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Carbon Prices and Inflation in the Euro Area

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Carbon Prices and Inflation in the Euro Area
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ABSTRACT: What is the effect of carbon pricing on inflation? This paper shows empirically that the consequences of the European Union's Emission Trading System (ETS) and national carbon taxation on inflation have been limited in the euro area, so far. This result is supported by analysis based on a panel local projections approach, as well as event studies based on individual countries. Our estimates suggest that carbon taxes raised the price of energy but had limited effects on overall consumer prices. Since future climate policy will need to be much more ambitious compared to what has been observed so far, including the need for larger increases in carbon prices, possible non-linearities might make extrapolating from historical results difficult. We thus also use input-output tables to simulate the mechanical effect of a carbon tax consistent with the EU's 'Fit-for-55' commitments on inflation. The required increase of effective carbon prices from around 40 Euro per ton of CO_2 in 2021 to around 150 Euro by 2030 could raise annual euro area inflation by between 0.2 and 0.4 percentage points. It is worth noting that the energy price increases caused by the rise in the effective carbon price to 150 Euro is substantially smaller than the energy price spike seen in 2022 following the invasion of Ukraine.

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WORKING PAPERS

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Executive Summary

There is broad consensus among policymakers that net carbon emissions need to be reduced to zero by mid-century in order to mitigate catastrophic climate change. In light of this urgency, and the many commitments made by governments, understanding the economic effects of climate policy is a priority. In this paper we focus on whether carbon pricing affects inflation in the euro area. We carry out three types of analyses.

First, we estimate the impact on inflation of changes to the price of carbon due to the Emissions Trading System and carbon taxes in the euro area, using a panel local projections approach with a set of fixed effects and macroeconomic controls. We find that carbon taxes have not contributed meaningfully to inflation in the euro area during the period of analysis, and where they have, the impact is likely to have been short-lived. Our results instead suggest that carbon taxes changed relative prices, raising the cost of energy, without a significant overall increase in the prices of goods and services.

Second, we exploit two cases in which countries experienced significant increases in tax rates over a short period of time. We estimate event studies based on the Finnish tax revision in 2011 and the French carbon tax enactment in 2014, by constructing a respective counterfactual economy without a carbon tax. Although consumer prices grew slightly faster in these cases, compared to the counterfactual economies, the difference is small over a five-year horizon after the tax change (0.15 percentage points per year).

Third, we simulate the consumer price effects of an effective carbon price increase consistent with the EU's 'Fit-for-55' goals, based on detailed input-output tables. Since future policy will have to be more ambitious than what has been observed historically, which complicates out-of-sample predictions, this exercise complements the regression analysis by quantifying the mechanical impact of a plausible carbon price path. The results imply an increase in overall consumer prices of between 0.2 and 0.4 percentage points annually at the euro area level over 2022-2030, depending on the degree of pass-through from producer to consumer prices, with some heterogeneity across countries. It is worth noting that the resulting increases in the price of fossil fuels and electricity are significantly smaller than those observed in Europe during 2022, as a result of the war in Ukraine.

I. Introduction

There is little doubt that climate change is the challenge of our time, requiring tremendous efforts both domestically and internationally to limit greenhouse gas emissions and promote the green transition to prevent a catastrophic rise in global temperatures. Countries in Europe have committed to de-carbonizing their economies over the next decade and beyond (e.g. ‘Fit-for-55’ by the European Commission).[1] Despite broad consensus that more action is necessary, there remains uncertainty around the economic effects of climate policy. One key question for the medium-term inflation outlook in Europe and the euro area is: will the green transition lead to higher inflation?

Prominently, Larry Fink (2021) made headlines by predicting that climate policy would fuel global inflation. Moreover, the ECB has acknowledged that central banks should take inflationary effects related to the green transition into account in their policy actions (Schnabel 2022). Pisany-Ferry, in a series of contributions (for example, Peterson Policy Brief 2021), and the Governor of the National Bank of Belgium, Pierre Wunsch (2023), discuss the macro costs of the policies needed to address the climate emergency.[2] The chief economist of the European Commission’s Directorate General for Energy in a speech at the ECB’s Sintra forum (2023) laid out six different channels through which the green transition could impact prices: (i) changes in commodities and the energy mix, (ii) replacement of the capital stock and infrastructure, (iii) changes in overall demand and consumption patterns, (iv) possible changes in the cost of electricity driven by renewables, (v) the direct impact of carbon prices and taxation, and (vi) uncertainty and higher risk premia.[3] Here we focus on the direct impacts under (v), building on a vast literature, going back almost 30 years, on the channels through which carbon pricing impacts macroeconomic and development outcomes, which is summarized by Heine and Black (2019).

So, what is the state of carbon pricing in Europe? Carbon pricing has a relatively long history in Europe. Most countries have had some form of excise tax on fuels, with the first countries enacting explicit carbon taxes in the early 1990s. As of 2023, Europe remains a global leader in terms of carbon pricing. Many countries have enacted national carbon taxes with varying levels of ambition and, after a long period of very low prices, the flagship Emissions Trading System (ETS), that covers 40 percent of the European Union (EU) emissions, has seen prices at a comparatively high level of around 85 Euro per ton of CO2 since early 2022. It is worth noting that governments can affect the price of carbon in an economy in many ways other than the direct pricing of carbon, including indirect taxation, tariffs and subsidy polices for renewable energies, and regulation. In this paper, we focus narrowly on the carbon price that is due to national carbon taxation as well as the ETS price.

As of 2021, the base year for our simulations, the combined effective carbon price due to national carbon taxes and the ETS was roughly 40 Euro per ton in the euro area. Where do effective carbon prices need to go to deliver on the ‘Fit-for-55’ targets? Uncertainty around that level, and what other policy levers will need to be employed, is very high. The OECD (2021) summarizes research which estimates a 2030 effective carbon

[1] The Fit-for-55 package, announced by the European Union in 2022, is a proposal to reduce greenhouse gas emissions in the Euro bloc over the medium term. Specifically, it is designed to reduce emissions by 55 percent by 2030 (relative to 1990 levels) and achieve net zero by 2055. It features increases in the use of renewable energy sources, which are set to rise to 42.5 percent by 2030.

[2] https://www.piie.com/publications/policy-briefs/climate-policy-macroeconomic-policy-and-implications-will-be-significant and https://www.piie.com/sites/default/files/2023-06/2023-06-05wunsch-ppt.pdf

[3] https://www.ecb.europa.eu/pub/conferences/ecbforum/shared/pdf/2023/Gil_Tertre_paper.pdf

prices in line with the Paris agreement in the range of 50-225 Euro per ton of CO_2, with an central estimate of 120 Euro. Based on IEA analysis, Brand et al. (2023) in an ECB blog, assume an effective carbon price of 140 Euro per ton of CO_2 in 2030 to achieve the 'Fit-for-55' goals. Breckenfelder et al. (2023) in a comprehensive review cite a range of 50-150 Euro per ton of CO_2. In this paper we will assume an effective price of Euro per ton of $CO_2$by 2030 in line with the benchmark assumed in the October 2022 IMF World Economic Outlook. This implies an increase of 112 Euro in the effective carbon price over the 2021-2030 period (slightly above 12 Euro per year).

Following Russia's invasion of Ukraine, and the resulting surge in energy prices throughout Europe , the question of how carbon pricing affects consumer energy prices has received particular attention. But simple calculations suggest that the actual price movements seen in 2022 were much larger than the implied effects of a carbon price increase consistent with the 'Fit-for-55' 2030 goals. For instance, due to the supply shock, the (futures) price of diesel and electricity (for Germany) rose from 2.70 Euro per liter and 150 Euro per mwh in January 2022 to 4.18 Euro and 571 Euro by August 2022, respectively. Now suppose that, instead of these observed price increases of 55 and 280 percent, there had been no supply shock, but the EU had increased the price of carbon by 112 Euro/ton, in line with the carbon price of 150 Euro per ton assumed for 2030 above, in early 2022. The increase in carbon prices would have mechanically doubled the price of coal, but the increase in the price of diesel and electricity would have been comparatively limited, at 11 and 17 percent respectively.[4] In reality, the highest ETS price reached in 2022 was around 90 Euro per ton in August (rather than 150 Euro), such that the actual contribution of carbon prices to the spike in diesel and electricity prices was smaller still, and not more than around 5 percentage points, a fraction of the total 55 and 280 percent increases actually observed. Kuik et al. (2022) also confirm that carbon pricing has had a limited contribution to energy prices throughout 2021 and 2022.

This paper aims to address the specific question of how carbon pricing might affect inflation in the euro area.[5] We focus on the euro area for two reasons. First, Europe is a region with a long and extensive history of carbon pricing. Several euro area countries put a price on carbon through both the EU ETS and national carbon taxes, which have been the subject of several academic studies.[6] Second, the euro area serves as an interesting case study to estimate the macroeconomic effects of climate policy with limited monetary policy reactions to country-level shocks. Since the ECB's mandate is for the currency bloc, and so does not respond to individual country conditions, it allows for a cleaner identification of changes to national carbon prices.

The effects of climate policy on inflation in principle depend on two competing factors. On the one hand, in the public debate, pundits often liken the economic effects of carbon pricing to oil price shocks. A vast literature studying the economic effects of oil price changes implies potentially adverse consequences of increasing the cost of energy by pricing carbon (see e.g. Hamilton 2000, Kilian 2009). Indeed, to a first order approximation, one would expect a carbon tax to have both inflationary and contractionary properties, based on the oil price example.

[4] Detailed calculations for each energy category are presented in Table A.2. Note that the *relative* price changes caused by the 2022 energy price shock are very different from those achieved under desirable carbon pricing. Most prominently, the price of natural gas was higher than that of coal during parts of 2022, the exact opposite of what a carbon tax seeks to achieve.

[5] The monetary consequences of climate policy are a key concern for central banks in advanced economies more generally (see McKibbin et al. 2021).

[6] See e.g., Metcalf and Stock (2020), Konradt and Weder di Mauro (2022), Känzig (2022).

On the other hand, carbon price changes are conceptually different from oil price changes. Carbon tax implementation is more predictable, for example, often set at the start of a fiscal year, or even more in advance, and are intended to be permanent, unlike oil price changes which often prove temporary. The permanent nature implies that while carbon taxes change relative prices, they may not lead to broad price increases, as firms and households can adjust their consumption expenditure by switching towards less carbon-intensive goods and services (see Andersson 2019). Carbon taxes also frequently feature revenue recycling schemes (e.g. Klenert et al. 2018).[7] Indeed, the use of fiscal revenues generated from carbon taxation is an important factor in determining the macroeconomic impacts.[8] In addition, by internalizing the cost of carbon emissions, carbon pricing policies can spur investment in green technologies, bringing down their costs, and crowding in private investment (including, for example, via non-pricing policies such as feed-in tariffs and regulation) thus reducing the public investment needs over time.[9]

We investigate the extent to which carbon pricing in the euro area, due to carbon taxation and the ETS, contributes to inflation through three types of analysis. First, we draw on three decades of carbon pricing in the euro area to estimate the empirical response of inflation to carbon pricing. Specifically, we compute dynamic impulse response functions in a cross-country panel with annual data, controlling for output, energy prices, policy rates, and environmental regulation, as well as country fixed effects, based on the EU ETS carbon price and eight national carbon taxes. Our results suggest that carbon pricing does not lead to meaningful increases in inflation. The impulse responses of headline and core inflation show only a small and temporary impact and are estimated around zero after five years, although the impact is heterogenous across countries. Energy price inflation shows a small initial impact, but also does not increase significantly over the medium-term.

Looking at the level effect also confirms that the overall consumer price level is not affected meaningfully after five years. The price of energy shows an increase that is persistent over time, however. This is consistent with a view that carbon taxes change relative prices but do not lead to aggregate inflation (or changes in the price level). These results are consistent with a growing literature on the limited economic effects of carbon pricing in Europe (Metcalf and Stock 2020, Konradt and Weder di Mauro 2023). They are also consistent with evidence using microeconomic data and oil price changes (Gao et al. 2014), as well as models of relative price changes with inflation having both a transitory and a permanent component (Aoki 2001). Our findings are robust to various alternative specifications and to including additional controls but, as we discuss below, they might not be robust to the size of the shock, leading us to complement the regression analysis with some simple forward-looking simulations.

Second, in addition to the cross-country study focusing on the average effect, we carry out individual case studies to assess whether there are measurable economic effects if carbon pricing is more ambitious. The idea here is that the aggregate effects estimated above may mask the impacts of more sizable and abrupt carbon tax changes certain countries with less time for adjustment. We use an event study framework to assess the inflationary response to significant carbon tax changes in Finland (2011) and France (2014). This analysis

[7] As an example, the French government first announced its plans for a carbon tax in August 2013 and parliament voted in favor in December 2013. In conjunction with the tax enactment that came into effect in 2014, the government communicated the path of the tax rate over the next three years, until 2016.

[8] It is worth noting that the revenue recycling potential form the ETS is much lower than for broader carbon pricing policies for two reasons: (i) more volatile revenues from ETS, and (ii) ETS generally fall under the remit of sectoral ministries rather than finance ministries, who generally have less incentive to recycle revenues.

[9] Although it is not clear the crowing in of private investment would have any aggregate demand implications and therefore inflationary effects. Much would depend on the relative cost of borrowing between the public and private sector, the way in which public spending is financed (tax vs debt) and the efficiency of investment.

yields very similar conclusions. In both countries, we find little support for carbon tax changes leading to large price effects. By comparing the evolution of the prices in each country after the tax, relative to a plausible counterfactual economy based on other euro area countries (Abadie and Gardeazabal 2003), we find only minor differences in the headline Harmonised Index of Consumer Prices (HICP) over a five-year period.

Finally, one concern with extrapolating the empirical results is that historical carbon taxes, and their implied economic effects, might not be a good guide for the impacts of future policy, due to the limited scope and ambition of carbon pricing so far, relative to the 'Fit-for-55' goals for 2030. The final part of our analysis tries to answer the question: how large could the inflationary impacts of a linearly increasing carbon price be over the next eight years? To this end, we calibrate a set of simulations on the effects of ambitious climate policy, consistent with commitments made by euro area countries. We use detailed input-output tables covering 65 economic sectors and five types of energy inputs (see Ari et al. 2022) to compute the effect of carbon pricing on inflation by 2030.

Quantitatively, our simulations imply an increase in inflation of between 0.2 and 0.4 percentage points per year until 2030 under a carbon price path which takes effective carbon prices to 150 Euro per ton of CO2 by 2030. The magnitude of the inflation effect depends on assumptions on the strength of pass-through from producer to consumer prices, as well as demand side adjustments by households and firms. In our baseline scenario, with 75 percent pass-through to consumer prices and energy demand adjustments by firms estimated from the data, we find a cumulative effect on consumer prices of 2.7 percentage points by 2030.

Tentative results also suggest that the size of the cumulative effect varies widely across countries, depending on the energy intensity and energy mix of domestic production and electricity generation, the initial level of carbon taxation in the economy, as well as household preferences for energy-intensive goods and services.

Related Literature

Our paper is related to several strands of the existing literature, which can be classified into two categories of studies. The first tries to assess the effects of climate policy on inflation and output based on existing carbon taxes implemented since the early 1990s. By design, these studies mostly focus on early adopters of climate policy, including British Columbia and European countries.[10] The second strand of research is based on simulating the effects of different climate policies on economic variables using large-scale structural models.

Starting with the empirical studies, Metcalf (2019) and Metcalf and Stock (2020) study the economic effects of carbon pricing in British Columbia and a panel of European countries, respectively. Methodologically they use dynamic panel models and local projections to estimate the response of unemployment, GDP and emissions to carbon tax changes. Their results indicate that there is no evidence consistent with an adverse effect on output and unemployment. At the same time, they find a robust negative response of emissions to carbon pricing.

Focusing on the monetary side, Konradt and Weder di Mauro (2023) adopt a similar strategy to study the response of inflation to carbon taxation in European countries and Canadian provinces. Consistent with previous literature, the results point to close to zero effects of carbon tax shocks on inflation in both samples.

[10] Indeed, the earlier carbon pricing polices are started, the lower the final carbon price needs to be and the more gradually it can be phased in, thus resulting in smaller and less volatile real impacts (McKibbin et al., 2017)

Känzig (2022) is another recent study that sheds light on the emissions trading system in the EU. The study looks at European countries that tax carbon in the energy and power sectors in conjunction with national carbon taxes and uses an instrumental VAR strategy, constructed by isolating exogenous surprises in ETS futures prices around announcements that affect the supply of ETS certificates. For a shock calibrated to increase HICP energy by 1 percent, the authors find slightly larger effects, both on inflation (0.15 percent increase that fades out over 2 years) and industrial production (0.6 percent fall that persists over two years).

Potential explanations for the different results include different sectoral compositions. While the ETS applies to high emitters that are more likely to pass on emission costs (see Fabra and Reguant, 2014), national carbon taxes operate mainly through transportation, covering fewer total emissions, where higher costs may be more easily absorbed by firms or avoided through substitution for other forms of fuels or transport by households.

Model-based studies using computable general equilibrium models (CGE) find more sizeable, but not dramatically different effects. McKibbin et al. (2014) model a flat 15 USD per ton carbon tax in the US and find that it causes a rise in headline inflation by 0.8 percent in the first year. Goulder and Hafstead (2018) find that a more sizeable carbon tax of 40 USD per ton rising at 5 percent per year leads to a 1.5 percent fall in GDP by 2035, depending on the revenue recycling scheme. Chapter 3 of the IMF's October 2022 WEO report develops a fully-fledged global macroeconomic model for the energy transition (GMMET), encompassing detailed energy generation and consumption, as well as a transportation sector which allows the study of the economic effects of carbon policy. The findings point to modest effects on inflation in the Euro area, between 0.2 and 0.4 percentage points by 2030, in line with our own, much simpler, simulations. Similarly, work at the ECB (Breckenfelder et al., 2023) finds limited inflationary effects of carbon pricing policies.

Clearly the carbon pricing decisions taken by governments do not operate in a vacuum. Fiscal policy may respond to reduce the negative impacts of rising carbon prices on specific sectors or groups of consumers. Monetary policy would also likely act to dampen any adverse impacts on economic activity and inflation. It is not clear though whether monetary policy would need to tighten in response to higher inflation caused by rising carbon prices, or, in fact, ease in response to this supply shock (see chapter 3 of the IMF's October 2022 World Economic Outlook and the ECB's 2021 occasional paper No. 271). Del Negro et al. (2023) present a model which shows that climate policies may generate a tradeoff between the central bank's objectives for inflation and real activity. The presence and size of this tradeoff depends on how flexible prices are in the "dirty" and "green" sectors relative to the rest of the economy, and on whether climate policies consist of taxes or subsidies. And finally, structural policies may be called upon to either dampen the impact of carbon prices on specific sectors or facilitate the transition to a low carbon economy.

Another fiscal policy tool that has been studied extensively is VAT. These taxes tend to raise prices and generate inflation (e.g. D'Acunto et al. 2022, Benkovskis and Fadejeva 2014), since they are applied uniformly on all goods and services, allowing no substitution. One key difference between VAT and carbon taxes is that the latter explicitly aims at increasing the relative price of carbon intensive sectors and products and allows for substitution between energy sources of different carbon intensities.[11] In fact, Andersson (2019) shows that in case of Sweden the carbon tax elasticity of gasoline is three times larger than the price elasticity. Along this

[11] There are other important differences between carbon taxes and VAT, namely that VAT is an ad-valorem tax which amplifies swings in pre-tax prices while carbon taxes are specific-tax rates and so have a steady contribution to prices.

line, carbon prices might primarily affect relative prices, but not necessarily drive up overall inflation, consistent with models in the spirit of Aoki (2001).

Finally, there is a growing body of evidence that climate policies do lead to significant technological change and economies of scale in the low-carbon transition, but that these effects take time to materialize.[12] The result is that we might expect deflationary pressures to take root over a longer horizon as the unit costs for green technologies declines. To the extent that these shifts are driven by non-price climate policies (such as feed-in tariffs, regulation, strategic investments) the inflationary impacts of carbon pricing on inflation over the short-run may counteract the deflationary impacts from technological change over the longer term. In this paper we focus primarily on the short-run effects on inflation, as these are more straightforward to identify from an econometric perspective.

Our modelling exercise based on input-output tables is conceptually in line with Ari et al. (2022), and the results are of comparable magnitude to similar studies focusing on Austria (see Breitenfellner et al. 2022) and Germany (Noh et al. 2022). In both cases, the simulated effects on inflation are modest, in the same neighborhood as ours for euro area inflation.

The remainder of the paper is organized as follows. In the following section, we provide background information on the existing carbon pricing mechanisms in the euro area. Section 3 lays out the main empirical strategy and data sources and section 4 presents the results. In section 5 we turn to two individual cases, in the context of event studies. Our simulation exercise is described in section 6, before we conclude.

II. Three Decades of Carbon Pricing in the euro area

In the current framework, carbon emissions in the euro area, and Europe more broadly, are primarily priced through two types of policy instruments. The first, main lever is the EU emissions trading system (ETS), a cap-and-trade system encompassing stationary power plants and other big industrial emitters, as well as airlines (for flights within Europe). The second policy tool are national carbon taxes, enacted unilaterally by countries that primarily apply to the transportation sector. In countries with national taxes, both pricing schemes exist in conjunction, with little overlap (see World Bank Group, 2022).[13]

National carbon pricing

European countries have a long history of pricing carbon. Indeed, the first carbon tax globally was enacted in Finland and Poland in 1990. The Finnish carbon tax remains the largest carbon tax in the euro area today, at 60 Euro per ton after undergoing multiple amendments in 1997 and 2011. Before the 2000s, Slovenia is the

[12] See for example Grubb et al. (2018).

[13] In addition to national carbon taxes and the ETS, countries might implement complementary excise taxes on fuels and energy surcharges, as well as regulations to reduce emissions. Although they are important, the focus of our study are policies that price carbon directly and for which data are more readily available.

only other country currently part of the euro area that started pricing carbon in 1996, with a current rate of 16 Euro per ton.

Since the turn of the century more and more countries have levied taxes on carbon emissions. Two Baltic countries, Estonia and Latvia, began pricing carbon in 2000 and 2004, respectively. Despite their long existence, both taxes remain at very low levels today and cover only a minor share of total GHG emissions.

After 2010 national carbon taxes were implemented in several additional euro area countries. Portugal and Spain introduced taxes which started at low levels and remain modest today, between 12 and 18 Euro per ton of Co2. Ireland in 2020 announced a long term trajectory of carbon tax rate increases.[14] France enacted an ambitious tax that increased quickly from its initial level of 7 Euro in 2014, to 42 Euro in 2018. Further scheduled increases have so far been postponed.

Germany introduced a carbon price in 2021, increasing to 40 Euro in 2024. Austria, the Netherlands and Luxembourg also have more recent national carbon taxes. Due to their limited time span we do not include this latter group of national taxes in our sample.

Emissions Trading Scheme (ETS)

The EU ETS is a cap-and-trade system that applies to all EU27 countries, as well as Iceland, Norway, Liechtenstein, Switzerland and the United Kingdom. At the end of each year all companies that are part of the ETS have to surrender allowances according to their emissions. Allowances trade freely in a pan-European market and there are secondary financial products enabling active trading.

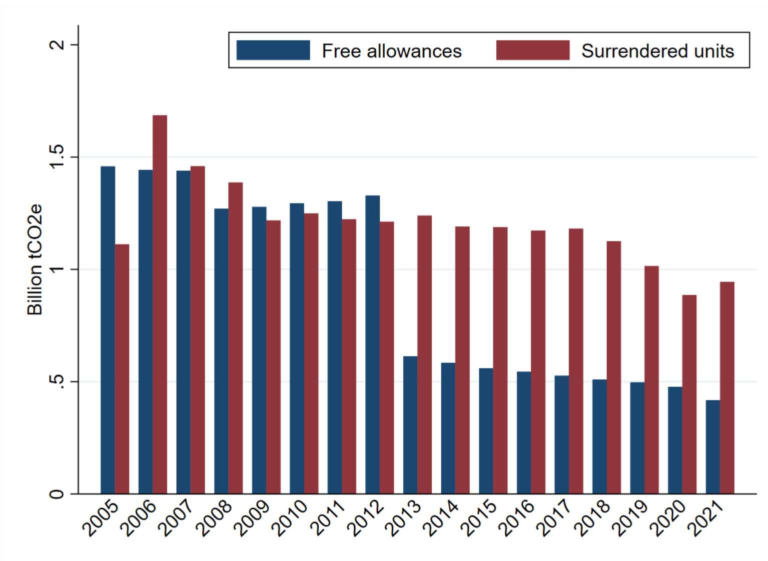
Enacted in 2005, the development of the ETS is often distinguished into three distinct phases. The first, pilot phase of the ETS lasted until 2008, and featured a high allocation of free allowances based on historical firm emissions, reflected in low prices. From the second phase in 2008, the number of certificates were more restricted, although prices remained low due to the sustained over-allocation of allowances and low demand around the GFC. The third phase, starting in 2013, saw the EU significantly reduce the number of free allowances (see Figure 1), moving instead to a largely auction-based system, and the total amount of allocations. As a result, prices of the ETS, between 2013 and 2020 were higher relative to the first two periods (see Figure 3).

As of 2021, more than 10,000 installations and firms are covered by the ETS, accounting for 1,572 MtCO2e, which represents roughly 40 percent of the EU's total GHG emissions. Moreover, the EU ETS has now entered the fourth phase, commencing in 2021. Among other amendments, it includes shipping companies and has an increased reduction factor of certificates. The linear reduction factor has been increased to 4.3 percent over 2024-27 and 4.4 percent over 2028-30.

[14] . Since 2020 annual increases of €7.50 per tonne of Carbon Dioxide emitted have been implemented. Multi annual rate increases are legislated to continue until 2030 when a rate of €100 per tonne of CO2 emitted will apply. The most recent increase applied with effect from 11 October 2023 bringing the rate to €56 per tonne of CO2 emitted. This rate applies to supplies of auto fuels and will apply to all other affected fuels as of 1 May 2024.

Prices have increased significantly in recent years. ETS prices stood around 25 Euro for much of the 2018-2020 period, then rose throughout 2021 to over 70 Euro by the end of the year and since 2022 have oscillated around 90 Euro, peaking at over 100 in March 2023.

Figure 1. ETS Free Allowances and Surrendered Units, 2005–21



Notes: Data from EU EEA.

In 2023, the EU adopted a reform of the ETS which, in line with the ‘Fit-for-55’ plans, sets an ambitious emission reduction goal of 62 percent by 2030 (relative to 2005 levels) for ETS-covered sectors (a significant increase compared with the previous objective of a 43 percent reduction target). The agreement also envisioned establishment of a new social Fund, which will support vulnerable households in the energy transition, and a separate emissions trading system (ETS II), expected to be implemented in 2027, to fossil fuels used in buildings, road transport, and certain industrial sectors.

In our empirical analysis, we exploit variation in countries’ carbon tax rates and coverages over time. This includes both the initial tax introduction as well as subsequent changes in taxes. In addition, we use variation in ETS coverages and prices, by computing an effective carbon price encompassing both policies, for each country.

III. Data and Empirical Strategy

Data

Our study builds a cross-country panel dataset of carbon pricing for euro area countries at an annual frequency covering the period 2000 to 2020. Our main source for climate policy variables is the Carbon Pricing Dashboard by the World Bank Group (2022), which encompasses data on carbon tax rates and bases for a large number of countries. We convert all tax rates to constant 2018 Euro per ton of CO2e emissions. The data also include the average annual price of the EU ETS, which we complement with figures on the emission coverage of the ETS in each country, constructed from the ETS reporting system.[15] To control for environmental regulation other than price and taxation policies, we use the OECD Environmental Policy Stringency Index.[16]

Table 1 summarizes the national carbon taxes enacted in euro area countries until 2018. Of the eight total taxes, only two were implemented before 2000, with half of the taxes coming into effect only in the last decade. Tax rates and coverage display considerable heterogeneity across countries. As of 2018, tax rates varied between 2 Euro per ton in Estonia and 58 Euro per ton in Finland, covering between 2 percent of total GHG emissions in Spain and 52 percent in Slovenia. Measured by total tax revenue, the French carbon tax was by far the most comprehensive, reflecting the size of the economy compared to most other countries. The combination of tax rate and coverage allows us to calculate effective tax rates for each country.

Table 1. National Carbon Taxes

Country	Tax rate (2018 Eur/tCO2e)	Tax coverage (% of GHG)	Enacted
Estonia	1.84	6	2000
Finland	58.13	36	1990
France	41.9	35	2014
Ireland	18.26	40	2010
Latvia	4.17	3	2004
Portugal	11.91	36	2015
Slovenia	17.28	52	1996
Spain	14.09	2	2014

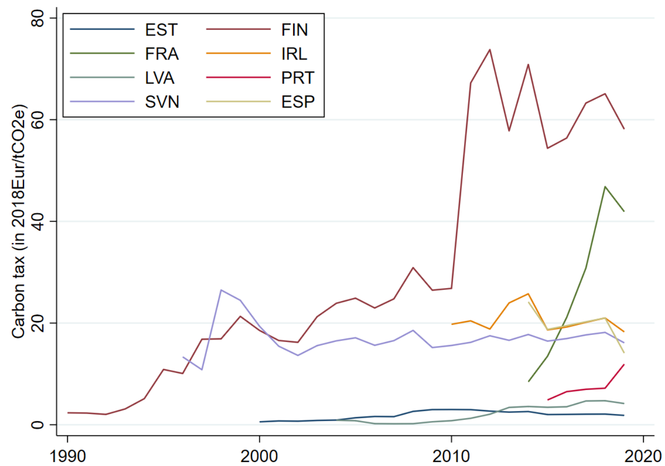
Notes: National carbon taxes, in 2018 euro per ton of CO2e emissions. Tax coverage is expressed as a percent of total greenhouse gas emissions, in 2018. Source: World Bank Carbon Pricing Dashboard.

We illustrate the path of these eight euro area carbon taxes over time in Figure 2. In most cases, we note that carbon taxes start at a low initial level and gradually increase over time, with a high degree of persistence. Nonetheless, carbon prices still display some variation, most pronounced for Finland which experienced a rapid increase in 2011 of 40 Euro per ton, followed by annual price swings of about 10 Euro per ton. We will exploit this variation in our empirical analysis.

[15] Although the ETS price is common for all countries in the sample, the coverage varies owing to the fact that the power sector accounts for different shares of total emissions in euro area countries.

[16] Specifically, we use the non-market based policies sub-index which does not include any carbon pricing or tax measures. We also use the CCPI Climate Policy sub index as a robustness check, although this includes carbon taxation.

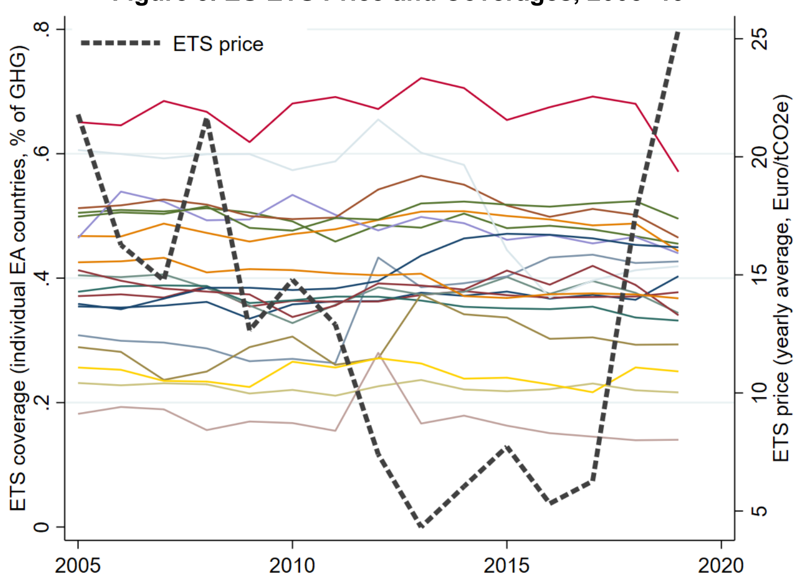
Figure 2. National Carbon Taxes in the EA, 1990–2019



Notes: National carbon taxes, in 2018 euro per ton of CO2e emissions. These are not effective tax rates. Source: World Bank Carbon Pricing Dashboard.

The main lever of climate mitigation in the euro area remains the common EU ETS. Figure 3 plots the average annual trading price for an allowance of one ton of CO2 (solid dashed line). Compared to the carbon taxes, it is characterized by greater price volatility (between 5 to 25 Euro in the period up to 2019) but, because it is common to the EU, does not vary across countries. The coverage of ETS, however, does vary by country, depending on the number of ETS installations and their emissions relative to the total emissions and output. Indeed, ETS sectors account for between 17 to 70 percent of emissions in euro area countries, fluctuating over time. This is a second source of variation in the price of carbon that we exploit in our analysis.

Figure 3. EU ETS Price and Coverages, 2005–19



Notes: Colored lines (LHS) show the coverage of the EU ETS in each euro area country. The dashed black line (RHS) shows the average annual emission certificate price, expressed in 2018 Euro per ton of CO2e emissions. Source: European Commission.

Our main dependent variable is headline inflation, which we construct from HICP data retrieved from Eurostat. We also use the disaggregated core, services, and energy sub-indices. We complement data on prices with output (GDP) from Eurostat, the structural fiscal deficit by the IMF, and a commodity price index from the IMF's World Economic Outlook (WEO) database. We use data from British Petroleum (BP) on the share of non-renewables in the energy mix, to proxy for a country's energy mix and interact it with the global commodity price index by the IMF.[17]

Table 2 summarizes the variables used in the empirical analysis and provides summary statistics. Our complete dataset covers 19 countries spanning 20 years, with a total of 285 observations.

Table 2. Main Variables, Descriptive Statistics, 2000–19

Variable	Source	mean	median	min.	max.	st. dev.
Carbon tax rate	World Bank	5.36	0.00	0.00	73.79	13.04
Carbon tax coverage	World Bank	0.11	0.00	0.00	0.52	0.18
ETS price	EEA	14.10	14.02	4.58	25.96	7.17
ETS coverage	EEA	0.40	0.39	0.14	0.72	0.12
Headline inflation	Eurostat	1.83	1.72	-1.72	14.19	1.80
Core inflation	Eurostat	1.35	1.31	-4.12	8.62	1.22
Energy inflation	Eurostat	3.31	4.23	-17.26	26.51	7.94
Services inflation	Eurostat	2.11	1.87	-4.65	14.31	1.79
GDP growth	Eurostat	1.19	1.81	-16.06	22.46	4.29
Share of non-renewables	BP	89.56	91.84	64.91	99.99	8.20
Commodity price index	IMF	164.93	157.69	91.39	234.79	47.08
Environmental policy index	OECD	2.70	2.72	1.40	4.13	0.55

Sources: World Bank Group, EEA, Eurostat, BP (Statistical Review of World Energy), IMF, OECD.

Empirical Strategy

Methodologically, we build on the existing literature that quantifies the economic effects of carbon taxes (Metcalf and Stock 2020, Konradt and Weder di Mauro 2023) based on local projections (Jorda 2005), adapted to panel data. Specifically, we employ panel-OLS to estimate:

$$\Delta HICP_{i,t+h} = \alpha_i + \Theta_h \tau_{i,t} + \beta(L)\tau_{i,t-1} + \delta(L)\Delta HICP_{i,t-1} + \mu(L)X_{i,t-1} + \pi(L)Z_{t-1} + \epsilon_{i,t}$$

where $\Delta \mathrm{HICP}_{i,t+h}$ is the year-over-year inflation rate, defined as the one period change in the log of country i's harmonized index of consumer prices h years ahead, and $\tau_{i,t}$ is the real effective carbon tax rate in country i in year t. In this setup, Θ_h is the effect of a change in the carbon tax rate on annual inflation h years ahead. It is estimated exploiting the exogenous component of the carbon price. That is, the movements in the carbon price that are not predicted by the lags and controls used.

[17] Non-renewables include oil, gas, coal, nuclear and hydrogen. Renewables include wind, solar, geothermal, biomass, biomethane, biofuels.

Importantly, relative to the previous literature our focus is on the total aggregate effect, and we build our carbon price variable, $\tau_{i,t}$, to incorporate both carbon taxes and EU ETS price as follows:[18]

$$\tau_{i,t} = ETS_t \times ETS\ Coverage_{i,t} + CT_{i,t} \times CT\ Coverage_{i,t}\ ,$$

where ETS_t is the common ETS price, $ETS\ Coverage_{i,t}$ is the country-level ETS coverage, $CT_{i,t}$ and $CT\ Coverage_{i,t}$ are the national carbon tax rate and emission coverage respectively, which are equal to zero in case there is no national carbon tax. Further, we also estimate local projections including effective carbon taxes and ETS prices separately.

Carbon prices are potentially endogenous to the prevailing macro-financial environment. For example, the price of carbon may change in response to economic conditions either directly, as a result of decisions by policymakers on carbon taxes (for example to raise additional revenue), or indirectly if the ETS price fluctuates mechanically in response to demand conditions. We address this endogeneity by including a varying set of (lagged) country-level covariates, $X_{i,t-1}$, and euro area covariates, Z_{t-1}. In our baseline specification, the country-level controls include GDP growth, the share of CO2 emissions in GDP, and changes in energy prices weighted by the energy intensity of the domestic economy. The euro area controls include euro area GDP growth and the policy rate in levels.[19] We also include country fixed effects, α_i. As is standard in the literature, we control for persistence in the tax rate, inflation, and additional controls, by including 4 annual lags of each variable.[20] Taken together, these controls and specification choices help to address most of the endogeneity concerns discussed above. We do not impose the recursiveness assumption on our specification, meaning that the control variables do not enter contemporaneously. Standard errors are robust and clustered on country (Montiel Olea and Plagborg-Moller 2019).

To illustrate the results, we plot the dynamic impulse response functions, Θ_h, over the short- to medium-term after a tax change. To assess the response of individual price components we also estimate the model separately with different subcomponents of the HICP basket as the dependent variable. Finally, to test if carbon pricing affects the price level, as opposed to its growth rate, we estimate the local projections model with the HICP index in levels as the dependent variable.

IV. Aggregate Results

National Carbon Taxes

In order to benchmark our estimates, we begin with the results based on national carbon taxes only, in the spirit of Konradt and Weder di Mauro (2023).[21] We draw on the eight carbon taxes enacted in euro area countries

[18] In some cases there can be overlap between national carbon taxes and ETS. In these, limited, instances our metric would be double counting to some degree.

[19] We test several sets of additional covariates, including the fiscal deficit and climate stringency indices, as well as replacing the euro area controls with year fixed effects. These changes do not change our main results.

[20] We also adopt the approach of Teulings and Zubanov (2014) to control for other tax changes within the forecast, with similar results.

[21] One distinguishing feature is that Konradt and Weder di Mauro (2023) focus on all European countries based on CPI data going back to 1985, whereas the present study includes only euro area members and uses HICP data to ensure consistency.

over the past three decades which have a sufficiently long time series. Figure 4 shows the dynamic impulse responses of headline inflation and its components to a one euro increase in the effective carbon tax.

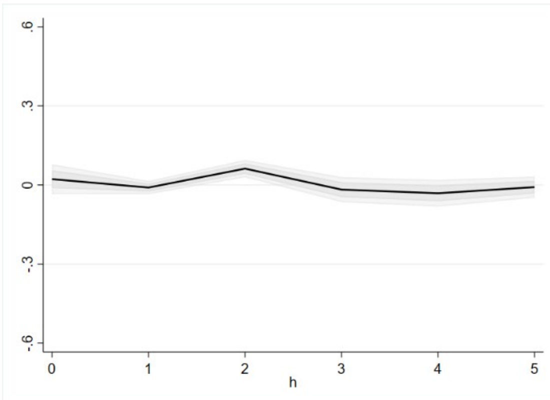
Starting with headline inflation (panel A), we find a modest response of inflation that lies around zero in most years. Only in the second year after the tax change do the error bands (90 percent) not include zero. In quantitative terms, a carbon tax increase of 30 euro per ton would imply a temporary 0.1 percentage point increase in headline inflation after two years, that fades out immediately after.

The dynamic impulse responses of core inflation (panel B) paint a similar picture. Inflation is muted and close to zero in all years following the tax change. In all but one case do the error bands include zero. This profile is comparable for the services component (panel D) of core CPI. In panel C, we estimate the same model but using energy inflation as the dependent variable. As expected, we see a more sizable initial increase in energy prices immediately following the tax (0.25 percentage points under a 30 Euro per ton change in the carbon tax), which, however, is not statistically significant. In the following years the response fades out and even turns negative, with large standard errors. The larger impacts on energy prices are more visible when looking at the price level (see discussion below).

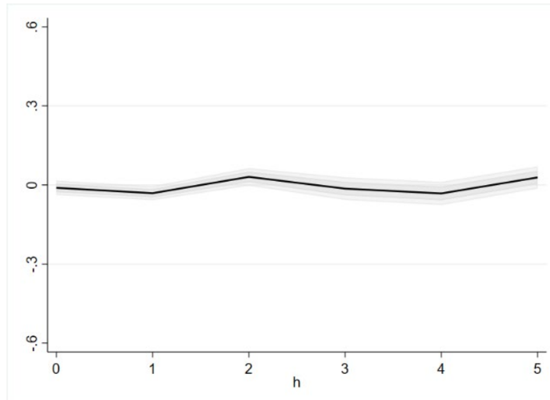
Overall, these results are consistent with prior findings in Konradt and Weder di Mauro (2023). The response of inflation to carbon pricing is muted and there is no robust evidence of aggregate inflationary effects. Any increase in prices associated with national carbon taxes is confined to energy inflation but does not propagate to the overall basket of goods and services.

Figure 4. Dynamic Impulse Responses of Inflation (in p.p.) to National Carbon Taxes

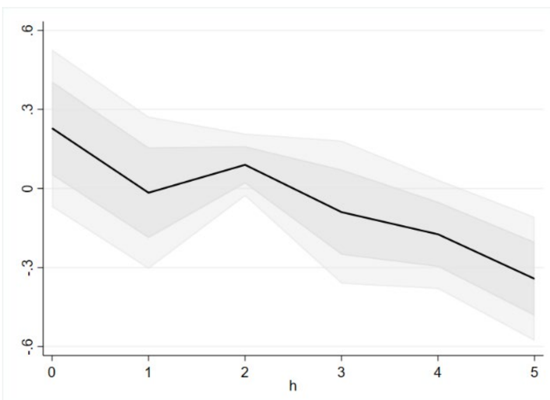
A. Headline inflation



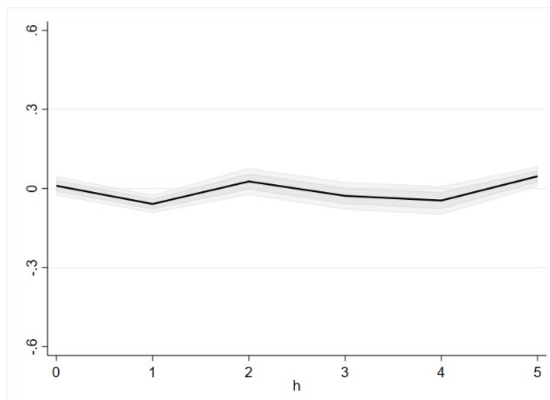
B. Core inflation



C. Energy inflation



D. Services inflation



Notes: All dynamic responses are expressed in percentage points, shaded gray bounds denote 68 and 90 percent confidence bands. Standard errors are clustered by country. Sample EA19, 2000-2019, based on an effective tax rate including national carbon taxes only. Horizontal axis shows years while vertical axis shows change in inflation or price level relative to t = 0. The size of the shock is standardized to 30 euro per ton.

Combined Impact of National Carbon Taxes and the ETS

In addition to national carbon taxes, euro area countries also price carbon under the umbrella of the EU ETS. In principle, due to differences in design and sectoral coverage, the effects might be different for the two policies (see Känzig 2022). Therefore, to assess the aggregate effect of carbon pricing we include the ETS in the tax variable, interacting it with its coverage.[22]

We estimate similar dynamic impulse responses of inflation subcomponents to changes in the total effective carbon tax in Figure 5. Overall, the profile of responses look very similar to those from national carbon taxes. Headline inflation (panel A) shows a slight increase on impact in the three following years, before fading back to zero. However, at no horizon are the estimates statistically significant at the 90 percent confidence level. Moreover, the responses continue to be modest in magnitude. An increase in the price of carbon of 30 Euro per ton would increase headline inflation by 0.05 percentage points on impact and peak at 0.1 percentage points after two years before falling back to zero after five years.

In the same vein, core inflation (panel B) barely reacts to the carbon tax change. At all horizons, the estimates are quantitatively small, and the 68 percent confidence bands always include zero. This suggests that there is little evidence of broad price effects for core goods and services. Indeed, separate estimates for services (panel D) and non-energy industrial goods (not shown) confirm this hypothesis. Turning to energy prices (panel C), we find a similar initial positive reaction that quickly fades out over time and is imprecisely estimated.

Overall, these estimates once again cast doubt on the notion that rising carbon pricing contributes to sizeable increases in inflation. When comparing the effects for the aggregate carbon price against national carbon taxes the differences are also negligible. On the one hand this might imply that carbon taxes and cap and trade lead to similar effects. On the other hand, much of the variation in the latter may simply be driven by national taxes. Indeed, Känzig (2022) finds more inflationary results for exogenous shocks in ETS prices, based on monthly data. This is potentially related to different sectoral coverage and scope of the ETS relative to national carbon taxes.

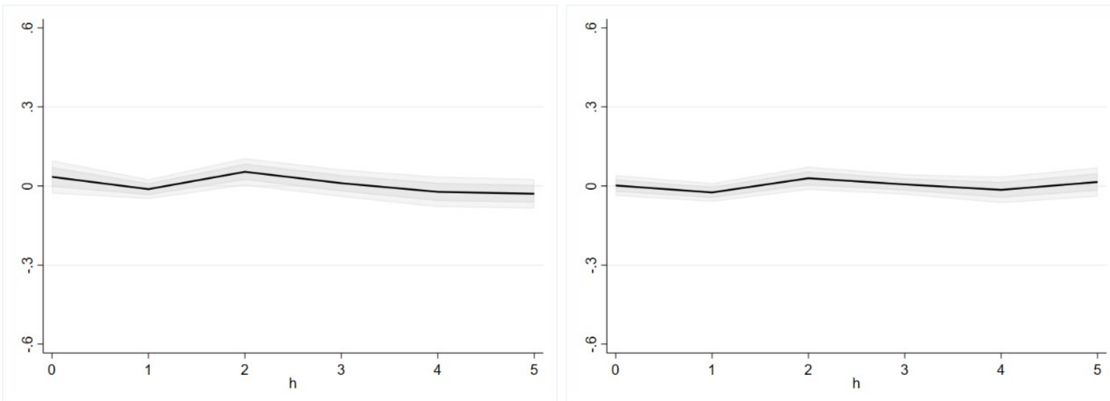
In principle, carbon pricing might not have a lasting impact on inflation (i.e. change in price level) but could instead affect the price level. For instance, one can imagine that a carbon tax is enacted and raises prices once, without affecting the future path of inflation. To test whether changes in the carbon tax affect the level of consumer prices, we use the level of HICP as the dependent variables, keeping the regressors the same.[23] The dynamic impulse response for headline HICP displays a positive, albeit not statistically significant, response across the entire horizon (panel A, Figure 6). The response of energy HICP (panel B) increases by 0.3 percentage points on impact and peaks at around 0.45 percentage points after three years although imprecisely estimated (90 percent confidence bands mostly include zero). This is a sizable impact on the level of energy prices, which one might expect given the high carbon intensity of the energy sector.

[22] We note that the ETS price is common to all countries in the sample, however ETS coverage varies between 20 and 70 percent and changes over time, depending on the share of ETS total emissions in each country.

[23] One potential concern for the estimation in levels is stationarity since all variables follow an upward trend. Nonetheless, we include the estimations here and a simple test rejects the null hypothesis of a unit root, when using country and time fixed effects (Levin et al., 2002).

Figure 5. Dynamic Impulse Responses of Inflation (in p.p.) to National Carbon Taxes and ETS

A. Headline inflation *B. Core inflation*



C. Energy inflation *D. Services inflation*

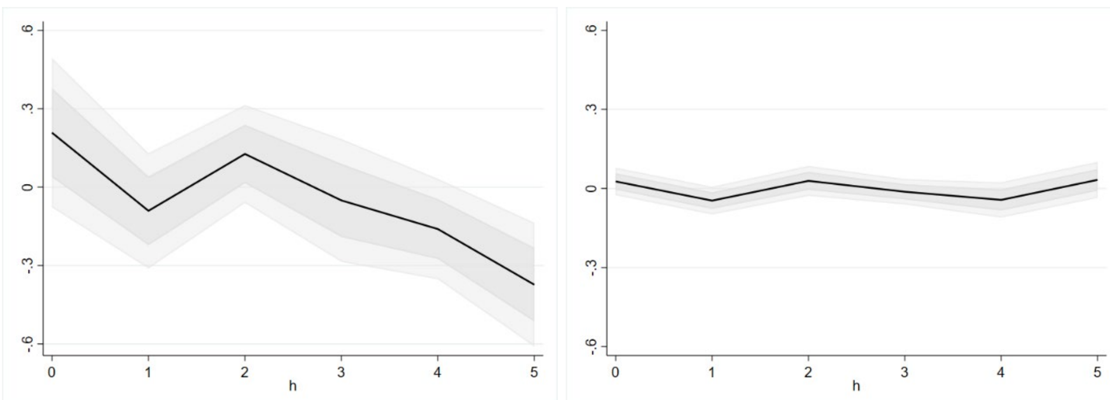
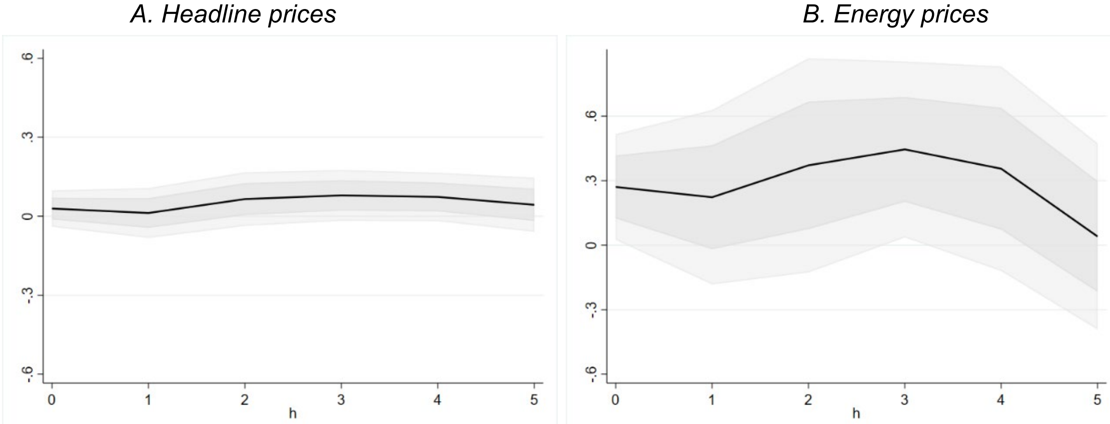


Figure 6. Dynamic Impulse Responses of Price Level (in p.p.) to National Carbon Taxes and ETS

A. Headline prices *B. Energy prices*



Notes: All dynamic responses are expressed in percentage points, shaded gray bounds denote 68 and 90 percent confidence bands. Standard errors are clustered by country. Sample EA19, 2000-2019, based on an effective tax rate including national carbon taxes only. Horizontal axis shows years while vertical axis shows change in inflation or price level relative to t = 0. The size of the shock is standardized to 30 euro per ton.

Indeed, the estimations in levels point to carbon taxes having a positive, but imprecisely estimated, effect on energy prices, as well as headline consumer prices. Nonetheless, the absent response of core pricessuggests that any upward pressure is confined to energy and does not affect other goods and services. The results are also consistent with a view that carbon taxes change relative prices, increasing the price of energy (at least for some years), but leaving aggregate prices unchanged.

Robustness

To ensure the robustness of our main results we test several alternative specifications. A first set of robustness tests involve including additional control variables capturing the fiscal stance and the tax revenue share, environmental regulation, and the 10-year bond yield in the estimations.[24] We also estimate a specification replacing EU level controls with time fixed effects.

Most of the carbon pricing we observe historically are characterized by modest tax rates and limited coverage. One concern is that estimates based on past policies are limited in predicting the effects of future, plausibly more ambitious, policies. Put differently, carbon pricing could have non-linear effects on inflation, with an increasing impact as the level and coverage increases. We try to address this concern by including the squared effective carbon tax in the local projections.

Similarly, a carbon tax could affect consumer prices differently depending on the carbon intensity of production, with larger effects in fossil-fuel dependent economies. To test this, we interact the effective tax rate with the share of non-renewables in a country's energy mix.

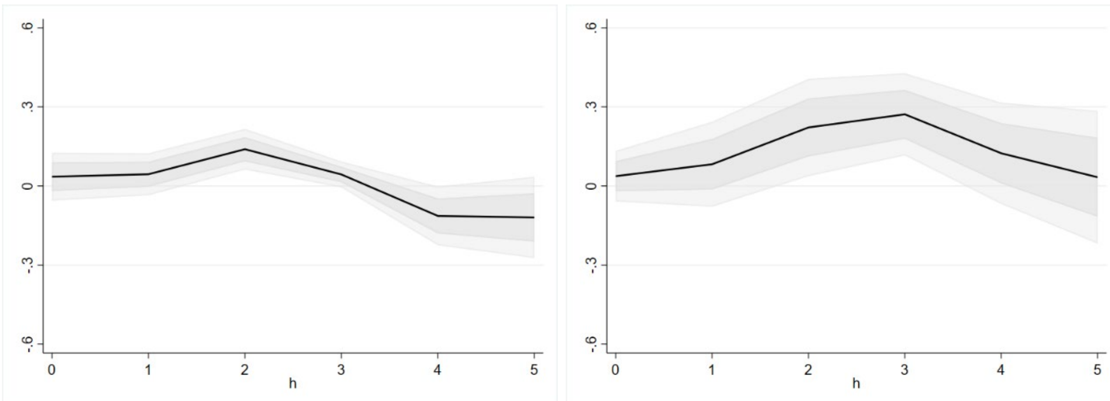
Our baseline results remain largely unchanged throughout the robustness tests, although the effects on inflation are now slightly larger, albeit still temporary in nature, and more precisely estimated. The IRFs for headline inflation and the HICP price level, including all robustness checks added, are presented in Figure 7 below.[25] Inflation increases by around 0.15 percentage points after two years, before declining to zero (possibly even negative) with a combined upward impact on the overall price level of around 0.3 percentage points after three years, before quickly fading out. In the next section we investigate possible heterogeneity in the impact of carbon pricing on inflation across countries.

[24] The addition of the tax revenue share is an attempt to control for revenue recycling (more recycling would lead to a stable fiscal deficit given more carbon tax revenue). We attempted to also control for broader measures of carbon taxation including the total carbon price and net effective carbon taxation from the Carbon Pricing Dashboard, as well as fuel taxes. However, the limited time span of these data severely restrict our sample size.

[25] See annex for individual robustness test results.

Figure 7. Robustness Tests

A. Inflation *B. HICP price level*



Notes: All dynamic responses are expressed in percentage points, shaded gray bounds denote 68 and 90 percent confidence bands. Standard errors are clustered by country. Sample EA19, 2000-2019, based on an effective tax rate including national carbon taxes only. Horizontal axis shows years while vertical axis shows change in inflation or price level relative to t = 0. The size of the shock is standardized to 30 euro per ton.

Cross-country heterogeneity

One benefit of the euro area setting is the possibility to exploit cross-country variation to investigate the mechanism by which carbon taxation affects prices. In this section, we ask whether the macroeconomic environment affects the pass-through of carbon taxes to prices. In particular, a carbon tax could have a larger effect on overall prices when inflation is already high or more persistent, as firms are setting prices more frequently, or when there is limited economic slack to facilitate a transition of labor or capital away from carbon intensive sectors. To test these hypotheses, we extend the baseline specification in Section III to include an interaction term that captures the state of the macroeconomic environment, as follows:

$$\Delta H\mathrm{ICP}_{i,t+h} = \alpha_i + \Theta_h \tau_{i,t} \times s_{i,t} + \beta(L)\tau_{i,t-1} + \delta(L)\Delta HICP_{i,t-1} + \mu(L)X_{i,t-1} + \pi(L)Z_{t-1} + \epsilon_{i,t}$$

where $s_{i,t}$ is a dummy variable capturing the state of the economy in country i at time t.

We construct two sets of dummy variables. The first takes a value of 1 if the inflationary process is highly persistent according to a simple Philips curve model for each country:

$$\Delta H\mathrm{ICP}_t = \rho \Delta H\mathrm{ICP}_{t-1} + \alpha \tilde{y}_t + \beta \mathrm{E}_t(\Delta H\mathrm{ICP}_{t+5}) + \epsilon_t$$

where $\Delta H\mathrm{ICP}_t$ is the inflation rate in a given country in year t, $\tilde{y}_t$ is a measure of the output gap taken from the IMF WEO, and $\mathrm{E}_t(\Delta H\mathrm{ICP}_{t+5})$ is expected inflation five years ahead taken from Consensus Economics. The inflation process is deemed to be persistent for countries in which ρ is estimated to be greater than 0.7.[26] The second dummy variable takes a value of 1 if the output gap for a specific country is positive in any given year,

[26] The existing literature finds a wide range of estimates for the coefficient on lagged inflation in a Philips curve model. See Fuhrer and Moore (1995) and Gali and Gertler (1999) for early evidence. We choose a cutoff of 0.7 so as to roughly balance the samples of high and low inflation persistence countries in our sample.

and 0 otherwise. By construction, the dummy variable capturing inflation persistence is constant over time for each country, while the output gap dummy varies over both country and time. Table 3 below summaries the two dummy variables.

Table 3. Inflation Persistence and Output Gap State Variables

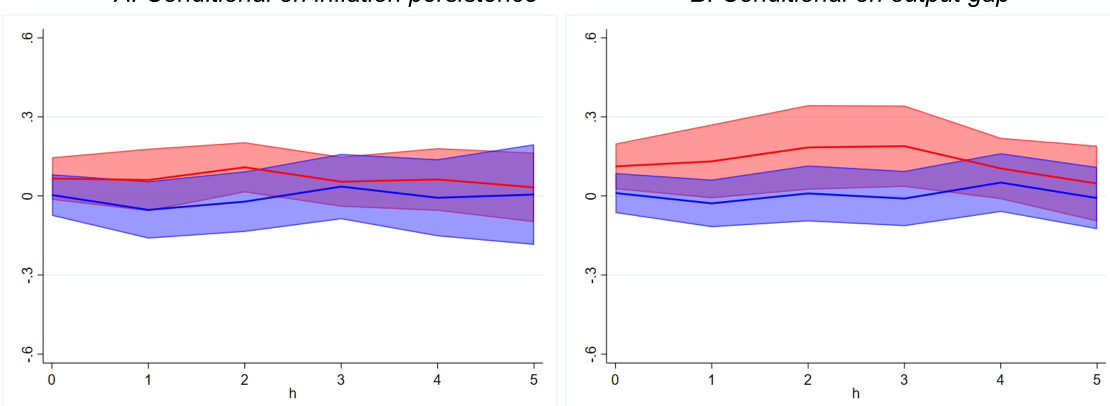
Variable	Observations	Mean
Inflation persistence	288	0.437
Output gap	342	0.439

Notes: Inflation is deemed to be persistent for countries in which the coefficient on lagged inflation is above 0.7. Inflation is persistent in the following 7 countries: Austria, Belgium, Finland, Greece, Italy, Netherlands, and Slovenia. The output gap dummy takes a value of 1 when the output gap is positive and 0 otherwise.

Given the larger potential impacts on the price level than on inflation, and to avoid possible collinearity between the state of the economy and dependent variables, the results presented in Figure 8 focus on the response of the HICP price index to changes in the carbon price. The price level increases more in response to increases in the carbon tax when the inflationary process is highly persistent (red lines) compared to when it is less persistent (blues lines), although the difference is not statistically significant (Panel A).The results are somewhat stronger when distinguishing positive and negative output gaps, with no impact of higher carbon prices when there is a negative output gap but a somewhat positive impact when the output gap is positive (Panel B).

Figure 8. Impact of Carbon Taxes on Price Level Conditional on Macroeconomic Environment

A. Conditional on inflation persistence *B. Conditional on output gap*



Notes: Red (blue) lines represent the IRFs when inflation displays high (low) persistence or the output gap is positive (negative). All dynamic responses are expressed in percentage points, shaded bounds denote 90 percent confidence bands. Standard errors are clustered by country. Sample EA19, 2000-2019, based on an effective tax rate including national carbon taxes only. Horizontal axis shows years while vertical axis shows change in inflation or price level relative to t = 0. The size of the shock is standardized to 30 Euro per ton.

V. Case Studies

Countries' experiences with carbon taxes vary widely across the euro area. One might hypothesize that the impact on inflation may be more pronounced in countries that put in place strong carbon tax regimes. To test this, we employ an event study approach, based on the synthetic control method (Abadie and Gardeazabal

2003, Abadie et al. 2010). This enables us to study the price response to a change in carbon taxation by comparing the path of the price level in a high carbon tax country with that in a plausible counterfactual country without the carbon tax.

We focus on two cases, Finland and France, which implemented sizable increases in carbon prices. The benefit of focusing on these two countries is that the large moves in carbon taxes announced in these countries can give a sense of responses to significant changes in carbon taxes. While part of these tax changes may have been expected, it is difficult to argue that the full extent of the tax changes could have been anticipated, and even less likely that firms and households would have had the time to fully adapt.[27] It is important to note however, that the synthetic control method is highly sensitive to the parameterization used, and to treat the results in this section as a sense check for the local projection results discussed in the previous section.

For Finland we consider the 2011 tax revision, when the carbon tax more than doubled, from 26 to 65 Euro per ton of CO2 in the span of one year. In the French example we focus on the tax enactment itself, which started at 7 Euro in 2014 and increased linearly to about 45 Euro per ton by 2018. Both policies were announced 6 months before they became effective.

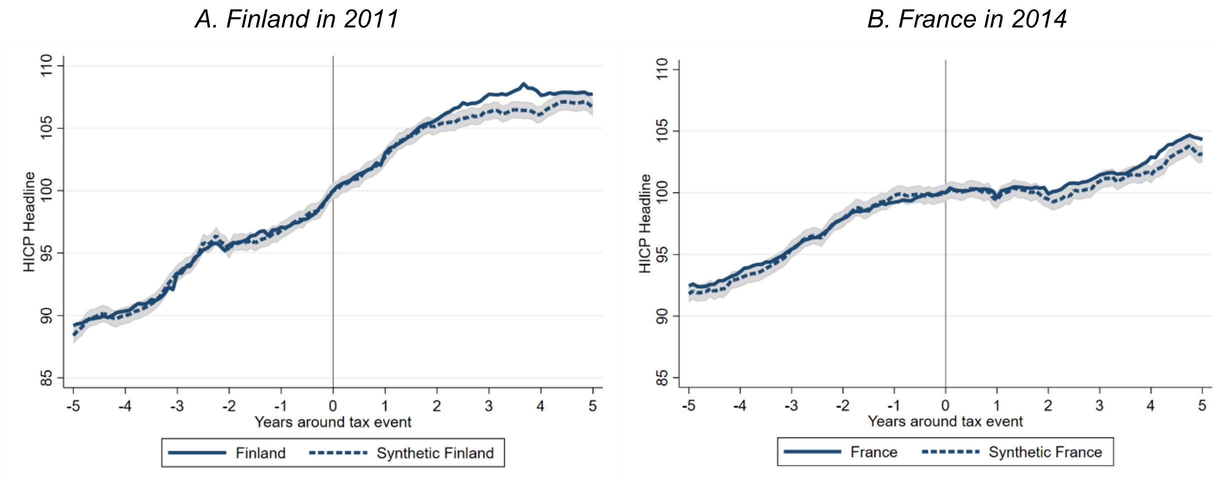
Another advantage of this approach is that it allows for higher frequency identification, capturing potential short-term effects related to carbon pricing. We use monthly data on headline consumer prices to construct counterfactuals for each of the two carbon tax economies. The data are seasonally adjusted, and we focus on a 5-year window around the tax changes. The counterfactual economy is constructed by minimizing the pre-tax difference in HICP, based on 60 total observations. We restrict the pool of potential counterfactual economies to euro area countries without a carbon tax in the 10-year event window. Comparing the path of consumer prices in the actual and counterfactual French and Finnish economies allows us to infer the effect that the carbon tax had on prices.

Figure 9 illustrates the results of the synthetic control method (SCM). Panel A shows the path of Finland's HICP (solid line) and its synthetic counterfactual (dashed line) in the 10 years around the tax increase of 2011. The gray shaded areas denote 90 percent confidence bands, based on the pre-tax differences. The two move almost in lockstep prior to the tax increase, illustrating the accuracy of the SCM. We also find little evidence of persistent divergence in the period after the tax change. Initially, Finnish HICP grows at the same rate as in the synthetic counterfactual economy. About two years following the tax change the HICP of Finland exceeds its counterfactual by about 2 percentage points. The gap closes again after four years and is within the confidence bands five years after the tax change.

The estimates are equally precise in the French case, illustrated by the narrow error bands. In the aftermath of the tax enactment, French consumer prices increase at a faster pace compared to its counterfactual. The difference is within the error bands until four years after the introduction of the tax, when the French HICP exceeds the counterfactual by about half a percentage point. Five years after the tax enactment and the difference in HICP is about 1 percentage point.

[27] We opted not to use a multi-treatment synthetic control method, as such methods are inherently sensitive to decisions such as the matching of variable and process, as well as the parameterization of treatment window. In addition, many countries in our sample saw only small changes in their carbon tax over the sample.

Figure 9. Event Studies



Notes: Headline HICP, seasonally adjusted, normalized to 100 in the month of the tax change. Donor countries for Finland: Malta, Luxembourg, Slovakia, Netherlands, with a root mean squared prediction error (RMSPE) of 0.35. Donor countries for France: Germany, Cyprus, Greece with a RMSPE of 0.33. Shaded bands are 90 percent confidence intervals based on the pre-tax difference (see e.g. Born et al. 2019).

Overall, these case studies point to measurable but modest aggregate effects even in instances where carbon tax increases were large. An important caveat to this analysis, however, is that the results are highly sensitive to the exact treatment date chosen. When we use the announcement dates of the tax reforms instead of the enactment dates, the effects look different, and even changes sign in case of France. Our main takeaway remains: an effect on the price level but overall lack of an inflationary effect that is confirmed in the case studies.

VI. Looking Ahead: Mechanical Effects of Future Climate Policy on Consumer Prices

So far, our empirical analysis has explored the effects of historical carbon pricing policies. However, there are legitimate concerns about the future climate outlook and the urgent need for action. A continuation of past policies is not going to be enough. While some countries in our sample, like Finland, already have fairly high carbon taxes, others will need to impose new taxes or significantly ramp up existing ones to meet target commitments (e.g. 'Fit-for-55'). Although useful in assessing the response to carbon pricing, empirical estimates face limitations in gauging the economic effects of future increases in carbon prices if there are non-linearities in the size of the carbon price increase.

To address this external validity issue, this section simulates a set of scenarios for thinking about the potential effects of future carbon price increases on inflation. Conceptually, we compute the mechanical effects of different carbon pricing policies using assumptions on price pass-through from producer to consumer prices and allowing for substitution of energy inputs by firms. The analysis builds on sectoral input-output tables (IOTs) with different energy inputs from GTAP[28], encompassed in the IMF's CPAT (see Black et al., 2022). Our

[28] See https://www.gtap.agecon.purdue.edu/databases/v10/index.aspx.

approach is in the spirit of Ari et al. (2022), who use the same framework to analyze energy price increases in Europe. Note that, in using IOTs, we implicitly abstract from any behavioral response from firms or households that would alter the structure of production and consumption decisions. The implication is that we constrain ourselves to study only the mechanical impacts of carbon pricing on inflation over the relatively near-term climate transition period of 2021-2030.

The IOTs include detailed information on energy inputs (coal, electricity, natural gas, crude oil and refined petroleum and coke) for 65 economic sectors of production in each of the 19 euro area countries. We complement this with energy-specific carbon intensities, retrieved from the European Environment Agency (EEA) and the U.S. Energy Information Administration (EIA), summarized in Table 4. For comparability we express all energy units in kilowatt hours using standard conversion rates. It highlights that coal has the highest carbon intensity, followed by crude oil and refined petroleum products.[29] The carbon intensity of electricity reflects the energy mix in EU-27 countries in 2020, which consists of petroleum products (35 percent), natural gas (24 percent), renewables (17 percent), nuclear (13 percent) and coal (12 percent). We add prices for each energy input as of January 2022. This allows us to compute the mechanical effects of a carbon tax on output prices in different sectors, depending on carbon and energy intensities.

In the next step, we manually map GTAP sectors to components (COICOP) of the HICP consumption basket. This is feasible for 55 of the 65 sectors, the remaining sectors mainly produce intermediate inputs (for example iron and steel) that are not directly consumed by households. Overall, the 55 sectors account for 70 percent of the overall HICP basket. We summarize the matching procedure in Annex II. Following the ECB's approach, we aggregate the country-level HICP indices using consumption expenditure weights, retrieved from Eurostat, to obtain the euro area aggregate.

In practice the effects of carbon pricing are endogenous to firms' and households' reactions to climate policy. For instance, households might adjust their use of transportation (Andersson 2019) while firms reduce emissions (Metcalf and Stock, 2020) and potentially switch to a less carbon-intensive energy mix. To capture some of these effects, we allow for adjustments in firms' energy consumption in each energy input. We empirically estimate the elasticity of emissions to carbon pricing following the same framework as in section IV.[30] For simplicity, we focus on contemporaneous elasticities, which are estimated at -0.24 percentage points for coal, -0.17 percentage points for electricity, -0.27 percentage points for natural gas and 0.001 percentage points for crude oil and refined petroleum.

Although we try to capture some demand adjustments to carbon pricing, our methodology does not fully endogenize households' or firms' substitution of carbon-intensive energy or substitution between energy intensive products versus other goods and services. An additional limitation of our approach is that it does not allow for technological advances that potentially reduce the cost of relatively less carbon-intensive goods and services.

[29] For oil, we use an average distillate fuel oil and road oil. In Annex I we also show results based on the carbon intensity of crude oil.

[30] Results contained in Annex I show that our results are not very sensitive to this adjustment by firms' energy demand.

Table 4. Energy Inputs, Carbon Intensities and Prices, 2021

Energy Input	Carbon intensity (tCO2e/KWh)	Price (2021) (Eur/KWh)	Price (2030) (Eur/KWh)
Electricity	0.00023	0.1503	0.1754
Coal	0.00033	0.0321	0.0681
Natural gas	0.00018	0.0847	0.1043
Petroleum	0.00025	0.2524	0.2797
Oil	0.00026	0.0535	0.0818

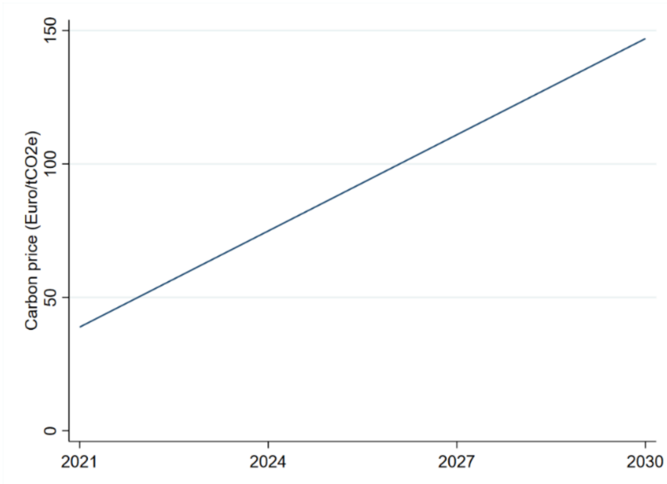
Notes: Energy carbon intensities (including combustion), expressed in tCO2e/kwh using standard conversion formulas. Prices are from January 2022, expressed in Euro/kwh using standard conversion rates. Electricity prices are for Germany. Sources: US EIA, EEA; Haver.

In our simulations, we consider a carbon price consistent with the net-zero target by 2055 set out by the European Commission’s ‘Fit-for-55’ agenda. As discussed above, the carbon price required to achieve this target, and the complementary policies needed, are highly uncertain. We assume a price of 150 Euro per ton, by the year 2030, in line with the baseline carbon price path used in Chapter 3 of the IMF’s October 2022 World Economic Outlook. Importantly, as a result of existing carbon taxes in 11 euro area countries as of 2021, as well as the price of the EU ETS, the effective carbon price starts at 38 Euro per ton at the euro area level in 2021, implying an annual increase in carbon prices of around 12 Euro per ton of CO2 between 2021 and 2030. Figure 10 illustrates the required path for carbon prices up until 2030. We consider the effects on inflation over a 9 year period, starting in 2022.[31] The last column of Table 4 lists the input-specific changes in prices associated with the increase of the carbon tax by 2030.

The response of consumer prices to changes in carbon pricing in our framework depends on the degree to which higher energy costs are passed on to consumer prices. Empirical work on the topic points to high pass-through of energy prices for power sector companies (Fabra and Reguant 2014) but smaller rates of pass-through for other sectors (Ganapati et al. 2020). In our baseline estimation, we therefore assume that producers pass on 75% of the price increases to consumers. For completeness, we show results also for full and 50% pass-through.

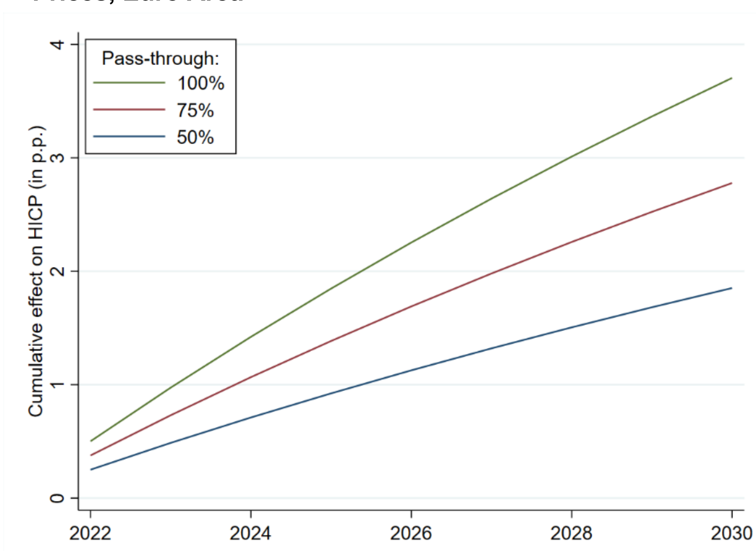
[31] As discussed above, ETS prices increased significantly since 2021, exceeding 100 Euro in early 2023 before dropping back somewhat.

Figure 10. Carbon Price Path Under Fit-for-55



Notes: Own calculations, based on a 147 Euro/ton carbon tax by 2030 to achieve the Fit-for-55 plan (UNFCCC).

Figure 11. Cumulative Effects of Carbon Tax on Consumer Prices, Euro Area



Notes: Simulation results based on IOTs, carbon intensities and 2021 prices for different rates of pass-through from producer to consumer prices. Firm energy demand elasticities by energy type are estimated from the data. The scenario is a 112 Euro/ton increase by the year 2030. Euro area results are obtained by aggregating over all countries using consumption weights.

We illustrate the effects graphically in Figure 11. The carbon tax increases consumer prices by 0.2 to 0.4 percent per year, depending on the degree of pass-through. By 2030, the cumulative effect on consumer prices ranges between 1.8 and 3.7 percentage points. In our baseline specification with 75% pass-through, the annual increase in consumer prices is about a third of a percentage point, adding up to a level effect of 2.7 percentage points by 2030.

Our results are comparable in magnitude to existing simulations for Austrian (Breitenfellner et al. 2022) and German carbon taxes (Nöh et al. 2020). The former points to increases in headline consumer prices between 0.1 and 0.2 percentage points annually, while the latter finds cumulative effects of up to 2.6 percentage points over a 6 year span. They are also in the same range as estimates by Delgado-Tellez et al. (2022), who find effects between 0.15 and 0.4 percentage points annually for the euro area under comparable scenarios.

Beyond the aggregate euro area effects, our data also allow us to assess the response of consumer prices to carbon taxation in individual member countries. Cross-country variation is driven by several factors. First, energy intensity and the energy mix of production. Based on the IOTs, Estonia, for example, uses more energy in its production processes than most other euro area countries. Moreover, Greek producers' energy mix is more reliant on coal and oil, whereas Estonian producers use a lot of oil, relative to other countries. A second factor is the initial level of carbon pricing, with effective taxes between 31 Euro per ton in Germany and 58 in Finland. Third, the energy intensity of electricity varies substantially across countries, between 0.6kg per kwh in Estonia and 0.06kg per kwh in France and Luxembourg. Finally, differences in consumer preferences for energy-intensive goods and services across countries are an additional source of heterogeneity. HICP basket weights for energy are as high as 15 percent in Slovakia, but only 6.6 percent in Malta.

All in all, assuming a pass-through of 75%, the impact on inflation varies from less than 1percentage point in Luxembourg to over 5percentage points in Lithuania, Estonia, and Greece. The heterogeneous effects by country highlight a potentially important source of inflation divergence within the euro area in the future. Carbon pricing is likely to affect countries' economies differently, depending primarily on the degree to which the domestic production depends on energy and fossil fuels. The potential for divergence in inflation rates as a result of climate policy could pose a challenge for the ECB monetary policy going forward.

VII. Conclusions

This paper presents three sets of analyses on the effects of carbon pricing on inflation in the euro area. First, we draw on carbon pricing policies in member countries to estimate their empirical effects on inflation. Using local projections estimated on a cross-country panel dataset, as well as individual country event studies, we find little evidence that carbon pricing has contributed meaningfully to inflation over the sample period. Our results are consistent with changes in carbon prices shifting relative prices and raising the cost of energy, without affecting the prices of core goods and services. As of 2021, effective carbon prices in the euro area were around one quarter of the level required by 2030 to achieve the carbon reduction targets set out in the EU's 'Fit-for-55' agenda. To assess the role of future policy, we therefore simulate the mechanical effects of ambitious additional carbon price increases, consistent with the these goals on consumer prices based on detailed input-output tables. We find that the increase in the carbon price, from around 40 Euro per ton of CO2 to 150 over the period 2021-2030, increases consumer prices between 0.2 and 0.4 percentage points annually at the euro area level over 2022-2030, depending on the degree of pass-through.

More broadly, one interpretation of our analysis, which is in line with previous academic research, is that the effects of carbon pricing on inflation have been modest. Based on the EU's 'Fit-for-55' goals, our simple, back of the envelope, calculations (see Annex I) further show that, for most energy types, the implied effects on energy prices are modest and orders of magnitude smaller than what European countries experienced during 2022. In fact, a normalization phase from high energy prices might offer an opportunity for countries to deliver on their climate commitments, by enacting ambitious climate policy during a period where energy prices are falling. Nevertheless, it is important to keep in mind that our numerical simulations assume that the carbon price is a good proxy for the overall policy intensity required to reduce carbon emissions. In practice, however, a carbon price will be one element of the broader policy mix which will include other regulatory and non-price measures.

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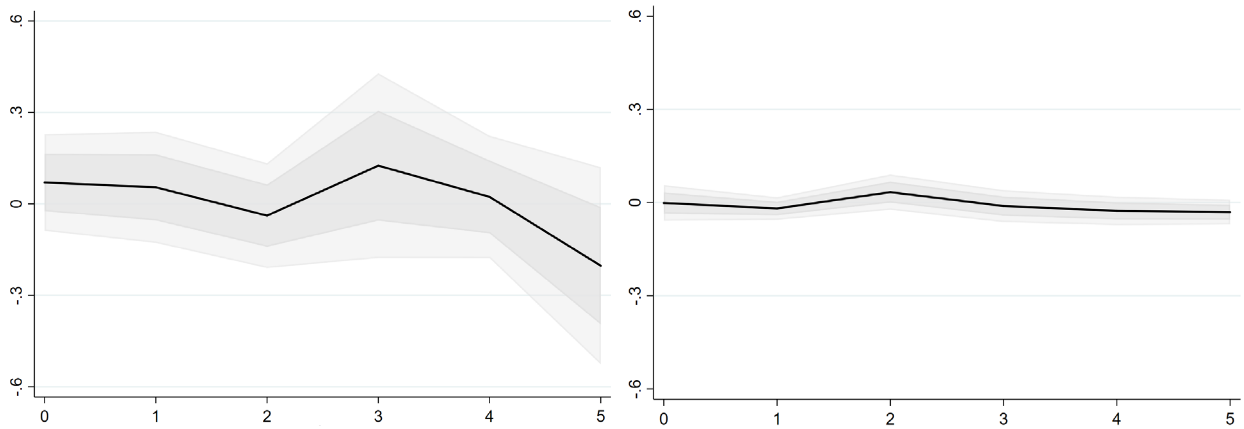
Annex I. Additional Tables and Figures

Figure A1. Additional local projections results for headline inflation

A. B. EU ETS only *B. National carbon tax only*

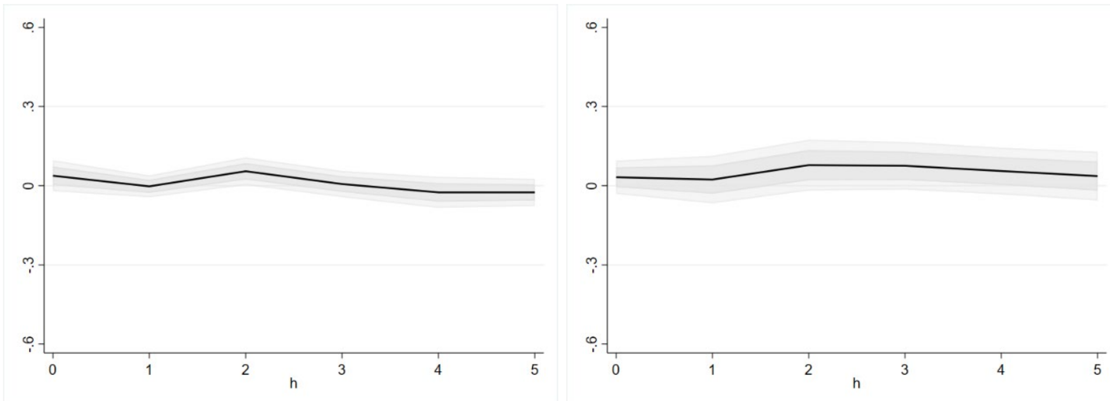


Notes: All dynamic responses are expressed in percentage points, shaded gray bounds denote 68 and 90 percent confidence bands. Standard errors are clustered by country. Sample EA19, 2000-2019, based on an effective tax rate including national carbon taxes only. Horizontal axis shows years while vertical axis shows change in inflation or price level relative to t = 0. The size of the shock is standardized to 30 euro per ton.

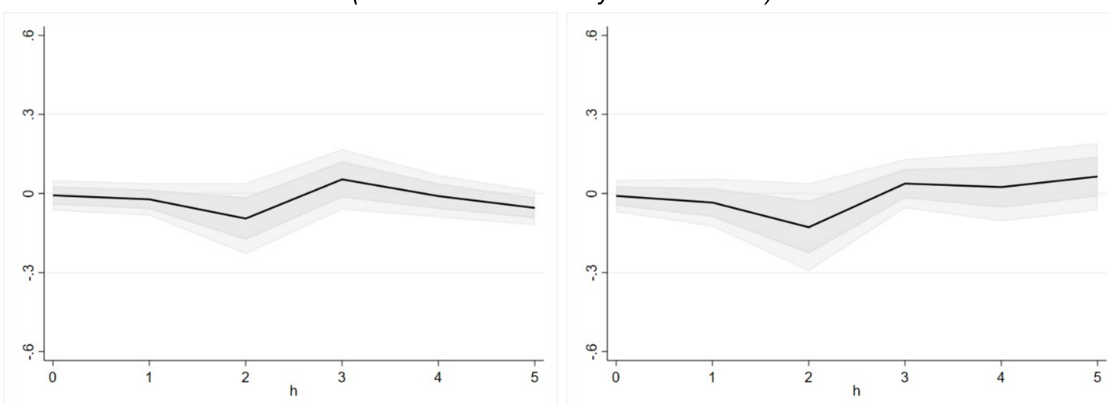
Figure A2: Robustness checks

A. Inflation *B. HICP price level*

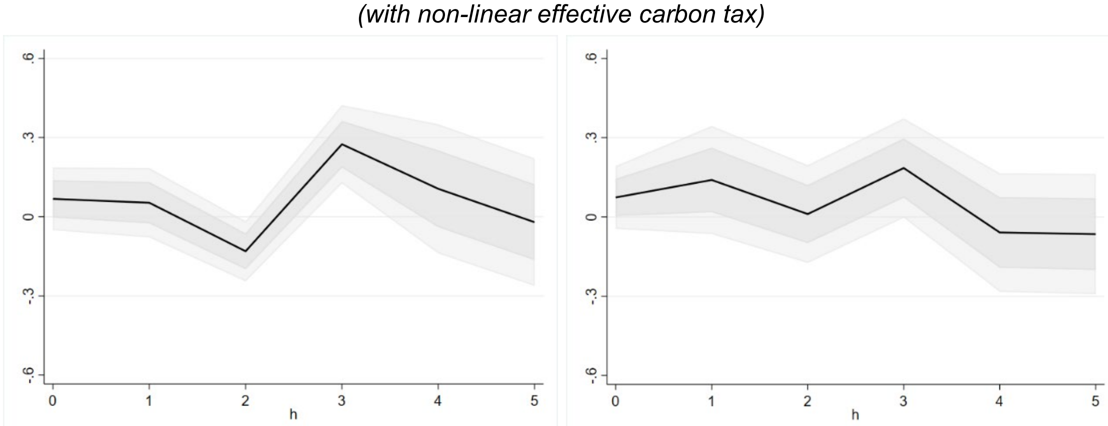
(with year fixed effects instead of euro area controls)



(with additional country level controls)



(with non-linear effective carbon tax)



Notes: All dynamic responses are expressed in percentage points, shaded gray bounds denote 68 and 90 percent confidence bands. Standard errors are clustered by country. Sample EA19, 2000-2019, based on an effective tax rate including national carbon taxes only. Horizontal axis shows years while vertical axis shows change in inflation or price level relative to t = 0. The size of the shock is standardized to 30 euro per ton.

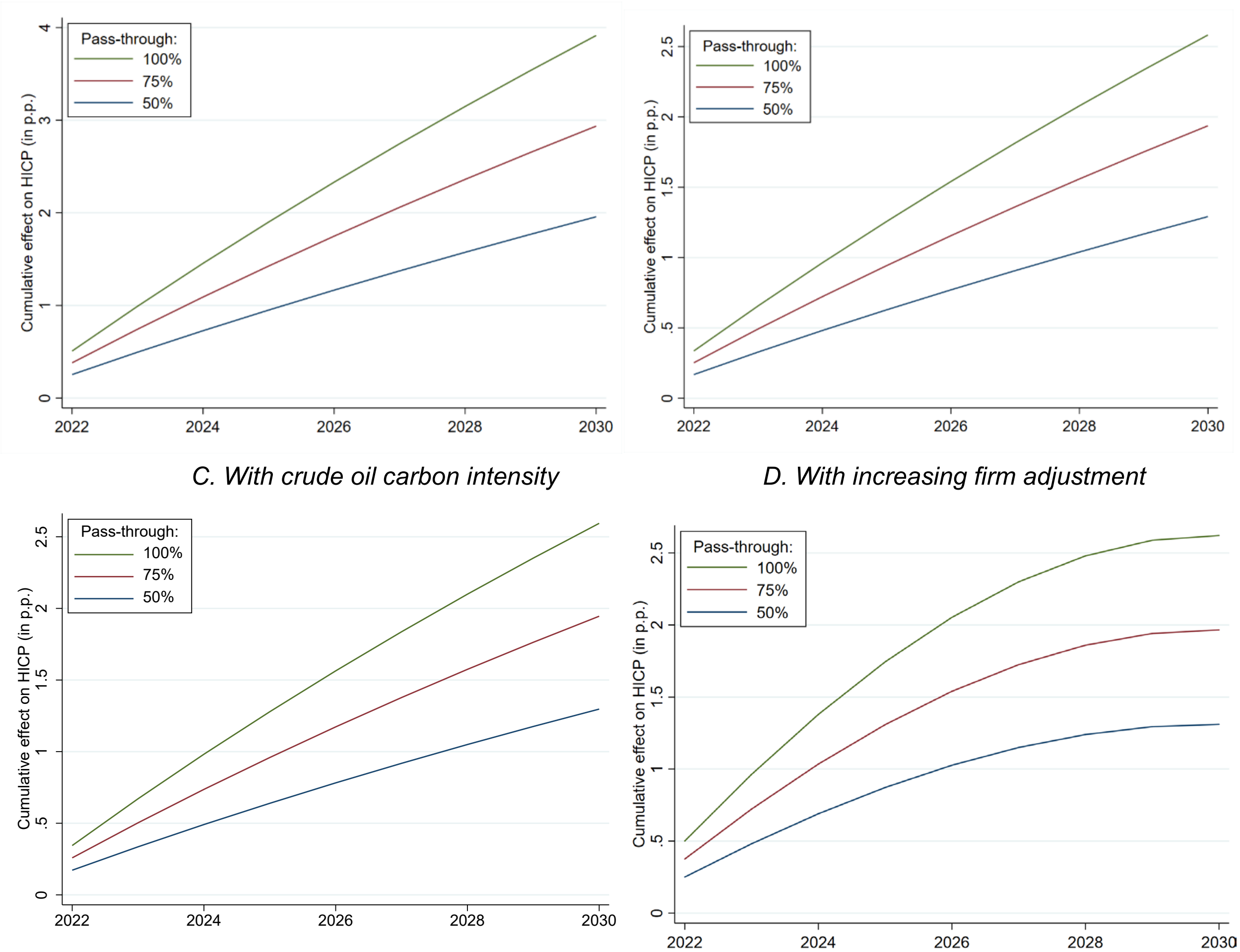
Table A2. Energy Prices in 2022, Fit-for-55 Implied Prices

	Prices						Fit-55 scenario I		Fit-55 scenario II	
	2017-21	2021	2022				112 Eur/tCo2e tax (initial tax of 38 Eur/t)		112 Eur/tCo2e tax (Initial tax varies by type)	
Energy type	mean	mean	Jan.	Max.	% chg.	Oct.	Price	% chg.	Price	% chg.
Gas (Eur/mwh)	23.0	46.2	84.7	239.9	183.3	123.3	104.8	23.8	97.6	15.3
Oil (Eur/barrel)	61.6	71.5	91.2	122.8	34.7	94.8	104.4	14.5	108.9	19.4
Coal (Eur/t)	90.8	132.4	200.5	398.0	98.5	397.4	434.0	116.5	350.6	74.9
Electricity (Eur/mwh)	42.4	76.1	150.3	571.2	280.2	68.8	175.9	17.1	166.7	11.0
Diesel (Eur/gallon)	6.6	7.4	10.2	16.2	58.3	16.2	11.5	12.0	11.5	12.3

Notes: Natural gas prices are retrieved from the Dutch TTF index. Oil prices correspond to Brent crude index, coal is an average of Rotterdam and Newcastle indexes. Electricity prices (for Germany) correspond to Epex spot day-ahead index, diesel prices are taken from the EU Gasoil index. Fit-for-55 scenario based on UNFCCC estimates. Carbon intensities: 0.18t/mwh for natural gas, 0.118t/barrel of oil, 2.08t/t coal, 0.229 t/mwh electricity and 0.010t/gallon of diesel. Sources: US EIA, EU EEA; Haver, Thomson Reuters; IMF staff calculations.

Figure A3. Additional Simulation Results

A. Without firm adjustment *B. Without unmatched sectors*



Notes: Simulation results based on IOTs, carbon intensities and 2021 prices for different rates of pass-through from producer to consumer prices. Firm energy demand elasticities by energy type are estimated from the data. The scenario is a 112 Euro/ton increase by the year 2030. Euro area results are obtained by aggregating over all countries using consumption weights. Panel A shows results without allowing for firms' energy demand adjustments. Panel B shows results excluding the ten unmatched sectors GTAP sectors. Panel C is based on simulations using the carbon intensity of crude oil, instead of refined oil products. Panel D uses a linearly increasing elasticity of substitution for firms' energy demand.

Annex II. GTAP to HICP matching

Table A1: Matching GTAP sectors to HICP categories

GTAP sector	HICP category (COICOP)	GTAP sector	HICP category (COICOP)
Wheat	Bread, cereals (CP0111)	Coal	Solid fuels (CP0454)
Other food	Bread, cereals (CP0111)	Pharmaceuticals	Pharmaceutical products (CP0611)
Rice	Bread, cereals (CP0111)	Motor vehicles, trailers	Motor cars (CP0711)
Processed rice	Bread, cereals (CP0111)	Other transport equipment	Motor cars (CP0711)
Other grains	Bread, cereals (CP0111)	Sale, repair of motor vehicles	Maintenance, repair of vehicles (CP0711)
Cattle meat	Meat (CP0112)	Water transport	Transport services (CP073)
Cattle	Meat (CP0112)	Air transport	Transport services (CP073)
Other animal products	Meat (CP0112)	Land, pipeline transport	Transport services (CP073)
Other meat	Meat (CP0112)	Information, communication	Communications (CP08)
Fishing	Fish, seafood (CP0113)	Computer, Electronics	Information equipment (CP0913)
Raw milk	Milk, cheese, eggs (CP0114)	Rubber, plastic	Other recreational items (CP093)
Milk	Milk, cheese, eggs (CP0114)	Recreation, other services	Recreational, cultural services (CP093)
Oil seeds	Oils, fats (CP0115)	Paper, paper products	Newspapers, books (CP095)
Vegetable oils	Oils, fats (CP0115)	Human health, social work	Education (CP10)
Fibres, crops	Vegetables (CP0117)	Education	Education (CP10)
Vegetables, fruits	Vegetables (CP0117)	Accommodation, Food services	Restaurants, hotels (CP11)
Sugar, molasses	Sugar, jam, honey (CP0118)	Electrical equipment	Electrical appliances (CP1212)
Cane, beet	Sugar, jam, honey (CP0118)	Government services	Social protection (CP124)
Other crops	Food products n.e.c. (CP0119)	Insurance	Financial services n.e.c. (CP126)
Beverages, tobacco	Alcohol, tobacco (CP02)	Other financial intermediation	Financial services n.e.c. (CP126)
Leather, related products	Garments (CP0312)	Other business services	Other services n.e.c. (CP127)
Wearing apparel	Garments (CP0312)	Other manufacturing	Furniture, furnishings (CP051)
Textiles	Garments (CP0312)	Non-ferrous metals	n.a.
Wool	Garments (CP0312)	Forestry	n.a.
Real estate activities	Actual rentals for housing (CP041)	Non-metallic mineral products	n.a.
Construction	Actual rentals for housing (CP041)	Iron, steel	n.a.
Water, waste management	Refuse collection (CP0442)	Mining extraction	n.a.
Electricity, air conditioning	Electricity (CP0451)	Warehousing, support	n.a.
Gas manufacture, distribution	Gas (CP0452)	Lumber	n.a.
Gas	Gas (CP0452)	Machinery, equipment	n.a.
Oil	Liquid fuels (CP0453)	Chemicals	n.a.
Petroleum, coke	Liquid fuels (CP0453)	Fabricated metal products	n.a.

Notes: Output sectors from GTAP, HICP categories from Eurostat.

PUBLICATIONS