Carbon Pricing and Inflation Expectations: Evidence from France

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Abstract

This paper studies the impact of carbon pricing on firms' inflation expectations and discusses the potential implications for what constitutes the core of most central banks' mandate: price stability. As in Känzig (2022), carbon policy shocks are identified from changes in carbon futures price around regulatory events. The shock series is combined with French firm-level survey data. We document that a change in the price of carbon increases firms' inflation expectations. We then investigate how firms' business conditions are affected by carbon policy shocks and we find that firms' own expected and realised price growth respond similarly to inflation expectations. The effect on price expectations is more persistent than on actual price growth leading to positive forecast errors in the medium-/long-run. Finally, we show that a sizable share of the increase in inflation expectations is due to second-round effects. Firms rely on their own business conditions to form expectations about the aggregate price dynamics. Therefore, the expected positive growth in their own prices significantly contribute to the observed increase in inflation expectations.

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)

"Well, the world is running out of time to deal with the climate crisis, and the Fed has an important role to play here, and I hope the Fed will step up"

Elizabeth Warren at Jerome H. Powell's Nomination Hearing (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, Member of the Executive Board of the ECB, at the Italian Banking Association (2022)

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

This paper studies the potential effects that carbon pricing has for price stability. Carbon pricing is seen as one of the most important policy tools currently adopted to reduce emissions and, therefore, to mitigate the long-term shifts in temperatures and weather patterns. However, carbon pricing potentially affects prices and 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 of firms' inflation expectations as well as their own expected and realised price growth. Moreover, in the long-run the effect on expectations is more persistent than on actual price changes leading to positive forecast errors. Finally, we show that there is both a

direct effect on aggreagte inflation expectation but that also a significant share of the overall effect is due to indirect effects through changes in firms' own business conditions.

We measure exogenous changes in the carbon price using the carbon policy shock series developed in Känzig (2022). The author identifies 113 regulatory events that influenced the supply of emission allowances in the European Union Emissions Trading System (EU ETS). The series of carbon policy surprises is then computed from the change in the carbon futures price in a tight time window around the regulatory news. The surprises are then aggregate at monthly level and used as 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 monthly frequency firms' inflation expectations and the expected own price growth over the next three months. The survey is restricted to firms in the industry sector. Once per quarter, data on actual price growth over the last three months are provided. 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 realised price growth closely follow each other confirming that expectations translate into actual decisions. However, price forecast errors, defined as realised minus expected price growth, responds positive 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.

The ability of a central bank to stabilise 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 finding 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 (2021) 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 finds 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.

The impact of carbon policies go beyond their macroeconomic impact. The carbon policy shocks used in this paper are developed by Känzig (2022) 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 (2022) 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. (2022) show that more carbon-intensive countries are generally more affected, brown sectors do not respond differently than the green sector but within a sector, brown firms tend to suffer more. We contribute by focusing on firm-level responses. Using survey data from France we evaluate how firms' aggregate and own price expectations respond to changes in carbon price.

The second strand is the literature that studies the importance of climate change and the relative policies for central banks. Both monetary authorities and academics are thoroughly assessing to what extent and through which channels climate change is a threat for 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 policy currently adopted, can affect price stability. We show that changes in carbon price are 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 a even stronger increase in inflation expectations. Overall, our findings suggest that this climate policy potentially reduces price stability which at the core of many central banks' mandate.

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 are 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 the one of professional forecasters. Candia et al. (2021) show that the inflation expectations of U.S. managers, much like those of households, are far

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

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

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 as primary determinant of their inflation expectations. Using the same survey of French manufacturing firms of this paper, Andrade et al. (2022) document that firms use the local prices they observe to make inferences about aggregate price dynamics despite the changes in local prices having no aggregate effects.

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 over-estimate 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 consequently its outcomes. In a series of randomized controlled trials, Coibion et al. (2019) and Coibion et al. (2020a) induce an exogenous variation 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.

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

2 Data

2.1 Firm Level Data

The main data used for this project is the French Outlook Survey in the manufacturing sector ("ECI: Enquête de conjoncture dans l'industrie"). This survey conducted in the industry aims to provide early information on the trend of activity in the sector. The survey is conducted monthly, and additional questions are asked quarterly (January, April, July and October). The companies executives are asked 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 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.

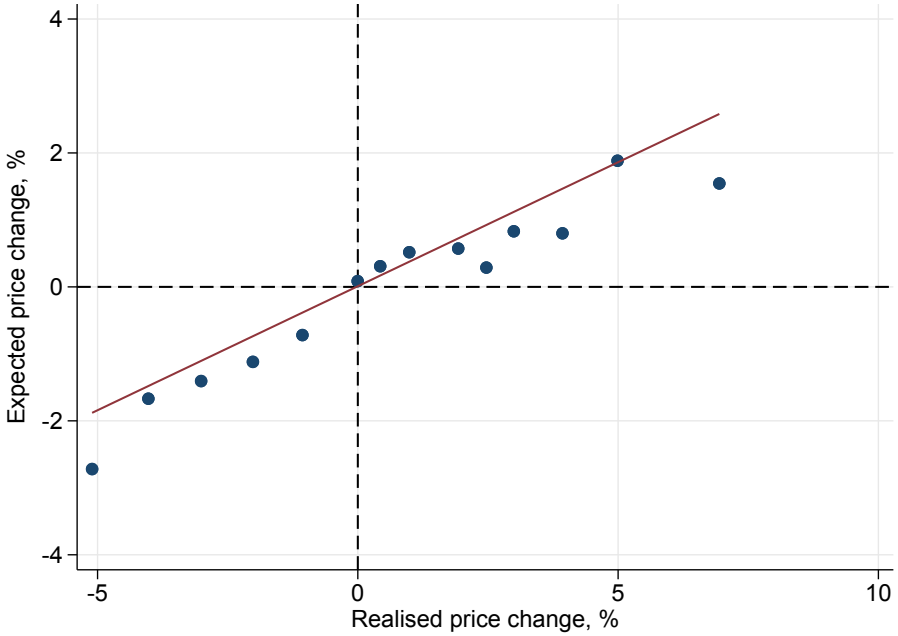
Monthly, the firms are asked about their qualitative assessment of the inflation expectation (either increasing, flat or decreasing) as well as their expectation for their own prices differentiated by individual products. Additionally they are asked quarterly for a quantitative 3-months ahead price forecasts for their own prices, as well as the quantitative price changes in the last three month, allowing us to differentiate between expectations and realizations. As shown in Figure 1, the answers are of high quality as expected price changes are highly associated with actual price changes in the following quarter.

2.2 Carbon Policy Shock Series

The carbon policy shocks are computed following the procedure developed by Känzig (2022) 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 price 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.

Figure 1: Past and expected future price changes

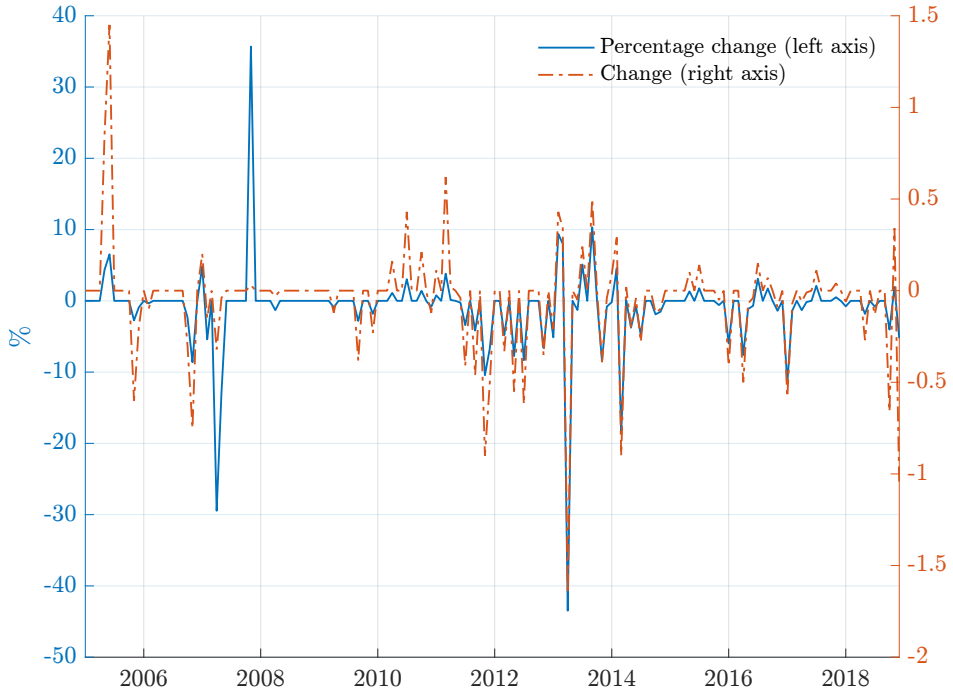


Notes: This figure shows the relationship between firms' own expected price change and the realised price growth.

Känzig (2022) identify 113 events from 2005 to 2018 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 difference in the log settlement price of the EUA futures contract between the day of the event and the day before. Since in some periods, the futures price is close to zero, as robustness checks, we also considered the simple difference in settlement price rather than the percentage change. The results for this alternative specification are reported in Section 5.

The daily surprises are then aggregated into a monthly series by summing over the daily surprises in a given month. In months without any regulatory events, the series takes zero value. The resulting carbon policy surprise series, computed as percentage change as well as simple difference, are shown in Figure 2. Until 2008, during the period when the EUA futures price was relatively close to zero, the two series are poorly correlated. But the two series are highly correlated after 2008. Given the high correlation between the series, the main results hold under both specifications.

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 external instrument in a VAR model with eight variables spanning the period from January 1999 to December 2018: 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

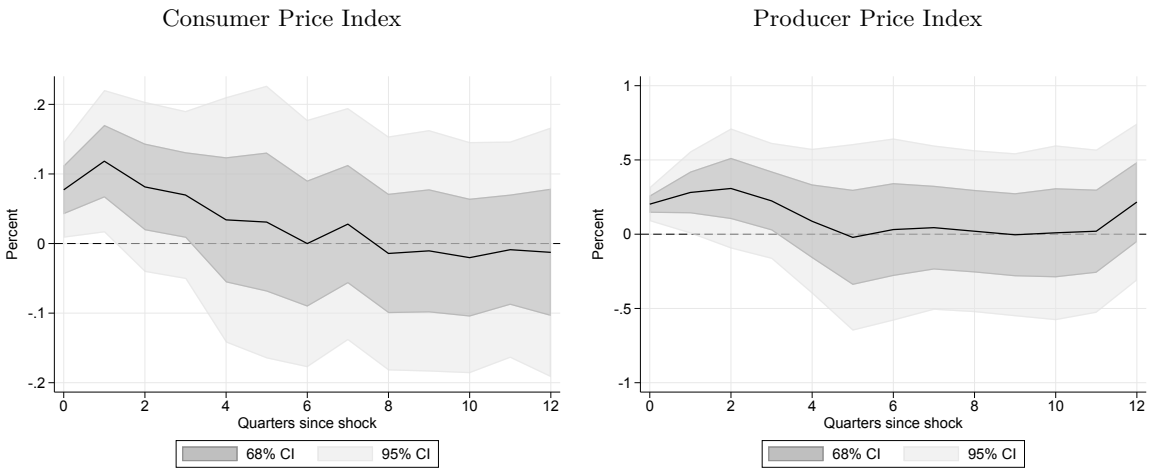
The Proxy-VAR used to obtain the carbon policy shock series includes macroeconomic variables for the EA-19 members. Before evaluation how carbon policy shocks affect French firms' expectations, it is important to assess the aggregate effects that these shocks have in France.

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. The main dependent variables are the log of Consumer Price Index (CPI) as well as of Producer Price Index (PPI). The coefficient of interest is β_h which captures the response of the dependent variable to a carbon policy shock for each horizon h.

Figure 3: Macro responses to carbon policy shocks



Notes: The figure plots the response to a carbon policy shock, normalized to increase the HICP energy by 1 percent on impact, for the CPI (left panel) and the PPI (right panel). The dashed lines are the point estimate and the shaded areas are the 95 percent confidence bands, respectively. The horizontal axis is in quarters.

The responses of CPI and PPI to a climate policy shock are reported in Figure 3. Following a carbon policy shock that results in a one percent increase of the HICP energy component on impact, both price series significantly and persistently increase. The shock increases CPI by around 0.1 percent and PPI by 0.2 percent on impact before they slowly converge back to zero after 5/6 quarters. The inflationary effects are both statistically and economically meaningful.

In line with the findings from Känzig (2022) for the EA-19 members, the results confirm that carbon policy shocks has 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. 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.

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

$$\sum_{k=0}^{h} \mathbb{I}\left\{E_{t+k}^{i} y_{t+k+1}^{i,j}\right\} = \alpha_h^i + \beta_h CPShock_t + \sum_{p=1}^{P} \theta_h^{p,i} X_{t-p}^{i,j} + \varepsilon_{t,h}^{i,j}, \tag{2}$$

for $h = 1, ..., 16$. $E_{t+k}^{i} y_{t+k+1}^{i,j}$ is the dependent variable, e.g., own price expectations or realised 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 $E_{t+k}^{i} y_{t+k+1}^{agg}$. $\mathbb{I}\{\}$ takes value $\{-1, 0, 1\}$ depending on whether firms expect the dependent variable to decrease, stay the same or decrease. α_h^i are firm fixed effect, $X_{t-p}^{i,j}$ is a matrix of controls and P is the number of lagged values[4]. Finally, standard errors are clustered at firm-date 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 in 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 which expect the dependent variable to decrease, stay the same or increase.

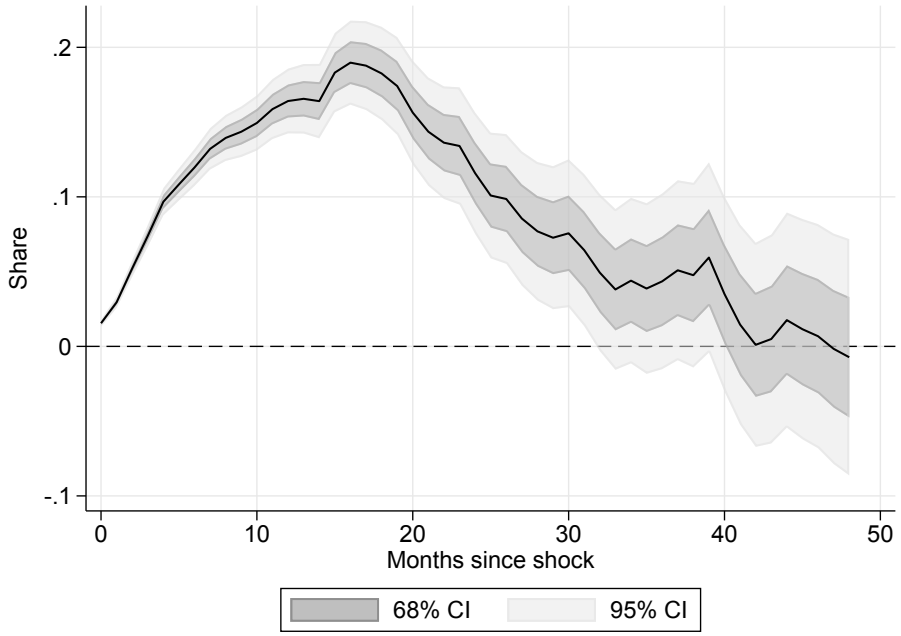
First, we evaluate how firms' inflation expectations are affected by carbon policy shocks. Second, we focus on firms' own price expectations, Third, we compare the effects on own price expectations with the realised price growth. Fourth, we study the price forecast errors responses to assess whether firms' expectations over- or under-react to changes in carbon

[4]In the baseline specification we control for 3 lags of the dependent variable for quarterly data and for 7 lags for the monthly data.

price. Fifth, we decompose the overall impact of carbon shocks on inflation expectations into its direct and indirect effect.

4.1 Inflation Expectations

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 dashed lines are the point estimate and the shaded areas are the 95 percent confidence bands, respectively. The horizontal axis is in months.

The cumulative response of firms' inflation expectations are 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 persistence observed at firm-level is higher than the one observed at aggregate level. This is most likely due to the fact that only firms from the manufacturing sector are part of the survey and firms operating in that sector are more exposed to this kind of shock.

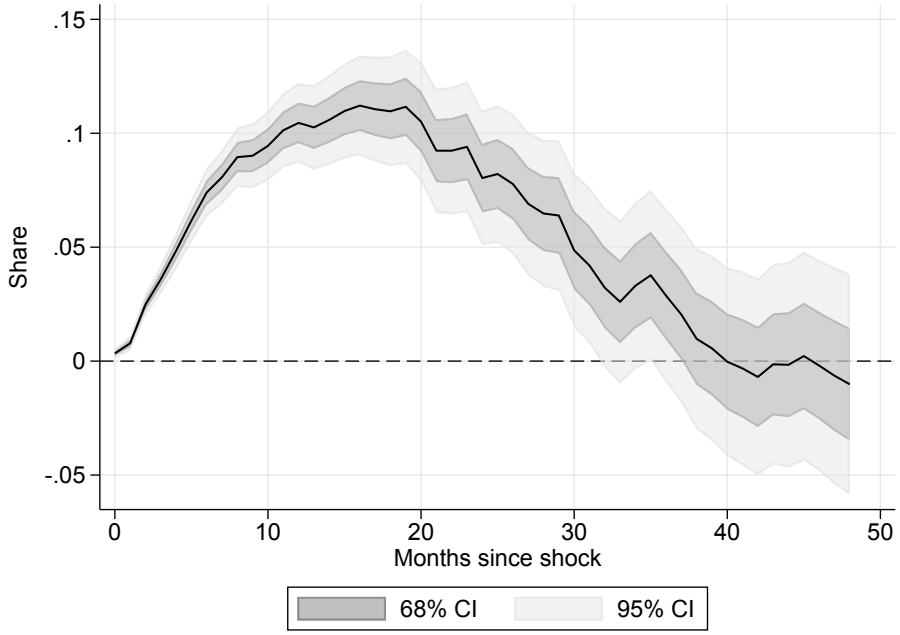
The increase in inflation expectations suggests that carbon policy might decrease price stability. Aggregate price expectations are one of the main determinants of actual inflation. Therefore, the rise in inflation expectations caused by changes in carbon price might lead to inflationary pressure on 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 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 it with other policies the transition towards a greener economy and stability of prices can coexist.

4.2 Own Price Expectations and Realised 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 second-round effects due to the impact on firms' own business conditions. We study this potential channel by evaluating the response of firms' own price expectations to carbon policy shocks.

Figure 5: Impact of carbon policy shocks on firms' own price expectations

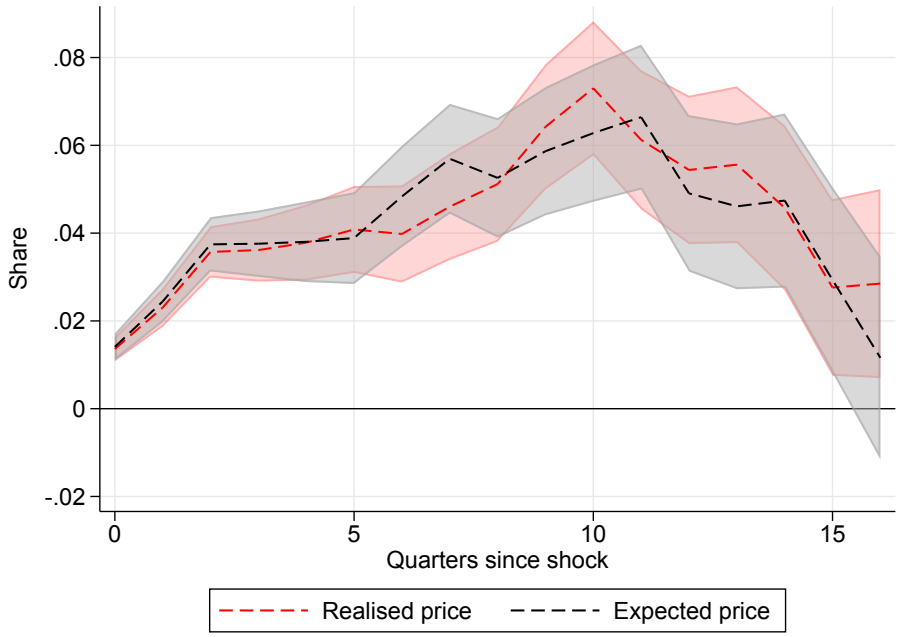


Notes: The figure plots the cumulative response to a carbon policy shock, normalized to increase the HICP energy by 1 percent on impact, for the firms' own price expectations. Price expectations take values {-1, 0, 1} for prices expected to decrease, stay the same or decrease. The dashed lines are the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

Figure 5 shows that in response to a carbon policy shock firms' own price expectations significantly and persistently increase. The shape and magnitude of the response is 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 is extremely persistent over time.

Once per quarter, the Quarterly Survey of Economic Conditions in the Industry asks firms about the realised price growth they experience over the past three months. The question is both qualitative and quantitative. Once per quarter firms report also their quantitative expectations about their expected price growth over the following three months. These questions can be exploited to shed new lights on the nature of firms' expectation formation process and how it is affected by carbon policy shocks.

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



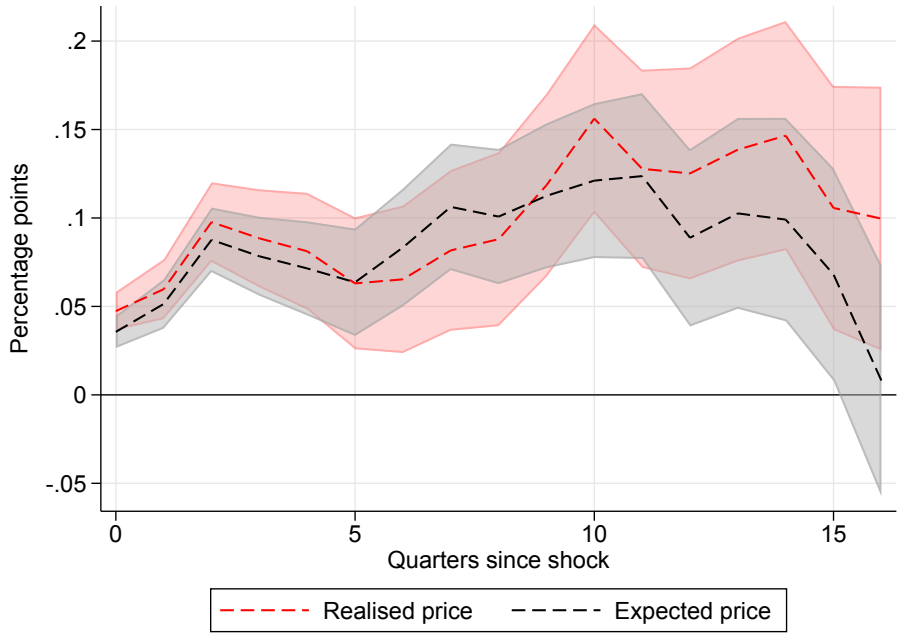
Notes: The figure plots the cumulative response to a carbon policy shock, normalized to increase the HICP energy by 1 percent on impact, for the firms' own price expectations as well as the realised price growth. Price expectations take values {-1, 0, 1} for prices expected to decrease, stay the same or decrease. Realised 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, respectively. The horizontal axis is in quarters.

We estimate equation (2) using the firms' expected and realised price growth from the qualitative response as dependent variable. The cumulative responses are reported in Figure 6. The impact of changes in carbon price on the average share of firms expecting price growth

is similar in magnitude and shape to the average share of firms that actually experienced a positive price growth.

Several conclusions can be drawn from the responses of expected and realised price growth. First of all, on top of at macro level, carbon policy shocks have inflationary effects at firm level as well. The realised price growth increases in response to a change in carbon price. Second, the strong co-movement between the two responses strengthen even further the quality of the data in the survey. Firms realised 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 7: Impact of carbon policy shocks on firms' own price expectations and realised 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 realised price growth. Price expectations and realised prices are measured as percent deviation. The dashed lines are the point estimate and the shaded areas are the 95 percent confidence bands, respectively. The horizontal axis is in quarters.

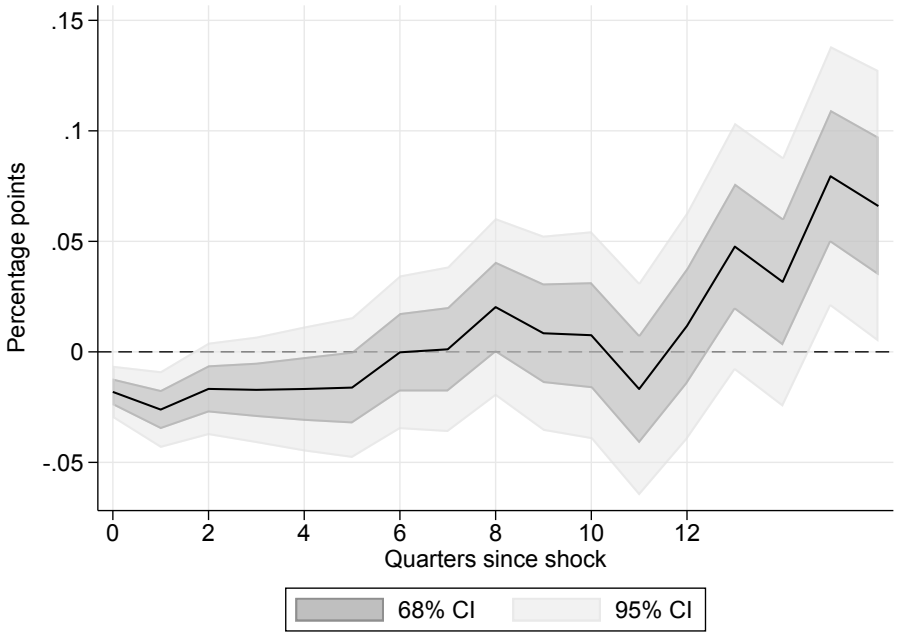
One could worry that while the share of firms expecting to raise prices and actually raising them are very similar, the actual price changes might differ significantly in magnitude. We report the responses of the quantitative variables in Figure 6. A carbon policy shock rescaled such that energy price increases by 1 percent induces an increase in expected and realised price growth of 0.05 percentage point on impact. The magnitude is comparable to the aggregate

price responses we document in Section 3. The cumulative responses persistently rises up to around 1.5 percentage 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 realised prices.

4.3 Price Forecast Errors

In the previous section we have documented that the average response of the firm level expected and realised 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 realisation. 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 realised price growth and the ex ante expectations.

Figure 8: 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 realised and the expected price growth. The dashed lines are the point estimate and the shaded areas are the 95 percent confidence bands, respectively. The horizontal axis is in quarters.

The response of price forecast errors is reported in Figure 8. As one can notice, the response is initially negative. This suggests that for the first two 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 10 quarters the forecast errors are not statistically different from zero but after 12 quarters the response turns positive for the remaining part of the time horizon considered. This suggests that 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

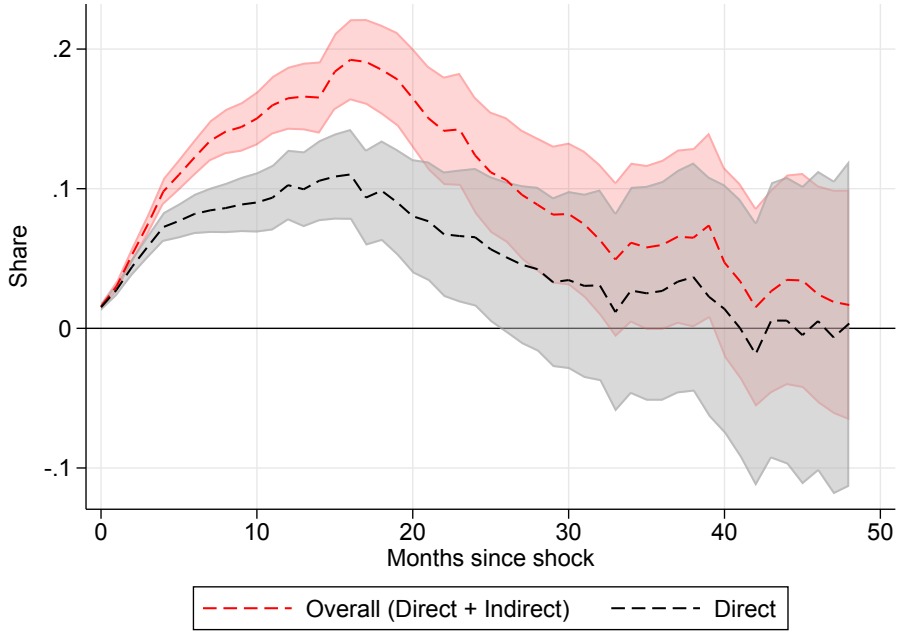
Carbon policy shocks have been found to sizably increase inflation expectations. Moreover, the shocks affect industry- and firm-specific factors leading to an increase in the firms' own price expectations. Since firms tend to extrapolate from their own business conditions in forming aggregate expectations,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

To distinguish direct and indirect effects empirically, we follow a similar procedure as in 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 include both direct and indirect effects. The second estimate is based on the same specification but also controls for the firms' own price and production expected change over the respective impulse response horizon. 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.

The results are reported in Figure 9. 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 entirely driven by direct effects. This is not surprising since the consequences of the shocks need a few months before actually materialising. After that, the size of the direct response is almost half the size of the overall response. Therefore, a significant share of the overall impact on inflation expectations is due to second-round effects on firm-specific business conditions. 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.

In conclusion, we have documented that changes in carbon policy shocks have a sizable and positive effect on inflation expectations. Moreover, firm-specific business conditions are

Figure 9: 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 and output expectations, the red dashed line shows the responses without controls. The shaded areas are the 95 percent confidence bands. The horizontal axis is in months.

also significantly affected leading to an increase in firms' own expected and realised price growth. In the medium-/long-run the effect on price expectations is more persistent than on the actual price growth. Finally, the indirect effects of carbon policy shocks through changes in the firms' business conditions play a major role in the response of inflation expectations.

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 their main product. Third, we consider an alternative measure for the carbon policy surprises. 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 the their respective lags. The results are shown in Figure 10.

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 is 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 expectation to a carbon policy shock only considering the product with the highest turnover. The cumulative responses are reported in Figure 11. The results are basically unaffected. Following a change in carbon price, firms' own price expectations significantly increase.

5.3 Shocks in level

Since 2005, there have been a few periods when the EUA futures price series was close to zero. Therefore, computing the carbon policy surprises as the percentage change in the EUA futures price might overestimate the importance of some regulatory events. As an alternative measure of carbon price surprises we then consider the simple change in futures price around the regulatory events. The monthly series of surprises is reported in Figure 2.

Figure 12 shows the cumulative response of firms' inflation expectations following a carbon policy shocks derived from this alternative surprise definition. As it can be noticed, the change in carbon price leads to a persistent and positive increase in inflation expectations in line with the baseline results. The same is observed for the response of firms' own price expectations which we report in Figure 13. Overall, the alternative carbon policy surprise definition do not alter the main conclusion of the paper: changes in carbon price are perceived by firms as inflationary.

6 Conclusion

Mitigating the negative consequences of climate change is one of the most important challenge 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 gas emissions. The monetary authorities around the world are adopting a more and more proactive role when it comes to support climate policies.

In this paper, we document that carbon pricing persistently increase firms' inflation expectations. This is done by combining the carbon policy shocks developed by Känzig (2022) 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 of firms' own price expectations as well as the ex-post realised price growth. The effect on expectations is more persistent than on actual price growth leading to positive price forecast errors in the medium-/long-run. Finally, 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.

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 to 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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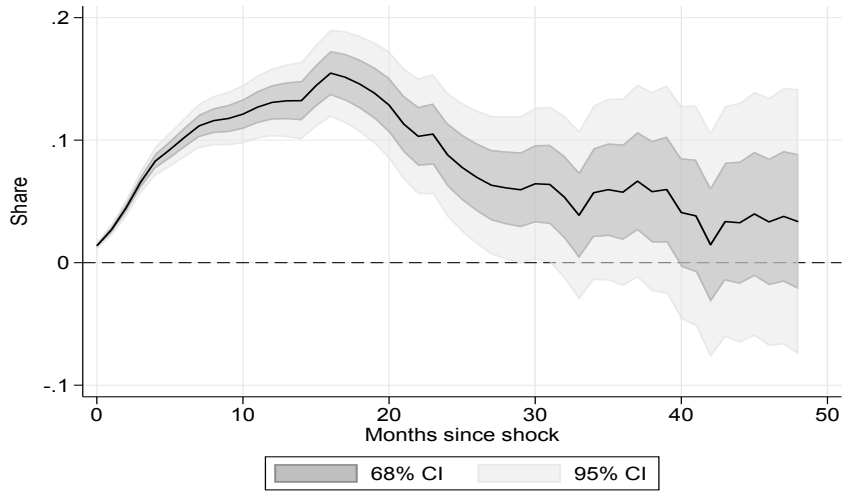
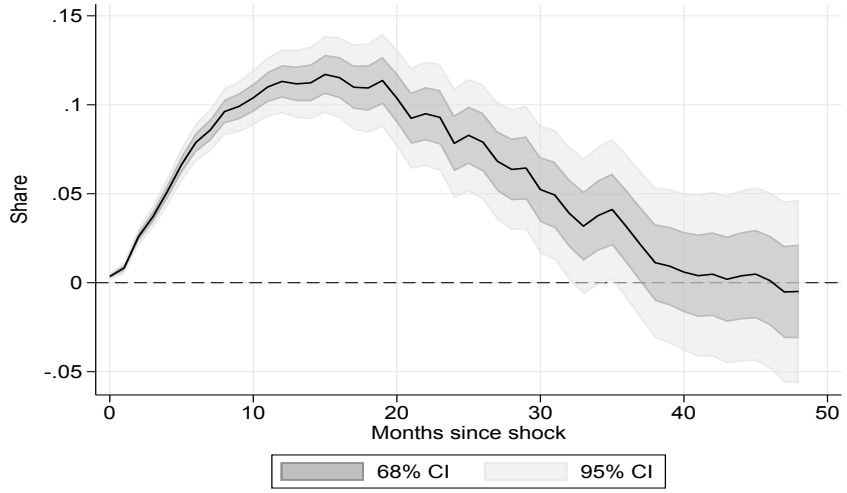
A Additional figures and tables

Figure 10: 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 percent confidence bands, respectively. The horizontal axis is in months.

Figure 11: 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 percent confidence bands, respectively. The horizontal axis is in months.

Figure 12: Impact of carbon policy shocks on firms' inflation expectations, alternative shock measure

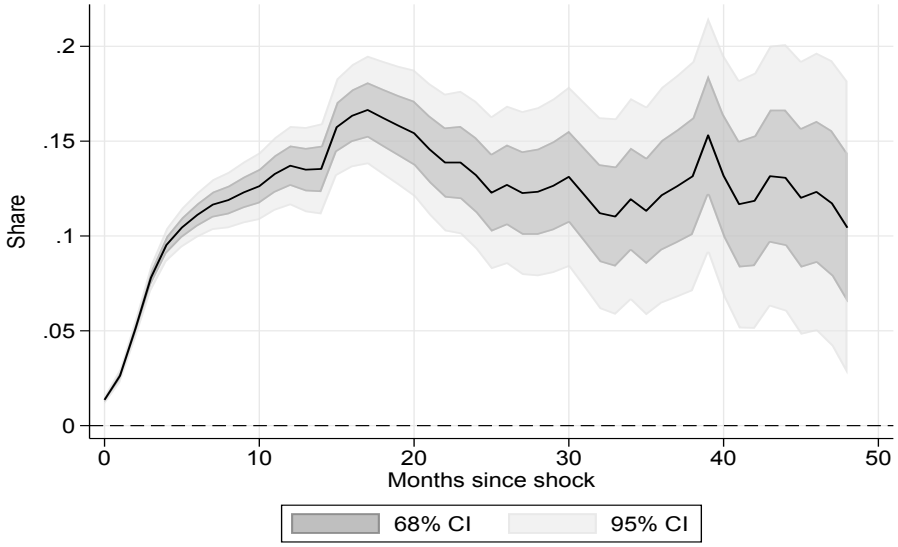


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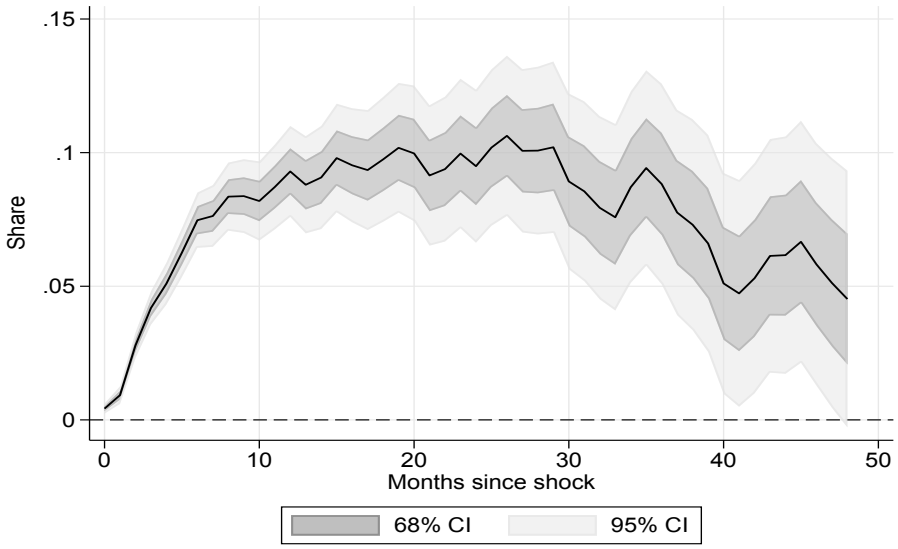
Figure 13: Impact of carbon policy shocks on firms' own price expectations, alternative shock measure



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