

NBER WORKING PAPER SERIES

CLIMATE POLICY AND THE ECONOMY:
EVIDENCE FROM EUROPE'S CARBON PRICING INITIATIVES

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Working Paper 31260
<http://www.nber.org/papers/w31260>

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
May 2023

We thank Gib Metcalf, Paolo Surico and Beatrice Weder di Mauro for helpful comments and suggestions. This is a preliminary version of a paper prepared for the IMF Economic Review Summer Conference "The Future of Macroeconomic Policy". Konradt acknowledges financial support from the Swiss National Science Foundation (grant 203892). The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

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NBER Working Paper No. 31260
May 2023
JEL No. E32,E62,H23,Q54,Q58

ABSTRACT

This paper investigates the impact of carbon pricing on the economy, with a focus on European carbon taxes and the carbon market. Our analysis reveals three key findings. First, while both policies have successfully reduced emissions, the economic costs of the European carbon market are larger than for national carbon taxes. Second, we explore four factors that explain this difference: fiscal policy and revenue recycling, pass-through and sectoral coverage, spillovers and leakage, and monetary policy. Our findings suggest that all four factors play a significant role. Third, we document substantial regional heterogeneity in the impacts of the carbon market, which crucially depend on the share of freely allocated emission permits and the degree of market concentration in the power sector.

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1. Introduction

Climate change is one of the greatest challenges of our time, with far-reaching implications for society, the economy, and the environment. Carbon pricing is increasingly used as a tool to mitigate climate change, with a growing number of jurisdictions adopting such policies either in the form of carbon taxes or cap and trade systems. However, the empirical evidence on the macroeconomic and environmental impacts of carbon pricing is still limited, and even less is known about the differential effects across regions. Developing a deeper understanding of these effects is essential to inform decision-making and guide the transition towards a sustainable future – balancing climate action, economic growth and equity concerns.

In this paper, we aim to fill this gap. We start with a discussion of the empirical strategies to study the economic impact of carbon pricing. A key challenge concerns the endogeneity of carbon prices, as economic factors can influence policymakers' climate policy stance. The European Union Emissions Trading System (EU ETS) provides a clean setting to identify the causal effect of carbon prices, by leveraging institutional features of the market combined with information contained in high-frequency financial data. As discussed in [Känzig \(2022\)](#), the idea is to isolate some plausibly exogenous variation in carbon prices by measuring how carbon futures prices change in a narrow window around regulatory policy news on the supply of emission allowances in the market.

An alternative strategy, as proposed in [Metcalf and Stock \(forthcoming\)](#), is to control for macroeconomic conditions that could affect the rate at which carbon is priced. With the appropriate set of controls, the argument is that any remaining variation in carbon prices is driven by plausibly exogenous factors, such as changes in political preferences for ambitious environmental policies, international climate policy pressure, or historically legislated policy schedules.

Using a yearly panel of European countries spanning the past two decades, we demonstrate that both identification strategies yield similar results when examining policy changes in the European carbon market. An increase in carbon prices leads to a significant rise in energy prices and a persistent fall in emissions. Higher carbon prices also have economic consequences. Headline consumer prices increase significantly, GDP and industrial production fall and unemployment rises. These findings are in line with the evidence in [Känzig \(2022\)](#), based on monthly and quarterly time-series data at the EU level.

To provide a complete assessment of climate policies in Europe, we then turn to the impacts of carbon taxes. While the European carbon market is the cornerstone of the EU's policy to combat climate change, many European countries have also enacted national carbon taxes. These taxes cover sectors and industries that are not part of the emissions trading scheme, such as the transportation and building sectors. The EU ETS on the other hand covers the most heavy emitting sectors, such as the power sector and energy-intensive industrial sectors, including oil refineries, steel or the chemical industry, and accounts for over 40 percent of the blocs emissions.

How do the impacts of the EU ETS compare to European carbon taxes? To uniquely attribute any differences in results to policy design, we estimate the effects of the two policies jointly, based on the same identification strategy and empirical specification. Interestingly, while both policies lead to significant emission reductions, the economic effects of European carbon taxes are quite different from the European carbon market. Specifically, our results imply smaller economic impacts of carbon taxes, consistent with the findings in [Metcalf and Stock \(forthcoming\)](#) and [Konradt and Weder di Mauro \(2022\)](#). We find some evidence for a short-lived economic downturn, particularly in the subset of Western and Northern European countries, however, the effects are smaller and less precisely estimated than for the European carbon market.

What can account for the differential impacts of the two policies? We investigate four hypotheses: fiscal policy and revenue recycling, pass-through and sectoral coverage, spillovers and leakage, and monetary policy. First, our results suggest that the recycling of tax revenues plays a crucial role in the transmission of carbon pricing policies. In the European carbon market, there is no direct redistribution scheme to compensate affected households. The majority of the revenues in the market are used for climate-related purposes. In contrast, European carbon taxes were often implemented as part of a broader tax reform, which included income tax reductions or subsidies to cushion the levy on households.

In fact, focusing on the more homogeneous subset of Western and Northern European countries we find significant heterogeneity in the effects of carbon taxes depending on whether carbon tax revenues are recycled or not. Countries that do not recycle revenues experience a substantial economic downturn while countries that recycle revenues only display a muted impact on economic activity. Interestingly, the emission response turns out to be comparable, suggesting that recycling tax revenues does not necessarily undermine emission reductions.

A second explanation relates to differences in sectoral coverage and pass-through across the two policies. European carbon taxes generally exclude the power sector, which is covered by the European carbon market. However, pass-through in the power sector tends to be particularly high because of market segmentation and dependence on energy, while pass-through in other economic sectors is likely lower (Fabra and Reguant, 2014). Indeed, we find that higher ETS prices lead to a significant increase in consumer and producer prices, whereas the price impacts for European carbon taxes are more muted. The difference is particularly stark for oil prices. We document a sizable and persistent increase in oil prices following price changes in the European carbon market, which also covers European oil producers and refineries. In contrast, oil prices do not respond significantly and even tend to fall in response to European carbon tax changes. These results emphasize the role of sectoral coverage coupled with differences in pass-through.

Third, when comparing national carbon taxes with EU-wide carbon prices, it is important to account for the broader effects at the European level. For instance, while the strong economic integration among European countries could help cushion the impacts of national tax policies, the EU-wide carbon market affects all member states more uniformly. Supporting this notion, our findings suggest that carbon taxes, which cover only 10 percent of the bloc's total emissions, lead to comparatively smaller EU-wide emission reductions. Further, national carbon taxes are potentially subject to carbon leakage to other European countries without a carbon tax, which could undermine the overall effectiveness of the policy. Although carbon leakage from the EU ETS to non-European countries is a possibility, the barriers are likely larger (see Dechezleprêtre et al., 2022).

Fourth, we examine the role of monetary policy in accounting for the differential effects of the two policies. While it is plausible that monetary policy leans against inflationary pressures emerging from EU ETS prices, we would not expect a similar response to national carbon policies, especially given that the effects on prices appear muted to start with. Indeed, we find a significant increase in interest rates only after an increase in ETS prices, but not for national carbon taxes.

Finally, we investigate potential differences in the regional impacts of the carbon market. Although all European countries are subject to the emissions trading scheme, not all countries are equally exposed. In fact, our results point to significant heterogeneity, depending on the share of free allowances countries receive and the concentration in national electricity markets. We find that countries which received a larger share of free allowances display weaker economic impacts, as pass-through in these countries tends to be lower. On the other hand, countries with highly concentrated electricity markets expe-

rience stronger economic effects. The energy price increase in these countries is larger, causing a stronger fall in output and employment. Furthermore, our findings imply somewhat more severe economic effects in countries with a browner energy mix and a more labor-intensive economy reliant on services. The former can again be explained by a stronger increase in energy prices, as carbon-intensive energy producers face relatively higher costs to pass on. The latter is likely related to the fact that labor-intensive sectors tend to be more cyclical and thus the second-round effects through the labor market are more pronounced.

These country-level determinants have important implications for the distributional effects across European regions. We find the strongest economic impacts are not concentrated in the poorest countries but in the second quartile of the per capita income distribution. The fact that countries in the bottom quartile are disproportionately compensated with free allowances can account for these findings. Countries in the second quartile on the other hand receive relatively few free allowances and tend to feature more concentrated electricity markets.

Related literature. This paper contributes to a growing literature studying the effects of climate policy and the effects of carbon pricing specifically. Although there is a growing body of work showing the effectiveness of such policies in reducing emissions ([Martin, De Preux, and Wagner, 2014](#); [Andersson, 2019](#), among others), less is known about their economic effects. A number of studies have analyzed the macroeconomic effects of the British Columbia carbon tax, finding no significant impacts on GDP ([Metcalf, 2019](#); [Bernard and Kichian, 2021](#)). [Metcalf and Stock \(2020, forthcoming\)](#) study the macroeconomic impacts of carbon taxes in European countries. They find no robust evidence of a negative effect of carbon taxes on employment or GDP growth. In a similar vein, [Konradt and Weder di Mauro \(2022\)](#) document that carbon taxes in Europe and Canada do not appear to be inflationary.

In a recent study on carbon taxes in Scandinavian countries, [Kapfhammer \(2023\)](#) confirms the emission reductions but documents more pronounced adverse effects on economic activity. Similarly, [Känzig \(2022\)](#) finds that higher carbon prices in the EU ETS lead to a persistent increase in consumer prices and a temporary, but substantial fall in economic activity. This evidence is also consistent with theoretical studies based on computable general equilibrium models that tend to find contractionary output effects, albeit at somewhat smaller magnitudes (see e.g. [McKibbin et al., 2017](#); [Goulder and Hafstead, 2018](#)). We contribute to this literature by providing a comprehensive assessment of carbon

pricing initiatives in Europe, with the aim to reconcile the previous empirical evidence. Our results highlight that coverage, revenue use and monetary policy are critical factors in determining the economic consequences of carbon pricing policies.

2. Identifying the Effects of Carbon Pricing

Identifying the dynamic causal effects of carbon prices on the economy and the environment is challenging for at least two reasons. The first concerns the possibility of simultaneity: poor economic outcomes could induce the government to reduce the carbon price or to postpone a planned increase or reform. The second relates to potential confounding factors: other economic or financial shocks could affect both carbon prices and the economy.

In this section, we discuss two strategies to identify the economic and environmental impacts of carbon pricing policies. The first is a high-frequency identification approach that can be employed in the context of carbon markets. The second is to control for potential endogeneity in carbon prices using a selection of global and country-level controls and fixed effects. The latter approach is more general as it can be employed to study carbon markets and carbon taxes, however, identification may be somewhat less credible because controlling for all relevant confounding variables can be challenging.

2.1. High-frequency identification

The first approach builds on the literature on high-frequency identification, which was developed in the monetary policy setting (Kuttner, 2001; Gürkaynak, Sack, and Swanson, 2005; Gertler and Karadi, 2015; Nakamura and Steinsson, 2018, among others) and more recently employed in the global oil market context (Känzig, 2021). Policy surprises are identified using high-frequency asset price movements around policy events, such as FOMC or OPEC meetings. The idea is to isolate the impact of policy news by measuring the change in asset prices in a tight window around the events. Känzig (2022) shows that this approach can also be applied to evaluate the impact of emissions trading schemes.

Carbon markets provide a suitable setting for high-frequency identification. First, they were only established recently and the regulations in place are frequently updated. These update events can have significant effects on the price of emission allowances. Second, there exist liquid futures markets for trading emission allowances and price data is available at a sufficiently high frequency. Exploiting this institutional framework, it is possible

to construct a series of carbon policy surprises by isolating how carbon prices change around regulatory events in the carbon market. By measuring the price change within a narrow window around the event, reverse causality of the state of the economy can be plausibly ruled out because it is incorporated in the price prior to the news and unlikely to change within the event window. [Känzig \(2022\)](#) develops this strategy in the context of the European carbon market, however, the approach is very general and could also be implemented to evaluate the performance of other cap and trade systems.

As discussed in [Stock and Watson \(2018\)](#), high-frequency surprises are better thought of as instruments than actual shock measures. Therefore, [Känzig \(2022\)](#) employs the high-frequency carbon policy surprises as an external instrument in a structural VAR model of the European economy. Under the assumption of (partial) invertibility, it is possible to obtain an estimate of the structural carbon policy shock. A key advantage of the VAR approach relates to aggregation. Using high-frequency surprises in regression models with low-frequency data, such as quarterly or annual data, can be challenging because of a power problem. Intuitively, high-frequency surprises tend to be small and sparse. At the same time, macroeconomic variables are hit by a myriad of other shocks over multiple quarters or years, rendering the signal-to-noise ratio too low ([Nakamura and Steinsson, 2018](#)). We circumvent this problem by obtaining a shock estimate using data at a higher frequency (in our case monthly), where the signal-to-noise ratio tends to be higher, and aggregating the extracted shock to the relevant frequency after (in our case yearly). In fact, using the shocks at the monthly, quarterly or even annual frequency produces consistent results while the results based on aggregated high-frequency surprises become less interpretable the lower the frequency.

Provided that we have a valid shock measure at hand, we can map out the dynamic causal effects on the variables of interest using local projections à la [Jordà \(2005\)](#). To fix ideas, we use the carbon policy shocks as identified in [Känzig \(2022\)](#), aggregated to the annual frequency by summing over the relevant monthly shocks in a given year t , $cps_t = \sum_{m=1}^{12} cps_{m,t}$. The resulting shock sequence is depicted in [Figure 1](#).

We can then compute the impulse responses using simple (panel) local projections:

$$y_{i,t+h} - y_{i,t-1} = \alpha_i^h + \beta^h cps_t + \sum_{j=1}^p \theta_j^h \Delta y_{i,t-j} + \Delta \mathbf{x}'_{i,t} \boldsymbol{\theta}_x^h + \varepsilon_{i,t+h}, \quad (1)$$

where $y_{i,t}$ is the outcome variable of interest in country i at time $t + h$ and β^h are the dynamic causal effects at horizon h . We control for p lags of the outcome variable, to

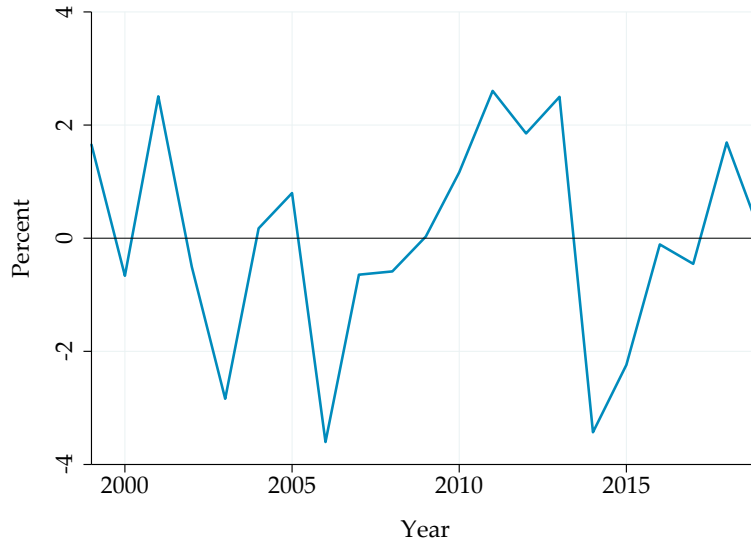


Figure 1: Carbon Policy Shocks in the European Carbon Market

capture its persistence. $\Delta x'_{i,t}$ is a vector of additional controls. Provided that the carbon policy shock is exogenous, it is not necessary to include any controls for identification. Nonetheless, we add a set of country-specific controls because it helps to improve precision. Note, however, that we do not include any European or global controls, as these are already controlled for in the monthly VAR model underlying the shock estimate (see [Känzig, 2022](#), for details). We also do not include lags of the shock variable. There is little evidence for autocorrelation in the shock series – the corresponding p-value of the Ljung-Box test is about 0.88 – and including lags of the shock produces similar results. Finally, we control for time-invariant country-specific characteristics using country fixed effects. The standard errors are computed using the lag-augmentation approach ([Montiel Olea and Plagborg-Møller, 2020](#)).

2.2. Control-based identification

An alternative strategy to identify the effects of carbon prices is the so-called “control-based” approach. As discussed in [Metcalf and Stock \(2020\)](#), it is useful to think of carbon prices as having two components: one component that is driven by past economic and financial factors, the other being orthogonal to the economy. The latter component could include, for instance, changes in political preferences for ambitious environmental policies, international climate policy pressure, or historically legislated schedules. The idea is then to control for past economic and financial developments to isolate some variation in

the carbon price that is plausibly exogenous.

Under this assumption, it is possible estimate the dynamic causal effects to a change in the carbon price using local projections, including the relevant economic controls. For comparability, we do so jointly for carbon prices in the EU ETS, $cp_{i,t}$, and national carbon taxes, $ctax_{i,t}$. The relevant variation in these policy instruments is shown in Figure 2.

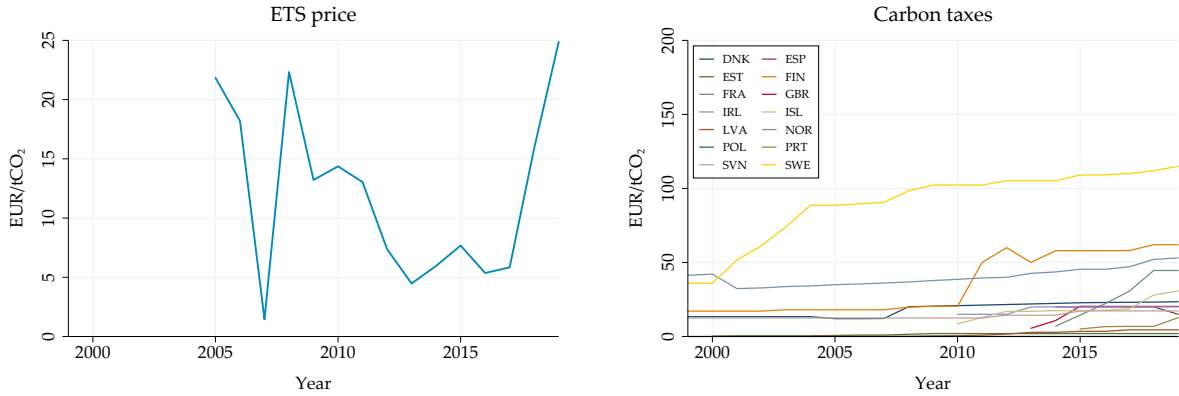


Figure 2: Carbon Prices in Europe

Notes: The left panel shows the EU ETS price since its introduction in 2005. The right panel shows European carbon taxes. Both are expressed in euro per metric ton of CO₂ or equivalent gas.

We can see that ETS prices experienced substantial variation, especially in the early phase. Carbon tax rates on the other hand are more stable. Furthermore, while the tax rates are on average quite comparable to ETS prices, there are some Scandinavian countries that levy substantially higher taxes. Following [Metcalf and Stock \(forthcoming\)](#), we include carbon prices and taxes in real coverage-weighted terms, deflating them using the relevant GDP deflator and weighting by the country-specific ETS and carbon tax emission coverage. Intuitively, this specification assumes that the impacts of carbon policies should be proportional to their overall tax burden. Specifically, we estimate:

$$y_{i,t+h} - y_{i,t-1} = \alpha_i^h + \beta_{ets}^h cp_{i,t} + \beta_{tax}^h ctax_{i,t} + \sum_{j=1}^p \theta_j^h \Delta y_{i,t-p} + \Delta \mathbf{x}_{i,t}' \boldsymbol{\theta}_x^h + \Delta \mathbf{z}_t' \boldsymbol{\theta}_z^h + \varepsilon_{i,t+h}, \quad (2a)$$

where $y_{i,t}$ is again the outcome variable of interest in country i and year t , and β_{ets}^h and β_{tax}^h are the dynamic causal effects at horizon h for an innovation in the ETS carbon price or the national carbon tax, respectively. For this identification strategy to work, the selection of controls is crucial. Therefore, in addition to the lags of the outcome variable, we include a comprehensive set of of country-specific controls $\Delta \mathbf{x}_{i,t}$ and controls at the

global or European level $\Delta \mathbf{z}_t$. Furthermore, we control for time-invariant country-specific characteristics using country fixed effects.

When we are interested in supra-national carbon pricing initiatives such as the European carbon market, it is not feasible to control for time fixed effects. As the relevant policy variation in this case is at the supra-national level, time fixed effects would absorb (most) of the relevant variation. By contrast, if we are interested in the effects of national carbon taxes, the policy variation is at the country level. In this case, controlling for time fixed effects is feasible and arguably even desirable to flexibly control for any latent global and supra-national developments. Therefore, we will also consider a variant of (2a), including time fixed effects:

$$y_{i,t+h} - y_{i,t-1} = \alpha_i^h + \gamma_t^h + \beta_{tax}^h \text{ctax}_{i,t} + \sum_{j=1}^p \theta_j^h \Delta y_{i,t-p} + \Delta \mathbf{x}'_{i,t} \boldsymbol{\theta}_x^h + \varepsilon_{i,t+h}. \quad (2b)$$

In this case, we subsume $\text{cp}_{i,t}$ in the country-specific controls $\mathbf{x}_{i,t}$ because our focus is on estimating the effects of national carbon taxes. This specification practically mirrors the one used in [Metcalf and Stock \(forthcoming\)](#) and [Konradt and Weder di Mauro \(2022\)](#).

The main advantage of the control-based approach is that it is more broadly applicable. In particular, we can study the effects of carbon taxes and cap and trade systems in the same empirical specification. Jointly estimating these effects in a unified model allows for better comparison of the effects of EU ETS prices and European carbon taxes. However, a key challenge is the selection of adequate controls. This is particularly relevant for ETS prices, which are market prices and thus continuously driven by supply and demand forces.

2.3. Data and empirical specification

We limit our analysis to countries that are part of the EU ETS. In particular, we use data on all countries that were in the system starting from phase 1 or 2, including the UK which was part of the European carbon market until 2020. We exclude Malta and Liechtenstein because of data limitations, leaving us with 28 countries. Of these countries, 14 have enacted national carbon taxes in addition to participating in the emissions trading scheme. Table B.2 in the Appendix presents some descriptive statistics on the countries in our sample.

We focus on the period from 1999, when the Euro was introduced, to 2019. Thus, we end the sample prior to the outbreak of the Covid-19 pandemic. While some European

countries had introduced carbon taxes as early as in the 1990s, these are relatively few. Focusing on this more recent sample ensures a balanced split of countries with and without carbon taxes. Furthermore, for many countries the relevant control variables are only available in the recent period. While the EU emissions trading scheme was only introduced in 2005, the planning for the system started already in the late 1990s when the EU ratified the Kyoto protocol. Therefore, we use 1999 as the start of the sample in case of the EU ETS as well. The results are robust to starting the sample in 2005 after the EU ETS went online.

As country-specific controls in (1)-(2b), we include HICP energy, HICP headline, real GDP, the unemployment rate and the policy rate. For the control-based model with no time fixed effects (2a), we also include EU-level controls, in particular EU real GDP to track EU-wide demand and a stock price index to proxy financial conditions. Furthermore, we use the Brent crude oil price to account for global developments in commodity markets. Controlling for financial variables is important as they are forward-looking and contain relevant information about the future economic development. As outcome variables, we focus on energy and headline consumer prices, GHG emissions, real GDP, industrial production, and the unemployment rate.

We include all variables in differences, except the policy rate, the unemployment rate and real oil and stock prices, which enter in (log-) levels. However, the results are robust to including all variables in levels. We include 2 annual lags of all control and for each outcome variable. For (2a)-(2b), we also include 2 lags of carbon prices and taxes.

Our study builds on data from a number of different sources. The EU ETS prices are retrieved from Datastream, which we complement with information on verified emissions from the EU transaction log. For carbon taxes, we use data from the World Bank's Carbon Pricing Dashboard, which provides information on carbon tax rates and emission shares. The macroeconomic and financial data is sourced from the OECD, Eurostat and FRED. We provide a detailed overview of the data sources in Table B.1 of the Appendix.

3. Results

3.1. The impacts of the European carbon market

We now turn to the discussion of the empirical results. Figure 3 shows the impulse responses to a carbon policy shock, identified using high-frequency techniques. We normalize the shock to increase energy prices by one percent on impact. We can see that the

shock leads to a significant increase in energy prices and a persistent fall in emissions. This has consequences for the economy as well. Headline consumer prices increase and economic activity falls, as indicated by the decline in real GDP and industrial production, and the uptick in unemployment. The responses are very similar to the ones reported in [Känzig \(2022\)](#) based on EU-wide aggregates. We confirm these results here in a panel of European countries, accounting for country-specific factors using national controls and fixed effects. It turns out, however, that the results are robust to the selection of control variables. In fact, estimating responses using pooled OLS with no controls produces comparable results.

In a next step, we investigate whether using ETS prices in a control-based approach produces results that are consistent with the high-frequency strategy. Figure 4 shows the impulse responses to an increase in the coverage-weighted real ETS price by one euro. We can see that the control-based approach yields estimates that are qualitatively very similar to the high-frequency approach. The signs of the responses as well as the relative magnitudes are all consistent. However, the increase in energy prices turns out to be much more persistent, which results in more persistent effects on economic activity. One potential explanation relates to the different variation used for identification. The high-frequency approach leverages unexpected movements in carbon futures prices in response to climate policy news. On the other hand, the control-based approach relies on variation in carbon prices that cannot be explained by past macroeconomic and financial variables. As such, the latter approach may also capture slower-moving trends in carbon prices, which may help explain the difference in persistence.

Overall, these results support the notion that the control-based approach is successful at identifying the dynamic causal effects of changes in European carbon prices. It is important to note, however, that the control-based approach can be somewhat sensitive to the selection of controls and the specification of the model. This problem is more acute in the context of cap-and-trade prices than for carbon taxes. As we have seen, carbon taxes display less variation over time and there tends to be a lot of sluggishness in the political process to adjust the taxes. This might explain the low sensitivity to controls for carbon taxes. On the other hand, ETS prices are market prices determined by myriad of supply- and demand-side forces. This highlights the virtues of the high-frequency identification approach in this setting, which isolates plausibly exogenous variation in carbon prices and is in turn less sensitive to the selection of controls.

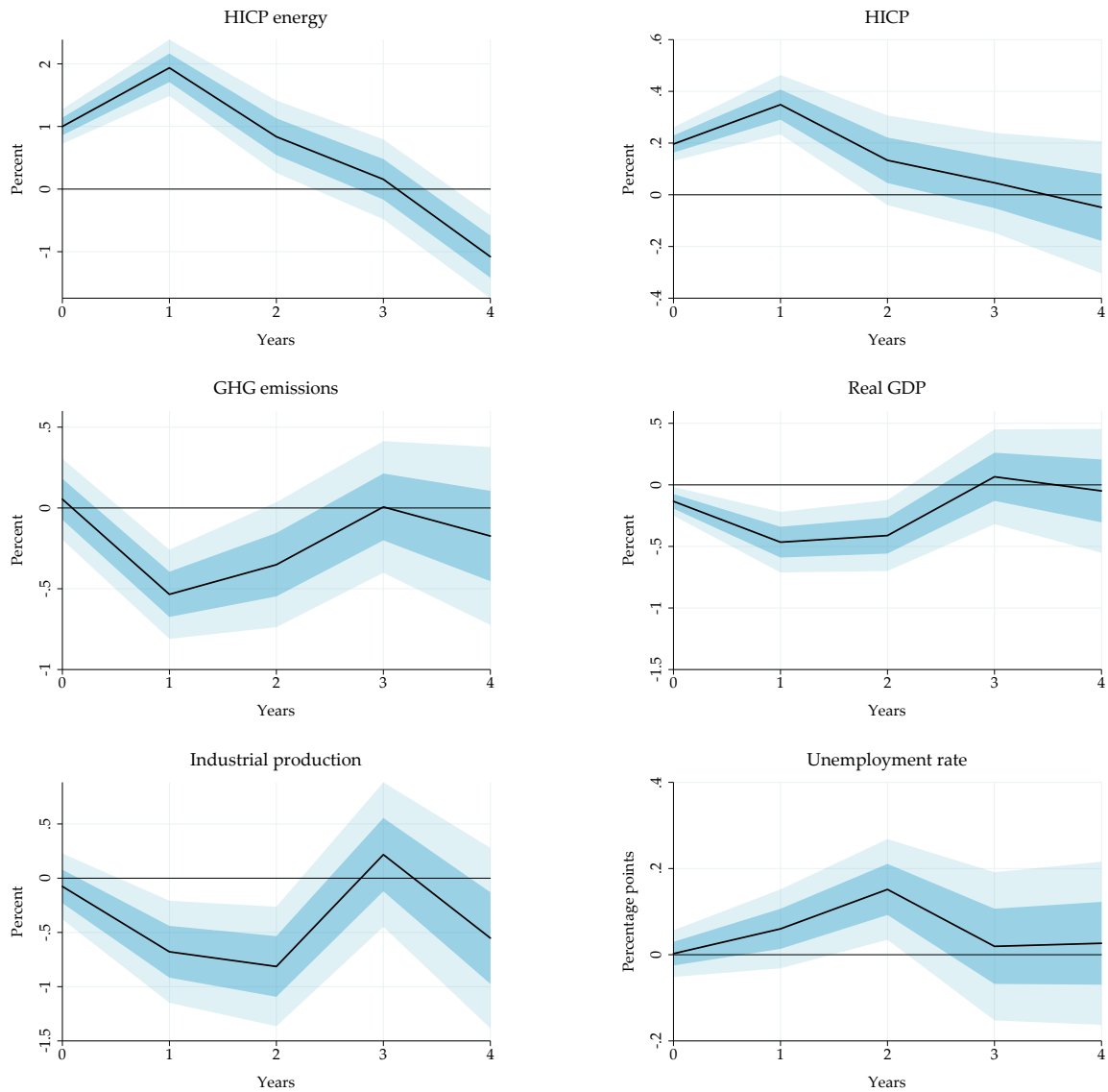


Figure 3: The Effects of Carbon Policy Shocks in the EU ETS

Notes: Impulse responses to a carbon policy shock identified using the high-frequency approach, normalized to increase energy prices by one percent on impact. The solid line is the point estimate and the dark and light shaded areas are 68 and 95 percent confidence bands, respectively.

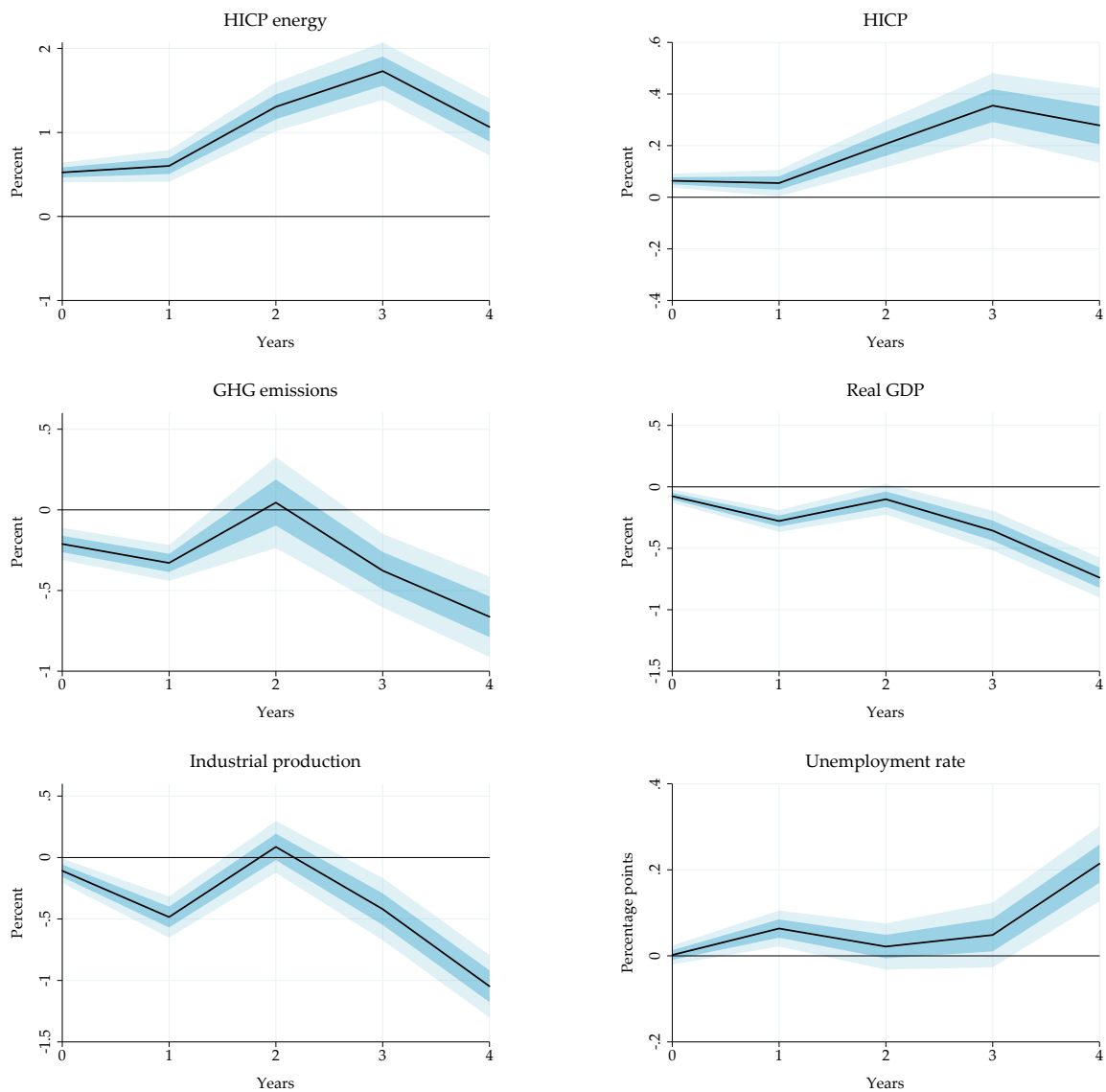


Figure 4: The Effects of Carbon Price Innovations in the EU ETS

Notes: Impulse responses to an innovation in the ETS carbon price identified using the control-based approach, normalized to increase real coverage-weighted carbon prices by one euro. The solid line is the point estimate and the dark and light shaded areas are 68 and 95 percent confidence bands, respectively.

3.2. The effects of the European carbon taxes

How do the effects of European carbon taxes compare to the impact of changes in EU ETS prices? Figure 5 presents the responses to an increase in the effective carbon tax by one euro from the specification with time fixed effects. While carbon taxes also lead to a persistent fall in GHG emissions, we can immediately see that the economic effects are quite different from price changes in the carbon market. Energy prices increase, but the response is not that pronounced and rather imprecisely estimated.

Turning to the economy, we do not find a significant response of headline consumer prices, output or unemployment. Headline consumer prices tend to increase over time but the response is not significant. GDP does not change much over the first couple of years but then even tends to increase. Industrial production falls slightly in the short term but subsequently reverses. The unemployment rate does not change significantly. Apart from emissions and the short-term increase in energy prices, all responses are rather imprecisely estimated and not statistically significant. Overall, these results confirm the findings in [Metcalf and Stock \(forthcoming\)](#) and [Konradt and Weder di Mauro \(2022\)](#) who estimate a very similar model, albeit on a longer sample and with a slightly different set of controls.

For comparison, we also show the responses of the model with global and EU-wide controls instead of year fixed effects. We can see that the responses of the two models are very similar. This suggests that our selection of controls does a relatively good job in capturing common macroeconomic and financial developments across European countries.

The European Union is a diverse group of countries with varying levels of economic development. Carbon taxes have been mainly implemented in Western and Northern Europe, which are typically wealthier regions that have also displayed higher economic growth in recent years. In contrast, Southern and Eastern European countries tend to be relatively poorer and exhibit higher unemployment rates. Among these countries, only Poland, Portugal, Slovenia and Spain have adopted a carbon tax. However, Portugal and Spain have done so only recently, in the mid-2010s, and Poland has a very low tax rate that covers a negligible share of emissions. It is therefore interesting to explore to what extent the impact of carbon taxes may vary across different regions. To this end, we estimate the effects of carbon taxes on the more homogeneous sample of Western and Northern European countries that is also more balanced in terms of carbon tax adopters

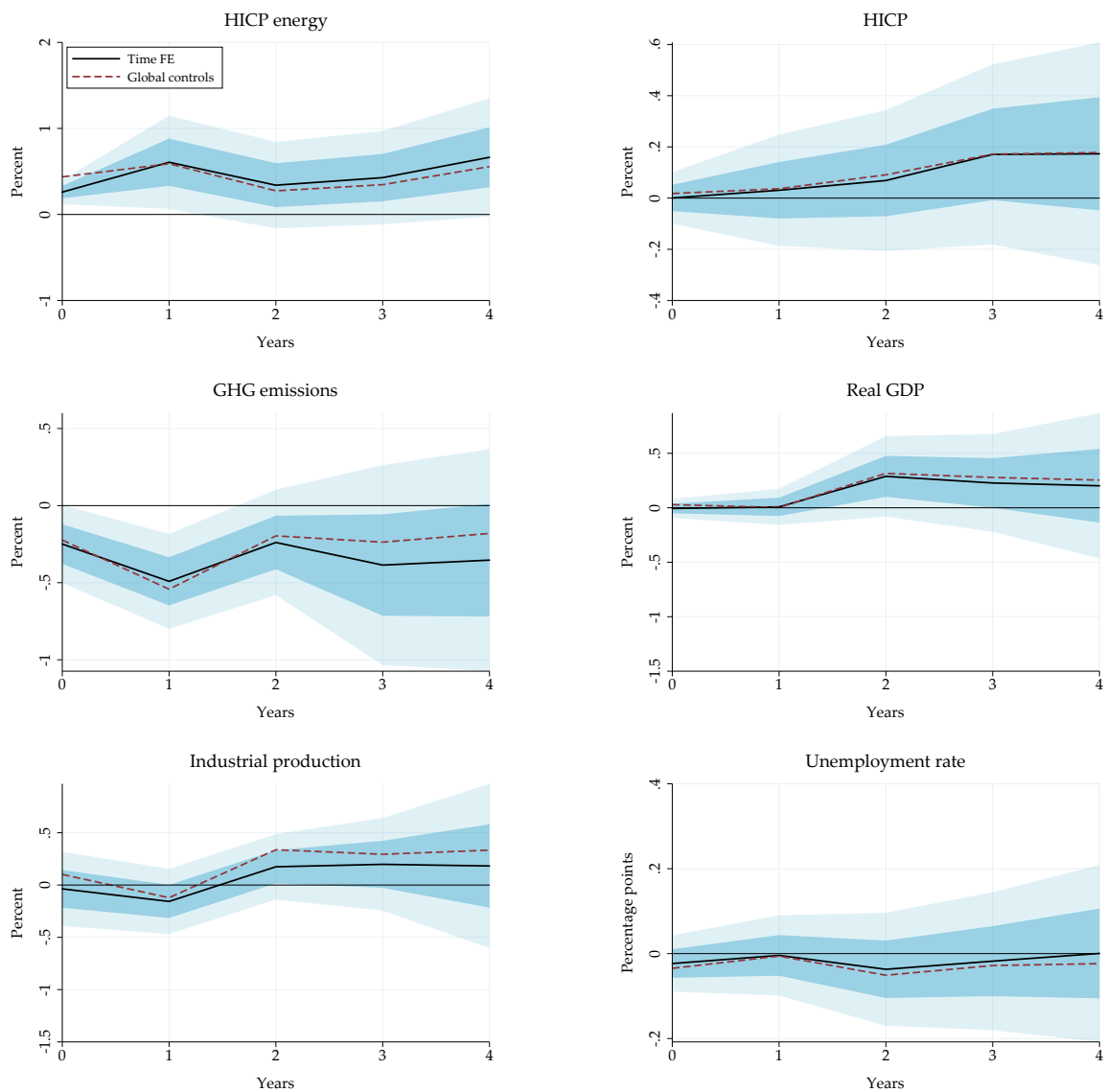


Figure 5: The Effects of European Carbon Taxes

Notes: Impulse responses to an innovation in European carbon taxes identified using the control-based approach, normalized to increase real coverage-weighted carbon taxes by one euro. The solid line is the point estimate and the dark and light shaded areas are 68 and 95 percent confidence bands, respectively.

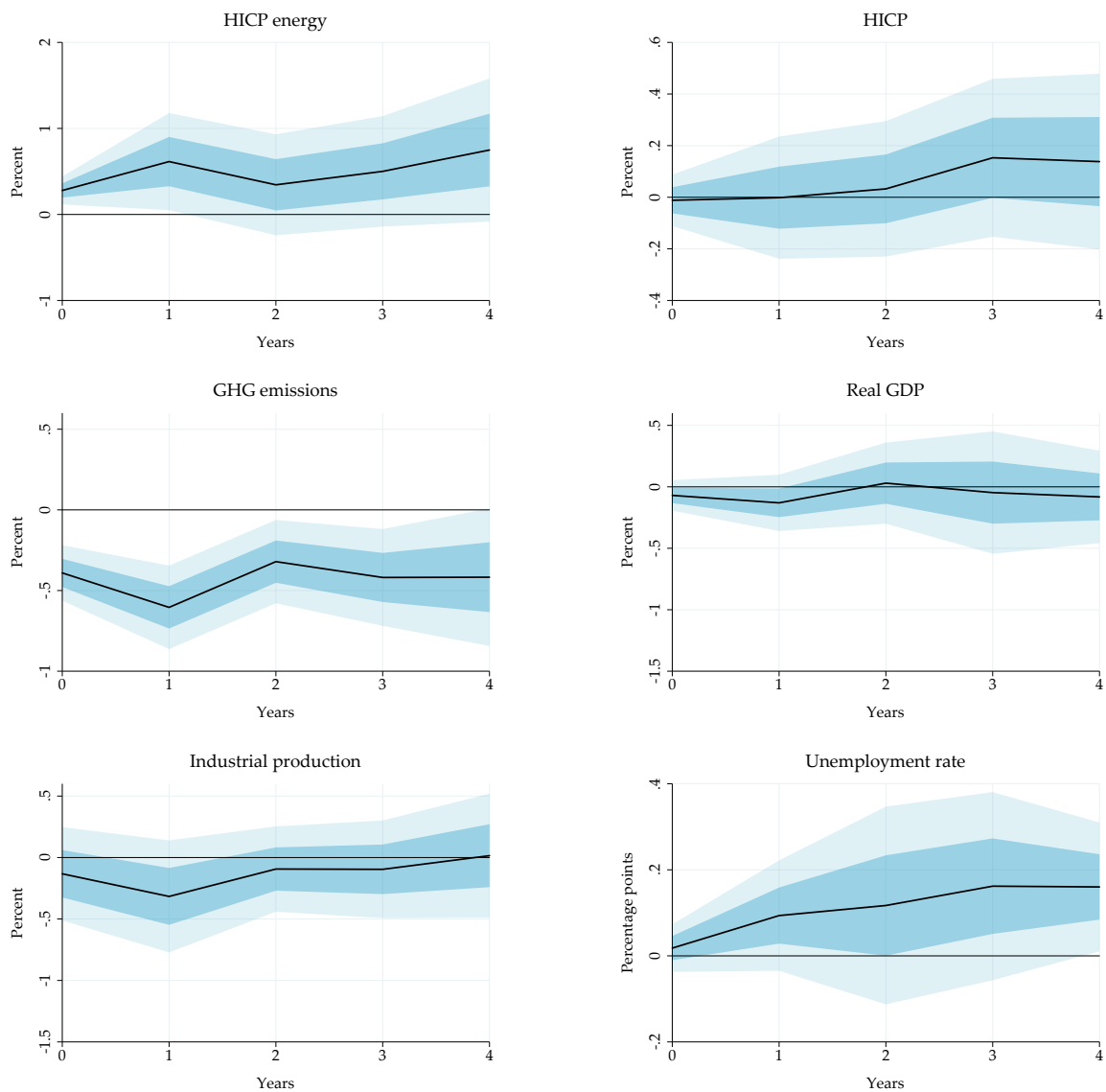


Figure 6: The Effects of Carbon Taxes in Western and Northern Europe

Notes: Impulse responses to a carbon tax innovation in Western and Northern European countries identified using the control-based approach, normalized to increase real coverage-weighted carbon taxes by one euro. The solid line is the point estimate and the dark and light shaded areas are 68 and 95 percent confidence bands, respectively.

and non-adopters.¹

Figure 6 shows the responses to an increase in carbon taxes in the sample of Western and Northern European countries. We find that the fall in emissions is somewhat stronger in these countries compared to the overall sample. However, we also find more pronounced economic effects. GDP and industrial production fall, at least in the short term and the unemployment rate increases persistently. These effects are at least qualitatively similar to the impacts of EU ETS prices, even though they are not very precisely estimated. Quantitatively, the economic effects remain smaller, in particular for output and industrial production.

In the Appendix, we also display the results for the sample of Southern and Eastern European countries (see Figure A.2). For these countries, we find that both emissions and economic activity tend to increase after an increase in the carbon tax. However, the responses turn out to be very imprecisely estimated. These results should however be interpreted with a grain of salt given that with the exception of Slovenia, the coverage-weighted carbon tax rates in Southern and Eastern European countries tend to be around zero on average and display little variation over time, which complicates identification.

3.3. What explains the differential impact?

What drives the differential impact of the cap-and-trade and carbon tax policies? In this section we explore a number of explanations that may account for the observed differences. In particular, we focus on fiscal policy and revenue recycling, pass-through and sectoral coverage, spillovers and leakage, and monetary policy.

Fiscal policy and revenue recycling. A crucial factor for the transmission of carbon pricing policies is how carbon revenues are used. If revenues are used for subsidies or cutting other taxes, this can lower the burden for households and firms and thus mitigate potential adverse macroeconomic consequences (Goulder et al., 2019; Bernard and Kichian, 2021). Many European carbon taxes were implemented with the goal of recycling carbon tax revenues. The Scandinavian countries in particular enacted carbon taxes as part of a green tax reform, which included cuts to marginal income taxes. Similarly, some of the carbon tax increases coincided with reductions in income tax rates (see Metcalf and

¹We classify the countries based on the United Nations geoscheme. According to this classification the Northern and Western European countries in our sample are Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Iceland, Ireland, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Sweden, and the UK.

Stock, forthcoming, for more information). By contrast, in the European carbon market there is no direct redistribution scheme in place that could offset the higher costs faced by households. Instead, the vast majority of revenues in the system are earmarked and used for climate and energy related purposes. Therefore, we would expect stronger adverse economic effects compared to carbon taxes.

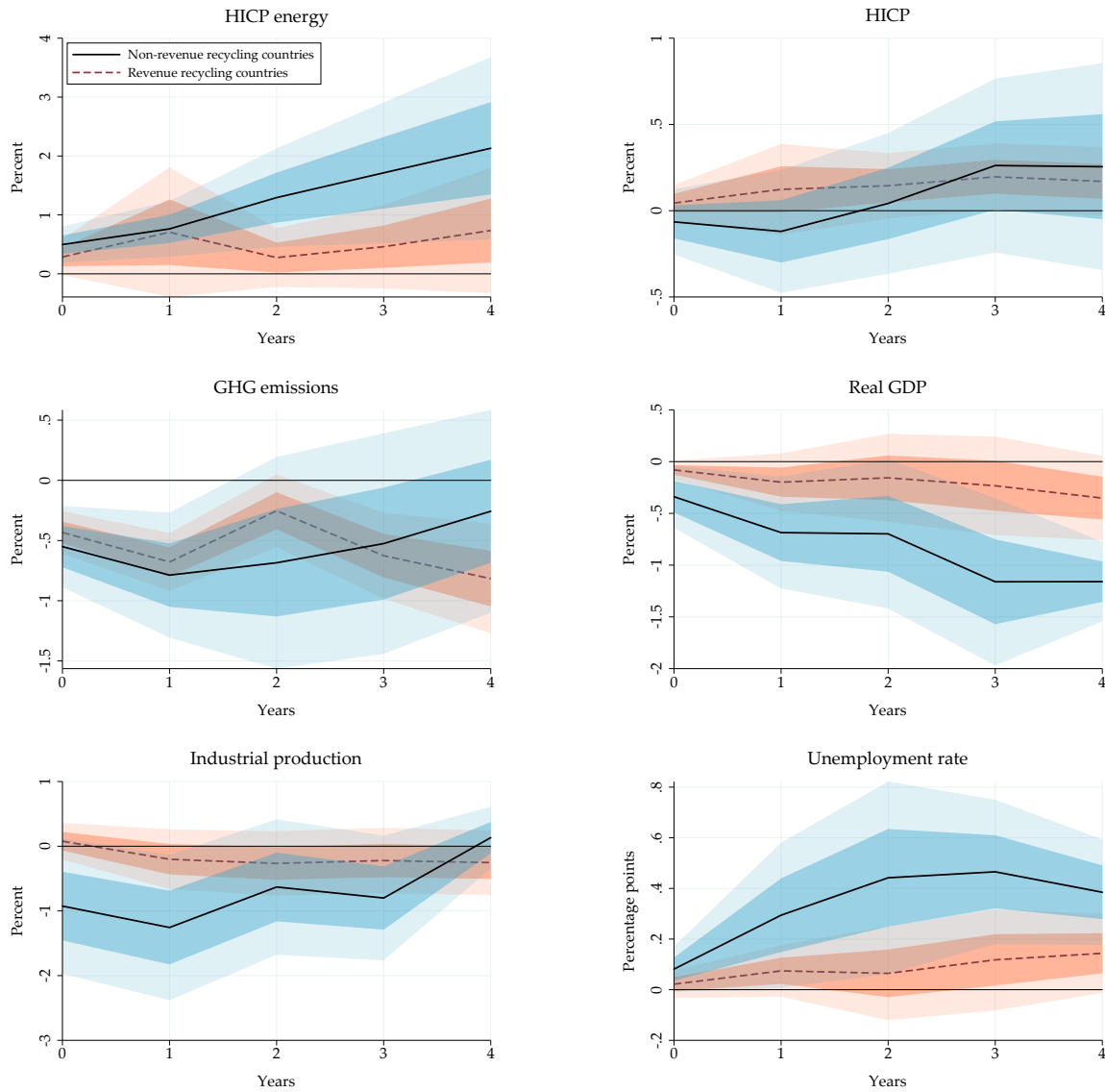


Figure 7: The Role of Revenue Recycling

Notes: Impulse responses to a carbon tax innovation in revenue (dashed line) and non-revenue recycling (solid line) countries in the Western and Northern European sample. The dark and light shaded areas are 68 and 95 percent confidence bands, respectively.

To shed more light on this, we compare the effects of carbon taxes in countries that stated an intention to recycle carbon tax revenues to countries that did not. We continue to focus on the more homogeneous sample of Western and Northern European countries. In that sample, the group of revenue recycling countries includes Denmark, Finland, Sweden, and Norway.

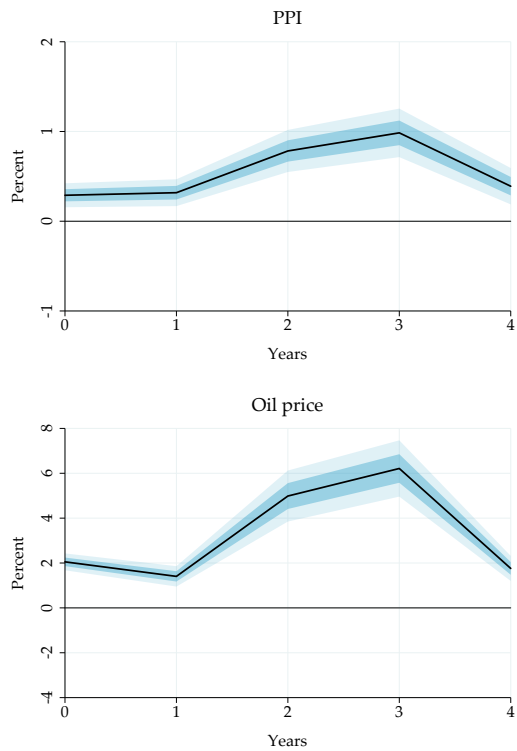
In Figure 7, we can see that carbon taxes had larger economic effects in countries that did not recycle tax revenues. GDP and industrial production fall strongly and significantly and the unemployment rate increases persistently. In fact, the magnitudes are comparable to an increase in ETS prices of similar proportion. By contrast, countries that recycled revenues display much weaker and insignificant economic effects. This evidence is suggestive that recycling revenues to lower the tax burden helps to cushion the economic impact of climate policies. Interestingly, recycling revenues does not seem to have a significant effect on the response of emissions. We find that both in recycling and non-recycling countries, emissions fall significantly. These results are consistent with the evidence in [Känzig \(2022\)](#), showing that redistributing carbon revenues can lower the economic costs of carbon pricing policies without compromising emission reductions to a significant extent.

It should be noted, however, that energy prices also increase more strongly in non-revenue recycling countries which, all else equal, implies larger economic effects. Therefore, we cannot attribute all the observed difference to revenue recycling. Furthermore, we classify countries to be revenue recycling based on stated intentions rather than actual outcomes, which could differ in practice. Nevertheless, our results are suggestive that revenue recycling plays an important role for the transmission of carbon tax policies.

Pass-through and sectoral coverage. Another potential explanation is related to pass-through. As we discussed above, the EU ETS and national carbon taxes apply to different sectors of the economy.² For instance, [Fabra and Reguant \(2014\)](#) show that pass-through in the power sector, in which carbon is predominantly priced through the EU ETS, is almost complete. By contrast, pass-through in other sectors is likely to be much lower. Indeed, [Ganapati, Shapiro, and Walker \(2020\)](#) document that changes in energy input costs of US manufacturing firms are only partially passed on to consumers. Consistent with this view, we find that consumer prices display a stronger, more significant response to changes in ETS prices compared to carbon taxes.

²We provide a more comprehensive overview of the main sectors covered by the EU ETS and European carbon taxes in Table B.3 in the Appendix.

Panel A: European ETS



Panel B: European carbon taxes

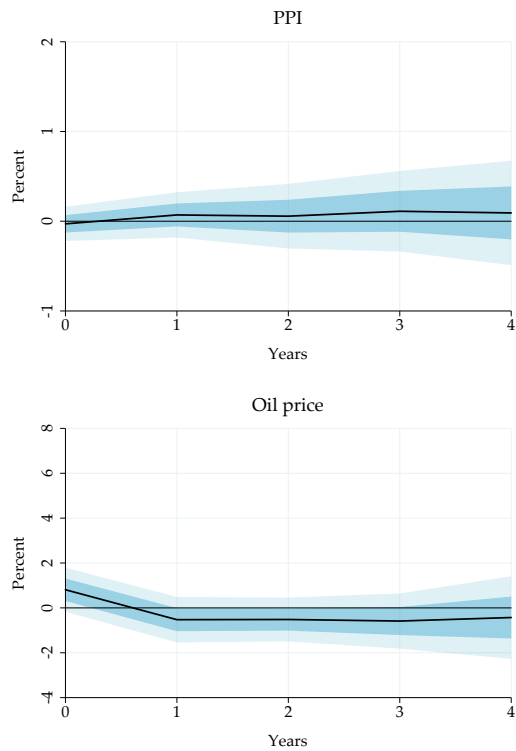


Figure 8: The Impact on Prices

Notes: Impulse responses to an innovation in the ETS carbon price (Panel A) and carbon tax (Panel B), identified using the control-based approach. For the carbon taxes, we focus on the the Western and Northern European sample. The dark and light shaded areas are 68 and 95 percent confidence bands, respectively.

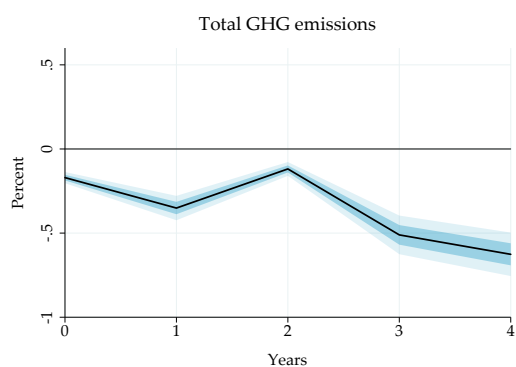
The differences in price impacts are even more apparent for producer prices. Figure 8 shows the responses of the producer price index to similarly sized increases in ETS prices and European carbon tax rates. While producer prices display a significant increase that mirrors the response of energy prices in the case of the EU ETS, they do not show any response to a change in carbon taxes.

Perhaps the starkest difference concerns the effect on oil prices. Note that the carbon market also covers European oil producers and refineries. Figure 8 shows the responses of Brent crude prices. We can see that higher prices in the carbon market lead to a strong and significant increase in oil prices. Conversely, oil prices do not change significantly and even tend to fall slightly following an increase in carbon taxes. In light of the substantial economic consequences of oil price shocks (Kilian, 2009; Baumeister and Hamilton, 2019;

Känzig, 2021), this is likely an important factor in reconciling the differential effects of the two carbon pricing policies.

Spillovers and leakage. Unlike European carbon taxes, which are implemented in a relatively uncoordinated fashion at the national level in select countries, the EU ETS is an EU-wide policy that affects all European countries. European member states are highly integrated and trade extensively with one another. This integration can help cushion the impact of national policies, as the economic activity in other countries will not be directly impacted by the policy. In fact, we find substantial differences in the effects of European carbon taxes in Western and Northern, and Southern and Eastern European countries, with the caveats discussed above. By contrast, the impacts of the EU ETS turn out to be more uniform (see Figures A.3-A.4 in the Appendix. In Section 3.5 we study potential heterogeneities of the EU ETS in more detail).

Panel A: European ETS



Panel B: European carbon taxes

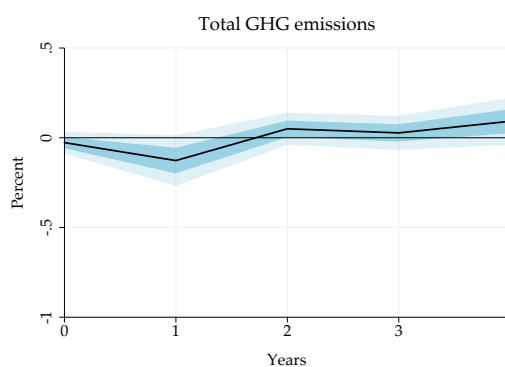


Figure 9: The Effect on EU-wide GHG emissions

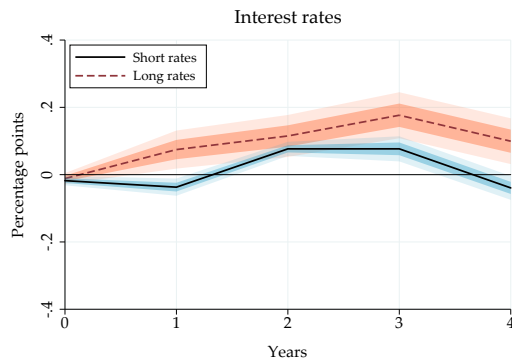
Notes: Impulse responses to an innovation in the ETS carbon price (Panel A) and carbon tax (Panel B), identified using the control-based approach. For the carbon taxes, we focus on the the Western and Northern European sample. The dark and light shaded areas are 68 and 95 percent confidence bands, respectively.

For the same reason, national carbon tax policies could be subject to carbon leakage. In response to higher carbon taxes in one European country, affected industries may move part of their operations to other countries without a carbon tax. This threat may be particularly acute within Europe, as the barriers for carbon leakage are likely lower. This can compromise or even overturn the emission reductions if emissions are shifted to countries with a higher emissions intensity. In fact, we find some evidence for carbon leakage in response to an increase in European carbon taxes. Figure 9 shows the responses for aggregate EU GHG emissions, estimated using the control-based approach. Following

an increase in the ETS price, EU emissions fall persistently. Reassuringly, the response is very similar to the average response from Figure 4. The situation is quite different for European carbon taxes. We have seen that these policies lead to a substantial reduction in emissions at the national level. However, at the EU level, the fall is more muted and the response turns insignificant after about two years. This finding is suggestive that some of the emission reductions in countries that have adopted a carbon tax were shifted to other European countries, thus offsetting the overall reduction in emissions to some extent.

Monetary policy. Monetary policy could also play an important role in accounting for the different effects of EU-wide and national carbon pricing policies. As [Känzig \(2022\)](#) documents, the European central bank appears to lean against the inflationary pressures associated with higher ETS prices, which likely exacerbates the effect on economic activity. As the policy is at the EU level and leads to an increase in EU-wide inflation, it is not implausible to expect a response of the European central bank. By contrast, for national carbon pricing policies in the euro area, we would not expect a monetary response, especially given that the effects on consumer prices seem to be rather muted to start with. This is indeed what we find. Figure 10 shows the impulse responses of short-term and long-term interest rates. While interest rates rise significantly after an increase in ETS prices, the response to a carbon tax increase turns out to be around zero and insignificant.

Panel A: European ETS



Panel B: European carbon taxes

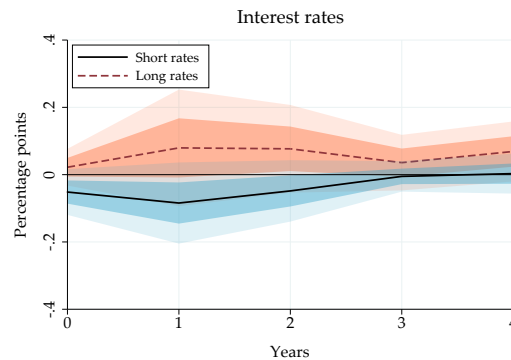


Figure 10: The Effect on Interest Rates

Notes: Impulse responses to an innovation in the ETS carbon price (Panel A) and carbon tax (Panel B), identified using the control-based approach. For the carbon taxes, we focus on the the Western and Northern European sample. The solid line is the point estimate and the dark and light shaded areas are 68 and 95 percent confidence bands, respectively.

Discussion. We have seen that both European carbon taxes and the carbon market have been successful at reducing emissions, however, there are also short-term economic costs. We provide evidence that revenue recycling and the sectoral coverage play an important role for the transmission of these policies. By recycling some of the carbon revenues, it is possible to mitigate the economic costs of the policy without compromising emission reductions to a significant extent. Furthermore, carbon pricing policies may be associated with different price effects depending on the sectors covered and the pass-through in these sectors. The pass-through turns out to be particularly strong in the energy sector, leading to widespread inflationary pressures. The effects on economic activity can be exacerbated if monetary policy leans against these inflationary pressures. Finally, we have seen that it is crucial that carbon pricing policies are broad in coverage. While we do not study carbon leakage to countries outside of the European union, we find some evidence consistent with carbon leakage within the bloc in response to national carbon tax policies.

Our results show that differences in pass-through as well as the fiscal and monetary policy responses can help account for the differential impacts of the European carbon market and carbon taxes. Another aspect that we abstract from is that due to data limitations, we only use explicit carbon taxes. In a recent study for Scandinavian countries, [Kapfhammer \(2023\)](#) computes effective tax rates, taking into account differences in coverage over time as well as implicit carbon taxes, such as energy taxes on liquid fuels. Based on the effective rates, the study confirms the emission reductions but also finds more pronounced adverse effects on economic activity, compared to explicit rates. We confirm these results for Scandinavian carbon taxes in our Western and Northern European sample, see [Figure A.5](#) in the appendix. However, the responses are less precisely estimated – highlighting the importance to assemble similar data for other European countries, to draw sharper inference on the effects of carbon taxes.

3.4. The overall impact of European carbon prices and taxes

Until now, we have studied the impacts of European ETS prices and carbon taxes separately. However, from a policy perspective understanding the joint impact of European carbon pricing initiatives is arguably equally relevant. To this end, we construct a series of real effective carbon prices for each European country, by summing the real coverage-weighted ETS price and, if applicable, the carbon tax rate.

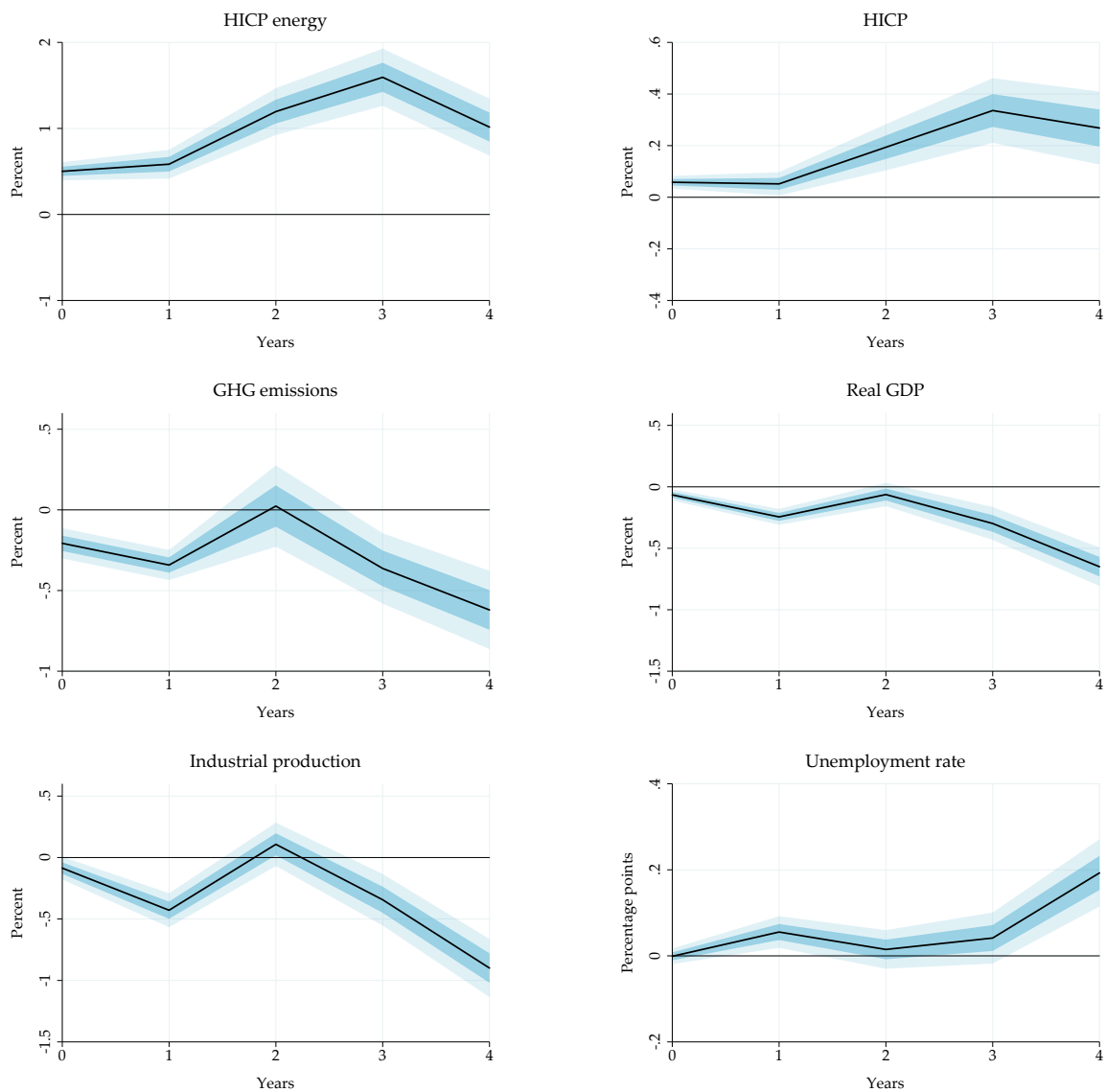


Figure 11: The Effects of European Carbon Prices and Taxes

Notes: Impulse responses to an innovation in the effective carbon price (ETS price and carbon tax) identified using the control-based approach, normalized to increase real coverage-weighted carbon prices by one euro. The solid line is the point estimate and the dark and light shaded areas are 68 and 95 percent confidence bands, respectively.

Figure 11 shows the impulse responses to an increase in the real effective carbon price by one euro. Overall, carbon prices have a meaningful impact on emissions and the economy. Emissions fall persistently while consumer prices rise and economic activity falls. The estimated responses closely track the responses to an innovation in the carbon market, consistent with the fact that the EU ETS is the cornerstone of the EU’s climate policy. As discussed in Section 3.3, the EU ETS can have much more pervasive effects than national carbon taxes, and thus appears to dominate the overall impact of carbon pricing policies at the European level.

3.5. Regional heterogeneity of carbon prices

In contrast to national carbon taxes, the European carbon market is a EU-wide policy and thus affects all European countries. However, given that the EU is a highly heterogeneous union, there are reasons to suspect that the impacts may vary across countries. In this section, we explore the potential unequal effects of carbon prices for different European regions, leveraging the high-frequency identification strategy.

We focus on high-frequency ETS shocks in evaluating the regional component of carbon pricing for the following reasons. First and foremost, carbon taxes only exist in a subset of European countries whereas all countries participate in the ETS and are subject to price fluctuations in the market. Second, including the necessary controls to tease out the endogeneity in carbon taxes may be challenging in smaller subsamples of the countries. This reflects again one of the virtues of the high-frequency identification strategy, which can be flexibly employed to estimate the dynamic causal effects at different levels of aggregation.

To study how the effects vary depending on a countries’ exposure, we include an interaction term in our local projections:

$$y_{i,t+h} - y_{i,t-1} = \alpha_i^h + \beta^h \text{cps}_t + \gamma^h \text{cps}_t * \text{exposure}_{t_0-1} + \dots + \varepsilon_{i,t+h}, \quad (3)$$

where γ^h captures the differences in the response to carbon policy shocks depending on the exposure. We standardize the exposure variable such that γ^h can be interpreted as the effect of having a one standard deviation higher exposure compared to the average country. As exposure variables, we mainly focus on the share of freely allocated allowances (relative to total emissions) and market concentration in electricity markets, constructed from the number of retail companies in each country. In addition, we also consider the share of non-renewables in primary energy consumption, and the service share of value

added. To ensure that climate policy does not affect the exposure variable, we use the latest annual observation before the start sample period.³

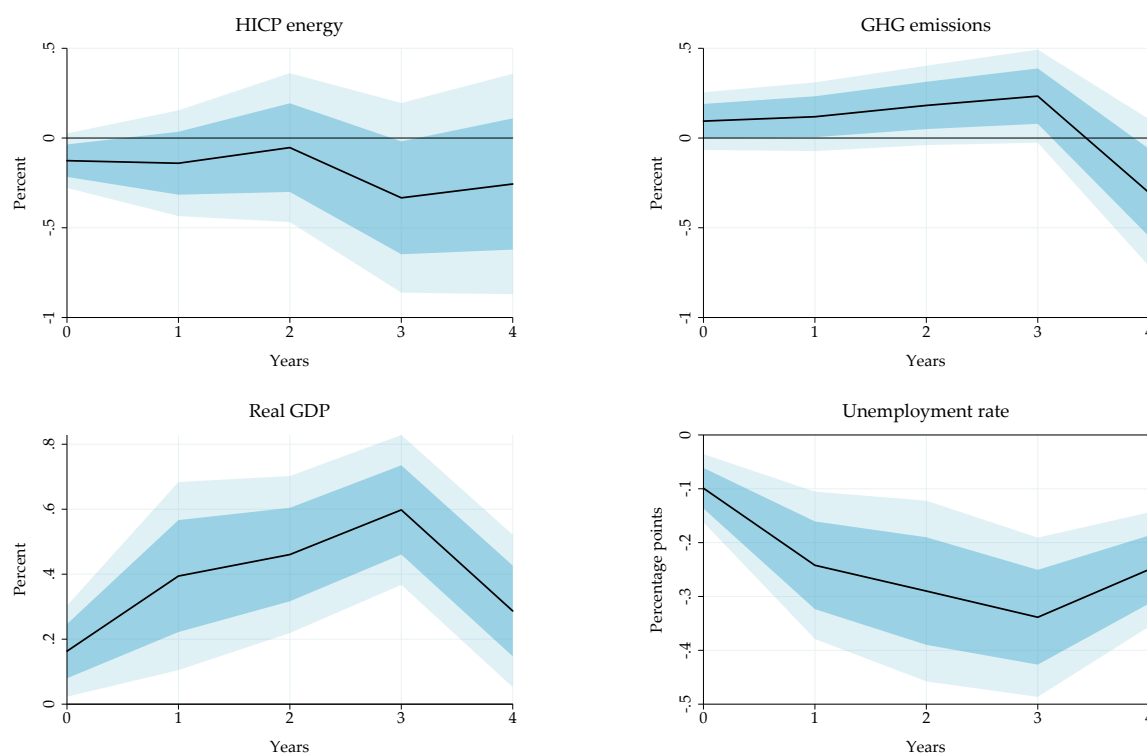


Figure 12: The Role of Free Allowances in the EU ETS

Notes: Impulse responses to a carbon policy shock, identified using the high-frequency approach, interacted with a country's share of free allowances to total emissions (standardized). The solid line is the point estimate and the dark and light shaded areas are 68 and 95 percent confidence bands, respectively.

We find sizable differences in the estimated responses depending on the share of freely allocated allowances. Figure 12 illustrates a weaker response of energy prices and a muted decline in emissions for countries with a higher share of free allowances. Moreover, we see markedly different effects on economic activity, with countries that received more free allowances experiencing attenuated effects on GDP and unemployment. Note that the share of free allowances varies quite a bit across EU ETS members (see Figure A.8 of the Appendix), between 56 percent in Norway and 123 percent in Lithuania, on average. In addition to targeting towards poorer member countries, free allowances were

³Due to data limitations, we use the country-specific sample average over the period between 2011 to 2019 to measure market concentration. In case of free allowances, we rely on data from 2005, the first year where free allowances were allocated.

allocated based on an assessment of countries' sectors that could be prone to carbon leakage.

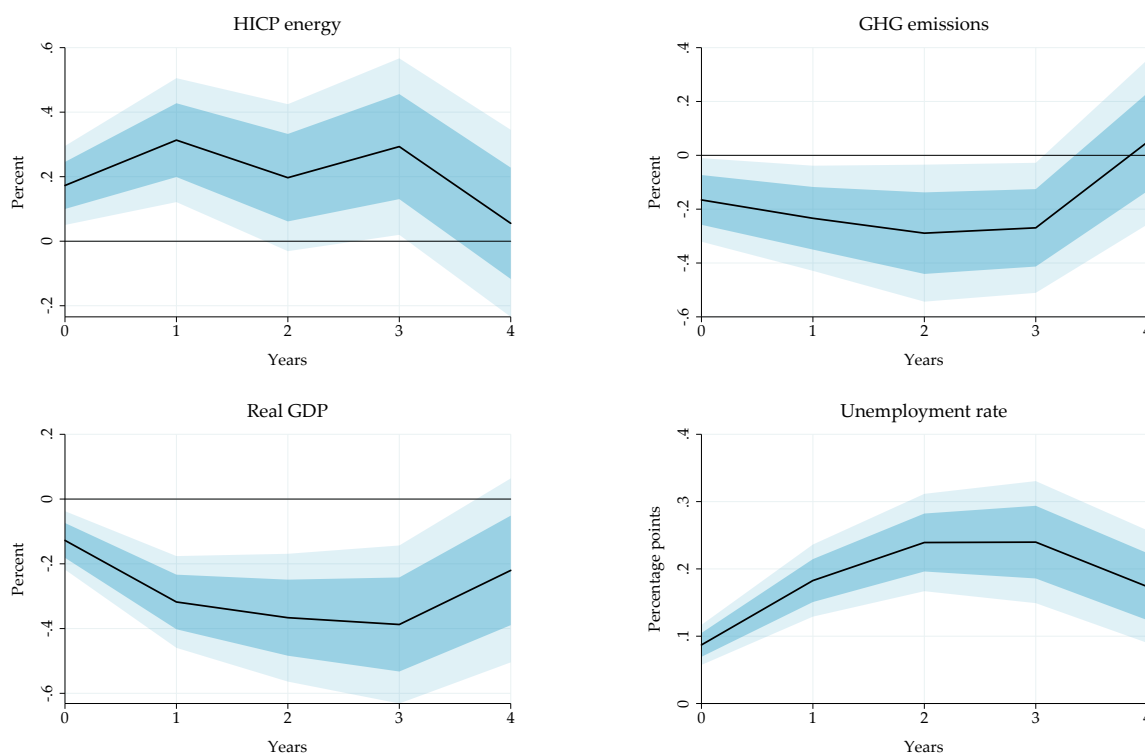


Figure 13: The role of Market Concentration in the EU ETS

Notes: Impulse responses to a carbon policy shock, identified using the high-frequency approach, interacted with a country's share of primary energy consumption per electricity retailer (standardized). The solid line is the point estimate and the dark and light shaded areas are 68 and 95 percent confidence bands, respectively.

Next, we evaluate how the degree of market concentration in European electricity markets, which is markedly different across countries, promotes the effects of carbon pricing. Figure A.9 of the Appendix illustrates these regional differences. For instance, the average French electricity retailer accounted for 15.7 terawatt hours (TWh) of primary energy consumption between 2011 to 2019, compared to only 2.7 TWh for German retailers. The degree of market concentration in turn affects the pass-through from carbon prices to energy and consumer prices, displayed in Figure 13. The effects on energy prices are stronger and more persistent in countries where electricity markets are more concentrated. Higher energy prices contribute to a greater fall in emissions. Furthermore, countries with more concentrated electricity markets experience stronger economic consequences following a carbon price shock, with a larger decline in output and more

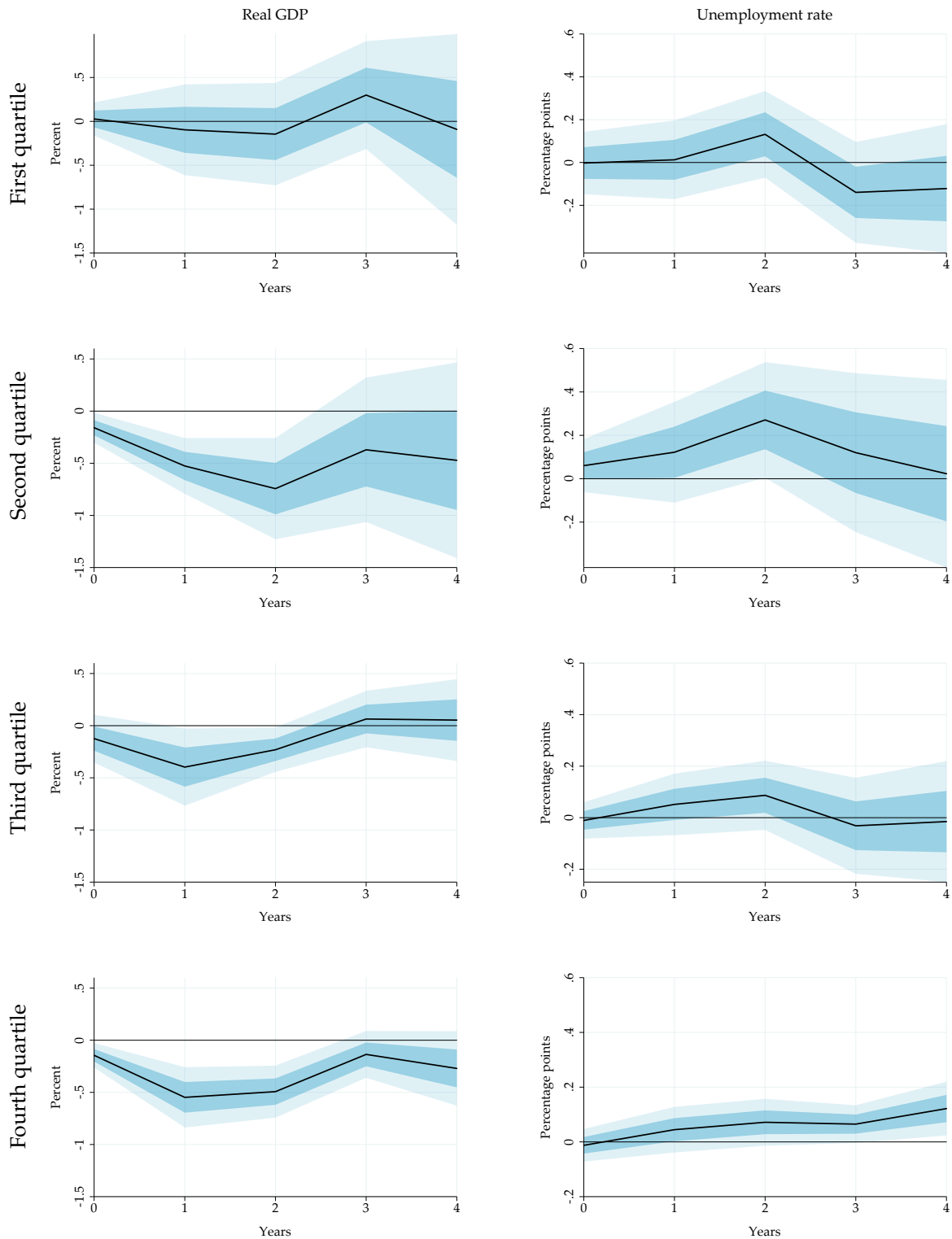


Figure 14: The effect of the EU ETS by income

Notes: Impulse responses to a carbon policy shock, identified using the high-frequency approach, separately estimated by GDP per capita quartile. The solid line is the point estimate and the dark and light shaded areas are 68 and 95 percent confidence bands, respectively.

unemployment.

We also investigate whether the effects of carbon policy shocks may differ depending on the energy mix and the sectoral composition of the domestic economy. We test both channels by using the share of non-renewables in primary energy consumption and the service share, respectively. Our estimates, presented in Figures A.6 and A.7 in the Appendix, suggest that energy prices increase more in countries with a more carbon intensive energy mix. Emissions in these countries tend to decrease by less while employment falls by more but the responses are not very precisely estimated. For countries with a high service share we find no significant difference in the energy price response but a stronger increase in the unemployment rate. This result illustrates that the sectoral composition does not only matter for the direct effects of the policy via energy prices but also for the indirect effects via wages and employment, as emphasized in [Känzig \(2022\)](#).

Another important question is whether rich and poor countries are equally affected by climate policy. To test for different effects by income, we partition the 28 countries into quartiles depending on their GDP per capita level in 1998, and separately estimate the local projections for each subsample. We focus on the responses of real GDP and the unemployment rate, depicted in Figure 14. Focusing on the first column, our estimates suggest that the contraction in GDP and the rise in unemployment is stronger in the top three quartiles, that is, richer countries, compared to the bottom quartile. In fact, we do not find evidence of a fall in output for the group of poorest countries. Instead, it seems that countries belonging to the second quartile suffer the largest fall in output. As we explain above, the distribution of free allowances and concentration of national electricity markets offer one explanation for these results. Indeed, we find that countries in the bottom quartile received the most free allowances (as a share of total emissions) and have the least concentrated electricity markets, on average (see Table A.1 in the Appendix). Conversely, the average country belonging to the second quartile received the fewest amount of free allowances and has the highest concentration in electricity markets.

4. Conclusion

Despite broad consensus of economists and policymakers that carbon pricing is the key tool to confront the climate challenge, the empirical evidence on the impact of these policies on emissions and the economy is still sparse. This paper provides new evidence in the context of Europe, contrasting the two major climate policies: the European carbon market and national carbon taxes. In a panel setting with a unified empirical approach,

we find that carbon prices were successful at reducing emissions but this comes at an economic cost. However, the economic consequences turn out to be larger for the European carbon market than for carbon taxes. We examine four different hypotheses for the differential impacts: the recycling of tax revenues, sectoral coverage and differences in pass-through, monetary policy, and spillovers and carbon leakage. We find that all four channels have likely played a role but revenue recycling as well as differences in pass-through seem to be particularly important. Finally, we document significant heterogeneity in the regional impacts of the European carbon market, which depend crucially on the share of freely allocated allowances and the degree of market concentration in electricity markets. Our results have important implications for policy design: recycling carbon revenues can mitigate potential adverse economic effects of carbon pricing, however, any complementary fiscal policies should take the sectoral composition and strength of pass-through into account.

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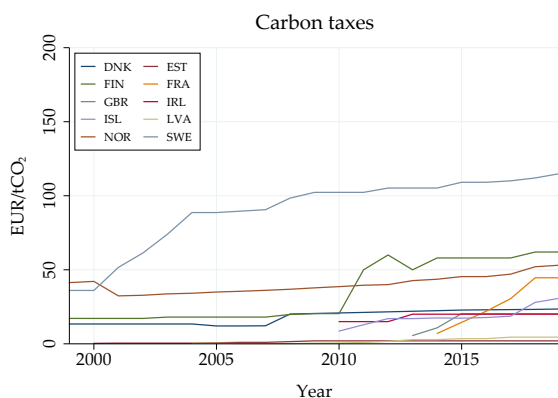
Appendix

A. Additional figures

This appendix provides some additional figures and tables not presented in the main text.

A.1. Carbon taxes in North-Western and South-Eastern Europe

Panel A: Western and Northern Europe



Panel B: Southern and Eastern Europe

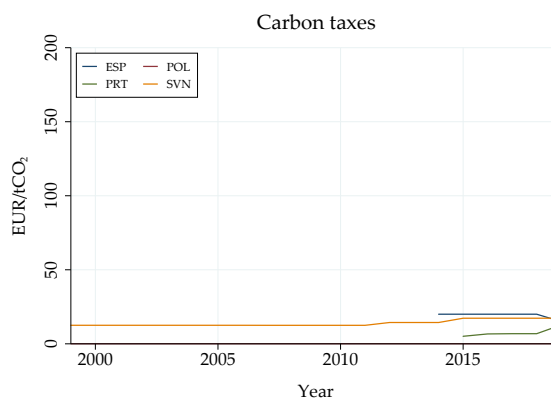


Figure A.1: Carbon Prices in European Regions

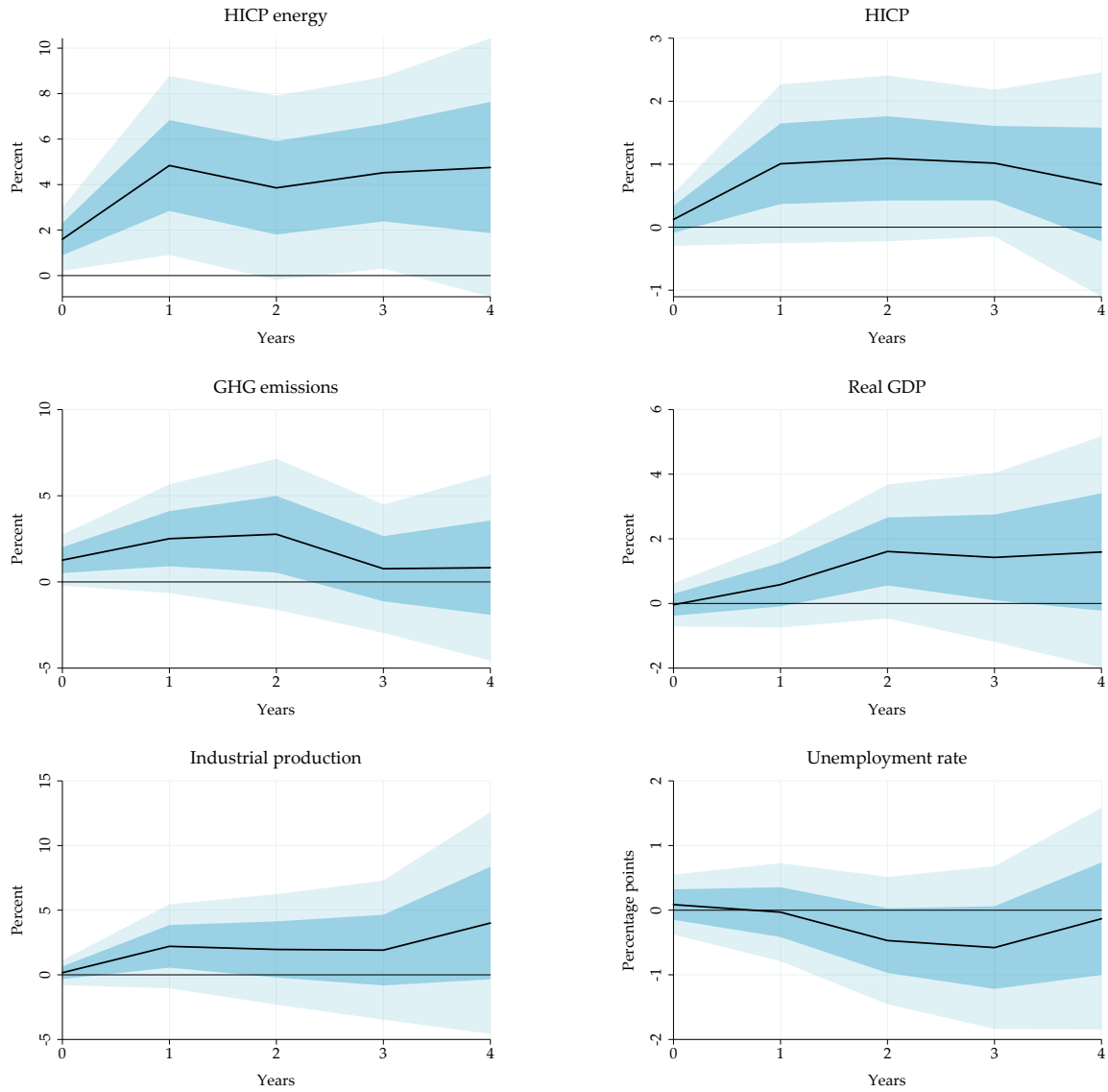


Figure A.2: The Effects of Carbon Taxes in Southern and Eastern Europe

Notes: Impulse responses to a carbon tax innovation in Southern and Eastern European countries, identified using the control-based approach. The solid line is the point estimate and the dark and light shaded areas are 68 and 95 percent confidence bands, respectively.

A.2. ETS prices in North-Western and South-Eastern Europe

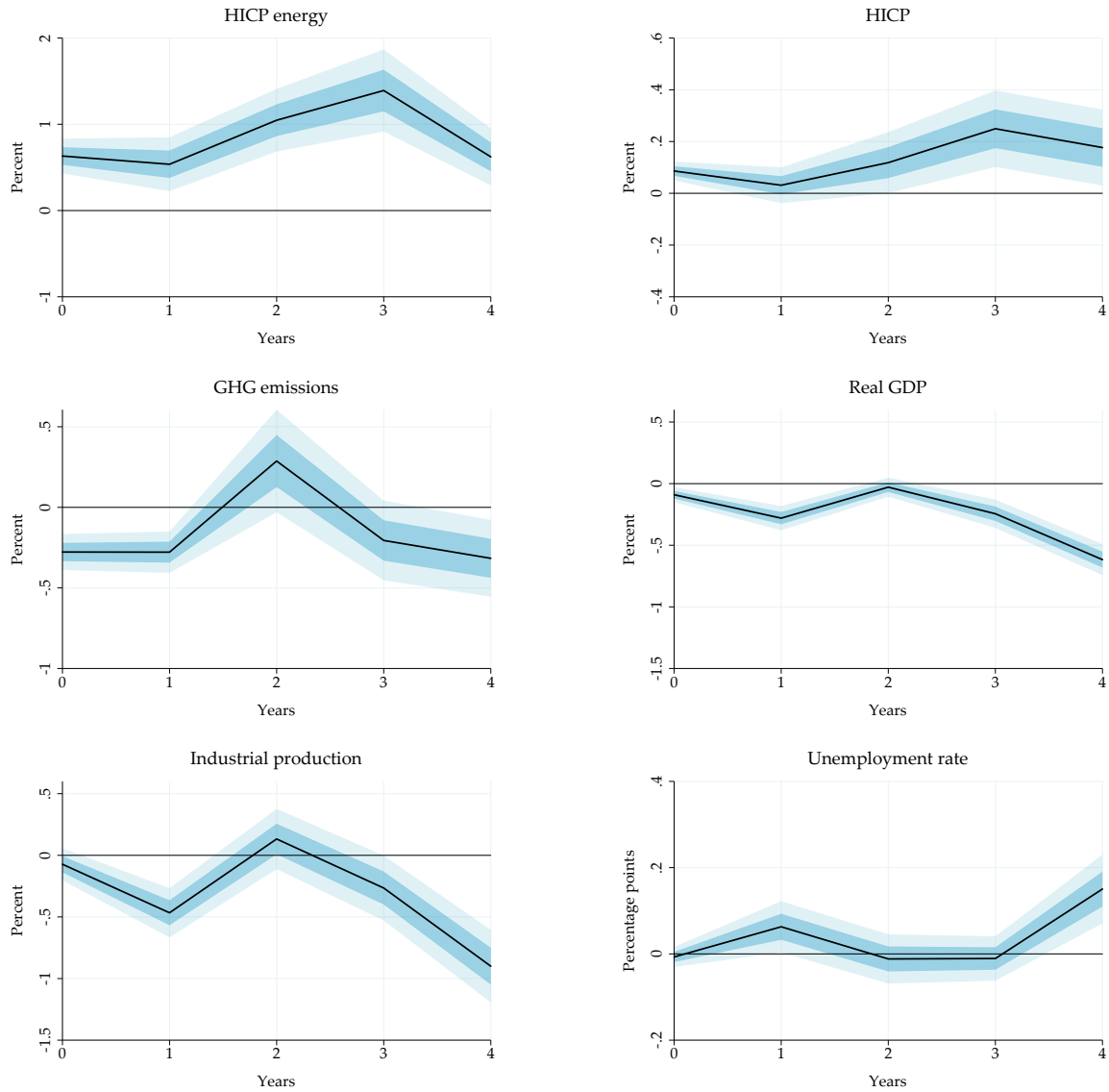


Figure A.3: The Effects of Carbon Policy Shocks in Western and Northern Europe

Notes: Impulse responses to a carbon policy shock, identified using the high-frequency approach. The solid line is the point estimate and the dark and light shaded areas are 68 and 95 percent confidence bands, respectively.

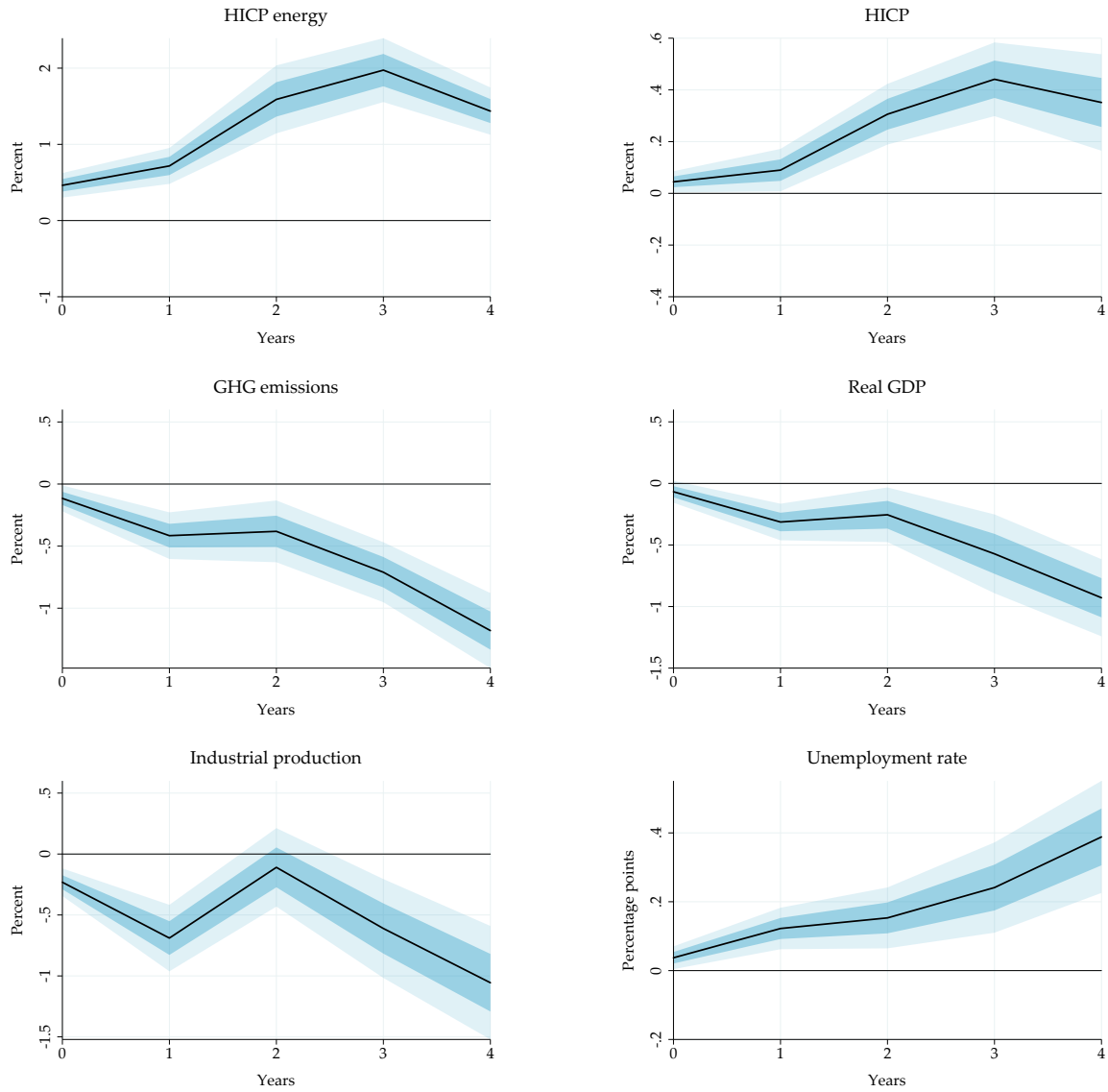


Figure A.4: The Effects of Carbon Policy Shocks in Southern and Eastern Europe

Notes: Impulse responses to a carbon policy shock, identified using the high-frequency approach. The solid line is the point estimate and the dark and light shaded areas are 68 and 95 percent confidence bands, respectively.

A.3. Scandinavian carbon taxes

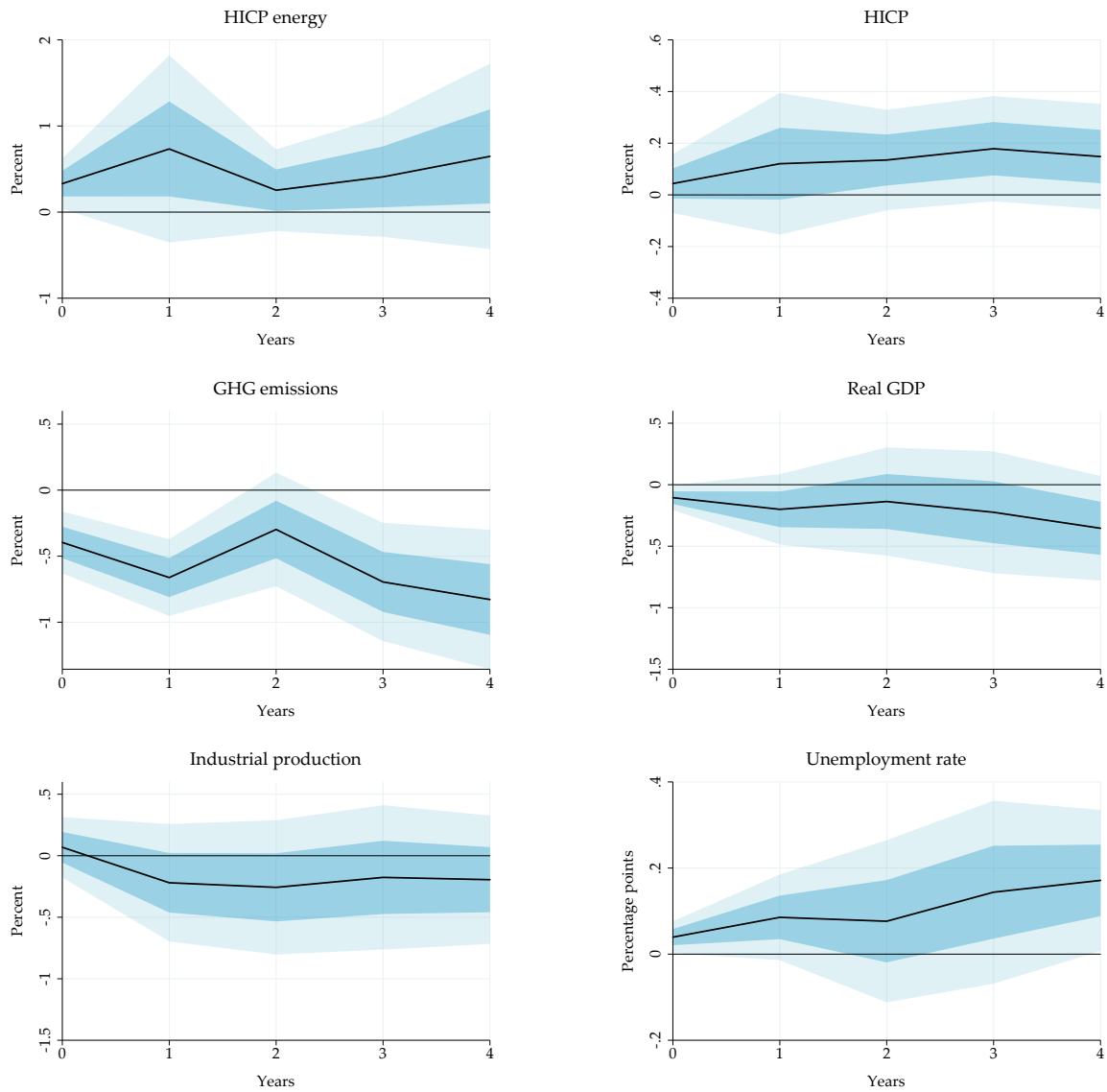


Figure A.5: The Effects of Scandinavian Carbon Taxes in the Western and Northern European Sample

Notes: Impulse responses to a carbon tax innovation in Scandinavia, estimated in the Western and Northern European sample using the control-based approach. The innovation is normalized to increase real coverage-weighted carbon taxes by one euro. The solid line is the point estimate and the dark and light shaded areas are 68 and 95 percent confidence bands, respectively.

A.4. Heterogeneity in carbon policy shocks

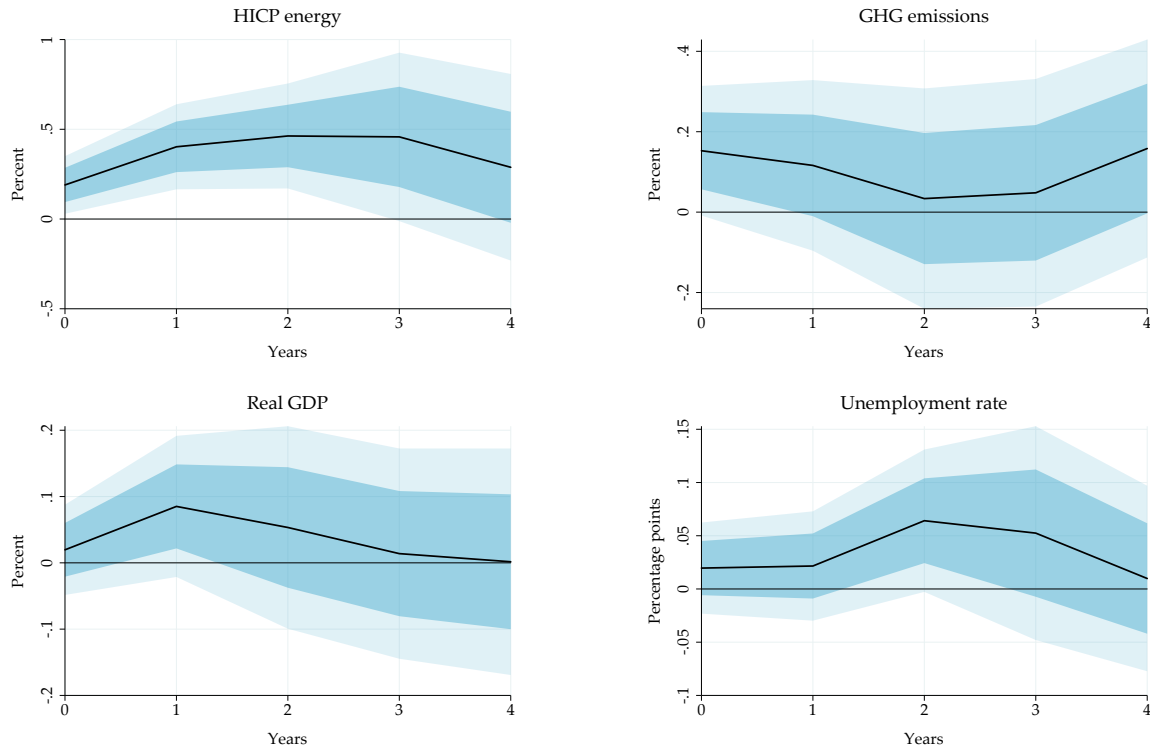


Figure A.6: Heterogeneity by Energy Mix

Notes: Impulse responses to a carbon policy shock, identified using the high-frequency approach, interacted with a country's share of non-renewables in primary energy consumption (standardized). The solid line is the point estimate and the dark and light shaded areas are 68 and 95 percent confidence bands, respectively.

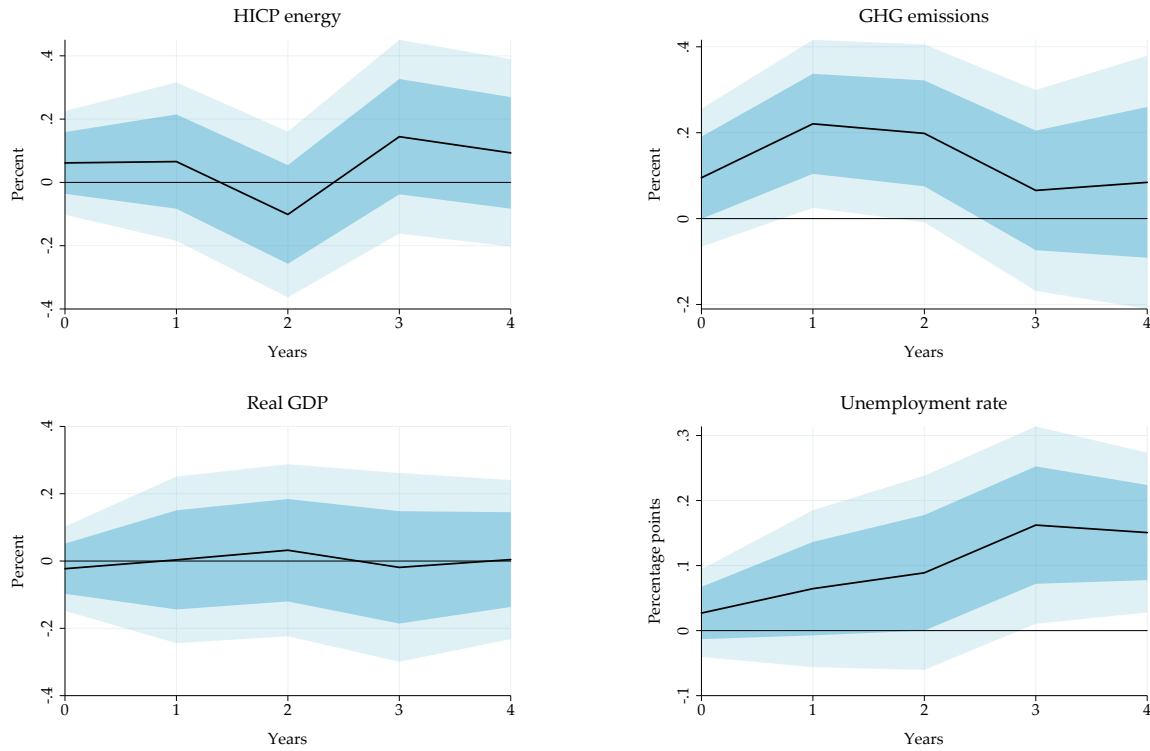


Figure A.7: Heterogeneity by Service Share

Notes: Impulse responses to a carbon policy shock, identified using the high-frequency approach, interacted with a country's share of services in value added (standardized). The solid line is the point estimate and the dark and light shaded areas are 68 and 95 percent confidence bands, respectively.

Table A.1: Summary Statistics of Interaction Variables by Income

Variable	GDP per capita quartiles			
	First	Second	Third	Fourth
Share of free allowances to total emissions	102.43 (39.56)	77.83 (36.27)	84.57 (30.69)	88.43 (28.58)
Primary energy per electricity retailer	4.25 (1.91)	9.01 (9.36)	9.52 (6.78)	6.30 (6.34)
Share of non-renewables in primary energy	93.10 (6.47)	89.80 (7.20)	90.56 (5.27)	75.62 (21.92)
Share of services in value added	66.35 (3.98)	70.05 (6.32)	71.88 (5.13)	73.76 (7.81)

Notes: All variables are expressed as sample averages per income quartile, with standard deviations in parentheses. Quartiles are constructed based on 1998 real GDP per capita. First quartile: Bulgaria, Hungary, Lithuania, Latvia, Poland, Romania, Slovakia; second quartile: Cyprus, Czechia, Spain, Estonia, Greece, Portugal, Slovenia; third quartile: Belgium, Germany, Finland, France, United Kingdom, Ireland, Italy; fourth quartile: Austria, Denmark, Iceland, Luxembourg, Netherland, Norway, Sweden.

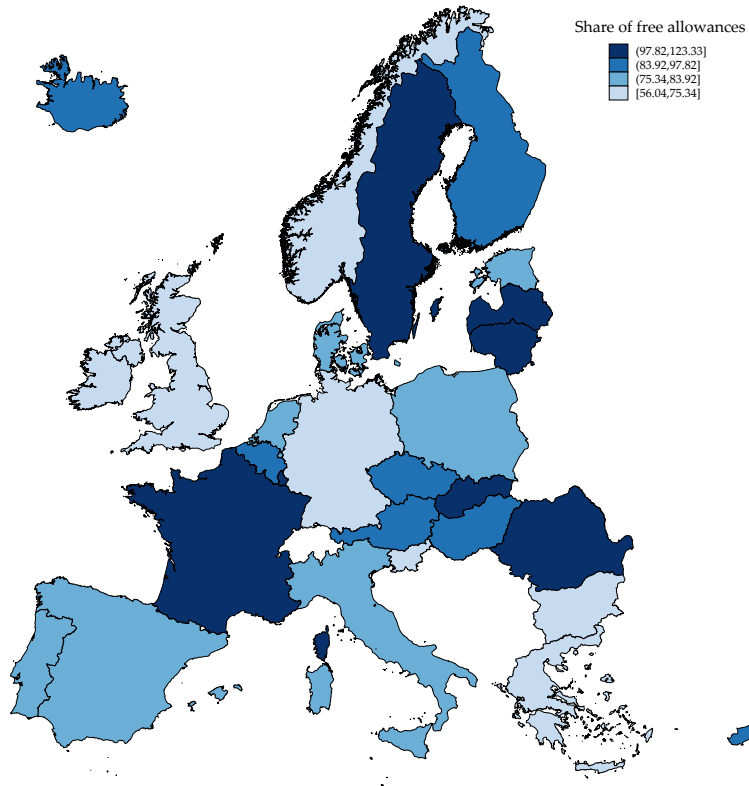


Figure A.8: The regional distribution of free allowances

Notes: Based on the average share of free allowances relative to total emissions.

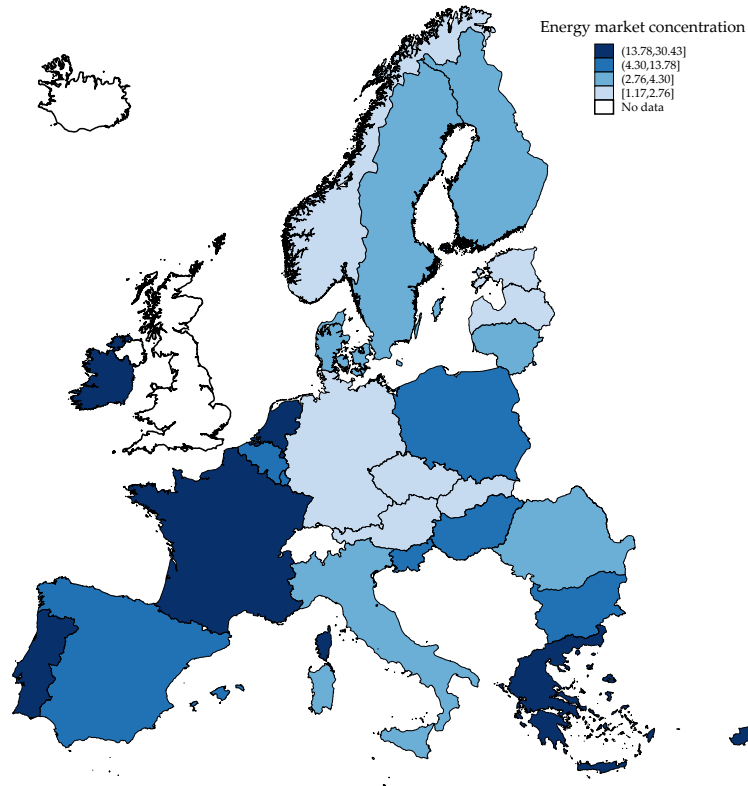


Figure A.9: The regional distribution of electricity market concentration

Notes: Based on the average amount of primary energy consumption per electricity retailer. Data for the United Kingdom and Iceland are missing.

B. Data

In this appendix, we provide more detailed information on the data sources as well as some descriptive statistics on our main variables of interest.

Table B.1: Data Description

Variable	Description	Source	Coverage
Panel A: Country variables			
Carbon tax rate	Tax rates in USD	World Bank Group	1999–2019
Carbon tax coverage	In percent of total emissions	World Bank Group	2019
ETS emissions	Verified emissions, incl. aviation	EU Transaction Log	2005–2019
ETS allowances	Freely allocated allowances, adj. for corrections	EU Transaction Log	2005–2019
Total emissions	Total GHG excl. LULUCF incl. aviation	Eurostat	1999–2019
Real GDP	Real gross domestic product	World Bank Group	1999–2019
Industrial production	Excl. construction	Eurostat	1999–2019
Unemployment rate	ILO estimate	World Bank Group	1999–2019
HICP Energy	HICP energy	Eurostat	1999–2019
HICP	HICP all items	Eurostat	1999–2019
PPI	Industrial producer prices, domestic market	Eurostat	1999–2019
Long term interest rate	10-year government bond rate	OECD, ECB	1999–2019
Policy rate	Monetary policy interest rate	BIS	1999–2019
Primary energy consumption	Total primary energy consumption	BP & OWID	1999–2019
Non-renewable share	Share of non-renewables in primary energy	BP & OWID	1999–2019
Electricity retailers	Number of electricity retail companies	Eurostat	2013–2019
Service share	Share of services in value added	OECD	1999–2019
Panel B: EU variables			
Carbon policy shock		Känzig (2022)	1999–2019
ETS price	EUA front contract	Datastream	2005–2019
Real GDP	EU Real GDP	Datastream	1999–2019
Share price index	Euro STOXX	Datastream	1999–2019
Panel C: Global variables			
Oil price	Brent crude spot price	FRED	1999–2019

Table B.2: Descriptive Statistics

Variable	Observations	Mean	Median	St. Dev.
Panel A: Country variables				
Carbon tax rate (in €)	206	27.98	19.17	31.59
Carbon tax coverage (in %)	294	0.28	0.29	0.17
ETS emissions (in mn. tCO ₂)	420	68.08	28.23	96.98
ETS allowances (in mn. tCO ₂)	419	54.22	23.99	79.49
Total emissions (in mn. tCO ₂)	588	176.93	72.05	233.97
Real GDP (in bn. €)	588	512.69	199.13	761.96
Industrial production (index)	552	97.28	100.00	19.66
Unemployment rate (in %)	588	8.25	7.24	4.39
HICP Energy (index)	582	84.98	90.34	21.77
HICP (index)	588	88.27	91.47	14.24
PPI (index)	540	90.81	95.80	15.04
Long term interest rate (in %)	541	4.03	4.13	2.46
Policy rate (in %)	563	2.50	2.00	2.81
Primary energy consumption (in TWh)	588	730.10	341.54	948.81
Non-renewable share (in %)	588	86.45	93.10	17.95
Electricity retailers (number)	182	159.78	53.50	275.15
Service share (in %)	525	70.01	69.94	6.42
Panel B: EU variables				
Carbon policy shock (in %)	588	-0.00	0.03	1.83
ETS price (in €)	420	12.13	13.04	7.11
Real GDP (in tn. €)	588	10.06	10.18	0.70
Share price index (in €)	588	307.86	309.50	57.59
Panel C: Global variables				
Oil price (in €)	588	62.36	61.74	29.47

Table B.3: Main sectors covered by carbon pricing

Jurisdiction	Sectors
Panel A: EU ETS	
EU	Power sector, energy-intensive industry, aviation
Panel B: Carbon taxes	
Finland	Transportation, heating
Poland	
Norway	Transportation, industry, agriculture
Sweden	Transportation, heating, industry
Denmark	Transportation, heating
Slovenia	Buildings, transportation
Estonia	Transportation, industry
Latvia	Industry, power sector
Ireland	Industry, transportation
Iceland	Transportation
United Kingdom	Power sector
Spain	Industry
France	Industry, transportation
Portugal	Transportation, road and construction

Notes: Based on [Sumner, Bird, and Dobos \(2011\)](#), [Carl and Fedor \(2016\)](#), [Andersson \(2019\)](#), [Marten and Van Dender \(2019\)](#), [Metcalf and Stock \(forthcoming\)](#), [Konradt and Weder di Mauro \(2022\)](#). No data is available for Poland.