Carbon Pricing and Inflation Expectations: Evidence from France

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Abstract

This paper examines the impact of carbon pricing on firms' inflation expectations and its implications for central banks' price stability mandate. Carbon policy shocks are identified using high-frequency identification and combined with French firm-level survey data. A change in carbon price within the increases firms' inflation expectations as well as their own expected and realized price growth. The effect on price expectations is more persistent than on actual price growth, resulting in negative forecast errors in the medium-/long-run. We show that a significant portion of the increase in inflation expectations is driven by indirect effects. Firms rely on their own business conditions to form expectations about aggregate price dynamics. Therefore, the expected positive growth in their own prices significantly contributes to the observed increase in inflation expectations. Firms' responses to the shocks vary based on their energy intensity. Low energy-intensive firms are worse forecasters of the impact that the shocks will have on the evolution of their own prices.

Keywords: Climate policies, Carbon pricing, Inflation expectations, Monetary policy, Survey data.

JEL classification: E31, E52, E58, Q43, Q54

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1 Introduction

"In short, climate change has consequences for us as a central bank pursuing our primary mandate of price stability, and our other areas of competence, including financial stability and banking supervision"

Christine Lagarde at the International Climate Change Conference (2021)

"As we build a more sustainable economy, we face a new age of energy inflation (...) that can be expected to lead to a prolonged period of upside pressure on inflation. (...) Overall, therefore, monetary policy cannot simply ignore the effects of the green transition if they threaten to jeopardize the achievement of our primary mandate of price stability."

Isabel Schnabel at the ECB and its Watchers XXII Conference (2022)

"Given that the ECB's primary mandate is to preserve price stability, understanding the relationship between the transition to a greener economy and the price of energy is crucial."

Fabio Panetta at the Italian Banking Association (2022)

Central banks across the world have become more and more vocal about their commitment to climate change and are also facing additional pressure from policymakers to use their available toolset in such directions. Several monetary authorities have acknowledged the potential risks that climate change, and the policies adopted to tackle it, pose for economic and financial stability and some of them have already adopted a more proactive role, e.g., ECB (2021). However, the empirical evidence regarding the inflationary effects of the green transition is still limited and sometimes conflicting in their conclusion.

This paper studies the potential implications that carbon pricing has for price stability. Carbon pricing is seen as one of the most important policy tools to reduce emissions and, therefore, to mitigate the long-term shifts in temperatures and weather patterns. However, carbon pricing potentially threatens price stability which is at the core of almost every modern central bank's mandate. We document that increases in carbon prices indeed result in a rise in firms' inflation expectations as well as their own expected and realized price growth. Moreover, in the long run the effect on expectations is more persistent than on actual price changes leading to negative forecast errors. Moreover, we show that there is a direct effect of the shocks on aggregate inflation expectation but also that a significant share of the overall effect is due to indirect effects through changes in firms' own business conditions. Finally, we find that the lower the share of input costs devoted to electricity the less accurate the firms' own price forecast.

We measure exogenous changes in the carbon price using the carbon policy shock series developed in Känzig (2023). The author identifies 126 regulatory events during the period from 2005 to 2019 that influenced the supply of emission allowances in the European Union Emissions Trading System (EU ETS). The series of carbon policy surprises is computed from the change in the carbon futures price in a tight time window around the regulatory news. The surprises are then aggregated at a monthly level and used as an instrument in a proxy VAR to estimate the dynamic causal effects on the aggregate economy. The carbon policy shock series is identified from the residuals of this specification.

To evaluate how firms' inflation expectations are affected by carbon pricing policies, we combine the carbon policy shock series with French firm-level survey data. The survey, known as the Enquête de Conjoncture dans l'Industrie (ECI; "Survey of Economic Conditions in the Industry"), reports at quarterly frequency firms' inflation expectations, the expected own price growth over the next three months, and the actual price growth over the last three months. The survey is restricted to firms in the industry sector. The empirical specification we adopt is a panel local projection à la Jordà (2005).

We document that firms' inflation expectations significantly respond to carbon policy shocks. A similar effect is found for firms' own expected price growth. The responses of expected and realized price growth closely follow each other confirming that expectations translate into actual decisions. However, price forecast errors, defined as realized minus expected price growth, respond positively in the medium-/long-run suggesting that the impact of carbon policy shocks is more persistent on expectations than it is on actual price growth. We then decompose the positive response of inflation expectations into its overall and direct effect, i.e., the component of the response due to extrapolation from the firms' own business conditions. We find that the indirect effects are almost as important as the direct ones. Finally, we combine administrative balance-sheet data with the EACEI survey ("Survey on energy consumption in industries") to compute a measure of firm-level energy intensity. We document that the price forecast errors of low energy-intensive firms are much larger in response to carbon policy shocks.

The ability of a central bank to stabilize price growth crucially relies on its ability to control price expectations. At the same time, monetary authorities are becoming active players in tackling climate change. The findings of this paper suggest that carbon pricing is perceived by firms as inflationary. However, this does not necessarily imply that the pathway to a greener economy will cause a persistent rise in inflation. Higher taxes on fossil fuels and subsidies on green energy will impact their relative prices as well as their demand and supply. Ultimately, the overall effect on inflation will depend on the policy mix adopted.

Related literature. This paper contributes to three strands of the literature. First, the results complement the large body of empirical evidence on the effects of carbon pricing on the economy. The effectiveness of carbon pricing for emission reductions is well supported by empirical evidence (Ralf et al., 2014, Andersson, 2019). However, the impact on macroeconomic variables is still subject to debate.

Metcalf (2019) and Bernard and Kichian (2021) focus on the consequences of the British Columbia carbon tax documenting no significant impacts on GDP. Similarly, Metcalf and Stock (2020b) and Metcalf and Stock (2020a) do not find any adverse effects of carbon taxes in European countries on employment and GDP growth. Konradt and di Mauro (2023) study the potential inflationary pressure of carbon taxes in Europe and Canada and conclude that they are negligible. Moessner (2022) uses a dynamic panel estimation of New-Keynesian Phillips curves for 35 OECD economies from 1995 to 2020 and shows that an increase in prices of ETS by \$10 per ton of $CO2$ equivalents leads to an increase in energy CPI inflation by 0.8 percentage points and headline inflation by 0.08. For the California cap-and-trade market, Benmir and Roman (2022) find that carbon pricing shocks have sizable effects on the economy and result in an increase in the price of energy with negative consequences for the real economy.

From a theoretical perspective, Ferrari and Landi (2023) study in a simple two-period New Keynesian model the inflationary effects of a tax on emissions. The findings emphasize that the impact of carbon pricing on inflation crucially hinges upon households' expectations. Similarly, Del Negro et al. (2023) develop a two-sector New Keynesian model to analyze the inflationary effects of climate policies, with specific attention given to the different levels of price stickiness between the "dirty" and "green" sectors. Furthermore, Airaudo et al. (2023) use a small open economy model to conduct an assessment of the green transition's impact on output and inflation, with a particular focus on the role of fiscal policy.

The impact of carbon policies goes beyond their macroeconomic impact. The carbon policy shocks used in this paper are developed by Känzig (2023) who shows that exogenous variation in the carbon price due to regulatory events leads to an increase in inflation and a decrease in economic activity. Households along the income distribution are heterogeneously affected by the shocks mainly because of general equilibrium forces. Mangiante (2023) uses the same carbon policy shocks and documents that the real activity of poorer Euro Area countries is the most sensitive to changes in carbon price. Finally, Berthold et al. (2023) show that the effects of carbon pricing shocks are larger for more carbon-intensive countries and $CO2$ intensive firms. We contribute by focusing on firm-level effects. Using survey data from France we evaluate how firms' aggregate and own price expectations respond to changes in carbon price.

Second, we contribute to the literature that studies the implications of climate change and its mitigation policies for central banks. Both monetary authorities and academics are thoroughly assessing to what extent and through which channels climate change is a threat to the central banks' objective[1]. Batten et al. (2020) provide a comprehensive summary of the risks from climate change that could affect the macroeconomy and price stability.

For example, environmental disasters have been found to have large inflationary effects in emerging countries. Heinen et al. (2018) find that hurricane and flood destruction lead to an increase in consumer prices in Caribbean islands. A similar result is found by Parker (2018), who also documents heterogeneous effects across disaster types. Storms only temporarily increase food price inflation, floods also typically have a short-run impact on inflation whereas earthquakes reduce inflation excluding food, housing, and energy. Using panel local projections for 48 advanced and emerging market economies (EMEs), Faccia et al. (2021) show that hot summers increase food price inflation in the near term, especially in EMEs.

Climate change is not only a major source of concern for the central banks of developing countries. The issue is also on top of the agenda for the European Central Bank (ECB, 2021) and the members of the Executive Board (Schnabel, 2022). Moreover, modern central banks have seen an increase in public pressure to proactively contribute to the transition towards a low-carbon economy (Schoenmaker, 2021, Monnin, 2018, de Grauwe, 2019, Honohan, 2019, Lagarde, 2021, Schnabel, 2021).

We extend this literature by assessing whether carbon pricing, one of the main climate policies currently adopted, can affect price stability. We show that changes in carbon price are

[1]See, among others, of England (2015), Carney (2015), Batten et al. (2016), of England (2018), NGFS (2020), NGFS (2021), Boneva et al. (2021), Ferrari and Landi (2023)

perceived by firms as inflationary. On top of that, firms extrapolate from the anticipated path of their own prices in forming aggregate expectations. This results in an even stronger increase in inflation expectations. Overall, our findings suggest that this climate policy potentially reduces price stability which is at the core of many central banks' mandates.

Third, this work feeds into the broader literature on inflation expectations formation. How households form their expectations about aggregate future price dynamics has been thoroughly studied in the last years[2]. The evidence on firms' inflation expectations is more scarce mainly due to limited data availability.

The empirical evidence so far suggests that firms are more similar to households than professional forecasters in forming their aggregate expectations. For the U.S., Coibion et al. (2020b) report that disagreement in firms' inflation expectations is closer to the high levels observed for households rather than one of the professional forecasters. Candia et al. (2021) show that the inflation expectations of U.S. managers, much like those of households, are far from anchored and that the managers are largely uninformed about recent aggregate inflation dynamics or monetary policy. Kumar et al. (2015) find that firm managers in New Zealand rely on their shopping experiences as the primary determinant of their inflation expectations. Using the same survey of French manufacturing firms of this paper, Andrade et al. (2022) document that firms exploit the local prices they observe to make inferences about aggregate price dynamics despite the changes in local prices having no aggregate effects. Dovern et al. (2023) use data on growth expectations of German firms from the ifo Business Tendency Survey to show that firms rely on local information regarding their county, industry growth, and individual business situation when forming expectations about aggregate growth.

Households' inflation expectations have been found to be particularly sensitive to changes in gas prices[3]. This is due to the fact that gasoline is a frequently-purchased (salient) good. Households can easily observe any price changes and, given its high volatility, they tend to overestimate its importance for aggregate inflation. We extend these results to firms. We document firms' expectations strongly react to changes in carbon price and that firms rely on their own business conditions to infer the future aggregate price path.

Understanding how expectations are formed is of pivotal importance since changes in expectations affect agents' decisions and consequently their outcomes. In a series of randomized controlled trials, Coibion et al. (2019) and Coibion et al. (2020a) induce an exogenous variation

[2]See, among others, Coibion and Gorodnichenko (2012), Coibion and Gorodnichenko (2015a), Axelrod et al. (2018), Coibion et al. (2019)

[3]See Coibion and Gorodnichenko (2015b), Cavallo et al. (2017), and D'Acunto et al. (2021)

in inflation expectations by providing the survey participants with different forms of information regarding inflation. The authors document that this exogenous variation has subsequent effects on household spending. With a similar empirical strategy for a survey of Italian firms, Grasso and Ropele (2018) and Coibion et al. (2020c) find that higher expected inflation is positively correlated with firms' willingness to invest, leads them to raise their prices, increase demand for credit, and reduce their employment and capital. We show that the increase in expected price growth due to changes in carbon price is closely followed by an increase in actual price growth.

Road map. The remaining paper is organized as follows. Section 2 describes the data used in this paper. In Section 3, we 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, we perform a battery of robustness checks to strengthen the validity of the baseline results. Finally, Section 6 concludes.

2 Data

2.1 Firm Level Data

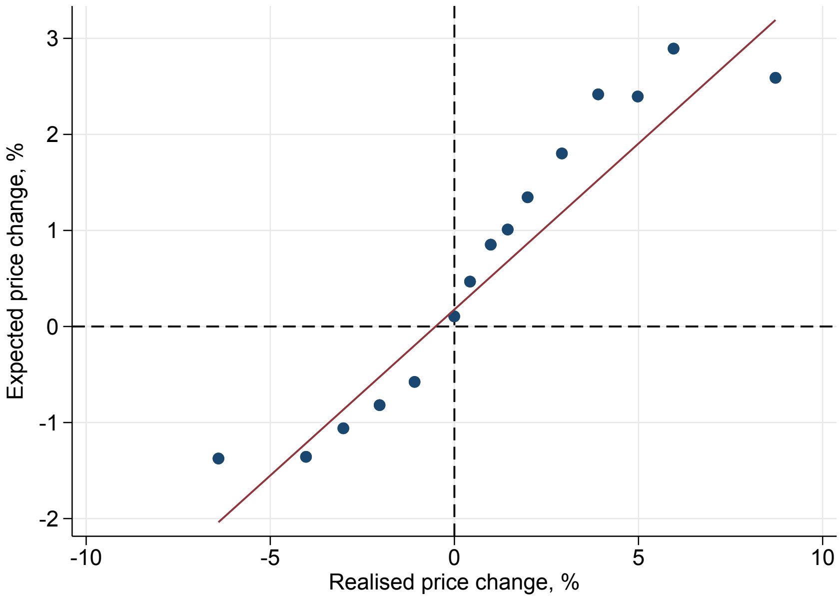
The main data set used for this project is the French Outlook Survey ("ECI: Enquête de conjoncture dans l'industrie")[4]. The survey is conducted by the French Economic Statistics Institute (INSEE) and researchers can access it after approval from the INSEE via restricted access to a secure data hub (Secure Data Access Center–CASD). It covers firms belonging to the manufacturing sector.

The survey is conducted monthly since 1992, and additional questions are asked quarterly (January, April, July, and October). Each quarter, on average 2,500 firms respond to the survey and over the sample period, approximately 9,700 unique firms participated. The panel dimension is particularly rich since on average a firm is part of the sample for 27 quarters. Overall, for the period of interest from 1999 to 2019 our data set contains approximately 300,000 individual product-specific observations (time x firms x product) and 230,000 firm-level observations (time x firm).

The company executives are asked via postal mail or the Internet both qualitative as well as quantitative questions regarding their expectations for a variety of business-related issues such as prices, employment, production, wages, factors constraining production, and the

[4]A detailed description of the methodology of the survey can be found *here*.

Figure 1: Past and expected future price changes



Notes: This figure shows the relationship between firms' own expected price change and the realized price growth.

economic outlook. Importantly, this survey also distinguishes between firm-specific questions and questions regarding aggregate measures. The most important dimension for this paper is the information about prices.

Monthly, the firms are asked about their qualitative assessment of the 3-month ahead inflation expectation (either increasing, flat, or decreasing) as well as their expectation for their own prices differentiated by individual products. Additionally, they are asked quarterly for quantitative 3-months ahead price forecasts for their own prices, as well as the quantitative price changes in the last 3 months. As shown in Figure 1, the expected price changes are positively correlated with the actual price changes in the following quarter. This suggests that the forecasts provided are of high quality as the higher the expected price growth the higher the realized price increase observed.

Table 1 provides some descriptive statistics for the main variables of interest at quarterly frequency. The qualitative responses, i.e., the 3-month ahead expected inflation, own price growth and the realized price growth over the past 3 months which take value $\{-1, 0, 1\}$ depending on whether firms expect the variable to decrease, stay the same or increase. Andrade et al. (2022) already show that the time series of the average realized price change matches quite well the evolution of the official PPI inflation rate for France again confirming the high

Table 1: Descriptive statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Expected inflation	0.097	0.635	-1	1	204,936
Realized price gr.	0.038	0.509	-1	1	278,261
Expected price gr.	0.068	0.521	-1	1	249,985
Realized price gr. (Quant.)	0.11	1.97	-10	10	267,452
Expected price gr. (Quant.)	0.222	1.523	-7	8	236,393

Notes: The table reports descriptive statistics from the ECI survey on French firms for the period 1999 to 2019. The data are at quarterly frequency for the 3-month ahead inflation expectations, price growth expectations (both qualitative and quantitative) and realized price growth over the past 3 months (both qualitative and quantitative). The qualitative responses are coded as a +1 if the firm expects the variable to increase, 0 if stays the same and -1 if decreases.

quality of the data. Moreover, the firms display significant heterogeneity in their forecasts of the aggregate as well as their own price growth.

2.2 Carbon Policy Shock Series

The carbon policy shocks are computed following the procedure developed by Känzig (2023) which we briefly summarize below. The main idea is similar to what has been done for monetary policy shocks (see, among others, Gürkaynak et al., 2005 and Nakamura and Steinsson, 2018). Monetary surprises are identified from changes in high-frequency asset prices around monetary policy announcements. By considering a tight window around the events, the change in price can be considered unexpected and exogenous. The same methodology is applied to variations in carbon future price around regulatory events.

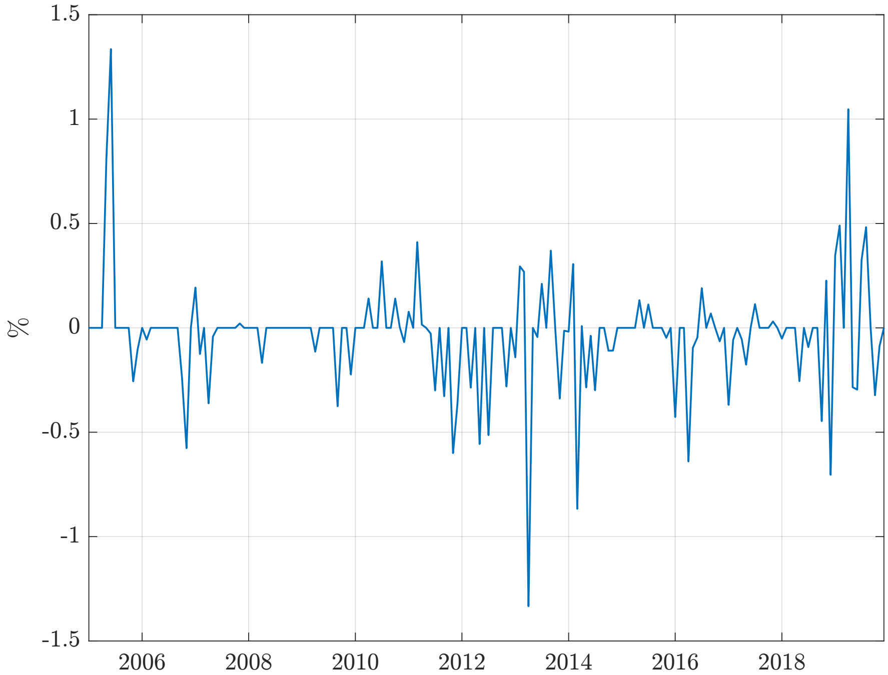
The European carbon market, established in 2005, operates under the cap and trade principle: a cap is set on the overall amount of certain greenhouse gases that can be emitted and, within the cap, emission allowances are auctioned off and traded in different organized markets.

Känzig (2023) identify 126 events from 2005 to 2019 concerning the overall cap in the European Union Emissions Trading System (EU ETS), the free allocation of allowances, the auctioning of allowances as well as the use of international credits. Carbon policy surprises are then computed from the changes in the futures price of the EU emission allowances (EUA) in the ICE since it is the most liquid market. In particular, the surprises are defined as the EUR change in carbon prices relative to the prevailing wholesale electricity price on the day before the event[5]. The daily surprises are then aggregated into a monthly series by summing

[5]As alternative measures we also use the difference in the settlement price and its percentage change. The main results are not significantly affected by the choice of the surprise measure.

over the daily surprises in a given month. In months without any regulatory events, the series takes zero value. The carbon policy surprise series are shown in Figure 2.

Figure 2: The carbon policy surprise series



Notes: This figure shows the carbon policy surprise series, constructed by measuring the percentage change (blue solid line, left axis) as well as the change (red dashed line, right axis) of the EUA futures price around regulatory policy events.

The carbon policy surprise series can be considered only a partial measure of the shock of interest due to measurement errors. To isolate the carbon policy shocks, the surprises are used as an external instrument in a VAR model with eight variables spanning the period from January 1999 to December 2019: 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. Apart from the unemployment and the policy rate, the other variables are in log levels and six lags of all variables are included. The carbon policy shocks are then extracted from the residuals of the monthly VAR (see Stock and Watson, 2018) and are normalized to increase the energy component of the HICP by one percent on impact.

3 French Macroeconomic Variables and Carbon Policy Shocks

The Proxy-VAR used to obtain the carbon policy shock series includes macroeconomic variables for the EA-19 members. Before evaluating how carbon policy shocks affect French firms' expectations, it is important to assess the aggregate effects that these shocks have in France. To do so, we estimate 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 $h = 1, ..., 16$. y_{t+h} is the dependent variable at time $t+h$ and $CPShock_t$ are the carbon policy shocks at time t extracted from the Proxy-VAR. In the baseline specification, we include three lags of the dependent variable and we correct for autocorrelation using Newey and West (1987) standard errors[6]. The main dependent variables are the log of the Energy Consumer Price Index (CPI), the CPI as well as of Producer Price Index (PPI) for France. 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 responses to a climate policy shock are reported in Figure 3. Following a carbon policy shock that results in a one percent increase of the Euro Area HICP energy component on impact, the French Energy CPI respond similarly by increasing by the same amount (top left panel). Moreover, both the French CPI and PPI series significantly and persistently increase (top right and bottom panel respectively). The shock increases CPI by around 0.1 percent and PPI by 0.3 percent on impact before they slowly converge back to zero after 7/8 quarters. The inflationary effects are both statistically and economically meaningful.

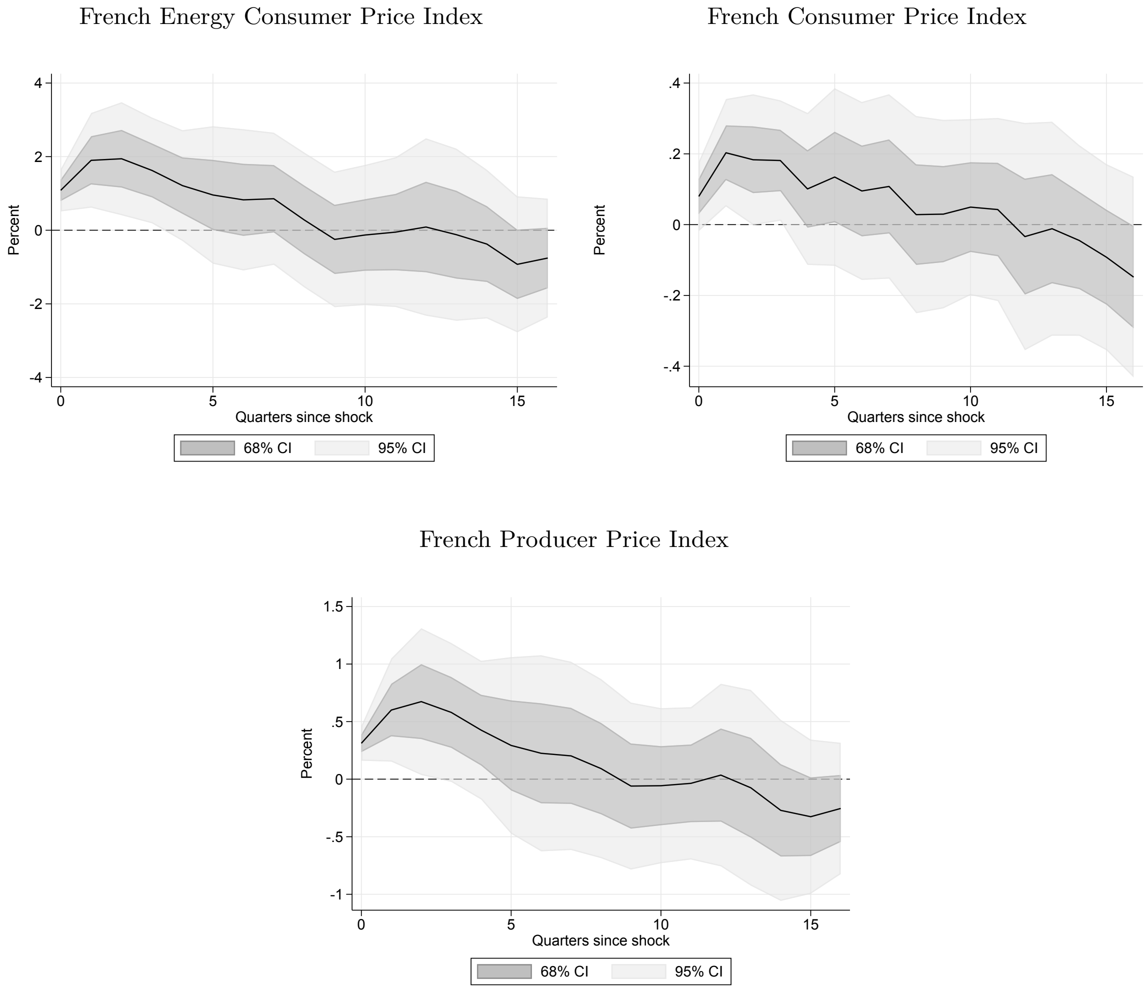
In line with the findings from Känzig (2023) for the EA-19 members, the results confirm that carbon policy shocks have sizable effects at the macro level for France. We can now study whether French firms' price expectations are affected by changes in carbon price.

4 Firms' Expectations and Carbon Policy Shocks

We have shown that aggregate prices increase following a carbon policy shock. We now shift our focus from macro- to firm-level variables. Firms are asked every month about what they expect to happen to aggregate prices as well as their own prices over the next 3 months. Moreover, once every quarter firms also report the actual price change they experienced over the past 3 months. To make our results comparable we consider all the variables at quarterly frequency. The high frequency of the data and the long panel structure make it an ideal survey to study how firms' expectations are affected by changes in carbon price.

[6] Including also lags of the shocks does not alter our results as the shock series displays almost no autocorrelation. Moreover, macroeconomic variables are not included as these are already controlled for in the monthly VAR.

Figure 3: 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 French Energy CPI (top left panel), CPI (top right panel) and the PPI (bottom panel). The black lines are the point estimate and the shaded areas are the 95 and 68 percent confidence bands, respectively. The horizontal axis is in quarters.

We estimate the average firm-level response to a carbon policy shock following the approach used by Andrade et al. (2022):

$$\sum_{k=0}^{h-1} \mathbb{I}\left\{E^i_{t+k} y^{i,j}_{t+k+1}\right\} = \alpha^i_h + \beta_h CPShock_t + \sum_{p=1}^{P} \theta^p_h X^{i,j}_{t-p} + \varepsilon^{i,j}_{t,h}, \tag{2}$$

for $h = 1, ..., 16$. $E^i_{t+k} y^{i,j}_{t+k+1}$ is the dependent variable, e.g., own price expectations or realized price growth, at time $t + k$ of firm i regarding its own product j. Since each firm gives a single answer to the question about the expected aggregate price change, when using inflation expectations as dependent variable the index j can be dropped and the dependent variable is equal to $E^i_{t+k} y^{agg}_{t+k+1}$. $\mathbb{I}\{\}$ takes value $\{-1, 0, 1\}$ depending on whether firms expect the dependent variable to decrease, stay the same or increase. α^i_h are firm fixed effect, $X^{i,j}_{t-p}$ is a matrix of controls and P is the number of lagged values[7]. Finally, standard errors are clustered at the firm level.

It is important to notice that the expectations of aggregate inflation and own price growth at monthly frequency are only qualitative. Therefore, the cumulative summation on the left-hand side can be interpreted as of the degree to which expectations respond to changes in carbon price. Due to the qualitative nature of the survey question the magnitude of the coefficient β_h does not have a direct interpretation but simply captures the share of firms that expect the dependent variable to decrease, stay the same or increase.

First, we evaluate how firms' inflation expectations are affected by carbon policy shocks. Second, we focus on firms' own price expectations, Third, we compare the effects on own price expectations with the realized price growth. Fourth, we study the price forecast errors response to assess whether firms' expectations over- or under-react to changes in carbon price. Fifth, we decompose the overall impact of carbon shocks on inflation expectations into its direct and indirect effects. Sixth, we assess whether firms heterogeneously respond based on their energy intensity level.

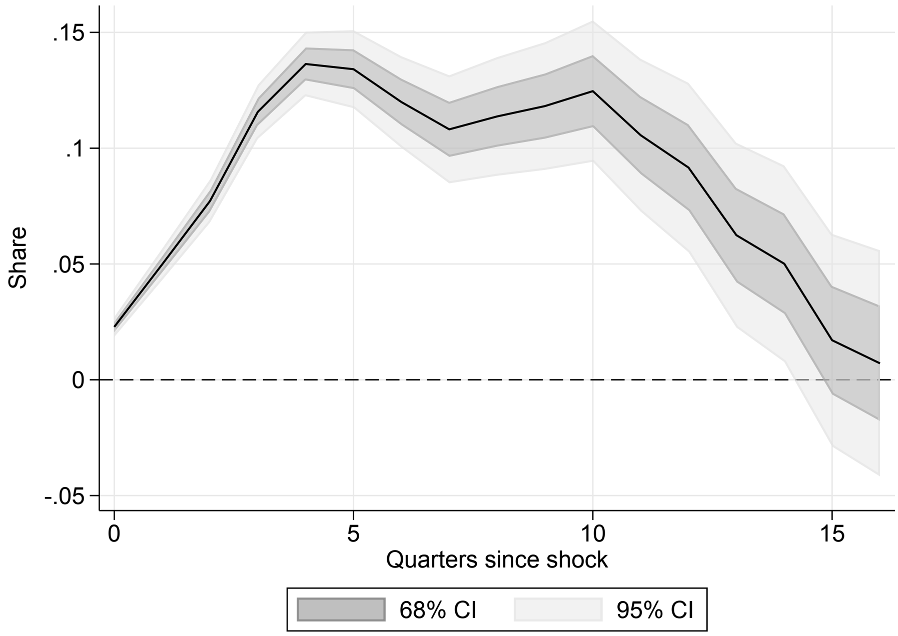
4.1 Inflation Expectations

The cumulative response of firms' inflation expectations is shown in Figure 4. The Figure reports the coefficients $\{\beta_h\}$ from equation (2). A carbon policy shock leads to a sizable and persistent increase in aggregate inflation expectations. The greater persistence observed in the firm-level response, in contrast to the aggregate responses depicted in Figure 3, is due to the fact that the dependent variable is cumulated within each firm to capture the effect of the shock on the qualitative variable over time.

The increase in inflation expectations suggests that carbon policy might decrease price stability. Aggregate price expectations are one of the main determinants of actual inflation. Therefore, the rise in inflation expectations caused by changes in carbon price might lead to inflationary pressure on the economy. On top of that, even though the survey asks only about the 3-month inflation expectation, medium- and long-term expectations, which are the targets of the central banks, are well known to be sensitive to variations in short-term expectations (Lyziak and Paloviita, 2016). However, it is important to underline that this finding does not

[7] In the baseline specification we control for 3 lags of the dependent variable.

Figure 4: Impact of carbon policy shocks on firms' inflation expectations



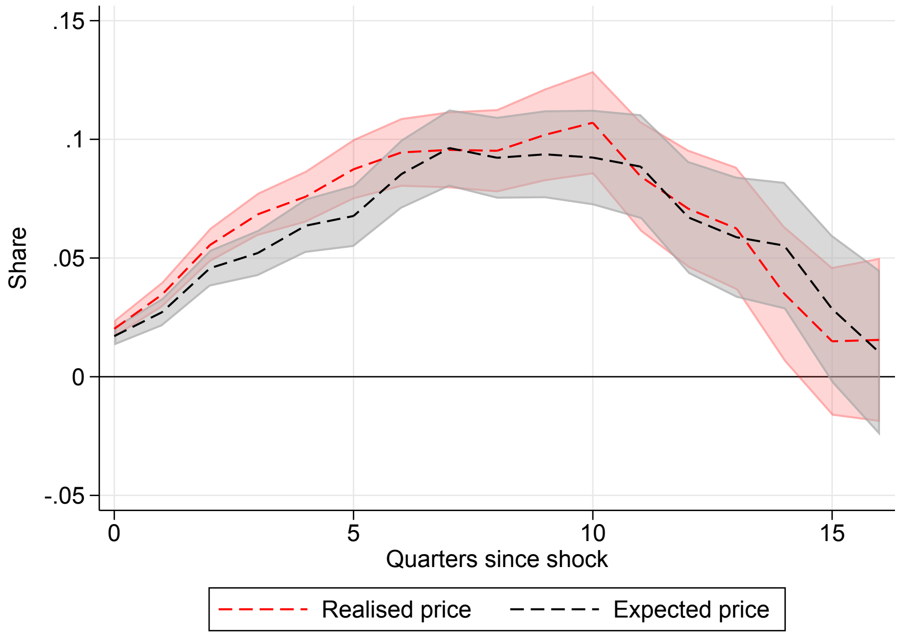
Notes: The figure plots the cumulative response to a carbon policy shock, normalized to increase the HICP energy by 1 percent on impact, for the firm level inflation expectations. Inflation expectations take values {-1, 0, 1} for aggregate prices expected to decrease, stay the same or decrease. The black lines are the point estimate and the shaded areas are the 95 and 68 percent confidence bands, respectively. The horizontal axis is in quarters.

imply that the green transition is necessarily at odds with price stability. Changing relative prices is a desired feature of the policy. Imposing a tax on carbon is only one of the tools currently available to tackle climate change and if properly complement with other policies the transition towards a greener economy and stability of prices can coexist.

4.2 Own Price Expectations and Realized Price Growth

To form expectations about the evolution of aggregate prices, economic agents usually rely on personal experience even when this information is orthogonal to aggregate dynamics. For example, using the same survey of this paper, Andrade et al. (2022) show that firms' inflation expectations significantly respond to changes in industry-specific inflation rates. Therefore, changes in carbon price might not only directly increase inflation expectations but also have indirect effects due to the impact on firms' own business conditions. We study this potential channel by evaluating the response of firms' own price expectations and realized price growth to carbon policy shocks.

Figure 5: Impact of carbon policy shocks on firms' own price expectations and realized price growth (qualitative)

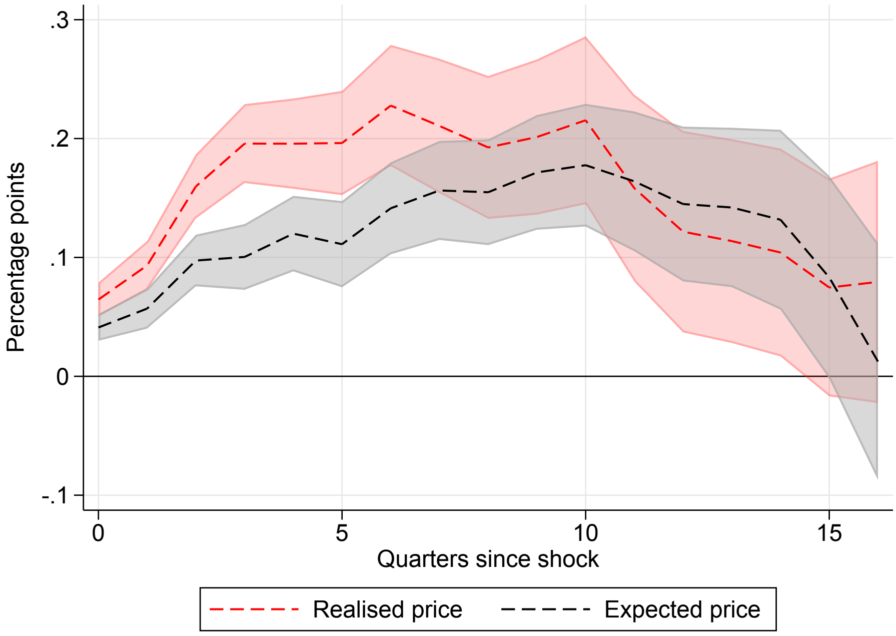


Notes: The figure plots the cumulative response to a carbon policy shock, normalized to increase the HICP energy by 1 percent on impact, for the firms' own price expectations as well as the realized price growth. Price expectations take values {-1, 0, 1} for prices expected to decrease, stay the same or decrease. Realized prices take values {-1, 0, 1} based on whether prices decreased, stayed the same or decreased. The dashed lines are the point estimate, and the shaded areas are the 95 percent confidence bands. The horizontal axis is in quarters.

We estimate equation (2) using the firms' expected and realized price growth from the qualitative responses as dependent variable. The cumulative responses are reported in Figure 5. The shape and magnitude of the responses are comparable to the one of inflation expectations. It follows that changes in carbon price lead to a rise in both aggregate and firm-specific price expectations and the effect are extremely persistent over time.

Several conclusions can be drawn from the responses of expected and realized price growth. First of all, on top of the macro level, carbon policy shocks have inflationary effects at the firm level as well. The realized price growth increases in response to a change in carbon price. Second, the strong co-movement between the two responses strengthens even further the quality 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, firms' expectations are an important driver of their actual decisions: when their own price expectations increase in response to a shock, firms tend to actually raise their prices.

Figure 6: Impact of carbon policy shocks on firms' own price expectations and realized price growth (quantitative)



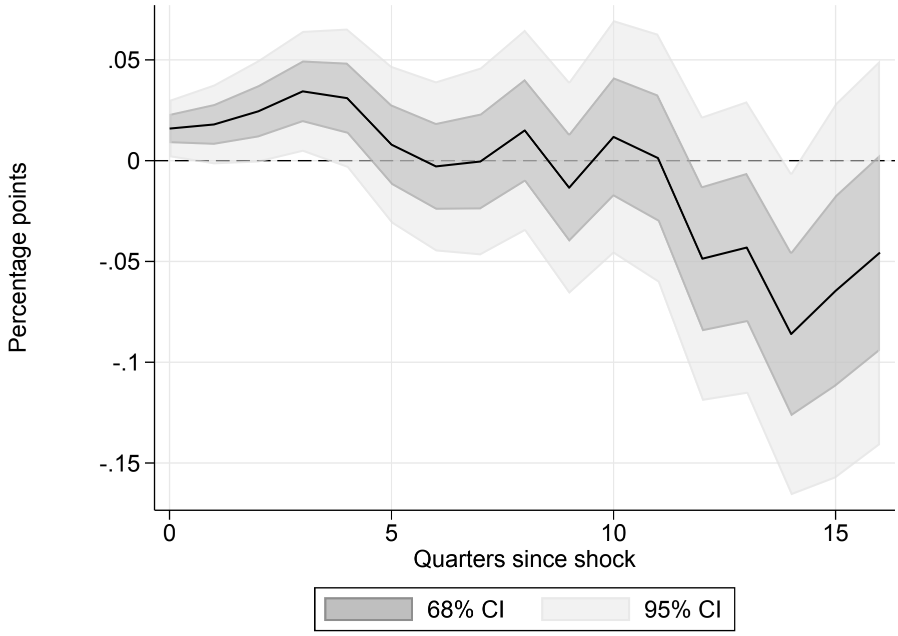
Notes: The figure plots the cumulative response to a carbon policy shock, normalized to increase the HICP energy by 1 percent on impact, for the firms' own price expectations as well as the realized price growth. Price expectations and realized prices are measured as a percent deviation. The dashed lines are the point estimate, and the shaded areas are the 95 percent confidence bands. The horizontal axis is in quarters.

One could worry that while the share of firms expecting to raise prices and actually raising them are very similar, the actual price changes might differ significantly in magnitude. We report the responses of the quantitative variables in Figure 6. A carbon policy shock rescaled such that energy price increases by 1 percent induces an increase in expected and realized price growth of 0.05 percentage points on impact. The magnitude is comparable to the aggregate price responses we document in Section 3. The cumulative responses persistently rise up to around 0.2 percentage points after 10 quarters and then they start decreasing. The effects of carbon policy shocks on the quantitative responses show that the shocks have a significant as well as economically meaningful impact on expected and realized prices.

4.3 Price Forecast Errors

In the previous section, we have documented that the average response of the firm-level expected and realized price growth closely follow each other. However, the similar responses do not exclude that firms' expectations about the evolution of their own price either under- or over-react to carbon policy shocks when compared to the actual realization. We evaluate whether this is the case by computing the response to a carbon policy shock of price forecast errors which is defined for the quantitative responses as the difference between the realized and the expected price growth.

Figure 7: Impact of carbon policy shocks on firms' own price forecast errors



Notes: The figure plots the cumulative response to a carbon policy shock, normalized to increase the HICP energy by 1 percent on impact, for the firms' own price forecast errors. Price forecast errors are measured as the difference between the realized and the expected price growth. The black lines are the point estimate and the shaded areas are the 95 and 68 percent confidence bands, respectively. The horizontal axis is in quarters.

The response of price forecast errors is reported in Figure 7. As one can notice, the response is initially positive. For the first five quarters, the impact of carbon policy shocks on firms' own price expectations is slightly more muted than the actual price changes they induce. For the following quarters, the forecast errors are not statistically different from zero but at the end of the time horizon considered the response turns negative. Therefore, the impact of carbon policy shocks on price expectations is more persistent than on actual price growth.

4.4 Direct vs Indirect Effects of Carbon Pricing

Carbon policy shocks have been found to sizably increase inflation expectations. Moreover, the shocks affect the industry- and firm-specific factors leading to an increase in the firms' own price expectations. Since firms tend to extrapolate from their own business conditions in forming aggregate expectations, one might expect that these indirect effects push inflation expectations even higher.

To empirically distinguish the contribution of direct effects, i.e., the direct impact of the shocks on inflation expectations, and indirect effects, i.e., the impact of the shocks on inflation expectactions *through* their effects on firm-specific business conditions, we adopt a procedure akin to that employed by Holm et al. (2021). We estimate two separate types of inflation expectations responses to carbon policy shocks. The first one is the baseline equation (2) which includes both direct and indirect effects. The second one is based on the same specification but also controls for the future path of the firms' expected own price[8] over the respective impulse response horizon:

$$\sum_{k=0}^{h-1} \mathbb{I}\left\{E^i_{t+k} y^{agg}_{t+k+1}\right\} = \alpha^i_h + \beta_h CPShock_t + \sum_{k=0}^{h-1} E^i_{t+k} y^{i,j}_{t+k+1} + \sum_{p=1}^{P} \theta^p_h X^{i,j}_{t-p} + \varepsilon^{i,j}_{t,h}, \tag{3}$$

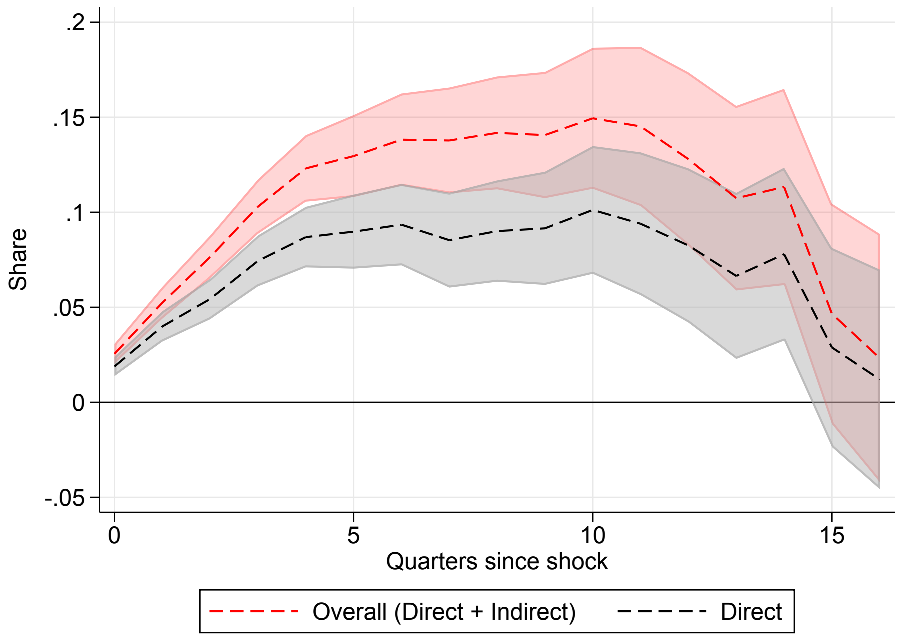
where the only change from (2) is the term $\sum_{k=0}^{h-1} E^i_{t+k} y^{i,j}_{t+k+1}$. The estimated coefficients from the second specification capture the direct effect of changes in carbon price on inflation expectations at horizon h holding firms' expected future business conditions constant over the same time period[9].

The results are reported in Figure 8. The red line shows the estimated impulse response of inflation expectations without the business controls and the black dashed line shows the one with controls. The contemporaneous impact is almost entirely driven by direct effects. This is not surprising since the consequences of the shocks need a few months before actually materializing. After that, the two responses start to significantly diverge and the size of the overall response is around 40% larger than the size of the direct response. Therefore, a significant share of the overall impact on inflation expectations is due to indirect effects on firm-specific business conditions. The exogenous increase in carbon price leads to a rise in firms' own price expectations which results in a further increase in inflation expectations beyond its direct effect. The result is particularly concerning for central banks because it increases the risk that high inflation becomes entrenched even after the original shock has faded away and it would make price stability more difficult to achieve.

[8] Controlling as well for the future path of production leads to similar results.

[9] Some firms do not provide both their inflation and own price growth expectations. To make the impulse responses of the two specifications more comparable we restrict our analysis to the firms for which both information are available such that the regressions are performed on the same sample. This results in marginally different responses of inflation expectations to a carbon policy shock in Figure 8 (red line) compared to those of Figure 4.

Figure 8: Direct and indirect effects of carbon policy shocks on firms' inflation expectations



Notes: The figure plots the cumulative response to a carbon policy shock, normalized to increase the HICP energy by 1 percent on impact, for the firms' inflation expectations. The black line shows the estimated impulse responses controlling for price expectations, the red dashed line shows the responses without controls. The shaded areas are the 95 percent confidence bands. The horizontal axis is in quarters.

4.5 Heterogeneity

Firms are not homogeneously exposed to changes in energy costs. Sectoral and individual characteristics could significantly influence the propagation of an increase in carbon price to firms' expectations. For instance, one might expect that the higher the input costs devoted to energy the higher is the firm sensitivity to carbon policy shocks.

To evaluate how different degrees of energy intensity affect the propagation of shocks to expectations, we match the French survey with two additional data sources. First, the administrative balance sheet data covers the universe of French firms and provides us with information at annual frequency on the total value of the firm input costs[10]. Second, the EACEI survey ("Survey on energy consumption in industries") reports the total expenditures

[10]In order to create a time-consistent firm identifiers we rely on the algorithm developed and used by De Ridder et al. (2022) and Burstein et al. (2020) which is based on previous work by Isabel Méjan see for example Di Giovanni et al. (2014)

by energy type. We can define different measures of energy intensity at the firm level. As a baseline measure, we compute the ratio between electricity and total input costs[11].

We then extend our baseline specification of equation (2) by introducing a categorical variable E_t^i which identifies different quartiles of the energy intensity distribution and which we interact with the carbon policy shock $CPShock_t$:

$$\sum_{k=0}^{h} \mathbb{I}\left\{E_{t+k}^i y_{t+k+1}^{i,j}\right\} = \alpha_h^i + \delta_{t,h} + \gamma_h E_t^i + \beta_h^E E_t^i \; CPShock_t + \sum_{p=1}^{P} \theta_h^p X_{t-p}^{i,j} + \varepsilon_{t,h}^{i,j}, \qquad (4)$$

where $\delta_{t,h}$ is the time fixed effects that absorb the carbon policy shocks and the aggregate variables. The coefficient β_h^E captures how firms are heterogeneously affected by the shocks according to their level of energy intensity. The interaction coefficients can be interpreted as the differential response to a carbon policy shock of the different quartiles in energy intensity relative to the baseline group (firms for which the ratio of electricity to total input costs belongs to the top 25%). To avoid endogeneity concerns, the categorical variable E_t^i is defined using data lagged one year. However, using contemporaneous data does not materially affect our results.

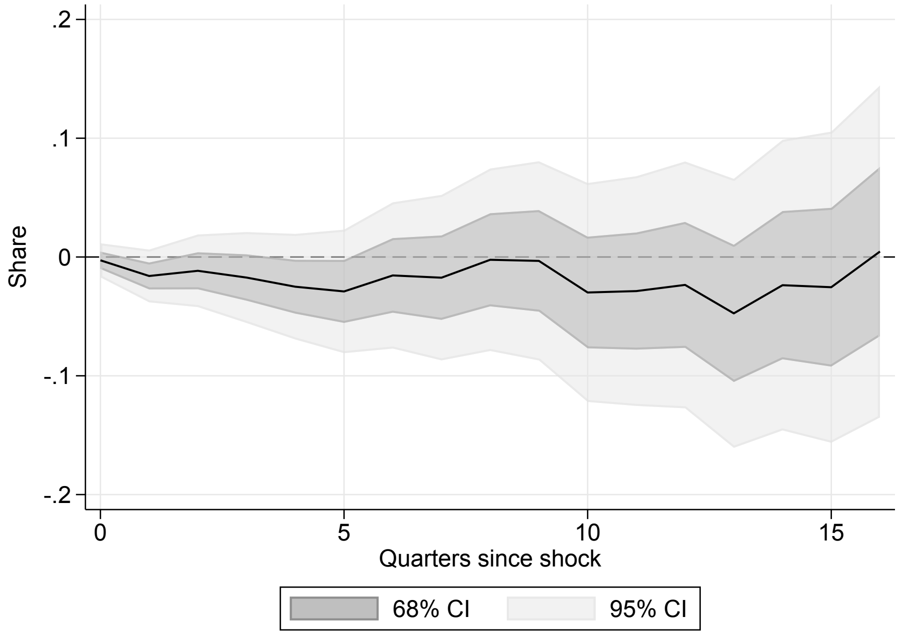
We start by focusing on the impact of carbon policy shocks on inflation expectations. Figure 9 plots the coefficient β_h^E of the interaction between the shock and the bottom of the energy intensity quartiles. Changes in carbon price seem to influence firms' inflation expectations homogeneously along the energy intensity distribution. We do not find any statistically significant differences in the responses of the firms belonging to the top quartile relative to those at the bottom.

We now shift our attention to firms' own price dynamics. In Figure 10 we report the same interaction coefficient using the price forecast errors as dependent variable, i.e., realized minus expected price growth[12]. The coefficients are positive and significant for almost the entire time horizon considered. This suggests that low energy-intensive firms tend to overreact relatively more in response to a carbon policy shock. Their own price expectations increase less compared to the actual price variation the change in carbon price induces resulting in larger price forecast errors.

[11]We focus on electricity expenditures since we expect them to be directly affected by the changes in carbon price. Using total energy consumption over input costs as measure of energy intensity delivers basically the same results. Moreover, the EACEI survey provides data on the firm's expenditures by different energy types. However, electricity is by far the most commonly used source. We have approximately 185.000 observations for electricity followed by gas with 112,000, butane with 44,000, fuel oil with 75,000, steam with 4,500, and coal with 800.

[12]Figure 13 reports the interaction coefficients using the firms' expected and realized price growth as dependent variables.

Figure 9: Impact of carbon policy shocks on firms' inflation expectations by energy intensity

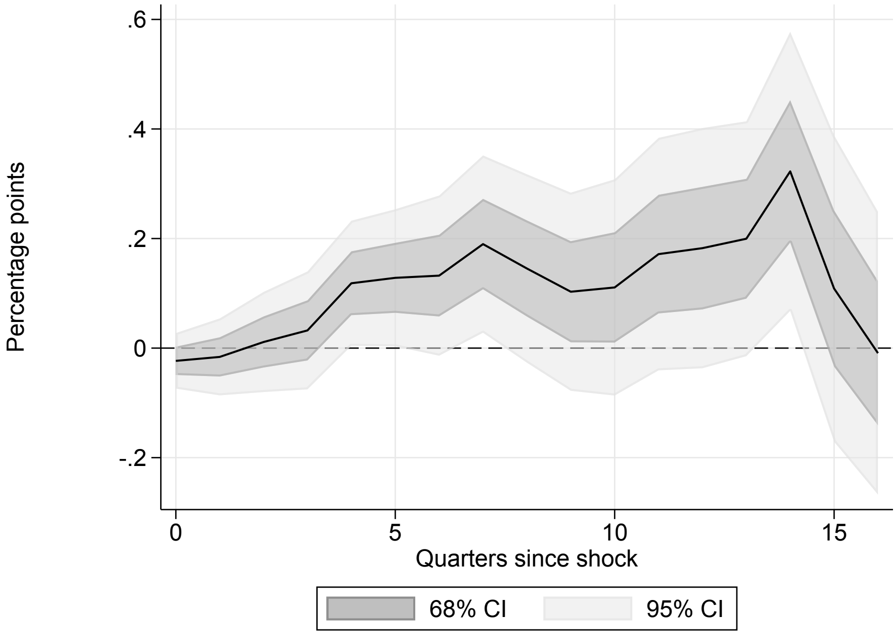


Notes: The figure plots the cumulative response to a carbon policy shock, normalized to increase the HICP energy by 1 percent on impact, for the firm level inflation expectations interacted with a measure of energy intensity. The coefficients can be interpreted as the differential response to a carbon policy shock of the firms in the bottom 25% of the energy intensity distribution relative to those in the top 25%. Energy intensity is measured as the ratio between electricity and total input costs. Inflation expectations take values {-1, 0, 1} for aggregate prices expected to decrease, stay the same or decrease. The black lines are the point estimate and the shaded areas are the 95 and 68 percent confidence bands, respectively. The horizontal axis is in quarters.

The effects are also economically important. Following a carbon policy shock, the forecast errors of the firms in the bottom quartile of the energy-intensity distribution are 0.2 percentage points higher compared to those at the top. The effect is particularly remarkable once compared to the average forecast error response reported in Figure 7. The shock induces an increase of 0.05 percentage points in the average forecast errors after one year but for low energy-intensive firms the forecast errors are 1.8 percentage points larger than for high energy-intensive firms. Therefore, the lower the input costs devoted to energy the worse firms are at forecasting the impact that the increase in carbon price will have on their prices.

In conclusion, we have documented that changes in carbon policy shocks have a sizable and positive effect on inflation expectations. Firm-specific business conditions are also significantly affected leading to an increase in firms' own expected and realized price growth. In the medium-/long-run the effect on price expectations is more persistent than on the actual price growth. Moreover, the indirect effects of carbon policy shocks through changes in the firms' business conditions play a major role in the response of inflation expectations. Finally, the

Figure 10: Impact of carbon policy shocks on firms' own price forecast errors by energy intensity



Notes: The figure plots the cumulative response to a carbon policy shock, normalized to increase the HICP energy by 1 percent on impact, for the firms' own price forecast errors interacted with a measure of energy intensity. The coefficients can be interpreted as the differential response to a carbon policy shock of the firms in the bottom 25% of the energy intensity distribution relative to those in the top 25%. Energy intensity is measured as the ratio between electricity and total input costs. Price forecast errors are measured as the difference between the realized and the expected price growth. The black lines are the point estimate and the shaded areas are the 95 and 68 percent confidence bands, respectively. The horizontal axis is in quarters.

low energy-intensive firms tend to poorly assess the impact that carbon policy shocks will have on the evolution of their prices.

5 Robustness

In this section, we perform some robustness checks to strengthen the validity of the main results. First, we add extra controls to the regressions. Second, we compute the response of firms' own price expectations to carbon policy shocks only for the main product produced by the firm. The plots are reported in Appendix A.

5.1 Extra Controls

As a first robustness check, we extend the baseline specification with additional control variables. We compute the cumulative response of firms' inflation expectations to a carbon policy shock controlling as well for expected aggregate production, expected own price and production, turnovers and their respective lags. The results are shown in Figure 11.

The inclusion of controls for aggregate expectations, firms' own business conditions, and size has a negligible effect on the estimated coefficients. The magnitude and the shape of the response of inflation inequality are consistent with the baseline result. Firms' inflation expectations increase following a change in carbon price.

5.2 Price Expectations of the Main Product

In the survey, firms report the expected price growth over the next 3 months for each of their own products. In the baseline regressions, we include all these expectations. It might be the case though that firms do not pay attention homogeneously to the business conditions of each one of their products but might prioritize the most important products.

We compute the response of firms' own price expectations to a carbon policy shock only considering the product with the highest turnover. The cumulative responses are reported in Figure 12. The results are basically unaffected. Following a change in carbon price, firms' own price expectations significantly increase.

6 Conclusion

Mitigating the negative consequences of climate change is one of the most important challenges of our generation. From governments to research institutions, from households to firms, every agent in the economy is called to contribute to the reduction of greenhouse gas emissions. Monetary authorities around the world are adopting a more and more proactive role when it comes to supporting climate policies.

In this paper, we document that carbon pricing persistently increases firms' inflation expectations. This is done by combining the carbon policy shocks developed by Känzig (2023) with French firm-level survey data. We find that firms' inflation expectations are particularly sensitive to changes in carbon price. Moreover, these shocks result in an increase in firms' own price expectations as well as the ex-post realized price growth. The effect on expectations is more persistent than on actual price growth leading to negative price forecast errors in the medium-/long-run. A significant part of the observed increase in inflation expectations is due to indirect effects, i.e., firms extrapolate from their own business conditions in forming aggregate expectations. Finally, firms that devote a lower share of input costs to energy expenditures tend to more poorly anticipate the impact that these shocks have on their prices.

Increases in the price of carbon are perceived by firms as inflationary. The empirical findings we provide suggest that carbon taxes, if not properly complemented with other green policies, might potentially be at odds with the core of the central banks' mandate, i.e., price stability. Higher short-term inflation expectations lead to higher actual prices which are likely to persist over time and propagate to longer-term inflation expectations with the risk of de-anchoring them from the inflation target. Therefore, policymakers and central bankers should carefully consider the optimal policy mix to advance the green transition without inhibiting the monetary authorities' ability to stabilize prices.

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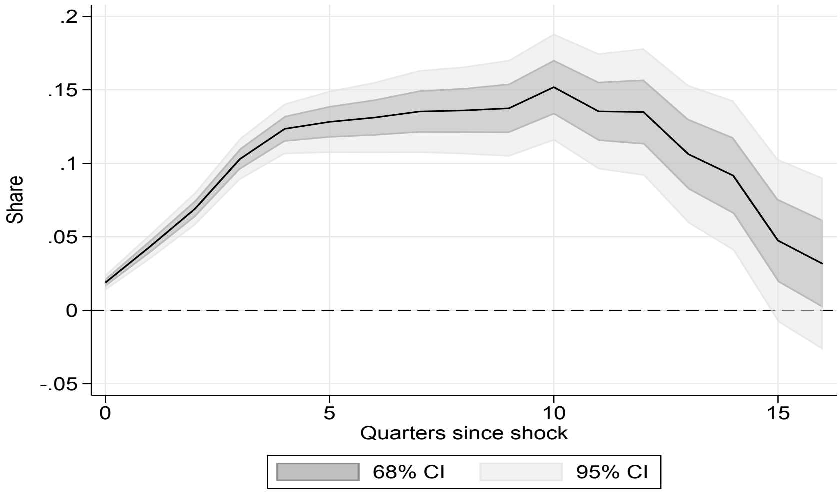
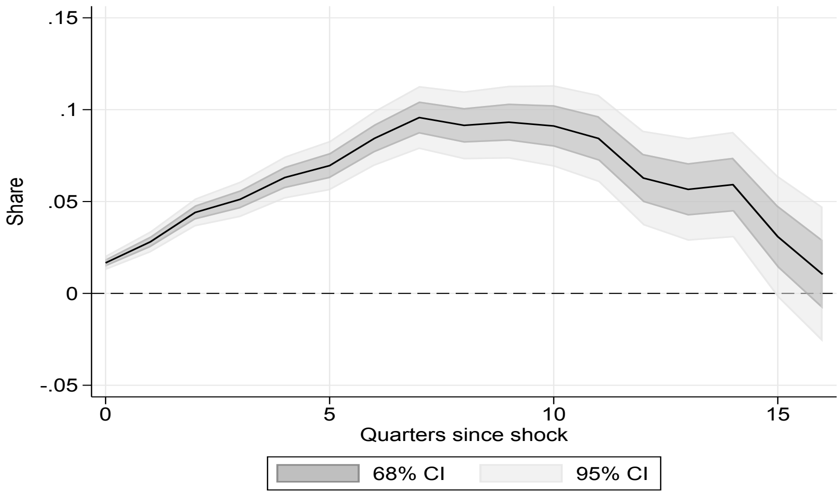
A Additional figures and tables

Figure 11: Impact of carbon policy shocks on firms' inflation expectations, extra controls



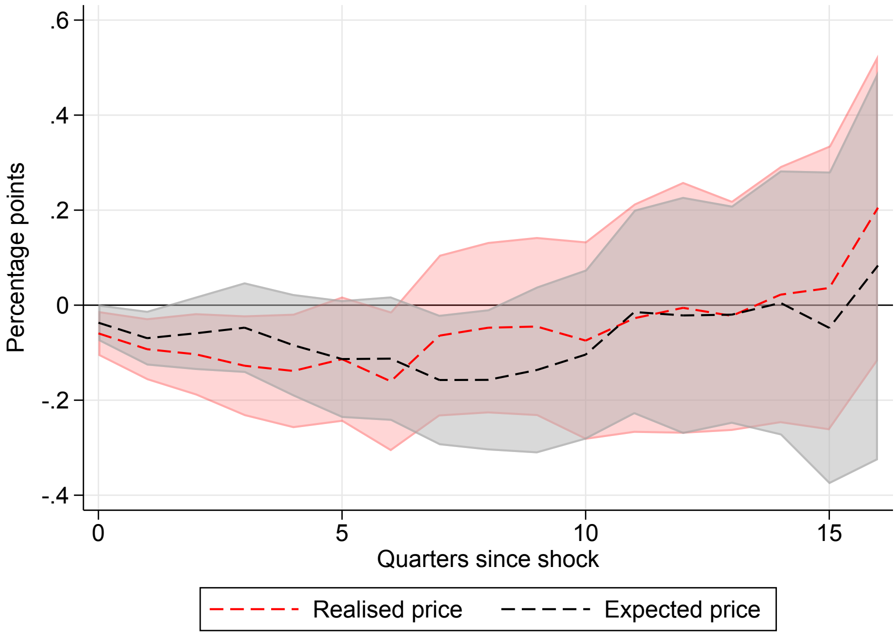
Notes: The figure plots the cumulative response to a carbon policy shock, normalized to increase the HICP energy by 1 percent on impact, for the firm-level inflation expectations. Inflation expectations take values {-1, 0, 1} for aggregate prices expected to decrease, stay the same or decrease. The dashed lines are the point estimate, and the shaded areas are the 95 and 68 percent confidence bands. The horizontal axis is in quarters.

Figure 12: Impact of carbon policy shocks on firms' own price expectations of their main product



Notes: The figure plots the cumulative response to a carbon policy shock, normalized to increase the HICP energy by 1 percent on impact, for the firms' own price expectations of their main product. Price expectations take values {-1, 0, 1} for prices expected to decrease, stay the same or decrease. The dashed lines are the point estimate, and the shaded areas are the 95 and 68 percent confidence bands. The horizontal axis is in quarters.

Figure 13: Impact of carbon policy shocks on firms' expected and realized price growth by energy intensity



Notes: The figure plots the cumulative response to a carbon policy shock, normalized to increase the HICP energy by 1 percent on impact, for the firms' expected and realized price growth interacted with a measure of energy intensity. The coefficients can be interpreted as the differential response to a carbon policy shock of the firms in the bottom 25% of the energy intensity distribution relative to those in the top 25%. Energy intensity is measured as the ratio between electricity and total input costs. Price forecast errors are measured as the difference between the realized and the expected price growth. The black lines are the point estimate and the shaded areas are the 95 percent confidence bands, respectively. The horizontal axis is in quarters.