Carbon Pricing and Firms' Expectations: Evidence from Italy

Giacomo Mangiante*

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Abstract

This paper examines the impact of carbon pricing on firms' expectations and decisions. By combining survey data from Italian firms with exogenous variations in the price of carbon, identified using high-frequency methods, it is shown that an increase in the carbon price raises firms' inflation expectations across various forecast horizons, from short-term (6 months ahead) to medium- and long-term (average between 36 and 60 months ahead). Similar effects are observed for firms' expected and realized price growth. Furthermore, both price forecast errors and inflation expectations disagreement among firms rise in response. These findings suggest the presence of information frictions in the firms' expectations formation process. Providing firms with information regarding the current inflation rate is found to significantly influence the pass-through of higher carbon prices to firms' expectations, indicating that central bank communication can play an important role in managing expectations during inflationary episodes. Finally, higher energy costs are perceived by firms as greatly contractionary, worsening their perceived and expected business and aggregate economic conditions. The influence on longer-term inflation expectations and the presence of information rigidities suggest that central banks, in their pursuit of price stability, should closely monitor the inflationary effects of climate policies and consider responding to them.

Keywords: Climate policies, Carbon pricing, Inflation expectations, Monetary policy, Survey data
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*Bank of Italy, Rome, Italy. Email: mangiante.giacomo@gmail.com
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1 Introduction

The relationship between central banks and climate policies has recently garnered significant interest from practitioners and the general public. While some monetary authorities, such as the European Central Bank and the Bank of England, have been vocal about their commitment to tackling climate change and have taken concrete actions, others have chosen to adopt a more limited role in this area. As clearly stated by the Chair of the Federal Reserve, Jerome H. Powell: "The Federal Reserve is not and will not be a climate policymaker" (Powell, 2023). Ultimately, the question of whether these policies are inflationary and to what extent central banks should respond to them is an empirical one. However, the existing evidence on this issue is limited and presents conflicting conclusions.

This paper examines the effects of carbon pricing on firms' expectations and pricing decisions. Carbon pricing, which involves setting a price on carbon emissions to reflect the external costs of greenhouse gas emissions, is a critical policy tool for reducing emissions and mitigating climate change. By combining aggregate data with firm-level survey data from Italy and an exogenous measure of changes in the price of carbon, I find that an increase in carbon prices leads to higher aggregate inflation, particularly in some energy-related subcomponents, as well as in both short- and medium-to-long-term inflation expectations among firms. A similar increase is observed in firms' own expected and realized price growth. In the initial quarters following the shock, firms tend to underestimate the impact of carbon price increases on their own prices, resulting in positive forecast errors. However, in the medium to long run, the effect on expectations becomes more persistent than the actual price changes, leading to negative forecast errors. Additionally, disagreement regarding future aggregate inflation rises.

Firms that receive information about the current inflation rate in Italy and the Euro Area are found to respond more strongly to carbon policy shocks. Moreover, firms perceive the shocks as contractionary, leading to a deterioration in both their perceived and expected business conditions, as well as in their outlook for the broader economy. Finally, the research underscores significant heterogeneity in firms' responses, driven by individual characteristics such as the factors firms consider important for their future price development.

Exogenous changes in the carbon price are measured using the carbon policy shock series developed by Känzig (2023). The author identifies 126 regulatory events between 2005 and 2019 that affected the supply of emission allowances in the European Union Emissions Trading System (EU ETS). Carbon policy surprises are calculated from changes in carbon futures prices within a narrow time window around these regulatory events, aggregated monthly, and then used as instruments in a proxy Vector Autoregression (VAR). The carbon policy shock series is derived from the residuals of this specification.

To assess the impact of carbon pricing on firms' expectations and decisions, I merge the carbon policy shock series with Italian firm-level survey data. The data is from the Survey on Inflation and Growth Expectations (SIGE), conducted quarterly by the Bank of Italy since 1999. This survey captures firms' expectations over various forecast horizons, ranging from 6 months ahead to the average between 36 and 60 months ahead, as well as their expected own price growth and realized past growth. The empirical approach used is a panel local projection as outlined by Jordà (2005).

I demonstrate that carbon policy shocks significantly increase Italian aggregate inflation and some of its energy-related subcomponents. Next, I analyze firm-level survey data and find that firms' inflation expectations strongly respond to changes in the carbon price, affecting both short-term and medium- to long-term expectations. Similarly, firms' expected and realized own price growth also rises following a carbon policy shock. Furthermore, price forecast errors (realized minus expected price growth) and disagreement (measured as either the difference between the 90th and 10th percentiles or the interquartile range of inflation expectations) both respond positively. These results are consistent with models of information rigidities, where firms do not fully utilize available information, leading to positive forecast errors and increased disagreement among firms following the energy shock. Moreover, forecast errors shift to negative in the medium to long run suggesting that firms over-extrapolate from past realizations.

The SIGE provides a subsample of the interviewed firms with information about the current inflation rate in Italy and the Euro Area. Since the expectations of these firms align more closely with actual aggregate inflation, and because inflation responds more strongly to carbon policy shocks than expected inflation, treated firms' inflation expectations are found to be more sensitive to these inflationary shocks. This effect is observed in both short- and medium-to-long-term inflation expectations, as well as in firms' expected and realized price growth.

Exogenous increases in the price of carbon are found to significantly worsen firms' perceptions and expectations about both their own business conditions and the broader economic environment. Following a carbon policy shock, firms anticipate a reduction in their workforce, a deterioration in investment conditions, and more challenging business conditions, both in the short term (3 months ahead) and in the medium to long term (3 years ahead). Lastly, I examine the heterogeneous effects of carbon policy shocks across different firm characteristics, including the factors they consider important for their own price evolution, their geographical location, and their sector. The pass-through of an increase in the carbon price to inflation expectations is not significantly influenced by whether firms view labor costs as a key price determinant. However, the pass-through is stronger for firms that consider raw material costs to be a major factor, and more muted for those whose prices are primarily driven by demand.

Central banks worldwide are assessing their role in addressing climate change. The presence of information frictions in firms' expectations formation processes warrants caution for monetary authorities; dismissing these shocks as purely supply-driven and choosing not to respond could have important negative effects. Firms' incomplete information in making forecasts could lead to significant second-round effects, as rising short-term inflation expectations may increase the persistence of the shocks. Moreover, the observed increase in medium- to long-term inflation expectations in response to a carbon policy shock indicates that central bankers should closely monitor the inflationary impacts of climate policies to prevent potential de-anchoring from the inflation target.

Related literature. This paper contributes to two strands of the literature. First, the results expand the empirical literature evaluating the economic effects of carbon pricing. Carbon pricing has been found to be effective in reducing emissions (Ralf et al., 2014, Andersson, 2019), but its effects on macroeconomic variables remain unclear.

At the aggregate level, the impact of carbon taxes on employment and GDP growth in European countries seems limited (Metcalf and Stock, 2020a; Metcalf and Stock, 2020b). A similar result is found by Metcalf (2019) and Bernard and Kichian (2021) for the British Columbia carbon tax on GDP. Konradt and di Mauro (2023) shows that the inflationary pressure of carbon taxes in Europe and Canada is negligible. Adopting a dynamic panel estimation of New-Keynesian Phillips curves for 35 OECD economies from 1990 to 2020, Moessner (2022) estimates that an increase in prices of ETS by \$10 per ton of CO_2 equivalents increases energy CPI inflation by 0.8 percentage points and headline inflation by 0.08. Benmir and Roman (2022) document that carbon pricing shocks in California's cap-and-trade market significantly increase energy prices and worsen the real economy situation.

The effects of carbon pricing might not be limited to macroeconomic variables. Different economic agents, sectors, or geographical areas might be heterogeneously exposed to changes in the price of carbon. Understanding the potential distributional effects of this policy should be incorporated into the design of optimal policy for the transition towards a greener economy. Känzig (2023), by developing the carbon policy shocks employed in this paper, uncovers important heterogeneous effects for households along the income distribution. Mangiante (2024) finds that the sensitivity of real economic activity to carbon policy shocks is higher for poorer Euro Area countries. Similarly, Berthold et al. (2023) focuses on the importance of emission intensity in the transmission of carbon policy shocks across countries.

The paper most closely related to this one is Hensel et al. (2024), which uses French survey data to examine how firms' expectations are influenced by the same carbon policy shocks developed by Känzig (2023), which are also employed here. Consistent with their findings, I confirm for Italy that carbon policy shocks lead to increases in aggregate inflation, firm-level inflation expectations, expectations of own price growth, and realized price growth, as well as initially positive and subsequently negative forecast errors.

This paper extends their results in several key ways. First, the French survey's inflation expectations are limited to a 3-month horizon, while the SIGE covers a broader range of forecast horizons, from 6 months to an average of 36 to 60 months ahead. This extended temporal scope is especially relevant for central banks, whose mandates often focus on medium-term inflation targets. The findings show that even medium- to long-term expectations are influenced by carbon policy shocks, highlighting the need for monetary authorities to closely monitor the inflationary impacts of the green transition. Second, unlike the French survey, which collects mainly qualitative responses (e.g., whether firms expect prices to rise, remain unchanged, or fall), the SIGE provides quantitative data. Firms report the expected percentage change in inflation, enabling a more precise assessment of the impact of carbon policy shocks on firm-level variables. Third, the quantitative nature of the SIGE responses allows for an analysis of disagreement across firms. While Hensel et al. (2024) also demonstrate that forecast errors respond positively to carbon policy shocks—consistent with models of information frictions—this paper further shows that disagreement among firms is significantly affected. This additional evidence helps distinguish between various expectation formation processes, aligning more closely with models featuring sticky information and rational inattention rather than noisy information. Fourth, the ongoing information treatment since 2012 creates a unique setting for evaluating the causal effects of providing firms with information about the actual inflation rate on the pass-through of exogenous increases in the price of carbon to firms' expectations. Given that firms heavily rely on the information provided in forming their expectations, the findings suggest that central banks can significantly influence firms' expectations and their responsiveness to shocks through effective communication.

Fifth, the richness of the SIGE data allows for an extension of the analysis to firms' perceptions and expectations about their own business and the aggregate economic conditions, providing a more detailed understanding of the pass-through of carbon policy shocks to the broader economy.

The second strand of literature to which this paper contributes is the study of expectations formation among economic agents. While the determinants of household expectations and their responsiveness to shocks have been extensively explored (Coibion and Gorodnichenko, 2012, 2015; Axelrod et al., 2018; Coibion et al., 2019), similar research for firms is less developed due to the more limited availability of firm-level survey data.

One key variable that influences household inflation expectations is the price of gasoline (Coibion and Gorodnichenko, 2015; Cavallo et al., 2017; D'Acunto et al., 2021). This is because gasoline is frequently purchased and its price is highly volatile, making it a significant focus for households. This study confirms and extends findings by Hensel et al. (2024), showing that firms' expectations also significantly respond to changes in energy costs.

Moreover, this paper offers new insights into the nature of information frictions in firms' expectation formation processes. Existing survey data across countries generally reject the notion that agents are fully informed when making forecasts. For instance, Gorodnichenko et al. (2018) finds that the dispersion in macroeconomic beliefs among New Zealand firms is consistent with rational inattention models (Sims, 2003; Reis, 2006; Bartosz and Wiederholt, 2009; Afrouzi, 2016). Coibion and Gorodnichenko (2012) demonstrates how expectations, forecast errors, and disagreement among various economic agents respond to aggregate shocks, supporting models with inflation frictions rather than full information. Angeletos et al. (2020) find that forecast errors for unemployment and inflation expectations in the Survey of Professional Forecasters initially increase in response to shocks, but subsequently decrease. This pattern is rationalized by the combination of dispersed information and over-extrapolation. The initial positive and subsequently negative response of French firms' price forecast errors to carbon policy shocks, as documented by Hensel et al. (2024), suggests that information frictions significantly impact firms' perceptions and reactions to climate policies. This study further contributes by showing that disagreement among firms increases following a carbon policy shock providing empirical evidence consistent with models of sticky information and rational inattention. Moreover, the stronger responses observed for firms receiving information about the actual inflation rate confirm that firms rely on this information to form their expectations, suggesting that their expectations can be influenced by transparent communication.

Road map. The remaining paper is organized as follows. Section 2 describes the data used in this paper. In Section 3, I show the impact of carbon policy shocks on aggregate prices. Section 4 reports the results of the main analysis on firm-level data. In Section 5, I perform a battery of robustness checks to strengthen the validity of the baseline results. Section 6 discusses some policy implications for central banks. Finally, Section 7 concludes.

2 Data

2.1 Survey data

Data on firms' expectations are sourced from the Survey on Inflation and Growth Expectations (SIGE), conducted quarterly by the Bank of Italy since 1999. The survey is designed to be nationally representative by stratifying the sample according to three characteristics: sector of activity, size class (based on the number of employees)[1], and geographical area (based on the firm's administrative headquarters). Each quarter, approximately 1,500 Italian firms are currently surveyed about both aggregate and business-specific variables.

The survey has been extensively used in the literature.[2] The dataset's rich time and panel dimensions make it particularly suited to evaluate the propagation of carbon policy shocks to firms' expectations. Over the sample period from 1999 to 2019, the SIGE includes around

[1] The survey is conducted only on firms with at least 50 employees.

[2] See, among others, Coibion et al. (2020), Bottone et al. (2021), Ropele et al. (2022), Bottone et al. (2022), Ropele et al. (2024a), Ropele and Tagliabracci (2024), and Ropele and Tagliabracci (2024).

70,000 firm-level observations (time x firm), with each firm participating in the survey for an average of 18 quarters.

I mainly focus on the following questions related to the firms' expectations about future inflation, their own expected price growth, and realized price growth:

- *What do you think the consumer price inflation will be in Italy: In six months? In one year? In two years? On average between three and five years?*
- *In the last 12 months, what has been the average change in your firm's prices?*
- *For the next 12 months, what do you expect will be the average change in your firm's prices?*

Firms respond to the SIGE questions by reporting the approximate percentage variation. The questions about different forecast horizons for inflation expectations have been included at various points in time. The question regarding 1-year expected inflation has been available since the survey's inception in 1999. The question related to 6-month ahead expectations was added in 2010q4. The 24-month ahead expectations question was introduced in 2009q1, and the question about the average expected inflation between 36 and 60 months ahead was included starting in 2014q1.[3]

Table 1 presents some descriptive statistics for the main variables of interest at the quarterly frequency. As observed, there is significant heterogeneity among firms in their aggregate and own price growth expectations during the period considered. For instance, the average expected inflation across different forecast horizons is close to the European Central Bank target of 2%, but the standard deviation is substantially above 2%. The tails of the distribution are also quite dispersed, with the 12-month ahead expected inflation ranging from 0% to 6% at the 5th and 95th percentiles, respectively.

Panel A of Figure 1 compares the time series of the aggregate Italian Consumer Price Index (CPI) growth with the average firm-level inflation expectations across different horizons.

[3]To limit the role played by outliers, the variables are trimmed at the 1st and 99th percentiles for each quarter. However, using raw data delivers basically identical results.

Table 1: Descriptive statistics

	Mean	Std. Dev.	P5	P95	Obs.
Main variables (firm-quarter)					
Expected inflation, 6-month ahead	2.11	2.44	0	8	54,503
Expected inflation, 12-month ahead	2.14	1.91	0.05	6	74,393
Expected inflation, 24-month ahead	1.99	1.87	0.02	5.8	57,294
Expected inflation, average 36-60 months ahead	1.92	1.86	0	5.5	44,864
Realized price gr., past 12 months	1.51	4.97	-5	10	75,261
Expected price gr., 12-month ahead	1.62	3.59	-2	8	80,049

Notes: The table reports descriptive statistics from the SIGE survey on Italian firms for the period 1999 to 2019. The data are at quarterly frequency.

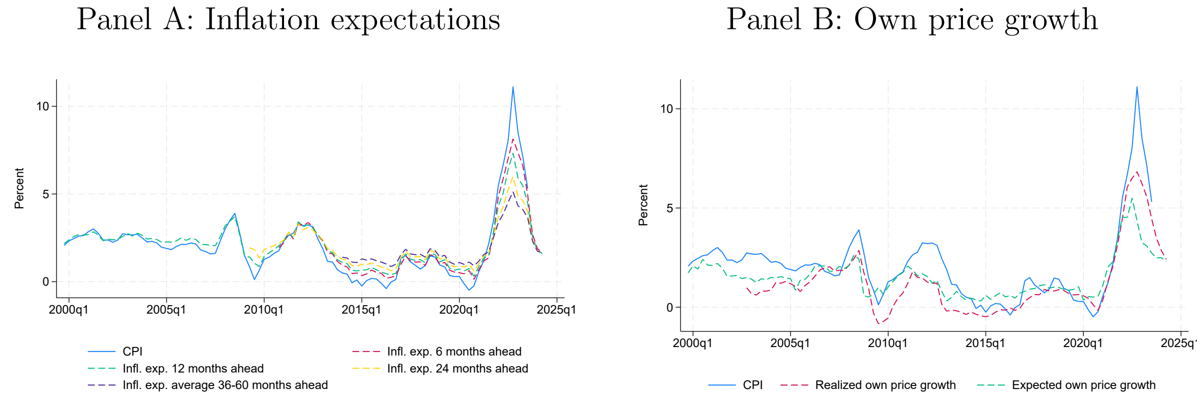
The series of expected inflation are strongly correlated with each other and with the actual CPI, confirming the survey's high representativeness for the aggregate economy. Panel B reports the time series for the 12-month ahead own price growth expectations and the realized price growth over the past 12 months. The two series closely follow each other, indicating that firms tend to report their true expectations.

2.2 Carbon policy shocks

The carbon policy shocks are computed following the procedure developed by Känzig (2023). I briefly summarize the approach here and refer to the original paper for a thorough description. Känzig (2023) identifies 126 events from 2005 to 2019 related to the overall cap in the European Union Emissions Trading System (EU ETS), such as the free allocation and auctioning of allowances, as well as the use of international credits. Carbon policy surprises are then derived from changes in the future price of EU emission allowances around these regulatory events. The underlying assumption is that by considering a small enough time window around each event, the price change can be considered unexpected and exogenous.

The surprises are defined as the EUR change in carbon future prices relative to the prevailing wholesale electricity price on the day before the event. The daily surprises are aggregated into a monthly series by summing the daily surprises within a given month. In

Figure 1: Time series of the Italian CPI inflation, firms' inflation expectations, own price growth expectations and realized price growth



Notes: The figure plots the time series of actual CPI growth for Italy alongside the measures of firms' inflation expectations across horizons (left panel) as well as own price growth expectations and realized price growth (right panel). The firm-level data comes from the SIGE survey.

months without any regulatory events, the series takes a zero value.

To clean the surprises from potential measurement errors, they are used as an external instrument in a VAR model (proxy-VAR) covering the period from January 1999 to December 2019. Eight variables are included in the VAR model: the energy component of the HICP, total GHG emissions, the headline HICP, industrial production, the unemployment rate, the policy rate, a stock market index, as well as the real effective exchange rate. The carbon policy shocks are extracted from the residuals of the monthly VAR (Stock and Watson, 2018) and are normalized to increase the energy component of the HICP by one percent on impact. The shock series is aggregated into a quarterly series by summing the monthly values.[4]

3 Macroeconomic variables and carbon policy shocks

The carbon policy shocks, derived following the approach of Känzig (2023), are computed using Euro Area-level variables. Therefore, as a first step, it is important to evaluate the

[4]The series of surprises is reported in Figure 12 of the Appendix.

aggregate effects of these shocks on the Italian economy. This is done by estimating the following local projection à la Jordà (2005):

$$y_{t+h} = \alpha_h + \beta_h CPShock_t + \sum_{p=1}^{P} \theta_h^p y_{t-p} + \epsilon_{t+h}, \tag{1}$$

for $h = 1, ..., 12$. y_{t+h} is the dependent variable at time $t+h$, $CPShock_t$ are the carbon policy shocks at time t extracted from the proxy-VAR[5], and ϵ_{t+h} is the error term. As control I include three lags of the dependent variable and correct for autocorrelation using Newey and West (1987) standard errors.[6] The coefficient of interest is β_h, which captures the response of the dependent variable to a carbon policy shock for each horizon h. The dependent variables are the year-on-year inflation rates of the Energy Consumer Price Index (CPI), the Producer Price Index (PPI), and the overall CPI for Italy.[7] I consider the annual growth rate rather than the log value to be consistent with the answers in the survey which report the expectations in percentage terms.

The responses to a carbon policy shock are presented in Figure 2. Following a shock that induces a one percent increase in the energy component of the Euro Area HICP, the Italian Energy CPI responds by a similar amount (Panel A). The shock also causes a substantial rise in the PPI (Panel B) and the overall CPI (Panel C). Specifically, the CPI increases by approximately 0.1 percent on impact before reverting to zero after 4 to 5 quarters.

In Figure 13 of the Appendix, I document comparable effects for alternative measures of energy prices: the single national price for wholesale electricity from the Gestore Mercati Energetici (GME)[8] and the inflation subcomponent *Electricity, Gas and Other Fuel price* (COICOP 04.5). The inflationary impacts of carbon pricing observed for Italy align with

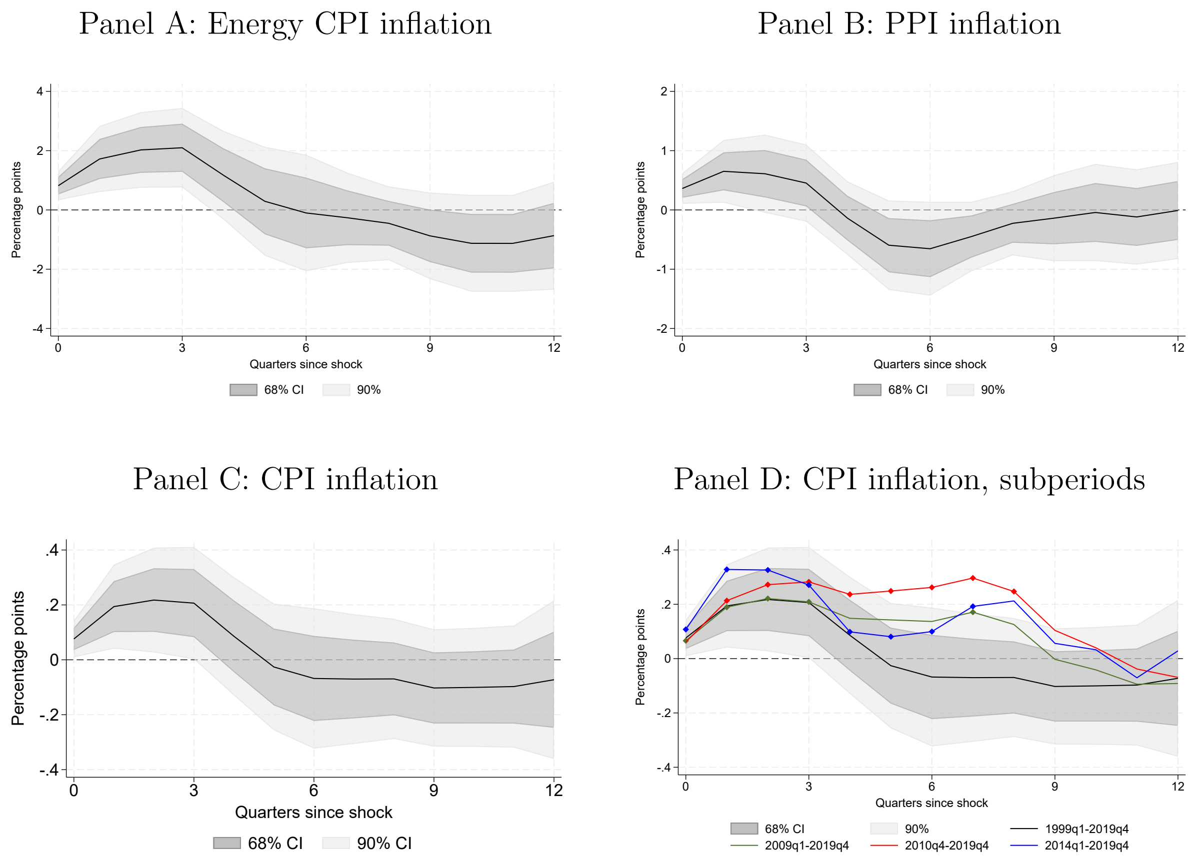
[5] The time period of the shock series is from 1999 to 2019. Restricting the sample to after the euro introduction, i.e., 2002q1 onward, does not affect the main results.

[6] In the baseline specification I do not include any European or global controls, as these are already accounted for in the monthly VAR model used to derive the shock estimate. Additionally, I do not include lags of the shock variable, as there is little evidence of autocorrelation in the shock series.

[7] Considering the Harmonized CPI delivers basically the same results.

[8] The data can be downloaded from the GME's website HERE.

Figure 2: Macro responses to carbon policy shocks



Notes: The figure plots the response to a carbon policy shock, normalized to increase the Euro Area HICP energy by 1 percent on impact, for the the year-on-year inflation rates of the Italian Energy Consumer Price Index (CPI) (top left panel), the Producer Price Index (PPI) (top right panel), aggregate CPI (top left panel) and the aggregate CPI for different subperiods (top right panel). The black lines are the point estimates and the shaded areas are the 90 and 68 percent confidence bands. The diamond-shaped coefficients in panel D indicate the statistically significant values. The horizontal axis is in quarters.

findings by Känzig (2023) and Hensel et al. (2024) for the Euro Area (19 members) and France. The effects of an exogenous increase in the price of carbon are both statistically and economically significant, albeit relatively short-term.

Finally, given that the questions regarding different forecast horizons in inflation expectations were introduced at different points in time, I assess whether the shocks remain well-identified when considering alternative subperiods. Panel D of Figure 2 shows the responses of the CPI starting from the baseline period in 1999q1, as well as from 2009q1, 2010q4, and 2014q1. The diamond-shaped coefficients indicate statistically significant values. The persistence of the effects varies slightly across subsamples, but the contemporaneous impact and the shape of the responses in the first 4 to 5 quarters are relatively consistent across different subsamples. This reassures the validity of the empirical specification adopted, even with shorter time samples.

4 Firms' expectations and carbon policy shocks

In the previous section, I documented that carbon policy shocks have inflationary effects at the aggregate level for Italy. I now shift the focus to the firm-level variables provided by the SIGE. To estimate the average firm-level response to a carbon policy shock, I follow the approach used by Andrade et al. (2022) and Hensel et al. (2024):

$$E^i_{t+h} y^i_{t+h} = \alpha^i_h + \beta_h CPS_t + \sum_{p=1}^{P} \theta^p_h X^i_{t-p} + \varepsilon^i_{t,h}, \tag{2}$$

for $h = 1, ..., 12$. $E^i_{t+h} y^i_{t+h}$ is the dependent variable, e.g., own price growth expectations or realized price growth, at time $t+h$ of firm i. The coefficient of interest is β_h which captures the effect of a carbon policy shock on the dependent variable. α^i_h are firm fixed effect, X^i_{t-p} is a matrix of controls, and P is the number of lagged values[9]. Standard errors are computed using two-way clustering at the firm and time levels. This approach controls for potential correlations within firms over time, accounting for correlations across firms within the same time period, which may arise from common macroeconomic shocks.[10] It is important to highlight again that the sample considered stops in 2019q4 so the Covid period and the recent high-inflation episode are excluded from the analysis.

[9]In the baseline specification, I control for three lags of the dependent variable.

[10]Similar results are obtained using Driscoll and Kraay (1998) standard errors.

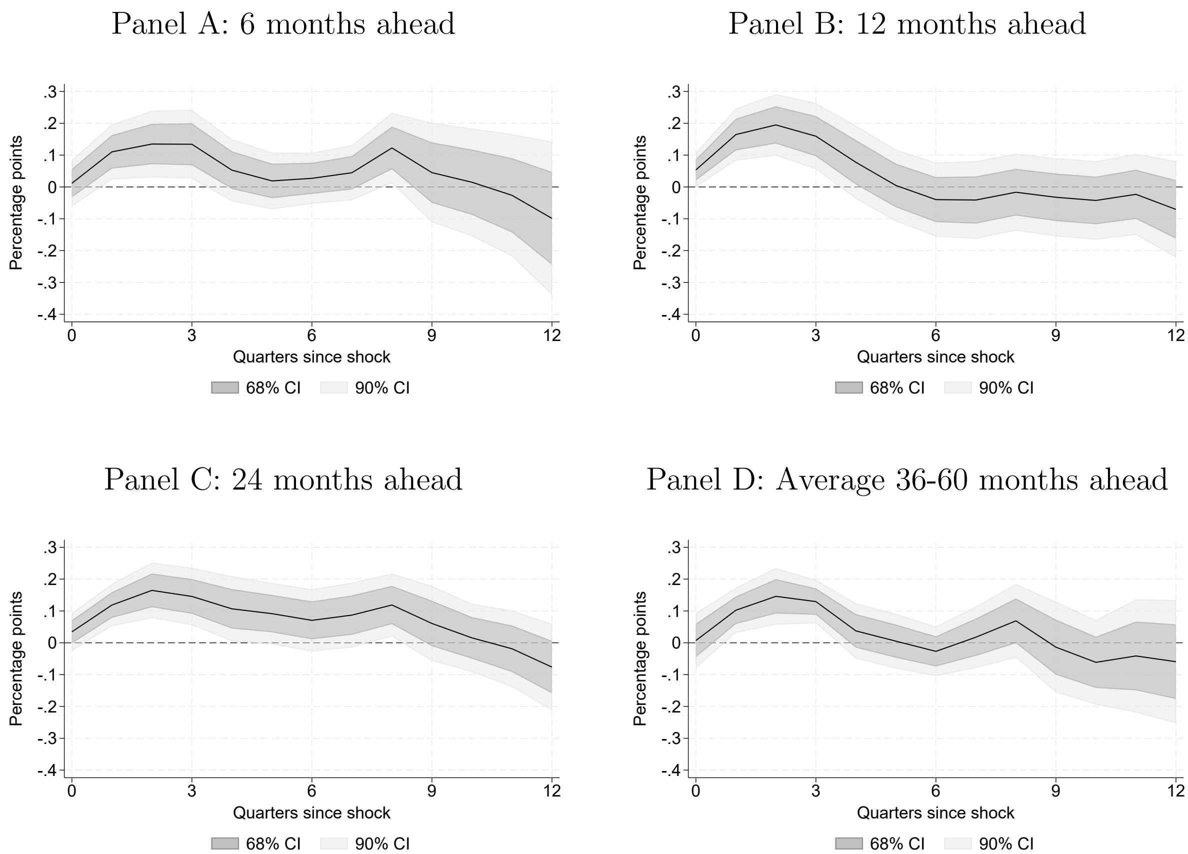
4.1 Inflation expectations

Figure 3 illustrates the response of firms' inflation expectations across various forecast horizons following a carbon policy shock. The shock triggers a significant increase in firms' expected inflation. The contemporaneous effect and persistence of the 12-month ahead inflation expectations (Panel B) closely resemble the response of the aggregate year-on-year inflation rate, as shown in Panel C of Figure 2. Firm-level inflation expectations increase by approximately 0.06 percentage points initially. After 2-3 quarters, the increase reaches nearly 0.2 percentage points before gradually converging back to zero in 4-5 quarters. A similar response is observed for the 6-month ahead inflation expectations (Panel A). The rise in short-term inflation expectations induced by the carbon policy shock aligns with findings from Hensel et al. (2024) for the 3-month ahead inflation expectations in France. The comparable responses between the firm-level and aggregate data further validate the representativeness of the survey.

The richness of the SIGE survey allows for an extension of these results to longer-term expectations. Both the 24-month ahead expectations (Panel C) and the average 36-60 months ahead expectations (Panel D) also respond positively following the shock. While the magnitudes of the responses are smaller, peaking slightly above 0.1 percentage points, the significance and persistence of the effects are comparable to those observed for the 12-month ahead expectations.

These findings are particularly concerning for central banks. The empirical evidence suggests that an exogenous increase in the price of carbon leads to a rise in firms' expected inflation. Furthermore, the effects are not limited to short-term inflation; even medium- to long-term expectations—often the focus of many monetary authorities' mandates—are not immune to the inflationary effects of carbon pricing, despite the fact that the effects on actual inflation dissipate after 4-5 quarters.

Figure 3: Impact of carbon policy shocks on firms' inflation expectations



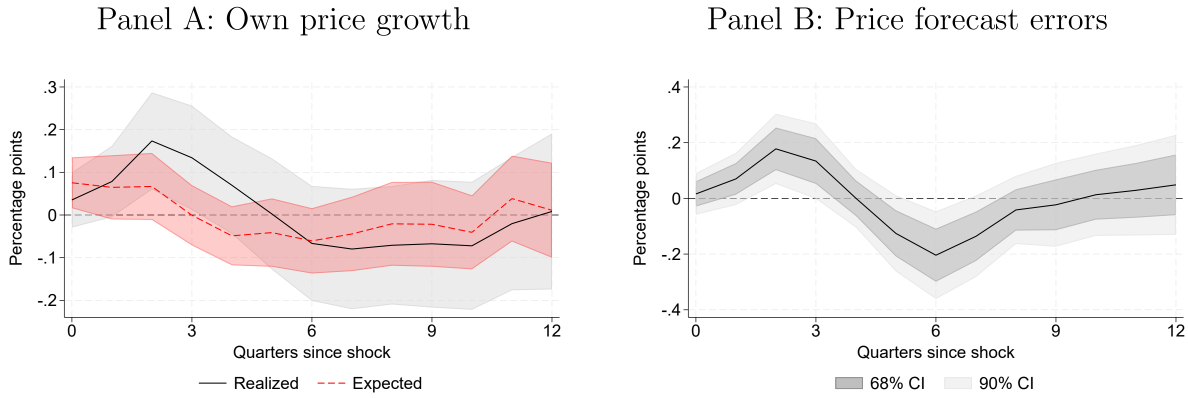
Notes: The figure plots the response to a carbon policy shock, normalized to increase the HICP energy by 1 percent on impact, for the firm-level inflation expectations at different forecast horizons. The black lines are the point estimates and the shaded areas are the 90 and 68 percent confidence bands. The horizontal axis is in quarters.

4.2 Expected and realized own price growth

In forming their expectations about the aggregate economy, firms often rely on changes in their business conditions (Andrade et al., 2022). Therefore, carbon policy shocks could influence inflation expectations not only through their direct effects but also by indirectly affecting firms' own price growth expectations and decisions. I evaluate whether this is the case by assessing the response of firms' 12-month ahead own price growth expectations and the realized price growth over the past 12 months to a carbon policy shock.

The responses of firms' expected price growth and realized price changes are reported in

Figure 4: Impact of carbon policy shocks on firms' own price growth expectations, realized price growth and price forecast errors



Notes: The figure plots the response to a carbon policy shock, normalized to increase the HICP energy by 1 percent on impact, for the firms' own price growth expectations and the realized price growth (left panel) as well as price forecast errors (right panel). Price forecast errors are measured as the difference between the realized and the expected price growth. The lines are the point estimate, and the shaded areas are the 90 and 68 percent confidence bands. The horizontal axis is in quarters.

Panel A of Figure 4. The shape and magnitude of these responses are comparable to those of inflation expectations and aggregate inflation.

A carbon policy shock, rescaled to induce a one percent increase in energy prices, causes expected price growth to increase by approximately 0.08 percentage points on impact. Further supporting the validity of the survey responses, realized price growth does not increase immediately following the shock, as it reflects price changes over the previous 12 months. Instead, it begins to rise one quarter after the shock, reaching its peak in the subsequent quarter at nearly 0.2 percentage points. These effects gradually dissipate after 4 to 5 quarters. The similar response patterns indicate a close alignment between higher price expectations and actual price increases. Overall, changes in carbon prices lead to an increase in both firms' aggregate and firm-specific price expectations.

Next, I investigate whether firms' expectations about the evolution of their own prices under or over-react to carbon policy shocks compared to the actual realizations. Equation

(2) is re-estimated using price forecast errors, defined as the difference between realized and expected price growth, as the dependent variable. The reference period for the forecast errors is the past 12 months. Therefore, forecast errors at time t are calculated as the actual price growth observed between $t - 12$ and t, minus the expectations that firms had 12 months earlier for the same period.

The response is reported in Panel B of Figure 4. Following a carbon policy shock, forecast errors initially increase peaking 2 quarters after the shock. This response indicates that the impact of carbon policy shocks on firms' own price growth expectations is more muted than the actual price changes they induce in the initial quarters. After 4 quarters the response turns negative before convergening back to zero after 7 quarters.

The initial positive response of forecast errors allows us to reject the hypothesis that firms are fully informed when forming their forecasts. If agents were fully informed, their forecast errors would not increase following the shock, as their expectations would already incorporate all relevant information (Coibion and Gorodnichenko, 2012). However, the empirical evidence suggests that in the initial quarters after carbon policy shocks, firms underestimate the overall effects these shocks will have on their own prices. The significant effect of an inflationary carbon price shock on forecast errors aligns with the predictions of models with information rigidities.

Moreover, the subsequent delayed over-reaction following the shock points towards the presence of both dispersed information and over-extrapolation (Angeletos et al., 2020). Firms are initially uninformed about the shock, leading them to make positive forecast errors. Over time, firms learn about the shock, so the information friction fades away. However, when forming their expectations, they tend to over-extrapolate from past realizations, resulting in their forecasts eventually over-reacting and leading to negative forecast errors. This pattern is in line with the evidence provided by Hensel et al. (2024) for French firms.

4.3 Disagreement about future inflation

The significant response of forecast errors to a carbon policy shock strongly indicates the presence of information frictions in firms' expectation formation processes. This data-driven evidence allows us to reject the hypothesis that firms are fully informed. However, positive forecast errors are a common feature across different models of information rigidities. A variable that can differentiate among these models is forecast disagreement among agents.

As shown by Coibion and Gorodnichenko (2012), in response to a shock, both full-information rational expectations models and noisy information models (Lucas, 1972, Sims, 2003, and Woodford, 2003) predict that disagreement should not change. In the former class of models, agents have access to all available information when making their forecasts. Therefore, they immediately update their information sets in response to a shock in fundamentals, resulting in no change in either their forecast errors or disagreement. In the latter class of models, agents observe only noisy signals about the economy. As they continuously update their information sets, shocks do not affect forecast disagreement.

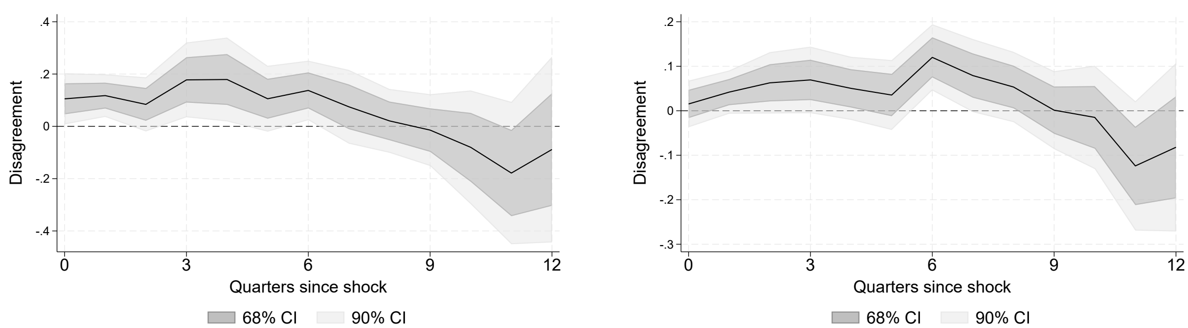
The opposite is true for the sticky information models (Mankiw and Reis, 2002 and Reis, 2006) and rational inattention models (Sims, 2003, Sims, 2006, Bartosz and Wiederholt, 2009, and Afrouzi, 2016). In the first class of models, agents update their information sets infrequently because acquiring and processing new information is costly. Therefore, in the first periods after an economic shock, only a subset of agents will be informed about it, leading to an increase in forecast disagreement. In the second class of models, agents allocate limited cognitive resources to process information optimally, leading them to focus only on aspects they deem most relevant while ignoring others. A shock like carbon pricing might be more relevant to some firms than others. For example, Hensel et al. (2024) document that high-energy intensive firms tend to be more responsive to this kind of shocks. This selective attention creates differences in expectations and an increase in disagreement. In Section 4.6 I evaluate whether firms' characteristics influence the pass-through of carbon policy shocks to firms' expectations and document, among other results, that the pass-through of carbon policy shocks to inflation expectations is stronger for firms considering raw materials prices an important driver for their prices and weaker for firms in the services sector.

By examining the response of forecast disagreement to carbon policy shocks, we can gain insights into which class of information rigidity models better describes firms' expectations formation processes. If forecast disagreement increases following a shock, it supports the sticky information and rational inattention models. Conversely, if disagreement remains unchanged, it aligns more closely with full-information rational expectations or noisy information models.

Figure 5: Impact of carbon policy shocks on the inflation expectations disagreement

Panel A: 90th-10th percentiles

Panel B: IQR



Notes: The figure plots the response to a carbon policy shock, normalized to increase the HICP energy by 1 percent on impact, for the disagreement across firms regarding the 12-month ahead expected inflation. Disagreement is measured as the difference between the 90th and 10th percentiles (left panel) or the interquartile range (IQR) (right range) of the inflation expectations. The lines are the point estimate, and the shaded areas are the 90 and 68 percent confidence bands. The horizontal axis is in quarters.

To analyze how firms' disagreement in inflation expectations responds to a carbon policy shock, I rely on two measures: the difference between the 90th and 10th percentiles and the interquartile range (IQR) of the 12-month ahead inflation expectations. The IQR, in particular, helps control for potential outliers that might bias the results. As models predict that disagreement should either increase or remain unchanged irrespective of whether the shock is inflationary or deflationary, I estimate Equation (2) using the absolute value of the shock.[11]

Figure 5 reports the responses of disagreement to a carbon policy shock. Following a carbon policy shock, both measures of disagreement increase. This rise in disagreement contradicts the hypothesis that firms are fully informed, as fully informed agents would immediately update their information sets, leaving no change in disagreement. Moreover, the observed increase in disagreement does not align with the predictions from noisy information models, where continuous updating of information sets would result in no change in forecast disagreement.

The positive response in disagreement is consistent with the predictions from sticky information and rational inattention models. Firms update their information sets infrequently or only partially due to the costs associated with acquiring and processing economic information. Consequently, it takes time for all firms to become aware of the shock and incorporate it into their forecasts. This leads to an initial increase in disagreement about future aggregate price movements, which takes around 7 to 8 quarters to converge back to zero.

Several conclusions can be drawn from the results so far presented. First, carbon policy shocks not only have inflationary effects at the macro level but also at the firm level. Inflation expectations across different forecast horizons are found to significantly respond to an exogenous increase in the price of carbon. Second, positive effects are documented also for both expected and realized firms' price growth. The strong co-movement between the two responses is further proof of the reliability of the data in the survey. Firms' realized price growth closely follows the expected prices, confirming that the expectations they provided are, on average, quite precise. Third, the observed information frictions, evidenced by positive forecast errors and increased disagreement, highlight the challenges firms face in fully and promptly integrating new information into their expectations. This underscores the need for central banks to closely monitor the inflationary impacts of carbon policies and consider these frictions in their policy responses.

[11] The dependent variables are the time series of the two different measures of disagreement so Newey and West (1987) standard errors are adopted.

4.4 Information treatment and firms' responsiveness to shocks

In recent years, central banks have increasingly relied on communication to manage the expectations of economic agents. By providing households and firms with information about the current economic environment, as well as projections for future developments, monetary authorities have adopted communication strategies as a key tool in policy. In this section, I evaluate the causal impact of providing firms with information about inflation on the firms' responsiveness to an exogenous increase in carbon prices.

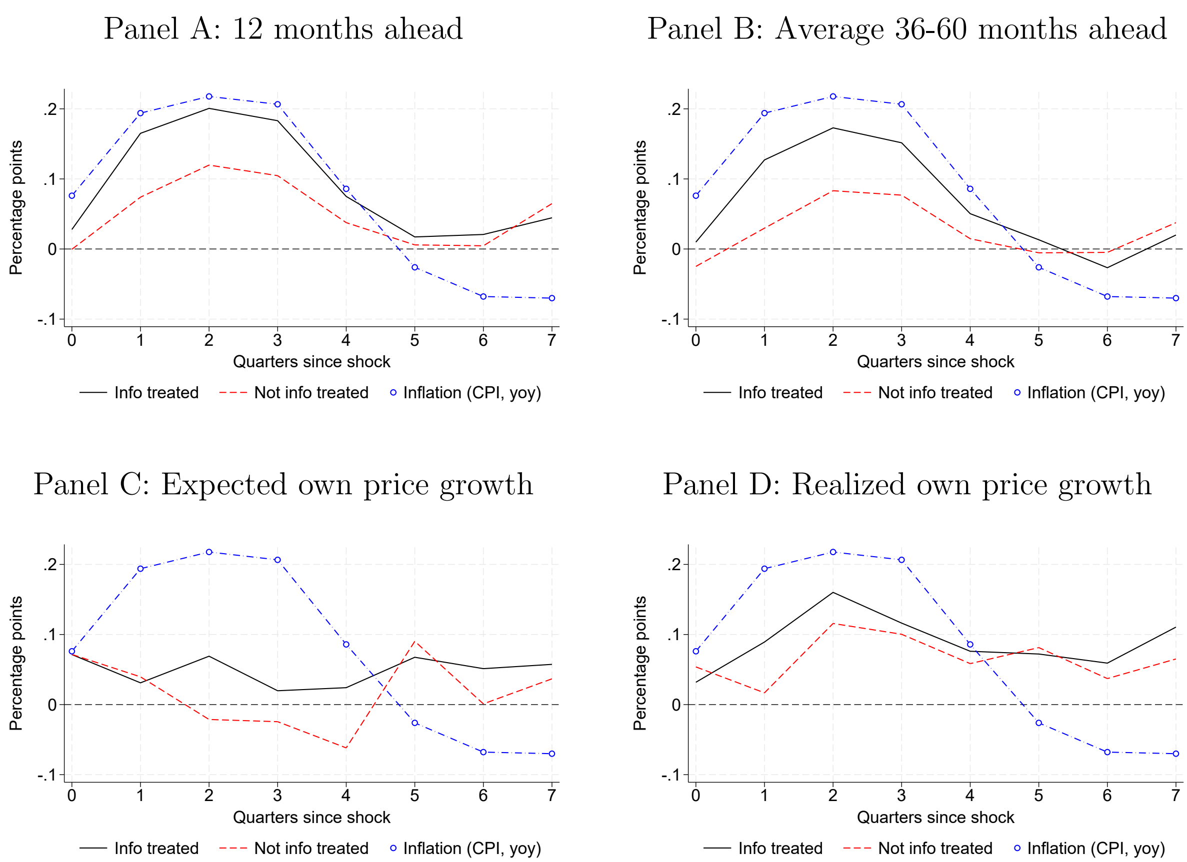
At irregular intervals, firms in the SIGE are randomly assigned to one of two groups. The first group is asked to report their inflation expectations for the next 12 months without receiving any additional information. The second group is asked the same question but only after being informed about the most recent inflation rates in both Italy and the euro area. Firms remain in their assigned groups until the next reshuffling, meaning that between reassignments, some firms consistently receive updated information while others do not. Before the third quarter of 2012, all firms were provided with identical information about recent inflation rates. Beginning in 2012q3, approximately one-third of firms were randomly assigned to the group that did not receive any information. In 2012q4 firms were reshuffled across the two groups and remained in their new assignments until 2017q2, when another reshuffling occurred. A final reassignment took place in 2019q4.

The unique prolonged duration of the treatment makes the SIGE an ideal setting for examining how providing firms with information about actual inflation influences their expectations and decision-making.[12] As illustrated in Figure 14 in the Appendix, the treatment significantly improves the alignment of treated firms' inflation expectations with actual inflation. Moreover, the treatment has been shown to impact not only the expectations of these firms but also their decisions regarding hiring and investment.

I examine whether the pass-through of carbon policy shocks to firms' expectations is influenced by their exposure to the information treatment. Figure 6 presents the responses

[12] See Coibion et al. (2020), Bottone et al. (2021), Ropele et al. (2022), and Ropele et al. (2024b).

Figure 6: Impact of carbon policy shocks on inflation and firms' expectations by treatment status



Notes: The figure plots the response to a carbon policy shock, normalized to increase the HICP energy by 1 percent on impact, for the firm-level expectations. The black lines are the point estimates for the firms which received the information treatment, the red lines for those which do not and the blue lines are the responses of aggregate CPI inflation in Italy. The horizontal axis is in quarters.

for treated (black lines) and untreated firms (red dashed lines), while the blue lines represent the response of aggregate CPI inflation in Italy to a carbon policy shock. Panel A reveals that the 12-month-ahead inflation expectations of treated firms respond more strongly to a carbon policy shock. The statistical significance of this difference is tested and confirmed in Figure 15 in the Appendix, where it is shown for all types of expectations. The figure displays the coefficients of the interaction between the carbon policy shocks and a dummy variable indicating whether a firm received the treatment.

At first glance, it may seem puzzling that providing firms with information about the current inflation rate actually increases their sensitivity to carbon policy shocks. However, this result is a consequence of the treatment's effectiveness in shaping firms' expectations. Specifically, since the response of actual inflation to a carbon policy shock is stronger than the response of firms' expected inflation, the expectations of treated firms align more closely with the actual inflation response. As a result, the treatment generates a notable difference in expected inflation, with a gap of nearly 0.1 percentage points two quarters after the shock.

The result extends beyond 1-year ahead expectations. Providing firms with information about the current inflation rate also increases their long-term inflation responsiveness to carbon policy shocks, as shown in Panel B. This effect is similarly observed for both expected and realized price growth (Panels C and D), though with a smaller, yet still statistically significant, magnitude.

Firms' inflation expectations respond strongly to the provision of information about actual inflation. Following an inflationary shock, expectations align more closely with actual inflation, leading to a stronger response in the treated group compared to the control group. It is important to emphasize that this does not suggest central banks should refrain from adopting a transparent and widespread communication strategy directed at households and firms. On the contrary, better-informed firms are able to allocate their resources—capital, labor, and inputs—more efficiently (Ropele et al., 2024b). Furthermore, these firms are better equipped to anticipate potential shocks, such as supply chain disruptions, and can adjust more swiftly to changes in fiscal or monetary policy.

4.5 Effects on the perceived and expected economic situations

The SIGE survey is exceptionally rich, not only in terms of expectations regarding price developments but also in capturing data on firms' perceptions of and expectations about the broader economic situation in Italy, as well as their own business conditions. To gain a comprehensive understanding of the transmission mechanisms of carbon pricing to the economy, I estimate the effect of an exogenous increase in the price of carbon on the following questions:

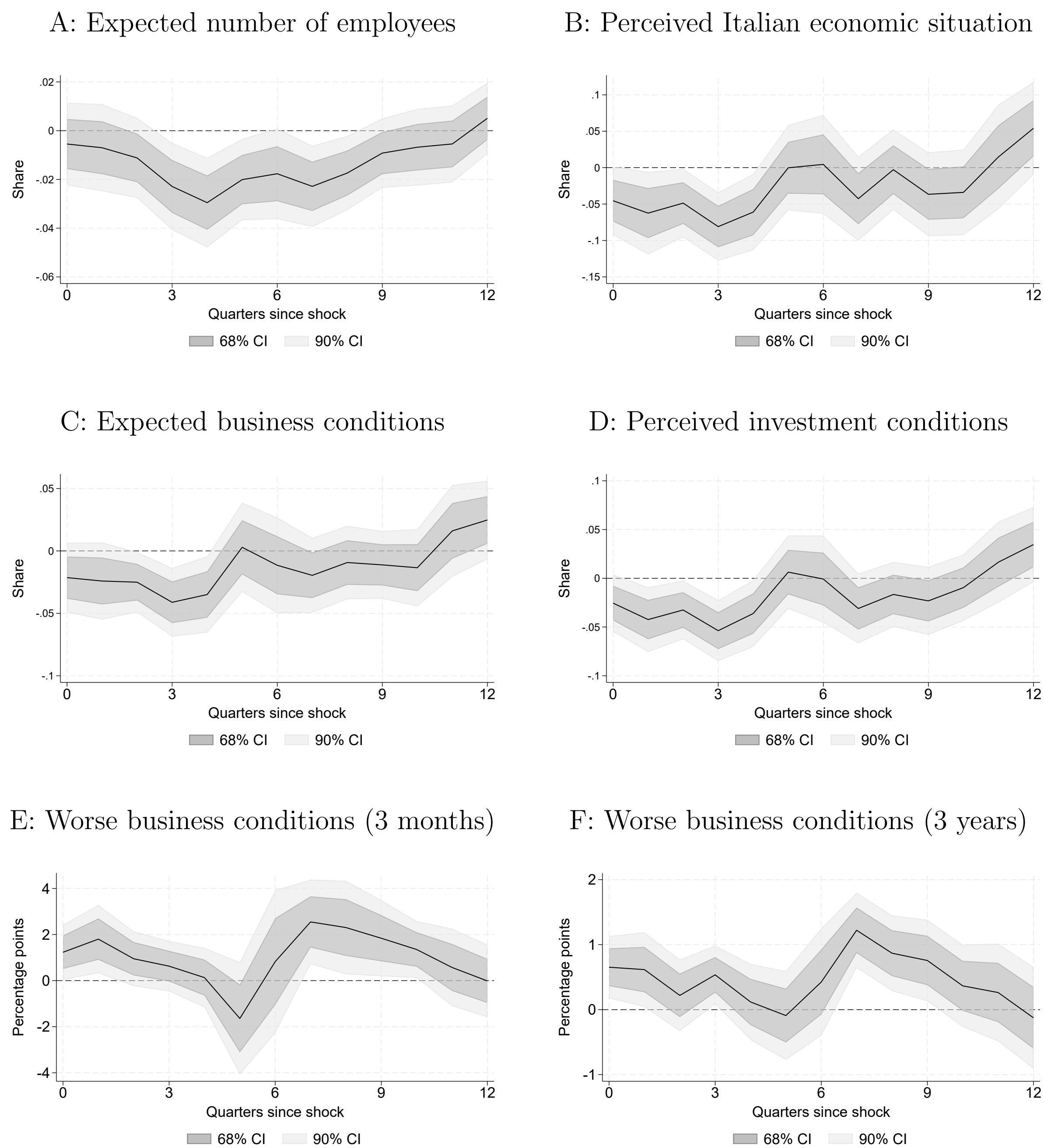
- *Your firm's total number of employees in the next 3 months will be lower, unchanged, or higher? (OCCTOT)*
- *Compared with 3 months ago, do you consider Italy's general economic situation is better, the same or worse? (SITGEN)*
- *How do you think the business conditions for your company will be in the next 3 months: Better, the same or worse? (SITIMP)*
- *Compared to 3 months ago, do you think conditions for investment are better, the same or worse? (SITINV)*

The variables are coded to take values $-1, 0, 1$, representing whether firms expect/perceive conditions to worsen, stay the same, or improve, respectively. Since the variables are qualitative, the regression coefficients capture the share of firms giving the same answer. Moreover, firms are also asked the probability that the business conditions of their company will be worse in the next 3 months (SITP3M) and in the next 3 years (SITP3A).

The responses to the first four questions are displayed in Figure 7. For all the variables considered, I observe a significant and persistent negative effect of the carbon price shock on firms' perceived and expected conditions. The effects are immediate for all variables, except for the expected total number of employees, which begins to decline after 1/2 quarters, as anticipated given the highly regulated nature of the Italian labor market. Following an exogenous increase in the price of carbon, firms plan to reduce their workforce and expect worsening conditions both at the national level and within their own businesses.

The bottom two panels of Figure 7 report the responses for the probability that firms will experience worse economic conditions in the next 3 months (Panel E) and the next 3 years (Panel F). The responses are positive and significant suggesting that firms believe

Figure 7: Impact of carbon policy shocks on firms' economic perceptions and expectations



Notes: The figure plots the responses to a carbon policy shock, normalized to increase the HICP energy by 1 percent on impact, for the firms' perceptions and expectations about the aggregate and business-specific conditions. The variables in Panels from A to D take values {-1, 0, 1} if expected to decrease, stay the same or decrease. The variables of Panels E and F take values from 0 to 100. The black lines are the point estimates and the shaded areas are the 90 and 68 percent confidence bands. The horizontal axis is in quarters.

that an exogenous increase in the price of carbon will worsen their conditions both in the short-term and in the long-run. The results confirm that firms perceive carbon policy shocks as supply-side disruptions, adjusting their price expectations upward while revising their economic outlook downward.

4.6 Heterogeneous responses across firms' characteristics

One might expect firms to not be homogeneously exposed to changes in energy costs. Sectoral and individual characteristics could significantly influence the propagation of an increase in carbon price to the firms' expectations and decisions. Hensel et al. (2024) document that low energy-intensive firms are worse at forecasting the impact that carbon policy shocks will have on the evolution of their prices and that firms operating in more competitive environments expect to be less able to pass the increased costs to the final price of their products. I explore how the pass-through of carbon policy shocks is affected by different forms of firms' heterogeneity: the factor considered important by each firm in influencing their own price, the geographical area, and the sector in which they operate.

I exploit a question in the SIGE which asks to what extent they believe different factors will affect their own prices in the next 12 months. The factors I focus on are labor costs, raw materials prices, and total demand. Firms report whether the factor has a positive (+1), neutral (0), or negative (-1) effect on the evolution of their prices as well as the intensity of the effect (from 1 to 3). Therefore, the variables range from -3 to +3. As there are not many observations on each distinct value, to have enough power I transform the categorical variables into dummies D_t^i which identify firms with positive responses relative to firms with zero or negative responses, i.e., the dummy is equal to one for values ranging from 1 to 3 and zero otherwise.

The other firms' demographic characteristics I consider are the geographical area based on the firm's administrative headquarters and their sector. The data are not particularly granular but they still provide interesting insights into the heterogeneous effects of carbon policy shocks. Firms are classified based on whether their headquarters is based in the northwest of Italy, the northeast, the center, or the south and the islands[13]. The sector variable classifies firms into manufacturing, services or construction.

To explore how firms are heterogeneously affected by carbon policy shocks, I extend the baseline specification of equation (2) by introducing a variable D_t^i which identifies different firms' characteristics and which is interacted with the carbon policy shock $CPShock_t$:

$$E_{t+h}^i y_{t+h}^i = \alpha_h^i + \delta_{t,h} + \gamma_h D_t^i + \beta_h^D D_t^i \; CPS_t + \sum_{p=1}^{P} \theta_h^p X_{t-p}^i + \varepsilon_{t,h}^i, \tag{3}$$

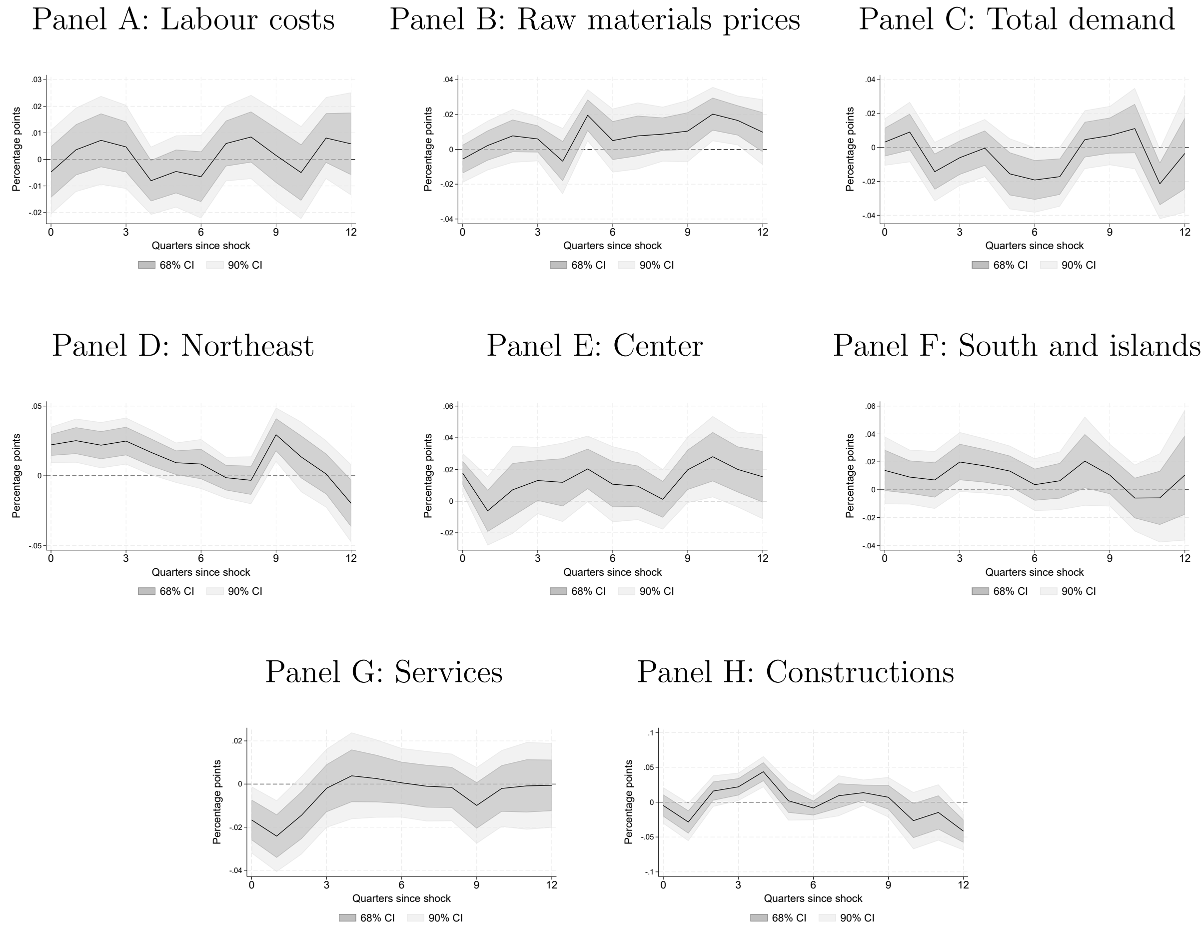
where $\delta_{t,h}$ is the time-fixed effects that absorb the carbon policy shocks and the aggregate variables. The coefficient β_h^D captures how firms are heterogeneously affected by the shocks according to their demographic characteristics. For the different factors, D_t^i is defined as a dummy equals one for firms that believe the factor has a positive effect on their future prices and zero otherwise. For the geographical area and the sectors, D_t^i is a categorical variable identifying the different regions and sectors[14]. The interaction coefficients can be interpreted as the differential response to a carbon policy shock relative to the baseline group. The different baseline groups are firms that believe a factor has none or a negative effect on their future prices, firms whose headquarters is located in the northwest of Italy, and firms in the manufacturing sector.

The heterogeneous effects of carbon policy shocks on firms' expectations according to their characteristics are reported in Figure 8. The Figure plots the interaction coefficients β_h^D. I document no significant difference in the pass-through to inflation expectations for firms considering labor costs important for their future prices relative to those that do not (Panel A). This is not surprising as an increase in energy costs is not expected to directly

[13]Italian regions are classified as follows. Northwest: Aosta Valley, Liguria, Lombardy, and Piedmont. Northeast: Emilia-Romagna, Friuli-Venezia Giulia, Trentino-Alto Adige/Südtirol and Veneto. Centre: Lazio, Marche, Tuscany and Umbria. South and islands: Abruzzo, Apulia, Basilicata, Calabria, Campania, Molise, Sardinia and Sicily.

[14]The dummies and the two categorical variables are included one at the time but adding them all at the same time does not affect the results.

Figure 8: Impact of carbon policy shocks on firms' inflation expectations by demographic characteristics



Notes: The figure plots the response to a carbon policy shock for the firms' 12-month ahead inflation expectations across different demographic characteristics. The coefficients reported are the interactions between the carbon policy shocks and the dummy identifying firms for which the different factors are important for the evolution of their prices as well as the categorical variables for the geografical area and the sector. The coefficients can be interpreted as the differential responses relative to the baseline categories, i.e., firms who consider the factor not important, firms from the northwest of Italy, and firms in the manufacturing sector. The black lines are the point estimates and the shaded areas are the 90 and 68 percent confidence band. The horizontal axis is in quarters.

affect labor costs. Therefore, whether a firm considers labor costs a key variable for their future price growth or not does not change how carbon policy shocks influence inflation expectations.

More interestingly, firms that consider raw materials prices important for their pricing decisions exhibit higher sensitivity to a carbon policy shock (Panel B). The positive and significant coefficients suggest that firms whose raw material costs are important sales price determinants have a higher pass-through from the increase in the price of carbon to their price expectations. This is likely because higher carbon prices directly translate into increased costs for raw materials, which are integral to their production processes. Finally, the opposite is true for firms whose prices are mainly demand-determined (Panel C). Firms that view total demand as crucial show a smaller response in inflation expectations. These firms might be more constrained in passing on higher costs to consumers due to demand sensitivity.

The results across geographical areas are presented in the middle panels. Compared to the baseline category of firms located in the northwest of Italy, only those in the northeast exhibit a slightly more vigorous response to a carbon policy shock (Panel D). Firms based in the central regions or in the south and the islands show no statistically significant difference in their responses (Panels E and F). The heterogeneous responses across regions most likely reflect differences in the industry composition.

Regarding sectoral heterogeneity, the pass-through of the carbon price increase 12 months ahead of inflation expectations is similar for firms in the construction sector and manufacturing (the baseline category), as illustrated in Panel H. However, the effect is more muted for firms in the service sector (Panel G). This finding is consistent with the evidence from Hensel et al. (2024), which demonstrates that the greater the share of energy costs in total input costs, the higher the sensitivity of expectations to carbon policy shocks. Since energy costs constitute a less significant input for service sector firms compared to those in construction and manufacturing, their expectations are less responsive to changes in carbon prices. In conclusion, firms' characteristics and their perceptions of factors influencing their prices significantly impact the extent to which carbon policy shocks affect their inflation expectations.

5 Robustness

In this section, I perform several robustness checks to further validate the main findings. First, I analyze the response of firms' expectations to carbon policy shocks using only the data from the period when all measures of inflation expectations are available, i.e., from 2014q1 onward. Second, I include macroeconomic controls in the specification. Third, to assess whether outliers or the survey composition might influence the results, I re-run the analysis using the cross-sectional average of firms' inflation expectations as the dependent variable.

As the first robustness check, I re-estimate equation (2) starting the sample from 2014q1. As previously noted, only the 12-month ahead inflation expectations are available from 1999, with questions about other forecast horizons being introduced later, the last being the long-term forecast in 2014q1. Therefore, I control that restricting the sample to the period in which all variables are available does not alter the baseline results.

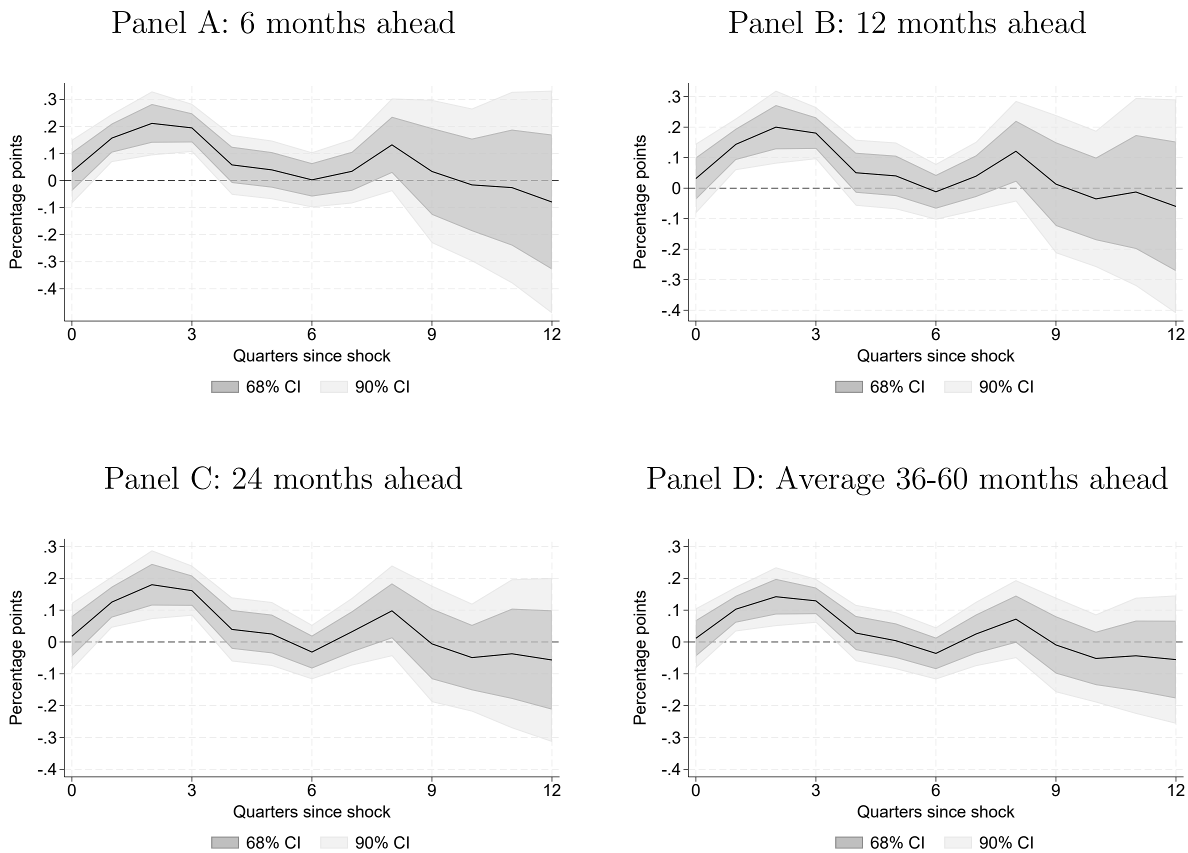
The results, presented in Figure 9, confirm that the main findings remain unchanged. An exogenous increase in the price of carbon still leads to a significant rise in firms' inflation expectations across all forecast horizons.

The shocks are constructed to be orthogonal to Euro Area economic conditions. Therefore, controlling for macroeconomic developments specific to Italy might be important for the estimated results. As additional robustness check, I extend the baseline specification by including Italian CPI inflation and unemployment rate, the European Central Bank policy rate as well as quarter fixed effects to absorb seasonality.

The results are reported in Figure 10. Controlling for aggregate macroeconomic variable and quarter fixed effects has basically no effect on the responses of the 12-month ahead expected inflation (Panel A) as well as the realized and expected own price growth (Panel B). The results are also robust to any possible combinations of these variables.

Finally, concerns about outliers or variations in survey composition potentially biasing the results are addressed by re-estimating the baseline specification using the cross-sectional

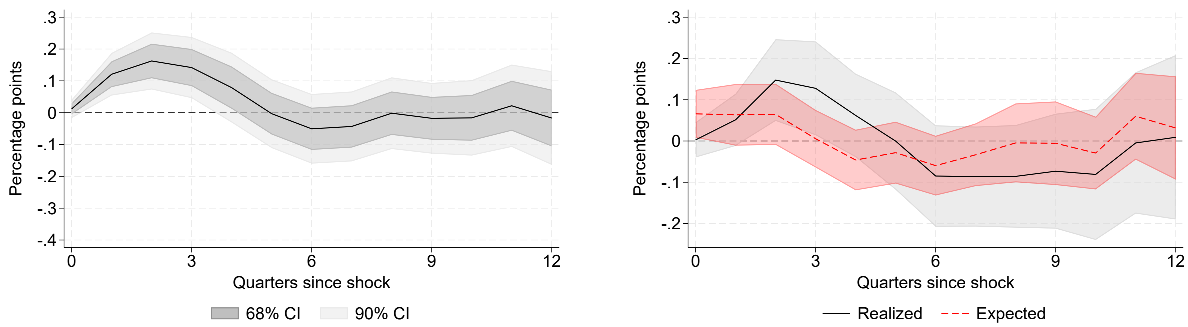
Figure 9: Impact of carbon policy shocks on firms' inflation expectations, common period



Notes: The figure plots the response to a carbon policy shock, normalized to increase the HICP energy by 1 percent on impact, for the firm-level inflation expectations at different forecast horizons. The time period considered spans from 2014q1 to 2019q4 when all the different horizons are available. The black lines are the point estimates and the shaded areas are the 90 and 68 percent confidence bands. The horizontal axis is in quarters.

Figure 10: Impact of carbon policy shocks on firms' expectations, macro controls

Panel A: 12 months ahead inflation Panel B: Expected and realized price growth



Notes: The figure plots the response to a carbon policy shock, normalized to increase the HICP energy by 1 percent on impact, for the firms' 12-month ahead expected inflation as well as the realized and expected own price growth. The specification also includes the Italian CPI inflation and unemployment rate, the European Central Bank policy rate as well as quarter fixed effects. The lines are the point estimate, and the shaded areas are the 90 and 68 percent confidence bands. The horizontal axis is in quarters.

average of firms' inflation expectations as the dependent variable[15]. The responses are presented in Figure 11. This approach, which mitigates the influence of outliers and survey composition changes, confirms that the baseline results are robust. Carbon policy shocks continue to show a significant impact on both short-term and long-term inflation expectations.

6 Discussion

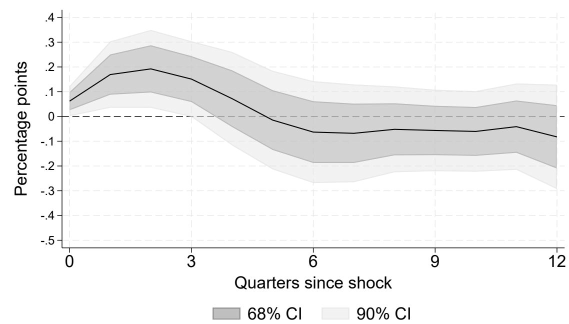
Following the post-COVID surge in inflation, partly driven by supply shocks, researchers and central bankers are revisiting the role of monetary authorities in managing energy shocks. This issue is becoming increasingly critical as energy shocks are expected to become more frequent and severe due to the escalating effects of climate change. At the same time, policies aimed at addressing climate change might generate inflationary pressures that central banks

[15]Similar results are obtained using the median.

Figure 11: Impact of carbon policy shocks on aggregate firms' inflation expectations

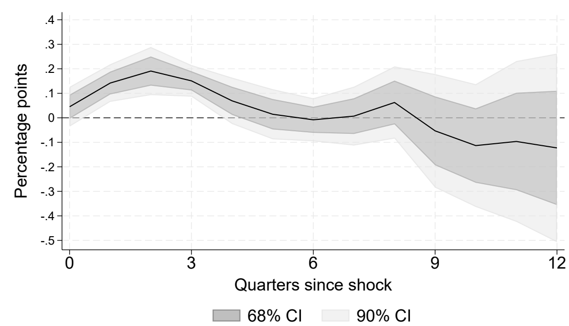
Panel A: 6 months ahead

Panel B: 12 months ahead



Panel C: 24 months ahead

Panel D: Average 36-60 months ahead



Notes: The figure plots the response to a carbon policy shock, normalized to increase the HICP energy by 1 percent on impact, for the cross-sectional average of the firm-level inflation expectations at different horizons. The black lines are the point estimates and the shaded areas are the 90 and 68 percent confidence bands. The horizontal axis is in quarters.

need to address.

As discussed by Bandera et al. (2023), traditional monetary economics suggests that central banks should not respond to supply shocks. The rationale is that these shocks are temporary and interest rate adjustments take time to impact the economy, making monetary policy an ineffective tool for immediate relief. Indeed, Figure 2 shows that the aggregate effects of such shocks diminish within 4-5 quarters. Furthermore, allowing for a temporary increase in aggregate inflation might facilitate a more efficient relative price adjustment across sectors[16].

However, "looking through" energy shocks may be suboptimal in the presence of information frictions and deviations from rational expectations. Just as gasoline prices significantly influence household inflation expectations (Coibion and Gorodnichenko, 2015, Cavallo et al., 2017, D'Acunto et al., 2021), energy costs affect firms' expectations, as evidenced by Hensel et al. (2024) for French firms and by the findings in this study. Allowing energy prices to rise, even temporarily, may lead to a more persistent increase in short-term inflation expectations, thereby exacerbating overall inflationary pressures.

Moreover, the initial positive forecast errors observed in response to a carbon policy shock, as documented for both France and Italy, indicate that firms are not fully informed when making their forecasts. The presence of information frictions could amplify the magnitude and persistence of the inflationary effects caused by energy shocks. This highlights the importance for central banks to counteract rising inflation to prevent second-round effects and avoid the potential de-anchoring of agents' expectations from the monetary authorities' target.

The novel findings of this paper further underscore this argument. The inflationary effects of energy shocks extend beyond short-term expectations to significantly impact medium- and long-term expectations, despite the aggregate effects fading within 4-5 quarters. This is particularly concerning for central banks, as it suggests a heightened risk of agents shifting their expectations away from the monetary authorities' target. Anchoring medium-term expectations is crucial for central banks in their pursuit of price stability.

Additionally, the increased disagreement in expected inflation aligns with sticky information models of information frictions and rational inattention. In these models, disagreement rises following a shock because firms either do not update their information continuously, leading to a delay before all firms are aware of changes in energy costs, or they focus primarily on variables they consider most relevant while disregarding others. To mitigate these

[16] See, among others, Aoki (2001), Guerrieri et al. (2022), and Rubbo (2023).

frictions, climate policies and their anticipated effects must be communicated clearly to the public, ensuring the effective dissemination of information.

The crucial role that central bank communication can play is further confirmed by the empirical evidence showing that providing firms with information about the current inflation rate influences the pass-through of the shocks. The evolution of firms' expectations is strongly shaped by the information provided by the Bank of Italy, which in turn affects their responsiveness to shocks. Therefore, transparent and clear communication by monetary authorities can play a pivotal role in managing expectations during inflationary episodes.

As the global economy transitions towards greener practices, central banks need to carefully consider their roles. The empirical results presented in this paper suggest that monetary authorities should not simply overlook supply-driven shocks. Maintaining price stability and keeping expectations anchored around the inflation target requires central banks to closely monitor and potentially counteract the inflationary effects induced by climate policies.

7 Conclusion

The role of central banks in addressing climate change remains a vibrant area of debate. On one hand, mitigating the adverse impacts of climate change is a collective responsibility. On the other hand, the potential inflationary effects of climate policies might create tensions with the central banks' core mandate of maintaining price stability.

This paper demonstrates that carbon pricing leads to increased inflation expectations among firms. By combining carbon policy shocks developed by Känzig (2023) with Italian firm-level survey data, it is shown that these shocks not only raise firms' expectations of their own price growth but also influence realized price growth, price forecast errors, and disagreement among firms. Furthermore, the pass-through effect is stronger for firms that receive information about the current level of inflation, and the shocks are found to significantly worsen firms' perceptions and expectations of both their own business conditions and the broader economic environment. Finally, significant heterogeneity in the effects of carbon policy shocks is observed, depending on firms' individual characteristics.

While carbon pricing generally results in temporary effects on overall inflation, the substantial information frictions in firms' expectations and the persistence of inflationary pressures in the long-term expectations suggest that central banks cannot simply disregard these energy shocks. There is a risk that short-term increases in inflation expectations could lead to higher actual inflation rates and also affect longer-term expectations, complicating the central banks' efforts to maintain price stability. Therefore, central banks should vigilantly monitor energy shocks and consider potential responses to mitigate their impact on inflation. Balancing the pursuit of price stability with the realities of climate policy-induced inflationary pressures is crucial for effective monetary policy.

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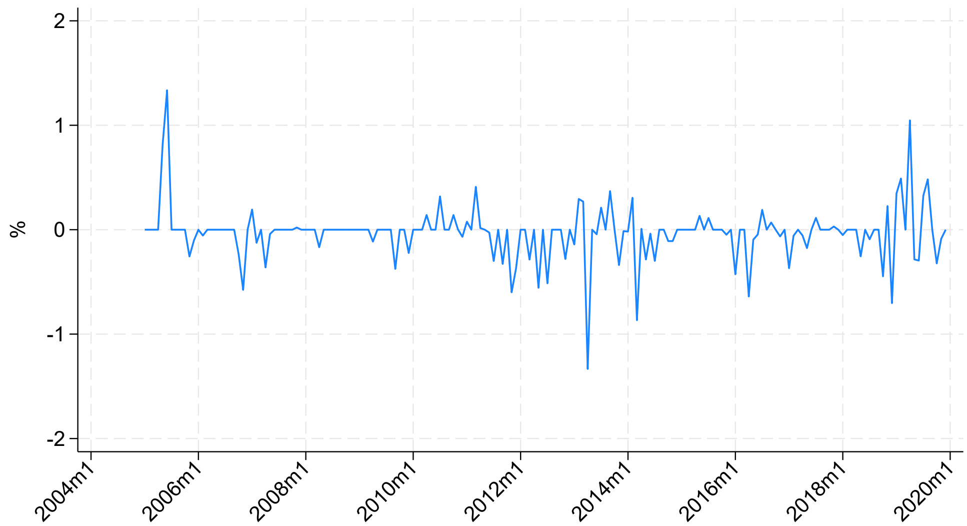
Appendix

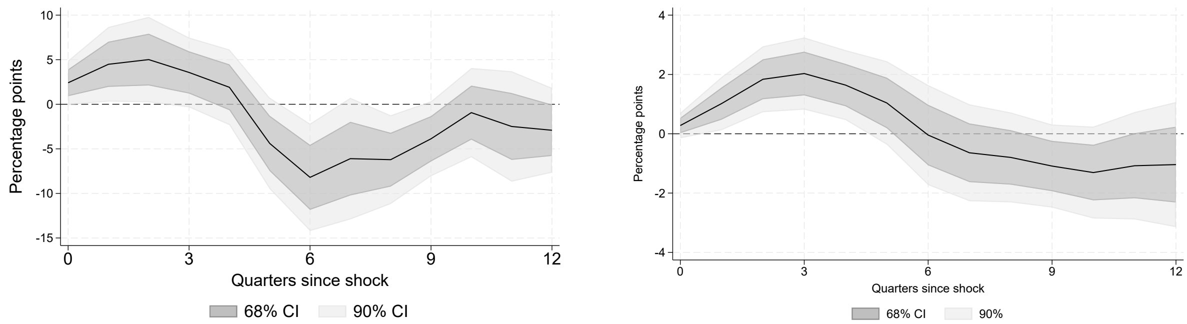
Figure 12: The carbon policy surprise series



Notes: This figure shows the carbon policy surprise series, constructed as the EUR change in carbon prices relative to the prevailing wholesale electricity price on the day before the event.

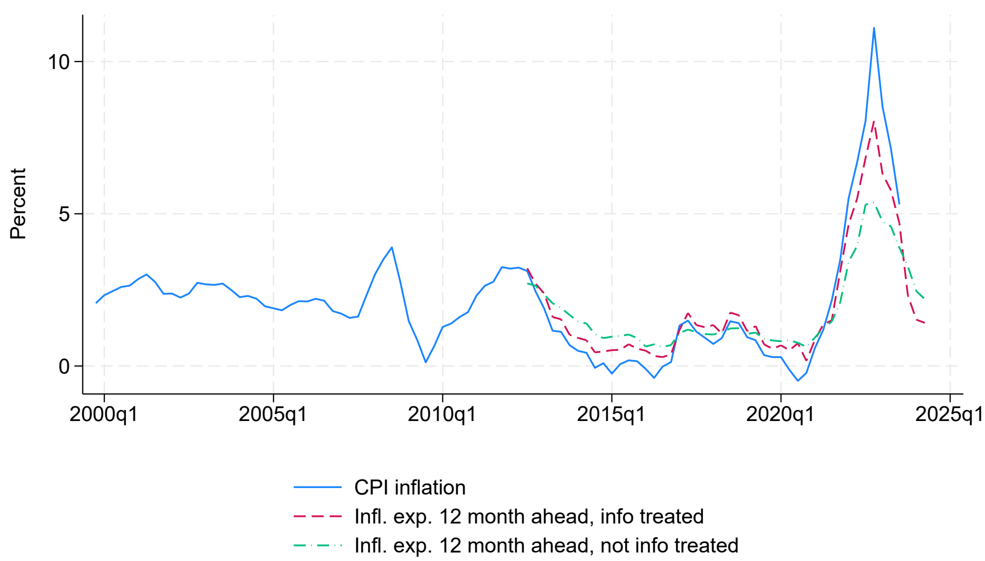
Figure 13: Impact of carbon policy shocks on energy prices

Panel A: Wholesale electricity prices   Panel B: Electricity, Gas and Other Fuel price



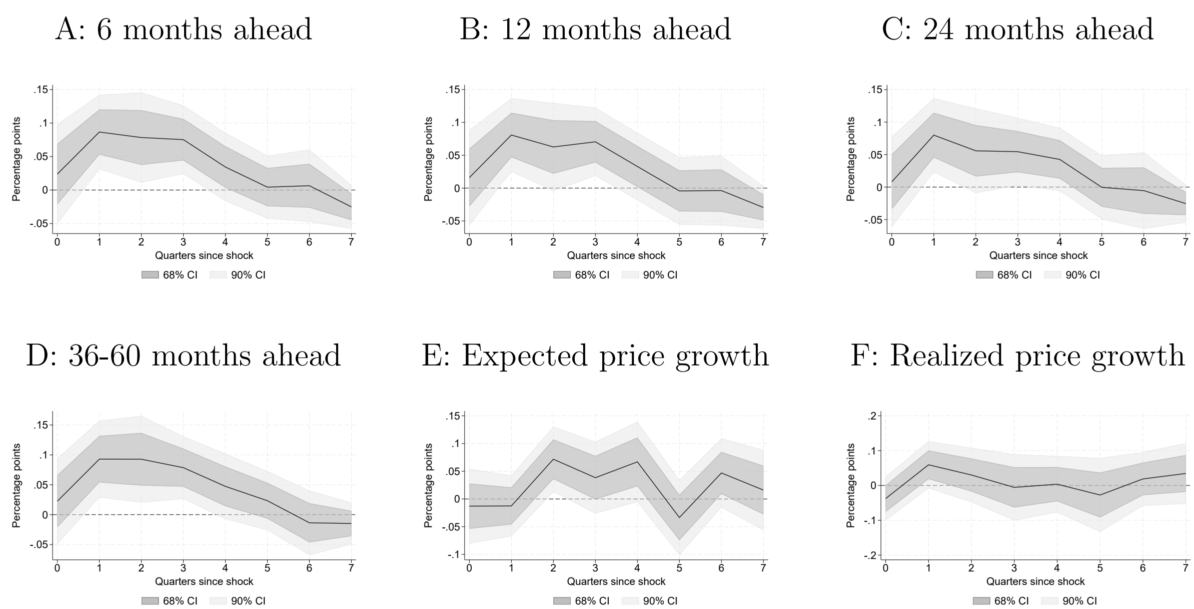
Notes: The figure plots the response to a carbon policy shock, normalized to increase the HICP energy by 1 percent on impact, on different measures energy prices. The response on the left panel are computed using as dependent variables the the year-on-year inflation rates of the wholesale electricity prices and the response on the right panel the inflation subcomponent *Electricity, Gas and Other Fuel price* (COICOP 04.5). The black lines are the point estimates and the shaded areas are the 90 and 68 percent confidence bands. The horizontal axis is in quarters.

Figure 14: Time series of the Italian CPI inflation and firms' inflation expectations by treatment status



Notes: The figure plots the time series of actual CPI growth for Italy alongside the measures of firms' 12-month ahead inflation expectations by treatment status. The firm-level data comes from the SIGE survey.

Figure 15: Differences in the expectations responses to carbon policy shocks by treatment status



Notes: The figure plots the response to a carbon policy shock for the firms' expectations. The coefficients reported are the interactions between the carbon policy shocks and the dummy identifying whether a firm has received the information treatment or not. The coefficients can be interpreted as the differential responses relative to the baseline category, i.e., firms who did not receive the information. The black lines are the point estimates and the shaded areas are the 90 and 68 percent confidence band. The horizontal axis is in quarters.