show in fact that supply-chain inflation displays significant dispersion across firms. Thus, if firms form their beliefs according to the heterogeneous prices set by their suppliers, dispersion in supply chain inflation gets reflected in inflation forecast disagreement. Also, the volatility of supply chain inflation and the costs associated to process macroeconomic news can lead to inattention to economy-wide developments. In fact, firms may just allocate their attention to idiosyncratic shocks which are more immediately relevant to their businesses and to which are inevitably exposed.[4]

These findings have policy implications in a number of areas. As firms form their beliefs based on local conditions which do not have aggregate implications, monetary policy can be thrown off its optimal path by reacting to changes in inflation expectations that are not leading to any actual change in inflation. Also, when firms set their inflation expectations according to the price conditions observed along the supply chain and these are different across firms, the channel we highlight in this paper can potentially lead to de-anchoring of inflation expectations.[5] This is particularly relevant in the post-COVID-

[3]Many survey-based studies use data on advanced economies with a history of low and stable inflation. One of the advantages of focusing on an emerging market is that inflation was generally higher and more volatile, making firms more attentive to it (Cavallo, Cruces and Perez-Truglia, 2017; Candia, Coibion and Gorodnichenko, 2021, 2022; Fuster and Zafar, 2022).

[4]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).

[5]The literature defines inflation expectation anchoring in a number of ways. These include the deviation

19 recovery, in which a mix of a gradual—and at times reversed—re-opening and strong demand generated bottlenecks in the supply chains. Finally, as firms act on the basis of their beliefs by setting their prices accordingly, forecast disagreement can translate into welfare-costly price dispersion.

This paper contributes to the literature documenting information frictions in the inflation expectations formation mechanism, highlighting a new channel through firms form their beliefs about aggregate inflation, namely the supply chain. The closest paper to ours is Andrade et al. (2022), where firms learn from inflation observed in the industry to which they belong. We find some evidence of that in Chile and a much stronger one for firms learning with firms they trade with. This is, after all, consistent with the notion that firms actually 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.

The literature on firms learning from observed prices (often referred to as salient) is limited, largely owing to data limitations. Born et al. (2021) show that German firms overreact to firm-specific developments and underreact to macroeconomic news. More evidence is available at the individual level. 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. Also, Coibion and Gorodnichenko (2015*b*) show that gasoline prices have an impact for inflation expectations. Kuchler and Zafar (2019) show that individuals extrapolate from counties' house-price changes to expectations about the real estate sector in the US economy. Compared to the literature based on household surveys, we argue that our results have a more direct relationship with monetary policy as, in the end, firms are the actual price setters in the economy.

The paper is also related to other strands of literature. In showing that firms respond to idiosyncratic shocks that have no aggregate consequences, it contributes to the literature showing violations of the full-information rational-expectations hypothesis (Coibion and Gorodnichenko, 2012, 2015*a*; Bordalo et al., 2020). Also, it relates to the literature on rational inattention, which shows that firms devote resources to process volatile

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 and Ramos-Francia, 2010; Dovern, Fritsche and Slacalek, 2012; Demertzis, Marcellino and Viegi, 2012). Our argument builds on the latter definition, for which inflation expectations should be close to each other to be well-anchored.

information that is more relevant for them (Mackowiak and Wiederholt, 2009; Pasten and Schoenle, 2016). Finally, it relates to the granularity hypothesis pushed forward by Gabaix (2011) for which idiosyncratic shocks can lead to aggregate consequences.

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, highlighting disagreement and inattention to macroeconomic news; and discusses their relationship with supply chain inflation. Section 4 presents the empirical results about the impact of supply chain inflation on aggregate inflation expectations, along with a series of robustness tests. 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. Following the end of the commodity supercycle and due to subdued aggregate demand, inflation fell from an average of 4.3 percent in 2015 to less than 2 percent in 2017. As aggregate 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 outset of COVID-19 pandemic. Stimulus policies to support aggregate demand and lockdown measures to fight the pandemic generated supply bottlenecks, which led inflation to spike in the last months of 2020 and in early 2021 to over 5 percent. This variation provides an ideal setting to study the expectation formation mechanism.

For the purpose of the analysis we combine confidential datasets from different sources. The first one is the expectation survey (*Índice Mensual de Confianza Empresarial*) run by the Central Bank of Chile, which is sent to an average of about 600 firms each month. Of these, two thirds answer the questions. The survey has been sent to firms since December 2004 and reached a total of 1,526 firms across waves and questions. It targets all large firms and randomly selected smaller firms, representing 35.5 percent of sales on average. Firms that answer the survey operate in four broad sectors: manufacturing, retail, construction, and mining.

The expectation survey asks a total of 18 questions. Of these, 16 are qualitative and two are quantitative; seven questions are about the current situation and 11 are about the future. However, the number of questions varies across sectors. The question we focus on in this paper elicits firms' expectations about aggregate CPI inflation expectations, and specifically asks: "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 on the universe of Chilean firms from the VAT registry maintained by the Internal Revenue Service.[6] From the invoices, we retrieve information about which firms are transacting, what goods and services, 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.[7] In what follows, we use the term product even 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.[8]

The third dataset includes firm-level information for the universe of Chilean firms that file for the income tax at the Internal Revenue Service.[9] From this dataset we collect monthly data on revenue and expenditures related to the purchase of materials. In addition, we retrieve the wage bill of the firms from the administrative records of the Social Security Treasury. Employers in fact submit information about their employees' wages to calculate the social security contributions and related withholding taxes.

Finally, we obtain 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.[10]

2.1 Supply chain inflation

We construct a firm-level index of input price inflation as follows. From the electronic invoices, we collect prices and quantities for each product j purchased by firm i during period t, p_{ijt} and q_{ijt}. 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

[6] 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.

[7] 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.

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

[9] The information is collected from form F29 (*Declaración Mensual y Pago Simultáneo de Impuestos*).

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

less than 10 Chilean pesos, $p_{ijt} \leq 10$; and (c) the purchased quantity is zero or negative, $q_{ijt} \leq 0$. Then, for each product purchased by each firm, we 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 limit extreme volatility in the indicator by trimming observations that lie outside of the $[-30, 100]$ percent change band.[11]

We also construct a firm-level index of sales price inflation following the same methodology that we employed for input price inflation. One should note, however, that the indicator of sales price inflation reflects price changes of business-to-business transactions. As we draw from the VAT registry to compute this indicator, business-to-consumer transactions are excluded from the calculation.

To summarize, our indicators of supply chain inflation consist of the percent change in the input costs that firms observe when they purchase inputs from their suppliers and percent change in the sales prices that firms observe when they sell their products to their customers. Figure 1 shows the cross-firm distribution over time of these indicators. A few facts stand out. First, both input and sales price inflation display significant cross-firm dispersion. Averaging the cross-sectional standard deviation over the sample period we obtain 23.6 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 with different prices, but it is consequential if firms use conditions observed along the supply chain to form their beliefs about aggregate variables. 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 -17 and 62 percent, respectively, while they are -10 and 50 percent for sales price inflation. Excluding the post-COVID-19 period during which 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 price inflation and sales price inflation right are right skewed.[12] 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

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

[12] This is also visible from the histograms in Figure A.1 of Appendix A.

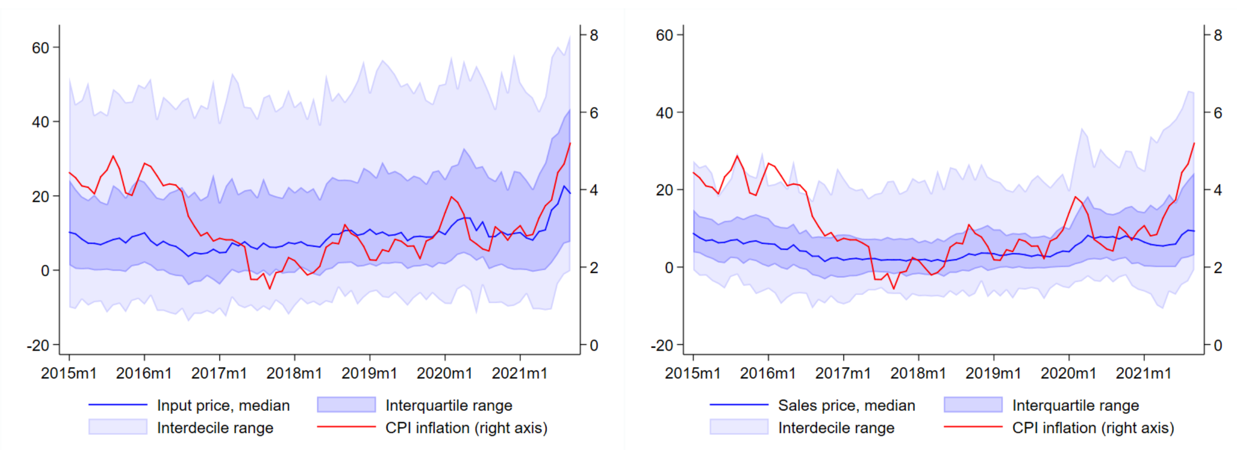
dispersion of sales price inflation, larger upside deviations remain visible.

Third, both input and sales price inflation display significant volatility over time compared to aggregate inflation. Input price inflation for the median firm hovered between 3.7 and 22.6 percent during 2015–2021, and the variable's standard deviation is 23.8 percent. Sales price inflation fluctuated slightly less, between 1.4 and 9.5 percent, and the variable's standard deviation is 17.5 percent. As a benchmark, aggregate 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 aggregate CPI inflation relatively well. The correlation coefficient for input price inflation is 35 percent and the one for sales price inflation is 69 percent, both significant at one percent significance level.[13]

Figure 1: Supply chain inflation

(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 median of the corresponding variable and the shaded areas denote the cross-firm interquartile range (dark blue) and the cross-firm interdecile range (light blue). The red line denotes actual CPI inflation.

Our indicator of input price inflation is a measure of the *domestic* price pressures that firms observe along the supply chain. However, firms involved in international trade may also experience price changes for the inputs that they purchase from *abroad* and change

[13] 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 a range of about 2 to 3 percent.

their domestic sales prices—and/or their export prices—accordingly. Most firms that answer the expectation survey have zero or a small share of imports in total purchases, but to test the robustness of our results to changes in prices of exports and imports we also construct firm-level measures of import and export price inflation.[14]

For each firm i and product j^*—where * is a superscript 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, $\pi^*_{it} = \sum_j \frac{p^*_{ijt} q^*_{ijt}}{p^*_{it} q^*_{it}} \pi^{50,*}_{ijt}$. As in the case of supply chain inflation, we drop observations outside of the $[-30, 100]$ percent change band.

With the objective of measuring the inflation pressures that the firm observes both domestically and abroad, we also produce an indicator of input price inflation that takes into account import price developments. This is a weighted average of input price inflation and import price inflation, where the weights are simply the share of domestic purchases and imports to the sum of the two. Analogously, we compute the weighted average of sales price inflation and export price inflation.

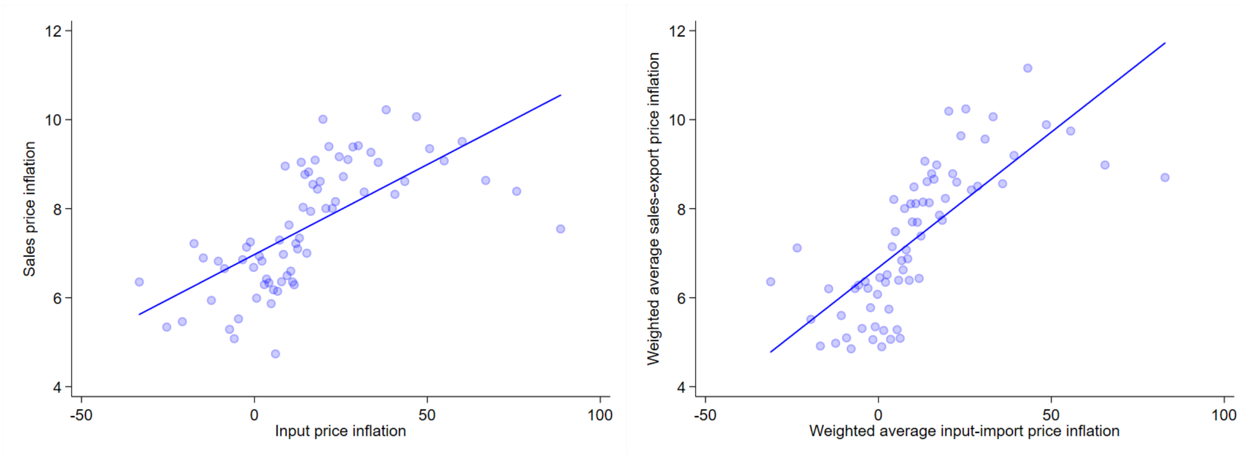
Figure 2 reports two binned scatter plots that illustrate the correlation between the domestic measures of supply chain inflation and the correlation between the measures that account for international trade. Panel 2a shows input price inflation and sales price inflation are positively, albeit weakly, 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. This heterogeneity in the pass-through likely reflects strategic considerations of firms that may take advantage of input price declines to boost their profits while absorbing large increases in input costs to maintain their customer base. Panel 2b conveys a similar message, with the weighted average of input and import price inflation being positively correlated with the weighted average of sales and export price inflation.

Finally, for the estimation of the Phillips Curve at the firm level, we compute firms' real marginal costs. We approximate these as the log of the ratio of firms' costs and sales, $\psi_{i,t} = ln(costs_{i,t}/sales_{i,t})$. Even in this case, we produce two alternative versions of the real marginal costs. The first uses exclusively domestic variables, so that $costs_{i,t}$ is simply the sum of domestic purchases and the wage bill and $sales_{i,t}$ denotes domestic sales. The

[14] As shown in Figure A.2 of Appendix A, 45 percent of the firms in the sample only purchase domestically.

Figure 2: Correlation between input price inflation and sales price inflation

(a) Domestic measures (b) Measures including international trade



Notes: Each dot represents the cross-firm average at any given time of input cost inflation and sales price inflation in panel 2a, and the weighted average of input and import price inflation and the weighted average of sales and export price inflation in panel 2b. The line denotes the linear fit. Data is residualized with respect to firm fixed effects.

second takes into account international trade by including imports in $costs_{i,t}$ and exports in $sales_{i,t}$.[15]

3 Disagreement, inattention, and the supply chain

In this section we present a few key facts about firms' expectations of aggregate inflation. First, we document that firms have substantially different views about next year's CPI inflation. Figure 3a 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 the target. During the sample period, the interdecile range is larger than 2 percentage points in a few instances and collapses to about 0.5 percentage points when inflation approaches the target.

The distribution of inflation expectations appears symmetric, except in a few instances. When it turns asymmetric, the right tail of the inflation expectation distribution is longer than the left one, even when inflation is below the target. However, Chilean firms do not appear to systematically predict inflation above observed inflation (an issue we will come back in Section 4).[16] Figure 3b indicates that firms' predictions in fact

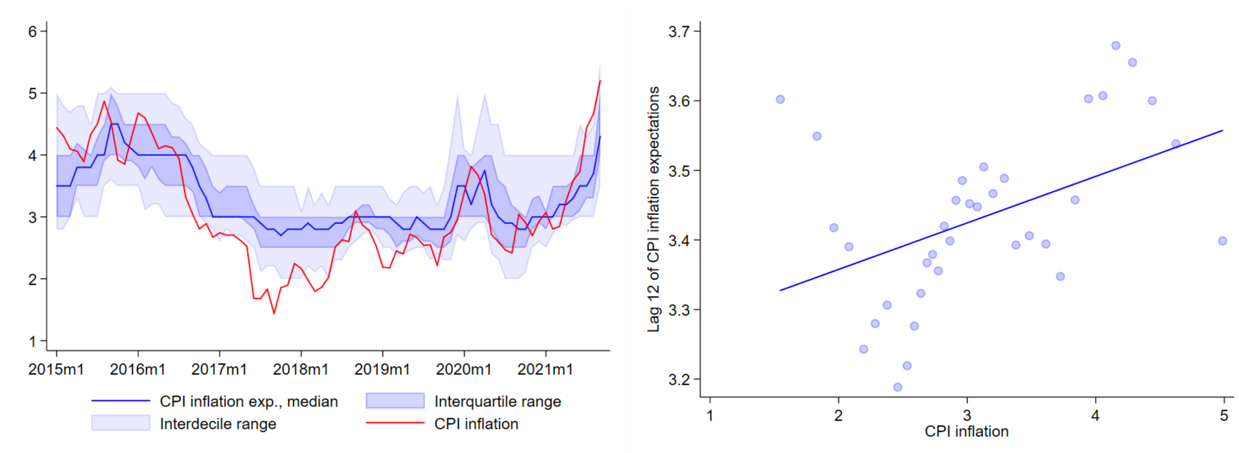
[15]Table A.1 in Appendix A reports the descriptive statistics for all variables used in the analysis.
[16]Coibion, Gorodnichenko and Kumar (2018) find that disagreement is large across firms in New Zealand

correlate with the inflation outcome.

Figure 3: Firms' disagreement about aggregate inflation

(a) Inflation expectation dispersion

(b) Inflation and firms' expectations



Notes: In panel 3a, the blue line denotes the median of firms' expectations about aggregate 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 actual CPI inflation. In panel 3b, each represents the cross-firm average at any given time of the twelfth lag of firms' expectations against actual CPI inflation, and the line denotes the linear fit. Data is residualized with respect to firm fixed effects.

We then examine whether firms are inattentive to macroeconomic developments. To do that, we compute the share of firm-month observations that display a change in expectations in response to a change in CPI inflation larger than half of its standard deviation. 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. Such swings, in fact, should lead firms to pay more attention to recent price developments.

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 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 in-

and that they generally predict a higher level of inflation compared to the observed one.

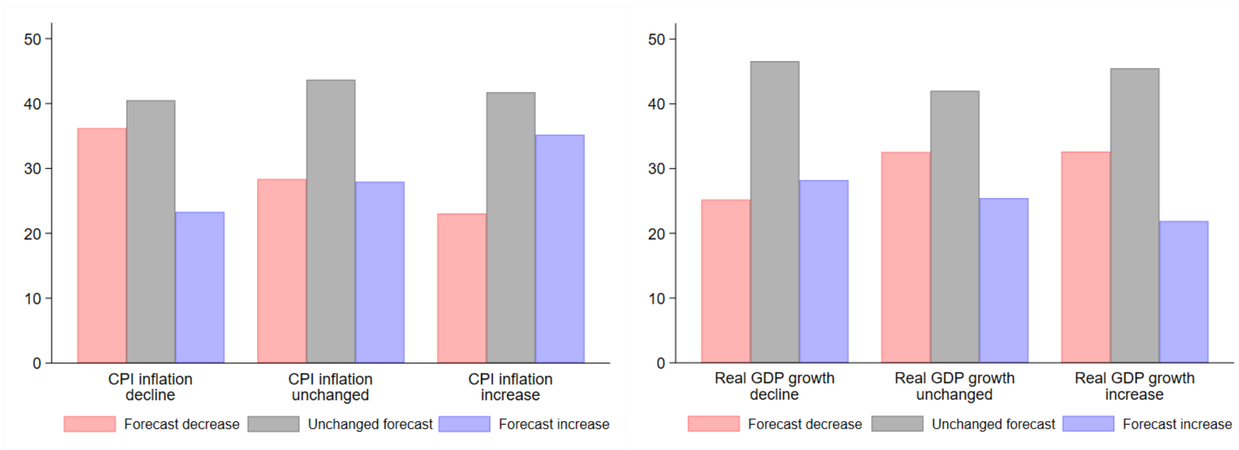
flation observed in the previous month, suggesting that other factors could potentially influence the way in which firms form their views.

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.

Figure 4: Inattention to macroeconomic developments

(a) Changes in CPI inflation

(b) 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 in the relevant variable is defined as a variation larger than half of its standard deviation; the gray bars denote the share of firm-month observations that report unchanged inflation expectations.

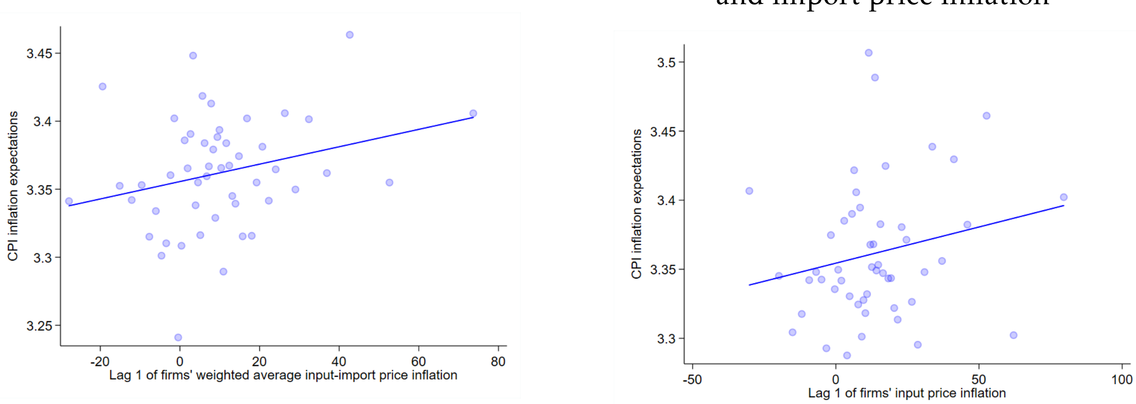
It is well documented that forecast disagreement and inattention are related and can arise both in a noisy information setting (Sims, 2003) and in a sticky information one (Mankiw and Reis, 2002). While we do not point to any specific source of information rigidity, we posit that there exist information frictions such that firms observe prices 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 some 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 of firms they trade with, which are not necessarily the same across firms and that do not have an aggregate effect. This, in turn would lead firms to be inattentive to inflation developments because they 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 aggregate expectations. The binned scatter plots in panels 5a and 5b depict a positive association between the previous month value of input price inflation and sales price inflation, respectively, and firms' aggregate inflation expectations. In the next section, we investigate this relationship further.

Figure 5: Supply chain inflation and inflation expectations

(a) Input price inflation

(b) Weighted average of input and import price inflation



Notes: Panel 5a presents a binned scatter plot in which each dot represents the cross-firm average at any given time of input price inflation and firms' aggregate inflation expectations, and the line denotes the linear fit. Panel 5b presents the same binned scatter plot replacing input price inflation with the weighted average of input and import price inflation. In both panels, data is residualized with respect to firm fixed effects.

4 Supply chain inflation and aggregate inflation expectations

The goal of this section is to empirically uncover the role of the supply chain in the expectation formation mechanism adopted by firms when they try to predict aggregate inflation. To do that, we estimate a reduced-form specification in the spirit of Andrade et al.

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

(2022)

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

where the dependent variable is the cumulative change in firm's i beliefs about next year's aggregate inflation in month $t+h$, with $h =, \ldots, 24$, with respect to its views as of the last month. The independent variables include two lags of the dependent variable to account for persistence in firms' inflation expectations; two lags of the supply chain inflation measure, $\pi_{i,t-p}$, which is either input price inflation or the weighted average of input and import price inflation; two lags of aggregate CPI inflation, $\pi_{i,t-p}$; and a set of controls, $X_{i,t-p}$, which consists of 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, 19] Finally, the specification includes firm fixed effects α_i^h.[20] Time fixed effects cannot be included as they would be collinear to the country-level information we want to condition on and retrieve a coefficient for, namely CPI inflation. Standard errors are clustered at the firm and time level.[21]

The coefficient of interest is γ_p^h, which traces the cumulative responses to innovations in prices that firms observe along the supply chain. As the specification includes aggregate CPI inflation, it effectively reveals the effect of supply chain shocks that do not have aggregate implications for inflation. If firms were rational, they would discard the information coming from shocks that do not have aggregate effects when forecasting aggregate inflation, and therefore the coefficient should be statistically insignificant. Yet, in presence of information rigidities, firms may not be able distinguish between shocks that have aggregate effects and those that do not, or they may not care about aggregate shocks as much as they do for shocks that have immediate consequences for their businesses. As a result, firms would end up assigning some weight to supply chain inflation when

[18] 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 (see `https://si3.bcentral.cl/estadisticas/Principal1/metodologias/EC/IND_DIA/ficha_tecnica_UF_EN.pdf` for more details).

[19] 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.

[20] The specification is related to the one in Boivin, Giannoni and Mihov (2009), where the authors use a factor-augmented vector autoregression for a large set of macroeconomic indicators and disaggregated prices.

[21] In addition, to the extent that there are suppliers that sell to many firms, time fixed effects would absorb the variation we are interested in. Large firms with a lot of connections is a common characteristic of the production network (Bernanke, 2007; Alfaro-Urena et al., 2018; Cardoza et al., 2020), including Chile (Grigoli, Luttini and Sandri, 2021).

forecasting aggregate inflation. The other coefficient 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 the measure of input price 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' (aggregate) inflation expectations. There is, however, the possibility that some firms answering the survey have enough market power to impose prices on their suppliers. While this might be true for a few but not for many of the firms in the sample, in the robustness section we further mitigate this concern by excluding firms that have less than 25 suppliers, effectively dropping firms potentially able to set sales prices on their suppliers.

The data we rely on differs in a number of aspects from the one used by Andrade et al. (2022) to study the impact of industry inflation on aggregate inflation expectations. These differences allow for a cleaner identification of the effects we are interested in. First, the survey question about aggregate inflation expectations is a quantitative one instead of a qualitative one, which allows us to obtain a quantitative estimate for the impact of a shock in supply chain inflation on firms' expectations about aggregate inflation.

Second, rather than using the industry price indices, we rely on input price inflation indices at the firm level. A higher degree of data granularity brings about a few key advantages. If firms are "islands" as in Lucas (1972) and they only observe the prices of the firms they trade with, our measures of supply chain inflation provide more direct measures of the prices that firms actually observe at any given time. In addition, as we observe the prices at which firms purchase their inputs, the risk of not capturing well the information that firms obtain is minimized. For example, firms may be buying from (and selling to) more than one sector, especially when sectors are finely defined and/or firms have different businesses. In these cases, inflation indices at the industry level may not provide the signal that firms actually observe. Finally, input price inflation is arguably more exogenous than industry inflation, which also depends on the same firm' pricing decisions (which in turn are likely affected by their expectations of future inflation).

Third, 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 along the supply chain and the moment in which they submit the answers to the survey, thereby reducing the chances that confounding factors taking place between these two moments end up biasing the estimates.

Figure 6 shows the results of the estimations.[22] Panel 6a reports the response of firms' expectations of CPI inflation to a shock in their input price inflation, conditional on CPI inflation. The plot indicates that firms' expectations of aggregate inflation are indeed responsive to conditions observed along the supply chain even when these have no effect on aggregate inflation: a 10 percentage point increase in input price inflation leads to a 0.02 percentage point increase in inflation expectations five months after the shock. In terms of a one standard deviation shock, this effect corresponds to an increase in aggregate inflation expectations of about 0.5 percentage point. The effect dies out over a 14-month period, likely reflecting the time needed for firms to realize that these changes in input prices are not determining aggregate inflation.

In panel 6b we report the response of firms' inflation expectations to a change in CPI inflation. A one percentage point increase in actual 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 one standard deviation shock, the size of estimated increase in inflation expectations at the peak reaches 0.4 percentage points, which is comparable to the one obtained for an increase in input price inflation. This is particularly remarkable given that firms are forecasting an aggregate variable. 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 at most to materialize, the impact coming from a change in CPI inflation is shorter-lived, dying within six months. One way to rationalize such short duration is to relate it the central bank's credibility, which is believed to intervene if expectations persistently deviate from the target.

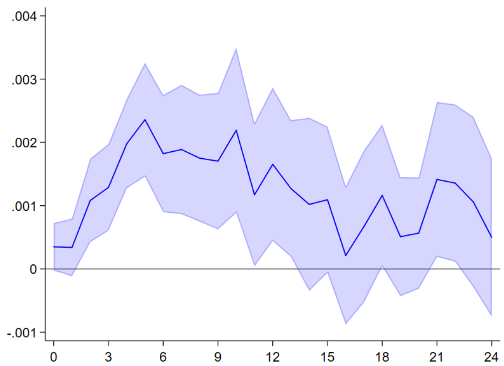
To test if the import price dynamics have the potential to alter these conclusions, we report the results for the specification that replaces input price inflation with the weighted average of input and import price inflation. The results in panels 6b and 6d resemble the ones of the domestic counterparts. However, the effect of a change in the weighted average of input and import price inflation is marginally smaller and takes more time to fade away. We conclude that our results hold even for firms that rely on international trade to source their inputs.

All in all, we interpret these results as evidence of firms confounding price variation along the supply chain with aggregate shocks. Put differently, firms attribute supply chain inflation shocks to aggregate forces, even if they do not have any aggregate consequences.

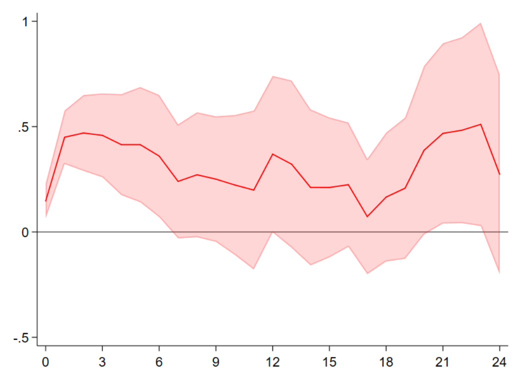
[22] Tables C.1 and C.2 of Appendix C report the results of the baseline regressions.

Figure 6: Supply chain inflation and aggregate expectations

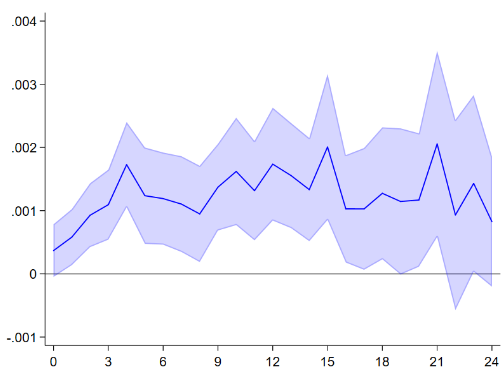
(a) 1pp increase in input price inflation



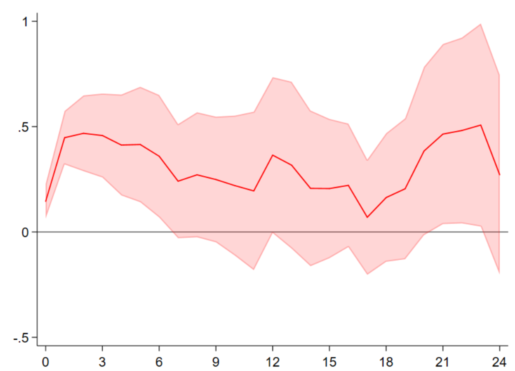
(b) 1pp increase in CPI inflation (regression with input price inflation)



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



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



Notes: The x-axes denote the number of months, 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 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

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

where $\pi_{s,t-p}$ is the inflation observed in industry s. To this end, we use a classification into 170 different industries, most of which are part of the manufacturing sector.[23]

Panel 7a of Figure 7 shows that an innovation in industry inflation leads firms to forecast higher aggregate 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 turns out to be more volatile. Also, the magnitude of the effect is somewhat larger: a 10 percentage point increase in input price inflation results in a 0.04 increase 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. Even assuming that supply chain inflation is the same as industry inflation, there remains the issue of firms operating at the intersection of different industries. For these firms, the inflation of a specific industry may turn out to be an imprecise proxy of what prices firms actually observe.

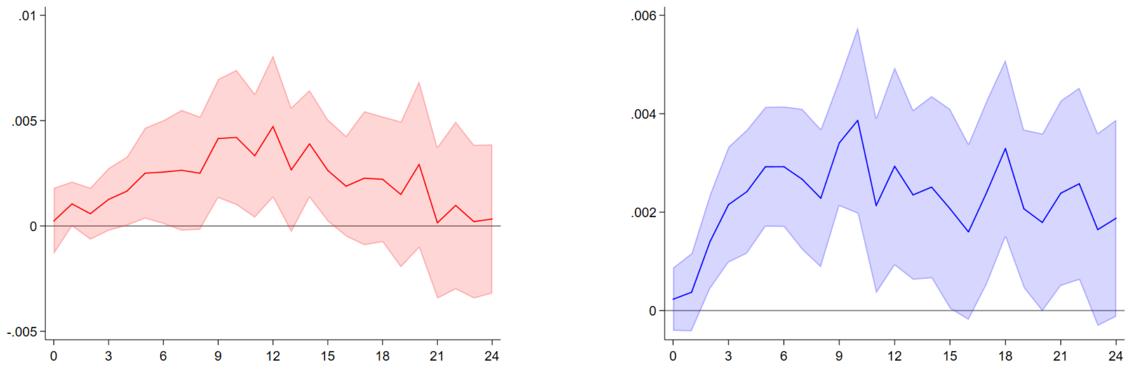
4.2 Orthogonality with respect to future inflation

We established that changes in prices along the supply chain that have no impact on aggregate inflation lead to changes in firms' inflation expectations. This result rejects the full-information rational-expectations hypothesis, which posits that shocks without aggregate consequences should leave firms' expectations about aggregates unaffected. This interpretation, however, hinges on the orthogonality of supply chain prices to aggregate inflation.

[23] We use the *Clasificador Chileno de Actividades Económicas*, which is an adaptation of CIIU Revision 4. The results are virtually unchanged when we use a less detailed classification with 42 industries.

Figure 7: Industry inflation

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



Notes: The x-axes denote the number of months, 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.

The specification in equation (1) imposes by construction that conditions observed by firms along the supply chain are *contemporaneously* orthogonal to aggregate inflation. Yet, there is the possibility that changes in firms' supply chain inflation have predicting power with respect to *future* aggregate inflation. In other words, it can be the case that firms are anticipating that a surge in supply chain prices will lead to higher aggregate inflation in the future.

To ensure orthogonality with respect to future aggregate inflation, we follow the procedure that Andrade et al. (2022) used for industry inflation applying it to supply chain inflation at the firm level. First, we run a battery of firm-by-firm regressions for all firms i to assess the non-predictability of future aggregate inflation with respect to current input inflation[24]

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

where non-predictability of future aggregate inflation would deliver a statistically insignificant $\gamma^{i,h}$ coefficient. Then, for each horizon we compute the share of firms for which supply chain inflation cannot predict aggregate inflation. And finally, we re-estimate our baseline specification in (1) excluding firms which supply chain inflation predicts future aggregate inflation.

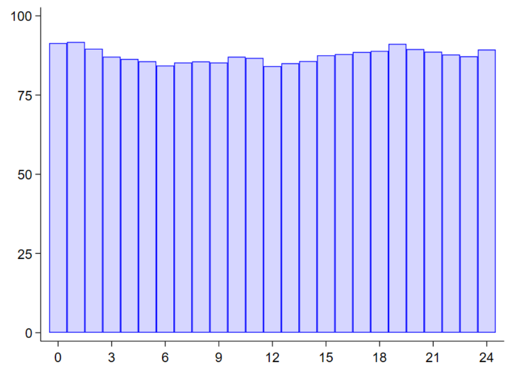
Figure 8a reports the results. At any given horizon, only a few firms present a statistically significant estimate of $\gamma^{i,h}$, already granting credibility of our baseline results. Panels 8a and 8c indicate that at least 80 percent of firms' supply chain inflation does not

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

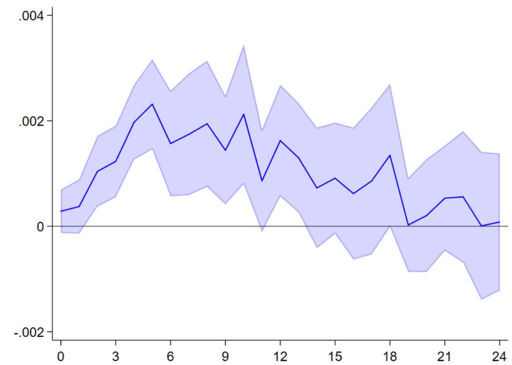
have any predictive power with respect to future aggregate inflation. Panels 8b and 8d report the results of the specification in equation (1) excluding firms for which input price inflation and the weighted average of input and import price inflation are not orthogonal to future aggregate inflation, respectively. The estimated responses are consistent to the ones obtained in our baseline set of results in Figure 6.

Figure 8: Orthogonality with respect to future aggregate inflation

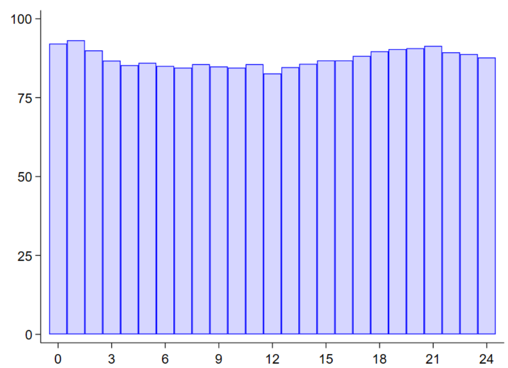
(a) Share of firms with input price inflation unrelated to future CPI inflation



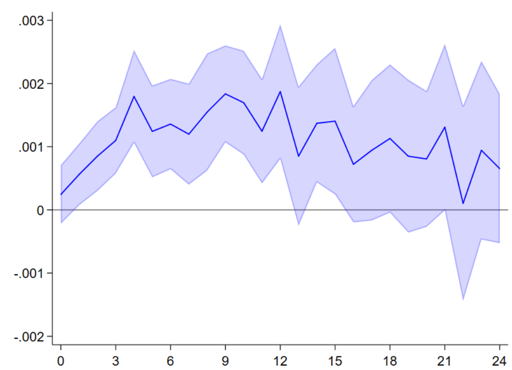
(b) 1pp increase in input price inflation



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



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



Notes: The x-axes denote the number of months. 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 A placebo test

As in Andrade et al. (2022), we perform a placebo test aimed at showing that our results are not an artifact of the empirical approach. In our case, however, the placebo test uses firm-level data rather than industry-level data. The 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

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

where by supply chain inflation we refer to input price inflation and the weighted average of input and import price inflation, alternatively. 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

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

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' aggregate inflation expectations. Figure 9 reports the point estimates. In the case of input price inflation, the results in panel 9a show that the point estimates cannot be distinguished from zero at virtually all horizons, providing further credibility to our results. In the case of the weighted average of input and import price inflation, the results in panel 9b are significant only at some horizons and the size of the coefficient is small.

4.4 Testing the full-information rational-expectations hypothesis

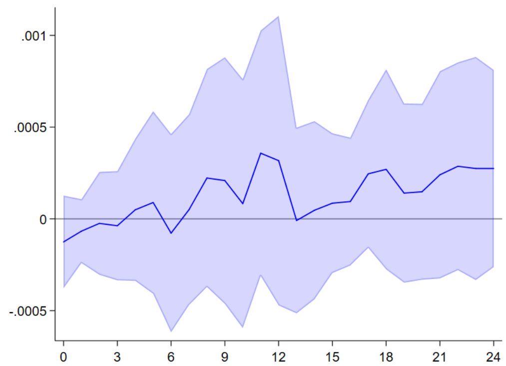
A more direct test of the full-information rational-expectations hypothesis consists in assessing whether a change in input price inflation lead to persistent forecast errors. In presence of rational inattention, for example, firms are less than fully informed about aggregate dynamics. As a result, they may consistently make predictions errors which would show up in a persistent response of the forecast error.

Thus, we estimate the following specification

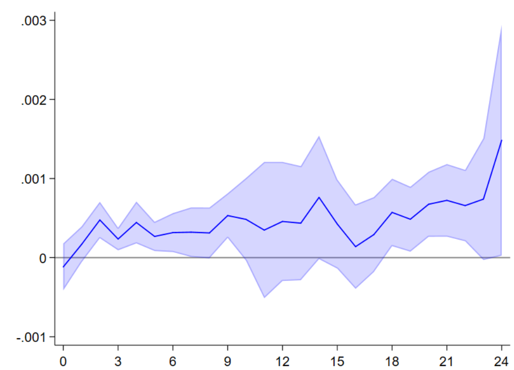
$$\pi_{t+h+12} - E_{i,t+h}\pi_{t+h+12} = \alpha_i^h + \sum_{p=1}^{P} \beta_p^h \pi_{t-p} + \sum_{p=1}^{P} \gamma_p^h \pi_{i,t-p} + \sum_{p=1}^{P} \theta_p^h X_{i,t-p} + \varepsilon_{i,t+h} \tag{6}$$

Figure 9: Placebo test

(a) 1pp increase in placebo input price inflation



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

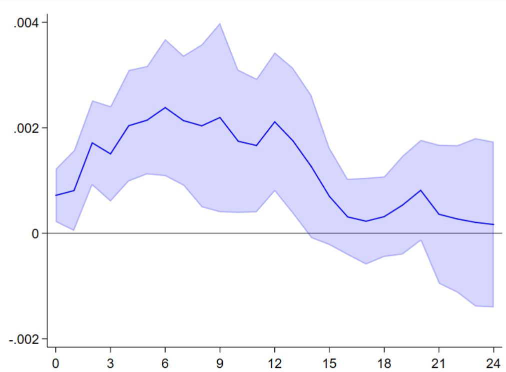


Notes: The x-axes denote the number of months, the lines denote the point estimates, and the shaded areas correspond to 90 percent confidence intervals computed with standard errors clustered at the firm and time level.

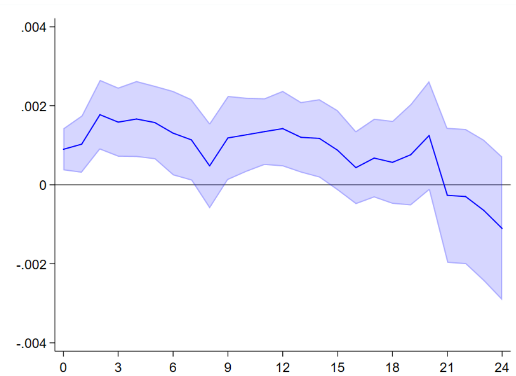
where the dependent variable is the forecast error of aggregate inflation. The results in Figure 10 show that firms systematically underpredict the inflation outcome, regardless of whether the dependent variable is input price inflation or the weighted average of input and import price inflation. This result, which is in line with the predictions of models with imperfect information, adds to the evidence showing violations of the full-information rational-expectations benchmark.

Figure 10: Test for full-information rational-expectations

(a) 1pp increase in input price inflation



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



Notes: The x-axes denote the number of months, 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.

4.5 Robustness

To ensure the robustness of our findings, we run a set of tests. In Figure 11, we only report the results of the robustness tests for an increase in input price inflation on firms' beliefs about aggregate inflation. However, results for the weighted average of input and import price inflation convey the same messages and are available upon request.

One argument jeopardizing the exogeneity of input price inflation with respect to firms' expectations of aggregate inflation is that firms may have enough market power to impose purchasing prices on suppliers based on their expectations for future inflation. We mitigate this concern by running our baseline specification in equation (1) after excluding all firms with less than 25 suppliers in any given month. The assumption is that firms with relatively suppliers are less likely to be able to impose prices on them. As shown in panel 11a, the results are similar to the baseline ones.[25]

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 11b 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 11c are consistent with the baseline ones.

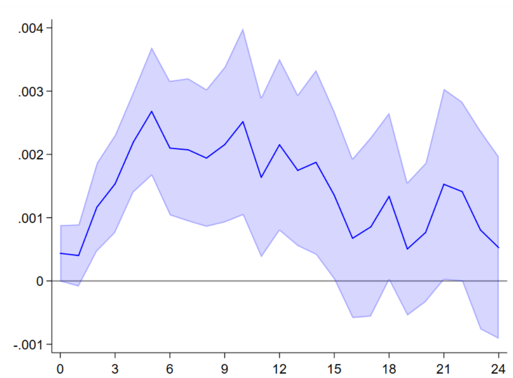
Our indicator of input price inflation may actually capture some of the price pressures that come from abroad, given that they are correlated. To isolate the impact of domestic price pressures observed along the supply chain, we control for import price inflation. The results in panel 11d corroborate 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 re-compute the standard errors following the procedure proposed by Driscoll and Kraay (1998) which corrects for cross-sectional dependence. As shown in panel 11e, 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 11f.

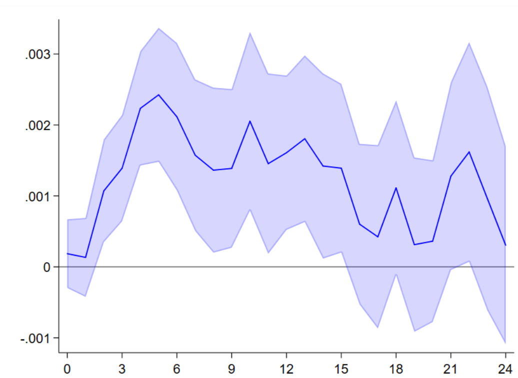
[25] Restricting the sample to firms with more than 50 suppliers does not affect the results.

Figure 11: Robustness tests

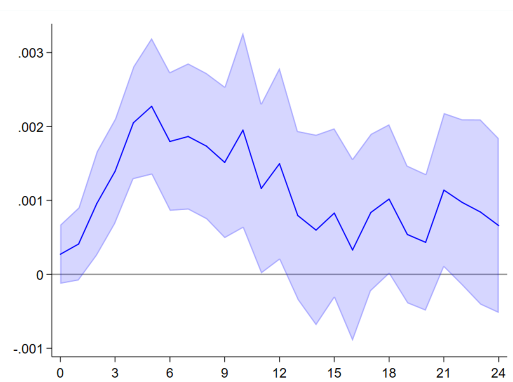
(a) At least 25 suppliers per firm



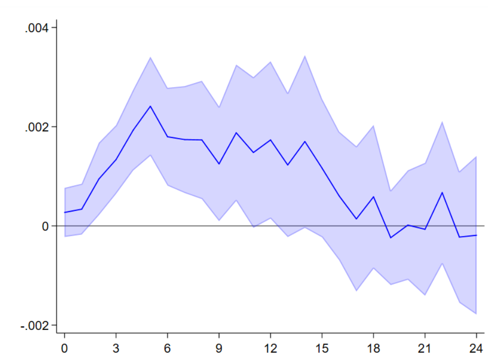
(b) More lags



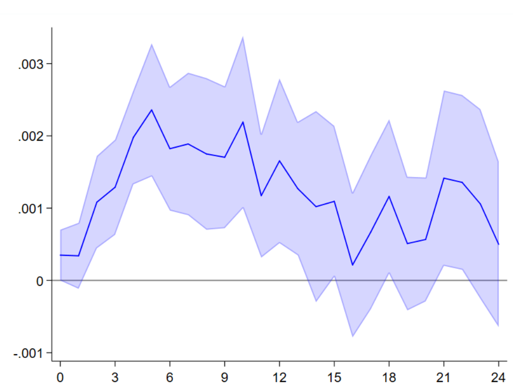
(c) No lags



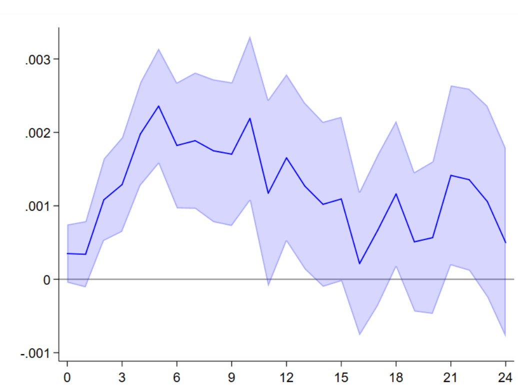
(d) Controlling for input price inflation



(e) Driscoll-Kraay standard errors



(f) Double-clustered standard errors



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

5 Price-setting behavior of firms

After establishing that firms use price changes observed along the supply chain to form their beliefs about future aggregate inflation, we now turn to examine if firms actually act on the basis of their beliefs. That is, do firms' price-setting decisions reflect their expectations about aggregate inflation?

To study the pricing decisions of firms, we derive the New Keynesian Phillips Curve (NKPC) at the firm level following Cloyne et al. (2016). This framework is characterized by nominal rigidities consisting of price adjustment costs as in Rotemberg (1982).[26] In this setting, firms maximize expected profits

$$E_{i,o}\sum_{t=0}^{\infty}\beta^{t}\left[p_{i,t}y_{i}-P_{t}\Psi_{i,t}-\frac{\gamma}{2}\left(\frac{p_{i,t}}{p_{i,t-1}}-1\right)^{2}P_{t}y_{t}\right]/P_{t} \tag{7}$$

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

$$y_{i,t}(d)=(P_{i,t}/P_{t})^{-\theta}Y_{t} \tag{8}$$

where $p_{i,t}$ and $y_{i,t}$ denote sales price and quantities of firm i at time t, respectively; P_t is the CPI and $\Psi_{i,t}$ is a measure of production costs, so that the multiplicative term represents the nominal cost of production; and $\psi_{i,t}=\delta\Psi_{i,t}/\delta y_{i,t}$ denotes the firm's marginal cost.

We can then derive the first order condition

$$y_{i,t}(1-\theta)+\psi_{i,t}\theta y_{i,t}\frac{P_{t}}{p_{i,t}}-\gamma\left(\frac{p_{i,t}}{p_{i,t-1}}-1\right)\frac{P_{t}}{p_{i,t-1}}y_{t}+\beta E_{i,t}\left[\frac{\lambda_{t+1}}{\lambda_{t}}\gamma\left(\frac{p_{i,t+1}}{p_{i,t}}-1\right)\pi_{i,t+1}\tilde{p}_{i,t+1|t}y_{t+1}\right]=0 \tag{9}$$

which we linearize to obtain the NKFP relationship

$$\pi_{i,t}=\beta E_{i,t}\pi_{i,t+1}+\frac{\theta\psi}{\gamma}\widetilde{\psi}_{i,t} \tag{10}$$

where $\widetilde{\psi}_{i,t}$ is the firm-specific real marginal cost.

5.1 Estimation

To the best of our knowledge, estimations of the Phillips curve at the firm level are virtually non-existent in the literature. This is largely because micro data on inflation ex-

[26] As pointed out by Cloyne et al. (2016), 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.

pectations 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 (as well as firm-level data on purchases of materials and the wagebill to compute firms' marginal costs) and estimate the following specification of the NKPC

$$\pi_{i,t} = \alpha_i + \beta E_{i,t}\pi_{i,t+1} + \frac{\theta\psi}{\gamma}\psi_{i,t} + u_{i,t} \tag{11}$$

where α_i are the firm fixed effects which account for unobserved cross-firm heterogeneity that is constant over time.

Before proceeding to the estimation, however, a few issues should be noted. The first issue is that we do not observe expectations of firms' price changes, $E_{i,t}\pi_{i,t+1}$. Rather, the survey question asks about aggregate inflation. However, we established in Section 4 that aggregate inflation expectations reflect, at least in part, firm-specific shocks (i.e., supply chain inflation) and our aim is really to test if firms set sales prices in line with these expectations. So, in (11), we approximate $E_{i,t}\pi_{i,t+1}$ with $E_{i,t}\pi_{t+1}$.

The second is related to the horizon of inflation expectations elicited in the survey, which is one year from the moment in which the question is asked. Treating the year-on-year changes in the variables as if they were related to monthly growth rates would in fact induce serial correlation and bias the estimates of the parameters. To address this, we aggregate temporally by summing 12 successive NKPC equations to express the current year-on-year growth rate in sales prices as a function of the expected year-on-year growth in prices

$$\pi_{i,t}^{12} = \alpha_i + \beta E_{i,t-11}\pi_{t+1}^{12} + \frac{\theta\psi}{\gamma}\psi_{i,t}^{12} + u_{i,t} \tag{12}$$

where the superscript 12 refers to the year-on-year growth rates for sales prices and inflation expectations and the sum of the monthly values for the real marginal cost.

Table 1 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 firms for which input price inflation is available (i.e., the same sample used in the estimation of the impact of input price inflation on inflation expectations). Columns (3) and (4) use the same sample as column (1) and (2), but the dependent variable is now a weighted average of domestic sales prices and export sales prices and the real marginal cost measure includes the cost of imports and the receipts from exports. The results suggest that firms do set prices according to their expectations of future aggregate inflation. Depending on the sample and the inclusion of exports and imports, the estimated coefficient indicates that a one 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. Our measure of marginal costs is borderline insignificant in all specifications.

Table 1: New Keynesian Phillips Curve Estimation Results

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

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

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 (10) featuring both firm-specific and aggregate inflation expectations.[27] 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 2 corroborate the evidence obtained so far. The coefficient on lagged sales price inflation is positive and significant, but rather small. A one percentage point increase in sales price inflation in the previous period is associated with higher 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.

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

Table 2: Hybrid Phillips Curve Estimation Results

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

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

6 Conclusions

This paper highlights a new channel through which firms form expectations about future inflation. That is, firms rely on observed price changes along the supply chain to predict aggregate inflation, even when supply chain inflation has no relevance for aggregate inflation either contemporaneously nor in the future. We also show that firms act on the basis of such expectations by pricing their sales accordingly.

Our findings are supportive of the island model of Lucas (1972), in which firms operate as if they were located on different islands and learn from a subset of islands they have some relationships with. By doing so, firms extrapolate an aggregate value for aggregate inflation from a local signal observed along the supply chain, even if such signal as no relevance for aggregate inflation.

Our results add to the evidence against the full-information-rational expectations hypothesis for which firms should disregard shocks with no aggregate consequences. These findings are instead 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. That is, since firms do not necessarily observe the same conditions along their supply chains (and these conditions are in fact dispersed), using input price inflation to forecast aggregate 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.

Finally, these findings have policy implications for monetary policy, expectation anchoring, and welfare. As firms form their beliefs based on local conditions which do not have aggregate implications, monetary policy can be thrown off its optimal path by reacting to changes in inflation expectations that are not leading to any actual change in inflation. Also, when 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 de-anchoring of inflation expectations. Finally, as firms act on the basis of their beliefs by setting their prices accordingly, forecast disagreement can translate into welfare-costly price dispersion.

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Appendix

A Descriptive statistics

Figure A.1 shows the distributions of the key variables used in the analysis and Table A.1 reports the descriptive statistics for all variables. 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

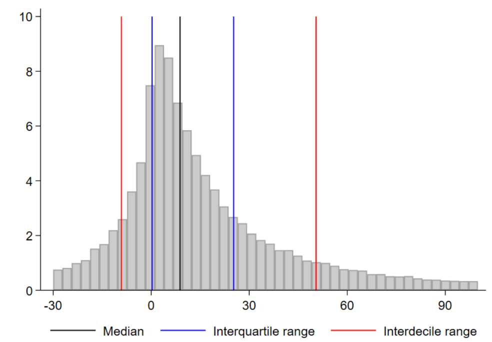
$$y_{i,t} = \gamma(p_{i,t} - p_t)$$

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

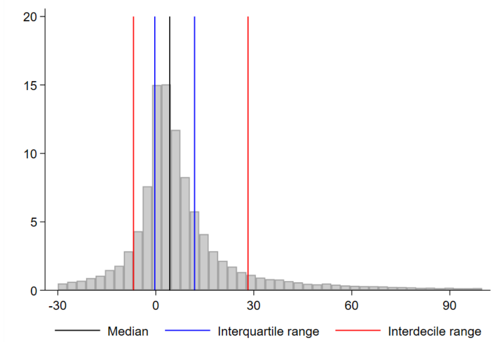
$$y_{i,t} = \gamma(p_{i,t} - E(p_t|I_{i,t-1}))$$

Figure A.1: Distribution of supply chain inflation, inflation expectations, and CPI inflation

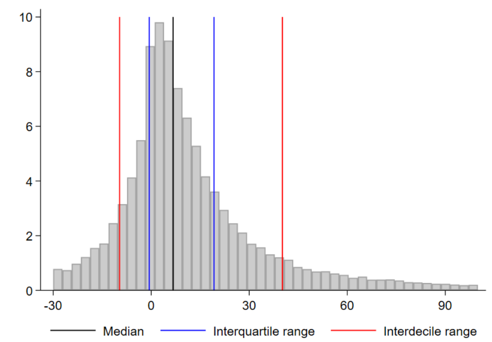
(a) Input price inflation



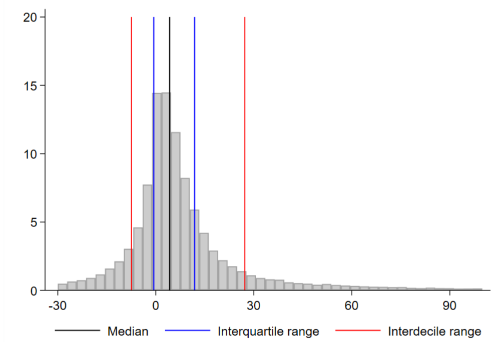
(b) Sales price inflation



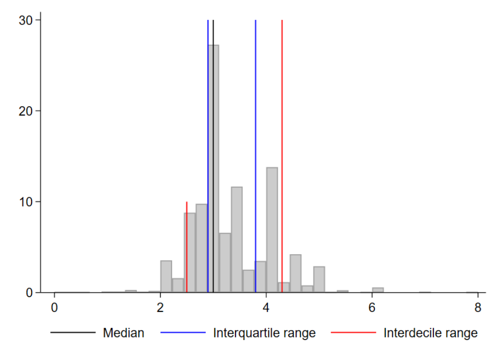
(c) Weighted average of input and import price inflation



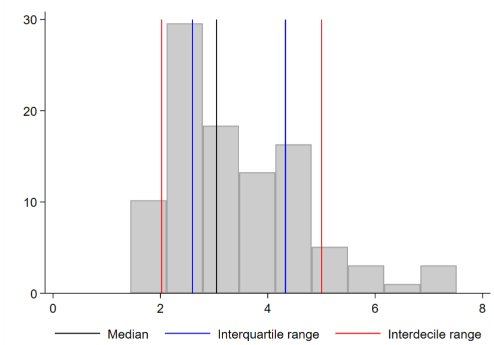
(d) Weighted average of sales and export price inflation



(e) Inflation expectations

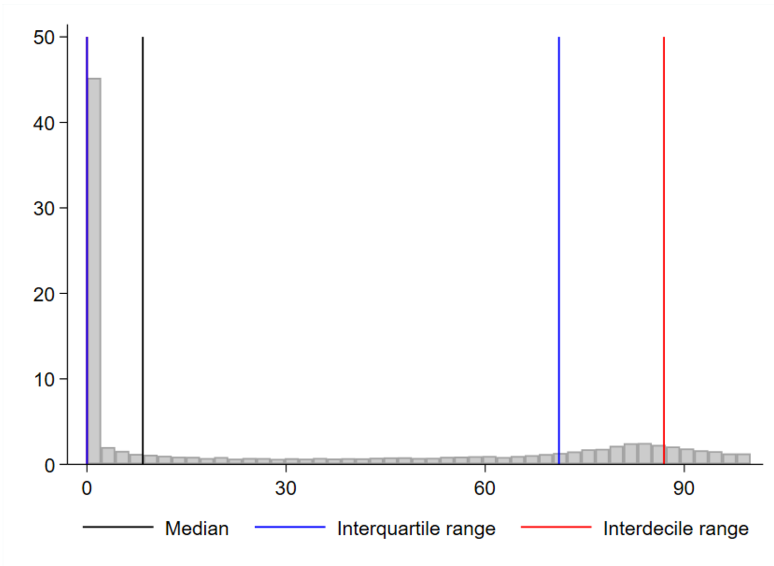


(f) CPI inflation



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



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, it 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 the weighted average of input and import 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 This table reports the results for the contemporaneous effect and the effect at the end of each quarter. All regressions include firm fiexed effects. Clustered standard errors at the 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: 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 time level in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.