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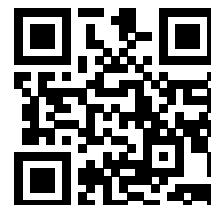
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Assessing the Global Impact of EU Carbon Pricing: Economic and Climate Spillovers

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Assessing the Global Impact of EU Carbon Pricing: Economic and Climate Spillovers*

Elias Hasler[†]

January 3, 2025

Abstract

This paper explores the global economic and climate spillovers of the European Union Emissions Trading System (EU ETS), leveraging exogenous variations in carbon prices identified through a carbon policy surprise series. Findings reveal that higher EU carbon prices lead to significant and sustained reductions in greenhouse gas (GHG) emissions, both within the Euro Area (EA) and globally, with no evidence of carbon leakage. Structural Scenario Analysis confirms that these reductions are driven by energy efficiency improvements rather than solely by declines in industrial production. The results highlight the transmission of the shock through the *Brussels Effect*, where EU carbon policies influence global standards, evidenced by stricter carbon policies abroad and shifts in investor behavior favoring green industries. Furthermore no region benefits economically from EU carbon pricing. Overall, the EU ETS proves effective in reducing emissions without being undermined by carbon leakage.

Keywords: Carbon Leakage; Spillovers; Carbon Pricing; Brussels Effect

JEL-Classification: E32; F42; F64; Q54; Q58

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1 Introduction

Addressing climate change is one of the most critical challenges facing our society today. Policymakers are increasingly adopting carbon pricing mechanisms to mitigate global warming and reduce greenhouse gas emissions. Recent studies indicate that the European Emissions Trading System (ETS) successfully reduces greenhouse gas emissions in Europe. However, implementing these policies comes with costs, including higher prices, increased unemployment, and decreased economic activity (Känzig, 2023; Hänzig and Konradt, 2023). Despite these immediate costs, the long-term benefits of averting a climate crisis significantly outweigh the short-term economic drawbacks (Carleton and Hsiang, 2016; Bilal and Hänzig, 2024). Moreover, carbon price shocks have been shown to produce substantial and persistent reductions in greenhouse gas emissions, which materialize faster and are more enduring than some of the economic consequences, thus increasing energy efficiency. However, are these reductions in greenhouse gas emissions in Europe offset by increased emissions elsewhere, thereby undermining the overall effectiveness of carbon pricing?

While the European experience provides valuable insights, climate change is an inherently global issue. Localized efforts, no matter how effective, can be undermined by carbon leakage, where emissions reductions in one region lead to increases in another. At the same time, the *Brussels Effect* suggests that the EU’s regulatory leadership can drive global standards, extending the impact of its carbon pricing policies beyond its borders (Bradford, 2020). This effect implies that the stringent carbon regulations of the European ETS may lead to emission reductions not only within Europe but also in other regions. Companies reduce their emissions in Europe, and this often spills over to other countries — either through the same multinational companies operating with similar standards elsewhere, through technological or policy spillovers that prompt broader adoption of cleaner practices. Whether carbon leakage offsets these efforts or the *Brussels Effect* prevails in spreading effective climate policies worldwide is crucial in determining the overall success of these regulatory measures. Against this backdrop, this paper aims to explore the global economic and climate spillovers resulting from the European ETS.

To achieve this, we first need to identify exogenous price variations within the EU ETS. Hänzig (2023) addresses this by utilizing the unique features of the EU ETS to develop a carbon policy surprise series. The EU ETS operates on a cap-and-trade mechanism, setting a cap on total greenhouse gas (GHG) emissions for regulated entities and allocating tradable emission allowances, thereby creating a carbon price and incentivizing emission reductions. By measur-

ing carbon futures price changes within a narrow window around regulatory announcements — a method known as high-frequency identification — this approach isolates the impact of these events on carbon prices, ensuring the series reflects only unanticipated carbon policy surprises. Using this carbon policy surprise series, which captures only exogenous price variations, I analyze the dynamic effects of carbon policy shocks to better understand the broader impacts of carbon pricing policies.

For the Euro Area (EA), I find that an increase in carbon prices results in a significant and persistent reduction in GHG emissions, albeit at the expense of higher prices, increased unemployment, and reduced economic activity, consistent with existing literature. Worldwide, both industrial production and GHG emissions also decrease, although the decline is not as rapid or strong as in the Euro Area for GHG emissions. Consequently, there is no evidence of carbon leakage; instead, the estimates suggest that GHG emissions worldwide also decline when EU carbon prices rise.

However, a concern is that the reduction in GHG emissions, both in the Euro Area and abroad, may primarily result from decreased industrial production. If emissions reductions are driven solely by decreased industrial output, this implies that the observed decline is merely a consequence of weaker economic performance rather than improvements in energy efficiency. While the impulse response functions suggest that the reduction in GHG emissions in the Euro Area is largely driven by higher prices that incentivize energy efficiency rather than reduced industrial production, this cannot be concluded for the global spillovers. In the latter case, the decrease in GHG emissions may be more closely tied to declines in industrial activity, indicating that the reductions are not necessarily due to enhanced efficiency but rather a contraction in economic output.

To quantify and assess the importance of the reduction in EA industrial production as a transmission channel to GHG emissions, I use Structural Scenario Analysis (SSA), introduced by [Antolin-Diaz et al. \(2021\)](#). SSA allows us to construct a counterfactual scenario where EA industrial production remains unchanged after a carbon policy shock, enabling us to evaluate the role of industrial production as a transmission channel. Interestingly, even when EA industrial production is unchanged, we still observe a persistent negative effect on both EA and worldwide GHG emissions after a carbon policy shock. These findings are encouraging from a climate policy perspective, as they suggest that the reduction in GHG emissions is not primarily driven by decreased industrial production. However, this raises the question of why GHG emissions continue to fall, particularly outside of Europe, where the reduction cannot be attributed to

higher prices and therefore an incentive to innovate and reduce emissions.

A possible explanation for the observed decline in worldwide GHG emissions is the *Brussels Effect*, where EU regulatory policies influence global standards, creating both de facto and, at times, de jure norms beyond their borders. Consequently, carbon policy shocks in the EU act as signals about future climate policies, not only within Europe but internationally. Stock markets, being inherently forward-looking, provide insight into how investors incorporate these future economic and regulatory expectations. I show that a carbon policy surprise increases the returns of green stock market indices while decreasing the returns of brown stock market indices, indicating that firms are incentivized to adopt cleaner practices. Furthermore, I demonstrate that carbon policies outside Europe become more restrictive following a carbon policy shock. This evidence supports the conclusion that the *Brussels Effect* outweighs the impact of carbon leakage by driving global emission reductions.

Lastly, I use region-specific data instead of aggregated data to examine whether the results are influenced by outliers and to identify if any individual region benefit economically from increased carbon prices in Europe or if there are instances of carbon leakage. Additionally, I detail the effects on different emerging markets regions. The findings indicate that no country significantly benefits from EU carbon pricing. However, there are instances of carbon leakage in the Eastern Europe / CIS region, warranting further research to understand the underlying reasons.

Related literature and contribution. This paper contributes to the literature on climate policies and their economic and climate impacts, particularly focusing on the cross-border effects of such policies. Early theoretical work on climate and economic spillovers of unilateral climate policies predominantly concluded that carbon leakage would occur, benefiting cross-boarder regions economically. This finding spurred further theoretical research on how to best prevent carbon leakage (Babiker, 2005; Demailly and Quirion, 2006; Fischer and Fox, 2012; Böhringer et al., 2017; Ernst et al., 2023, among others). However, empirical evidence on spillovers of climate policies is sparse, especially on a macro level.

The empirical evidence on carbon leakage is mixed. Aichele and Felbermayr (2012, 2015) find both economically and statistically significant carbon leakage resulting from the Kyoto Protocol. Similarly, Schroeder and Stracca (2023) study the effects of EU carbon taxation and find a statistically significant reduction in domestic carbon emissions. However, the carbon embodied in all domestic consumption goods decreases by only half as much and is not statistically

significant, suggesting some carbon leakage through increased carbon embodied in trade. Additionally, [Känzig et al. \(2024\)](#) identify carbon leakage to developing countries in Africa due to EU carbon policies, but only to low-income nations. In contrast, [Sato and Dechezleprêtre \(2015\)](#) also find statistically significant carbon leakage, although it is economically negligible, while [Naegele and Zaklan \(2019\)](#) find no statistically significant effect on imported carbon following the implementation of more stringent EU ETS regulations. Furthermore, in a comprehensive review of the literature on carbon leakage from the EU ETS, including firm-level studies, [Verde \(2020\)](#) concludes that the EU ETS does not lead to carbon leakage.

More broadly, this paper connects to the literature on domestic policy shocks and their international transmission. Recent examples include [Miranda-Agrippino and Ricco \(2021\)](#), who examine the economic spillover effects of U.S. monetary policy on other countries, and [Miranda-Agrippino and Rey \(2020\)](#), who investigate the impact of U.S. monetary policy on the global financial cycle. Other examples are, [Klein and Linnemann \(2021\)](#) who study the effects of U.S. technological advancements on G7 countries or [Jarociński \(2022\)](#) who analyze the reciprocal effects of EU monetary policy on the U.S. and vice versa.

Firstly, I contribute to the spillover literature by focusing on the spillovers of domestic climate policies, rather than the more traditional economic shocks such as technology or monetary policy. Secondly, using state-of-the-art macro-econometric techniques, I provide a comprehensive analysis of worldwide economic and climate spillovers from the EU Emissions Trading System. Unlike most studies of carbon leakage at the macro level, which focus on carbon embodied in trade flows, this research examines the GHG emissions in other regions and hence captures a more complete picture of carbon emission in certain regions. Furthermore, while most studies concentrate on the climate impacts of climate policies, this study also addresses the economic impacts, thereby providing a more holistic view of spillover effects.

By employing Structural Scenario Analysis, as introduced by [Antolin-Diaz et al. \(2021\)](#), I account for the domestic negative economic consequences that influence international economic activity and, consequently, global GHG emissions. Moreover, I investigate why carbon leakage does not appear and show evidence that carbon policy shocks have global ramifications for climate policies. Through a region-by-region analysis, I also uncover instances of carbon leakage that are masked by aggregate data. This research bridges a gap in the literature by examining both the economic and environmental dimensions of climate policy spillovers on a global macro level, and hence offering new insights into the mechanisms driving these effects.

Outline. The paper proceeds as follows. Section 2 provides information about EU carbon market and the identification strategy. In Section 3, I present the empirical framework and the econometric methodology employed to analyze the impact of carbon policy shocks. Section 4 discusses the aggregate impact on emissions and economic activity, and explores potential global spillovers. Section 5 delves into the transmission mechanisms of these spillovers, including counterfactual analyses and the role of market expectations and climate policies. Section 6 examines region-specific effects to assess heterogeneity and potential carbon leakage. Finally, Section 7 concludes with a summary of the findings and policy implications.

2 The EU Carbon Market and Identification

Institutional Background. The EU carbon market, officially known as the European Union Emissions Trading System (EU ETS), is the largest carbon trading system globally and a central pillar of the European Union’s efforts to combat climate change. Established in 2005, the EU ETS operates on a cap-and-trade principle, whereby a cap is set on the total amount of GHG emissions permitted by regulated entities, primarily large industrial installations and power plants. These entities are allocated a certain number of emission allowances, each representing the right to emit one tonne of CO₂ or its equivalent. The total number of allowances issued is determined by the cap, which declines over time in line with the EU’s emission reduction targets, thereby promoting a gradual reduction in emissions.

Under the EU ETS, regulated entities are required to surrender allowances equivalent to their actual emissions at the end of each compliance period. Entities with emissions exceeding their allocated allowances must purchase additional permits, either through auctions or on the secondary market, while those with surplus allowances can sell them. This market-based mechanism incentivizes emission reductions by enabling companies to profit from reducing emissions below their allocated levels and by creating a price signal for carbon, thereby trying to internalize the cost of pollution. The EU ETS covers various sectors, including energy-intensive industries, aviation, and electricity generation, and has undergone several reforms over the years to enhance its effectiveness, address shortcomings, and align with evolving climate objectives.

High frequency identification. While a portion of the price signal reflects the stringency of this climate policy, a significant portion of the price variation also stems from endogenous responses to economic conditions. To address this concern, [Känzig \(2023\)](#) uses the numerous reforms and adjustments within the EU ETS framework, along with the price fluctuations sur-

rounding regulatory events, to establish a carbon policy surprise series. By measuring price changes within a narrow timeframe around regulatory announcements, the carbon policy surprise series isolates the impact of regulatory events on carbon prices. Furthermore, only regulatory events about the supply of emission allowances are used. This ensures that events do not release other information like the demand of allowances or the state of the economy.¹ Consequently, reverse causality, wherein economic conditions influence the constructed series, can reasonably be ruled out. In this study, I follow this approach and use the carbon policy surprise series introduced by Känzig (2023).

Specifically, the carbon surprise series is calculated as the difference between European Union Allowance (EUA) futures prices around 113 regulatory events and the prices on the last trading day preceding the event. This difference is then normalized relative to the prevailing wholesale electricity price on the day before the event:

$$CPSurprise_{t,d} = \frac{F_{t,d}^{\text{carbon}} - F_{t,d-1}^{\text{carbon}}}{P_{t,d-1}^{\text{elec}}} \quad (1)$$

where $F_{t,d}^{\text{carbon}}$ is the settlement price of the EUA futures contracts and $P_{t,d-1}^{\text{elec}}$ is the wholesale electricity price in month t on day d .

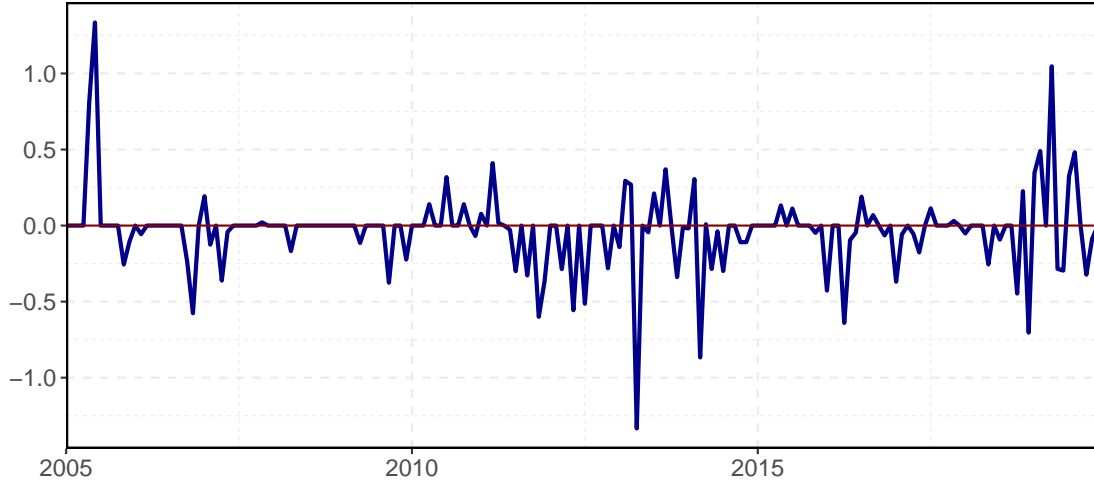


Figure 1: Carbon Policy Surprise Series

Notes: The carbon policy surprise series by Känzig (2023). The series is constructed as the price change of EUA around regulatory events and then normalized relative to the prevailing wholesale electricity price.

As usual in the high-frequency literature, the constructed surprise series is summed up to a monthly series. This monthly carbon policy surprise series is shown in Figure 1, months

¹Hence, also international conferences like the Conference of the Parties (COP) and other events are excluded.

without an event are set to 0. Lastly, [Känzig \(2023\)](#) performs a number of diagnostic checks. He shows, that the series is not serially correlated, forecastable by other variables or correlated with similar structural shocks like oil or uncertainty shocks.

3 Empirical Framework

Given our interest in understanding the causal dynamic responses of economic and climate variables to a carbon policy surprise shock, which results in price increases, our objective is to analyze impulse response functions. Therefore, we are faced with a choice between two main methodologies: Local Projections (LP) proposed by [Jordà \(2005\)](#) and Structural Vector Autoregressions (SVAR). A long held believe was that LPs are more robust to misspecification while SVARs are more efficient. However, recent research by [Plagborg-Møller and Wolf \(2021\)](#) demonstrates that both methods estimate the same impulse response function in population, irrespective of the identification scheme and the underlying data-generating process. Although this research establishes that SVAR and LP are not conceptually different, determining which estimator to employ in finite samples remains unclear from these findings. To address this, [Li et al. \(2024\)](#) provides guidance based on simulation studies. They reveal a bias-variance trade-off, where LP estimators exhibit lower bias compared to VAR estimators, albeit with a trade-off of significantly higher variance at longer horizons.

Given our interest in longer horizon impulse response functions, as shifts towards greener technologies or reductions in greenhouse gases may take a longer time to materialize following an increase in EU carbon prices, I follow their suggestion that least-squares VARs are the most attractive choice for longer horizon IRFs if the researcher also prioritizes precision.

3.1 Econometric Framework

Formally, let us consider a system of M variables denoted as $\mathbf{y}_t = (y_{1t}, y_{2t}, \dots, y_{Mt})'$ observed over T time periods. A vector autoregression model of p order (VAR) is specified as:

$$\mathbf{y}_t = \mathbf{b} + \mathbf{B}_1\mathbf{y}_{t-1} + \mathbf{B}_2\mathbf{y}_{t-2} + \dots + \mathbf{B}_p\mathbf{y}_{t-p} + \varepsilon_t \quad (2)$$

where \mathbf{b} is a $M \times 1$ vector of intercepts, \mathbf{B}_i are $M \times M$ coefficient matrices for $i = 1, 2, \dots, p$, capturing the lagged effects of the variables, and ε_t is a $M \times 1$ vector of error terms assumed to follow a multivariate normal distribution with mean zero and a positive definite covariance matrix Σ .

To estimate the dynamic causal effects – the impulse response functions (IRFs) – we utilize a block-recursive identification scheme. This is achieved by applying a Cholesky decomposition to impose restrictions on the covariance matrix of the error terms (Σ), decomposing it into a lower triangular matrix (L) such that $\Sigma = LL'$. This ensures that the shocks are ordered to reflect the assumed causal relationships among variables. Since our focus lies on the causal effects of a carbon policy surprise, we order the instrument z_t first, leading to $y_t = (z_t, y_{1t}, y_{2t}, \dots, y_{Mt})'$. Notably, [Plagborg-Møller and Wolf \(2021\)](#) demonstrate that employing an internal instrument approach – i.e., prioritizing the ordering of the instrument – consistently estimates the dynamic causal effect, even in the presence of measurement errors.

Lastly, confidence intervals are constructed using the moving block bootstrap method proposed by [Jentsch and Lunsford \(2019\)](#). This method is the most conservative choice and generally results in the wider confidence intervals, which, as noted by [Mertens and Ravn \(2019\)](#), can be particularly broad for the 90% confidence intervals. However, since this is still ongoing research, I stick with the conservative choice.

3.2 Empirical Specification

Following [Känzig \(2023\)](#), I jointly model the EU economy and carbon market using the following variables. Greenhouse Gas (GHG) emissions are included to capture the climate impact of carbon policy surprises². The price index and its energy component reflect the reaction of prices, while the two-year interest rate indicates potential subsequent monetary interventions. Industrial production and unemployment represent the state of the economy. Finally, Brent Crude Oil Price and the stock market, both deflated using the CPI, serve as the financial indicators. The model is estimated on a sample spanning from January 2000 to December 2019.

In a second step, to assess whether the EU ETS generates economic or climate spillovers beyond Europe, I add global variables to the VAR model: aggregated GHG emissions outside Europe³ and a non-European global industrial production index⁴. Further details on data sources, construction methods, and sources are provided in Appendix [A.](#)

Furthermore, following a broad literature, I estimate the VAR in log-levels, only the unemployment rate and two-year rate enter in levels. Lastly, I use six lags and a constant in the

²As in [Känzig \(2023\)](#), I use industrial production and energy prices as relevant indicators for the Chow-Lin temporal disaggregation. This temporal disaggregation is necessary to construct monthly time series, as GHG emissions data are only available on an annual basis.

³As with European GHG emissions, I use the Chow-Lin temporal disaggregation method with industrial production and headline prices as key indicators. Unfortunately, energy price data is unavailable for many countries, necessitating the use of headline prices.

⁴The index is constructed using production weights from the CPB.

baseline specification.

4 Spillovers from EU Carbon Pricing

4.1 Aggregate impact on emissions and economic activity

In this section, we explore the effects of a carbon policy shock on macroeconomic and emission variables within the Euro Area (EA) and examine whether such shocks spill over to the rest of the world. Figure 2 and 3 show the impulse response following a carbon policy shock that increases EA energy prices by 1% upon impact. The solid lines represent the point estimates, while the shaded areas indicate the corresponding 68 and 90 percent confidence intervals. Lastly, I focus on and discuss only the additional variables included when evaluating spillover effects.

Euro Area Variables. We begin our empirical analysis by examining the responses within Europe, presented in Figure 2. An unexpected tightening of carbon policy regulations, leading to increased carbon prices, triggers an immediate surge in energy prices and a sustained reduction in greenhouse gas emissions, indicating the effectiveness of carbon pricing in curbing emissions. However, there's a delayed decline in industrial production and a subsequent rise in unemployment, indicating the economic costs associated with carbon pricing. Additionally, the rise in energy and headline prices precedes an increase in the two-year rate, suggesting a tightening of monetary policy in response to inflationary pressures. Notably, the onset of central bank tightening coincides with a decrease in industrial production. Oil prices exhibit a short-lived increase followed by a gradual decrease.⁵ Lastly, the impact on stock prices is weak, with significance observed only at the three-month horizon, suggesting that carbon pricing has limited transmission through stock markets overall.

In terms of magnitude, measured at the peak of the responses, the shock increases energy prices by slightly over two percent, while headline prices experience an increase of 0.2%. Concurrently, greenhouse gas emissions decline as much as one percent, and industrial production contracts by more than 0.9%. The unemployment rate rises by 0.23 percentage points and interest rates by 0.68 percentage points. Lastly, oil prices surge by nearly 9 percent before experiencing a subsequent decline exceeding 4%, and the stock market rises by over 3 percent. All responses, except for stock prices, are economically and statistically significant.

The findings concerning the Euro Area (EA) variables align with those documented in

⁵The immediate increase in oil prices is expected since European oil producers and refineries are also covered by the EU ETS.

Känzig (2023). The impulse response functions reveal a persistent impact on GHG emissions and a modest negative effect on industrial production, suggesting an increase in energy efficiency. Regarding the transmission channels, the impulse response functions suggest that the effect of elevated carbon prices propagates through the energy and headline prices. Furthermore, Känzig (2023) also observes a surge in green innovation, which implies that firms perceive a positive carbon policy shock not merely as a transitory event, but rather as an indication of policymakers' commitment to addressing climate change. This could also explain the more persistent effect of GHG emissions.

Spillovers. Figure 3 shows the impulse response function for variables outside of Europe. Interestingly, the analysis reveals a downturn in worldwide industrial production and a reduction in GHG emissions outside of Europe. Unlike the in the EA, where GHG emissions exhibit a rapid decline followed by a sustained low level, emissions outside of Europe experience a more gradual reduction and appear to be a bit less persistent. Furthermore, the magnitude of emission reduction is less than observed in the EA, amounting to around 0.7%. Conversely, the impulse response function for industrial production exhibits a similar pattern within and outside of Europe. Regarding the extent of decline, non-EA industrial production contracts by 1.2%, which is slightly more than in the EA, but falls within a comparable range. Notably, both responses are economically and statistically significant.

These findings provide no evidence of carbon leakage, aligning with some existing literature (see, for example, Naegele and Zaklan (2019) or Verde (2020)). However, unlike prior studies, our use of a VAR framework allows for estimating the dynamic causal effect of EU carbon pricing on greenhouse gas emissions, revealing a significant, though gradual, decline in emissions. Given the similarity in the impulse response function shapes for industrial production within the EA and outside of Europe, along with GHG emissions outside of Europe, a question arises regarding the transmission mechanism of the carbon policy shock to countries beyond Europe.

The transmission mechanism of the shock outside the EA warrants further investigation. The observed decline in non-EA industrial production –and, more critically, the reduction in non-EA GHG emissions– could potentially be an indirect effect of the downturn in EA industrial production. This raises the possibility that elevated carbon prices may lack a lasting impact on GHG emissions outside of Europe, or worse, could mask instances of carbon leakage.

Robustness. Appendix C. presents a series of robustness checks to validate the findings. Firstly, I employ an external instrument VAR instead of an internal instrument VAR (Stock

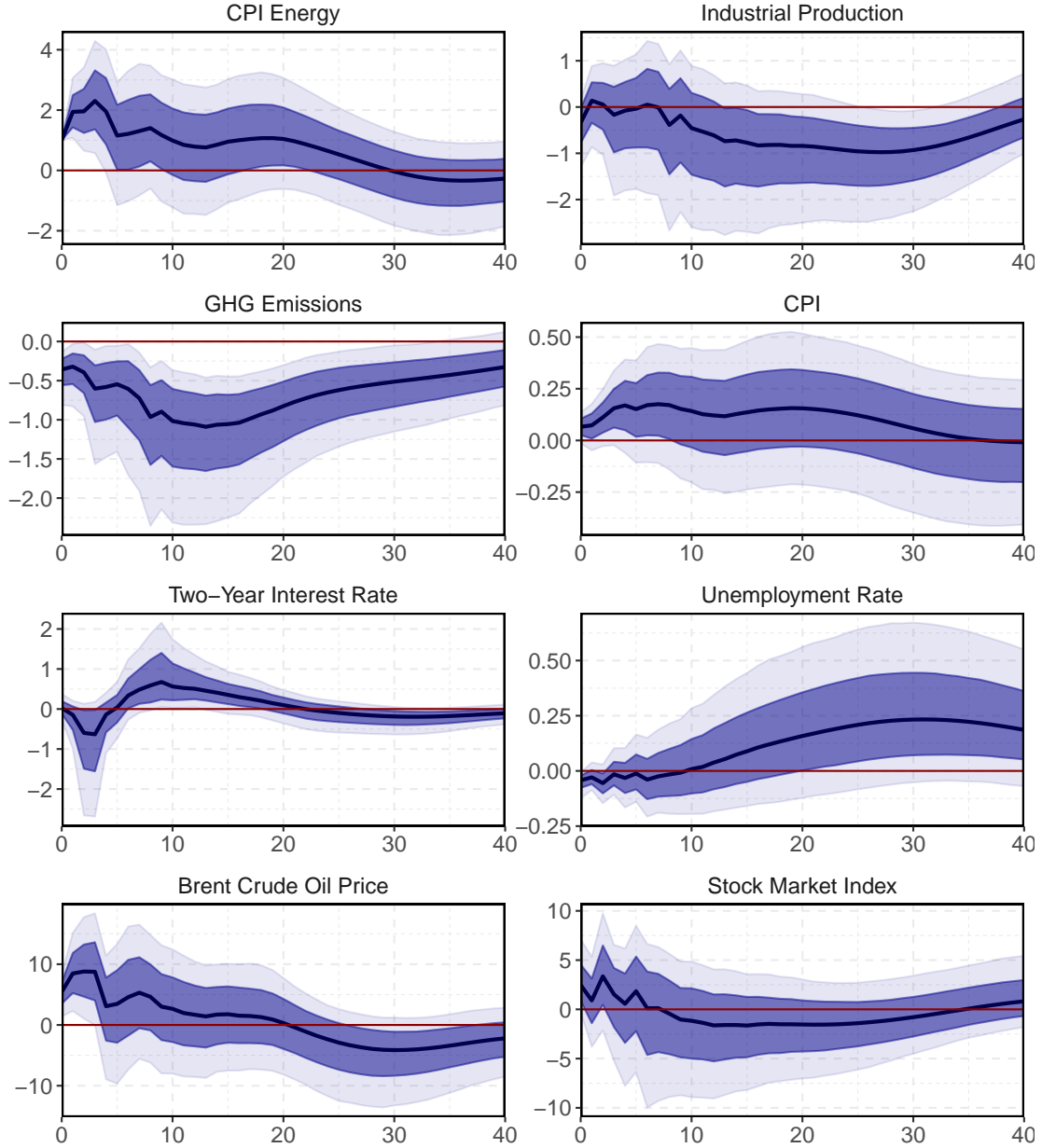


Figure 2: Impulse Responses to a Carbon Policy Shock within Europe

Notes: Impulse responses to a carbon policy shock, normalized to increase CPI energy by 1 percent upon impact. The solid line represents the point estimate, while the dark and light shaded areas indicate the 68 and 90 percent confidence intervals, respectively.

and Watson, 2012; Mertens and Ravn, 2013). Plagborg-Møller and Wolf (2021) demonstrate that both methods estimate the same impulse response function; however, the external instrument VAR entails an additional assumption of invertibility. Figure C.1 shows the impulse response functions obtained from the external VAR approach. Encouragingly, the results exhibit substantial similarity. However, the responses are slightly smaller when it comes to magnitude compared to the external instrument VAR; nevertheless, the response still remain persistently

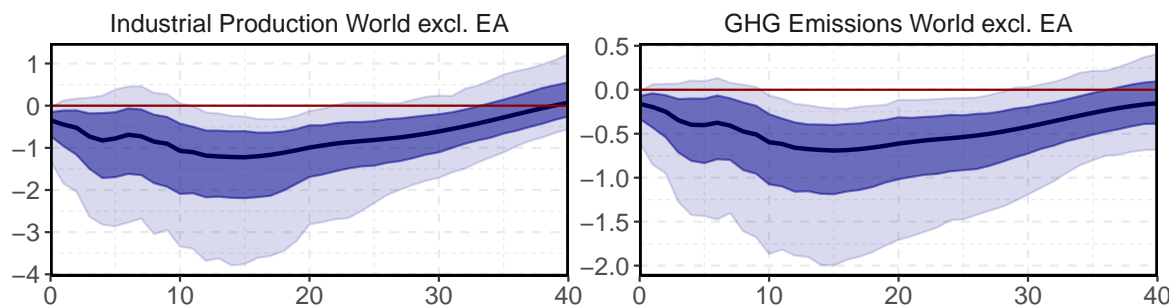


Figure 3: Impulse Responses to a Carbon Policy Shock outside of Europe

Notes: Impulse responses to a carbon policy shock, normalized to increase CPI energy by 1 percent upon impact. The solid line represents the point estimate, while the dark and light shaded areas indicate the 68 and 90 percent confidence intervals, respectively.

and significantly negative. The high degree of consistency between the IRFs bolster the previously presented findings about the spillover effects. Furthermore, some properties of the external instrument VAR will come in handy later when we explore the transmission mechanism.

Secondly, I estimate the internal instrument VAR with global Brent Crude Oil Prices instead of European ones, and a global financial market index instead of an European. This allows us to gauge if a carbon policy surprise shock transmits through global oil prices or financial markets and if they markedly change the response of worldwide industrial production or GHG emissions. Figure C.2 shows that the results stay virtually the same. Hence, this consistency in results underscores the robustness of the findings, affirming that they are not overly sensitive to the choice of variables in the VAR.

Lastly, in figure C.3, I provide evidence that the results are robust to different lag structures.

The findings remain consistent regardless of whether we employ an internal or external instrument VAR and the empirical specification concerning variables or lag structure.

5 The transmission of EU Carbon Pricing Spillovers

5.1 Counterfactual analysis

While the presence of interdependencies among variables is a notable advantage of Structural Vector Autoregression (SVAR) models, it can also complicate structural analysis, as the channels through which shocks propagate are not always evident. Structural Scenario Analysis (SSA), introduced by [Antolin-Diaz et al. \(2021\)](#), offers a popular approach for analyzing and quantifying the transmission channels of exogenous shocks in SVAR models (see, for example, [Breitenlechner et al. \(2022\)](#), [Geiger and Güntner \(2024\)](#), [Georgiadis et al. \(2024\)](#) or [Boer et al. \(2024\)](#)). In

our case, we seek to understand how variables react when we eliminate the indirect effect of a carbon policy shock transmitted via Euro Area (EA) industrial production.

The counterfactual scenario, where EA industrial production does not respond to a carbon policy surprise shock in period t , can be formalized as follows⁶. Assume the system is in its long-run equilibrium in period $t - 1$ before a carbon policy surprise occurs in period t . We then identify the minimal and least correlated shocks needed in periods $t, t + 1, \dots, t + h$ to neutralize the impact of the carbon policy surprise in period t on EA industrial production. Conceptually, this counterfactual represents the most likely scenario in which EA industrial production remains unchanged following a carbon policy surprise, therefore reflecting conditions that could realistically be observed.

To start with we rewrite the VAR model in equation 2 as a forecast of the endogenous variables and iterate forward from period t to $t + h$,

$$\mathbf{y}_{t,t+h} = \mathbf{b}_{t,t+h} + \boldsymbol{\phi}' \boldsymbol{\epsilon}_{t,t+h}, \quad (3)$$

where $\mathbf{y}_{t,t+h} \equiv (\mathbf{y}'_t, \mathbf{y}'_{t+1}, \dots, \mathbf{y}'_{t+h})'$ stacks the conditional forecasts of the endogenous variables and $\boldsymbol{\epsilon}_{t,t+h} \equiv (\boldsymbol{\epsilon}'_t, \boldsymbol{\epsilon}'_{t+1}, \dots, \boldsymbol{\epsilon}'_{t+h})'$, stacks the structural shocks for periods $t, t + 1, \dots, t + h$. The vector $\mathbf{b}_{t,t+h}$ represents the initial conditions at period $t - 1$ and $\boldsymbol{\phi}'$ captures the effects of the structural shocks in terms of impulse responses. Since we assume that the system is in its long-run equilibrium in period $t - 1$, $\mathbf{b}_{t,t+h} = 0$. The impulse responses to a period- t carbon policy surprise coincides with the forecast $\mathbf{y}_{t,t+h}$ conditional on $\boldsymbol{\epsilon}_{t,t+h}$, where the carbon policy shock is $\epsilon_t^{cp} = 1$, $\epsilon_{t+s}^{cp} = 0$ for $s > 0$, and $\epsilon_{t+s}^\ell = 0$ for $s \geq 0$, $\ell \neq cp$.

Next, we need to make sure, that a carbon policy shock does not affect EA industrial production since our goal is to receive a counterfactual where EA industrial production is unchanged after a carbon policy surprise. For that, we need a set of additional shocks $\tilde{\boldsymbol{\epsilon}}_{t,t+h}$ over the forecasting horizon $t + h$ who exactly offset the effect of a carbon policy surprise on EA industrial production. The counterfactual impulse response functions are then given by

$$\tilde{\mathbf{y}}_{t,t+h} = \boldsymbol{\phi}' \tilde{\boldsymbol{\epsilon}}_{t,t+h} \quad (4)$$

Since we are interested in the most likely scenario, rather than a scenario where a specific shock offsets the response of EA industrial production, I use the set of EA economic and

⁶The formal description of the SSA closely follows Breitenlechner et al. (2022), Geiger and Güntner (2024) and Georgiadis et al. (2024).

financial shocks – excluding GHG emissions – to construct a counterfactual where EA industrial production remains unchanged. Using multiple shocks also leads to multiple possible solutions. [Antolin-Diaz et al. \(2021\)](#) show how to select the shocks so they are the smallest and least correlated shocks possible. Hence, the counterfactual exercise represents a plausible scenario where the EA economic conditions following a carbon policy shock are such that EA industrial production remains the same.

Consequently, the impact of the shock through EA industrial production can be gauged as the disparity between the actual unrestricted impulse response function and the counterfactual impulse response function.

Figures 4 and 5 show the unrestricted actual impulse response functions in black, with the respective 68 and 90 percent confidence bands, and in red the counterfactual impulse response functions where the transmission channel through EA industrial production is shut down.

Euro Area Variables. Again we begin our empirical analysis by examining the responses within Europe, presented in Figure 4. The restricted impulse response functions of prices and macroeconomic variables show expected patterns. In the absence of an economic downturn, as indicated by a negative response in industrial production in the unrestricted response, prices remain elevated, resulting in prolonged restrictive monetary policy and consequently higher interest rates. The trajectory of unemployment rate evolves around zero over all horizons. Oil prices stabilize around zero after two years without descending much into negative territory, while the stock market experiences a higher and prolonged positive reaction. Notably, despite the absence of a decrease in industrial production, a pronounced negative response in greenhouse gas (GHG) emissions persists. This observation suggests that while a portion of the reduction in GHG emissions following a carbon policy shock can be attributed to diminished economic activity, the majority is not. These findings further bolster the interpretation that companies perceive a positive carbon policy shock not merely as a transient event but as a manifestation of policymakers’ commitment to addressing climate change.

Spillovers. Figure 5 shows the impulse response function for variables outside of Europe. The response of global industrial production displays a significant difference when the transmission channel through EA industrial production is eliminated. Evidently, a substantial portion of the adverse impact of EU carbon pricing on non-EA economic activity is transmitted via EA industrial production. This observation is consistent with research on business cycle synchronization and the intricate economic interdependencies between the Euro Area (EA) region and the world

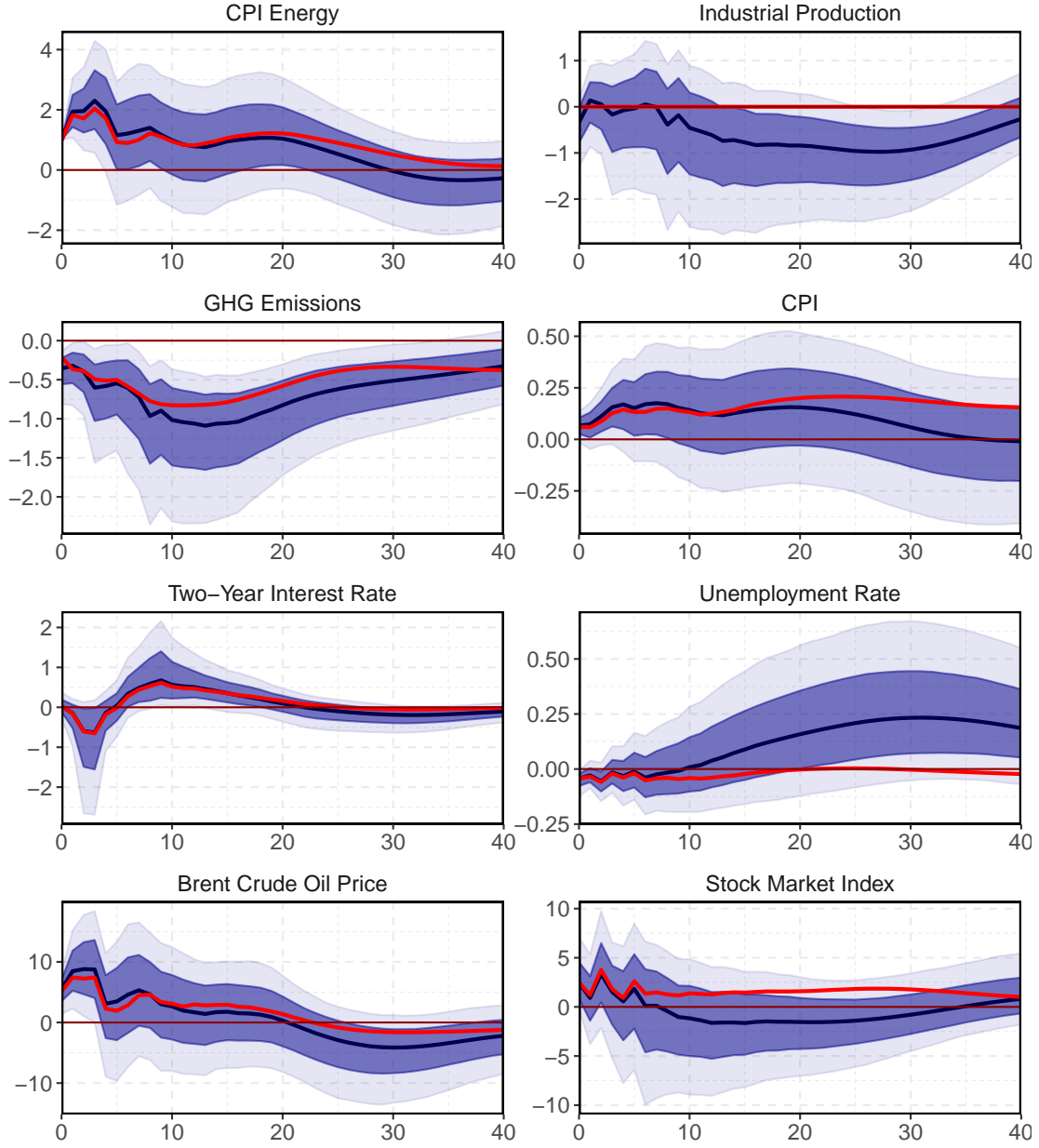


Figure 4: Impulse Responses to a Carbon Policy Shock and the Counterfactual within Europe

Notes: Impulse responses to a carbon policy shock, normalized to increase CPI energy by 1 percent upon impact. The solid line represents the point estimate, while the dark and light shaded areas indicate the 68 and 90 percent confidence intervals, respectively. The red line illustrates the counterfactual impulse response function, assuming no change in EA industrial production following the carbon policy shock.

economy, as documented in the literature (Frankel and Rose, 1998; Inklaar et al., 2008).

Despite the reduced impact on global industrial production in this counterfactual analysis, it is notable that GHG emissions outside Europe still experience a significant and similar decline compared to the unrestricted scenario. In the short run, some of the emissions reduction is driven by the contraction in industrial production. Nevertheless, the response remains negative,

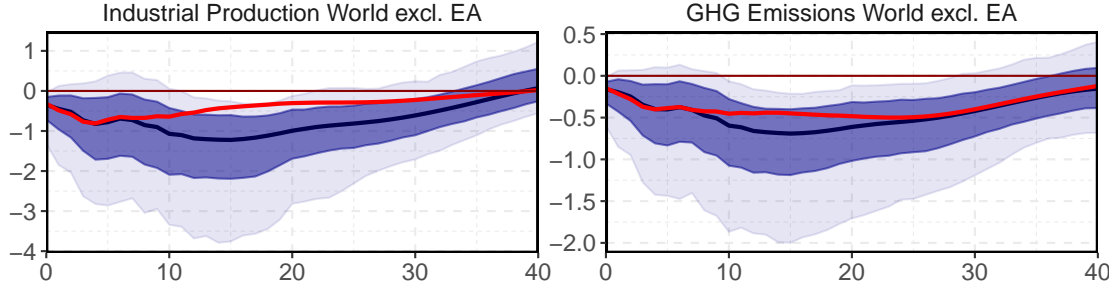


Figure 5: Impulse Responses to a Carbon Policy Shock and the Counterfactual outside of Europe

Notes: Impulse responses to a carbon policy shock, normalized to increase CPI energy by 1 percent upon impact. The solid line represents the point estimate, while the dark and light shaded areas indicate the 68 and 90 percent confidence intervals, respectively. The red line illustrates the counterfactual impulse response function, assuming no change in EA industrial production following the carbon policy shock.

showing a meaningful drop in GHG emissions. While these results are promising from a climate policy perspective, they raise important questions about the alternative mechanisms through which carbon policy shock spillovers occur when not transmitted via industrial production.

5.2 Are carbon policy shock interpreted as news about future climate policies?

Climate spillovers resulting from carbon policy shocks appear to transmit only weakly through industrial production. Consequently, we extend our analysis to explore whether a carbon policy surprise under the EU Emissions Trading System influences agents' expectations about climate policy, which would suggest the existence of the *Brussels Effect* regarding the EU ETS. Coined by [Bradford \(2020\)](#), the *Brussels Effect* describes the global reach of EU regulations, both in de facto and de jure terms, whereby stringent EU standards often shape regulatory practices worldwide. To explore this aspect, we first use stock market indices, as they reflect the market's anticipations regarding future economic developments, including those influenced by climate policies, particularly with respect to brown and green stocks ([Beaudry and Portier, 2006](#); [Monasterolo and De Angelis, 2020](#)). And secondly we check if actual regulations change by using the newly developed OECD Climate Actions and Policies Measurement Framework (CAPMF) ([Nachtigall et al., 2022](#)).

Stock market. We anticipate that if a carbon policy shock reinforces the market's perception of stricter climate policies in the future, brown stocks would depreciate in value, while green stocks would appreciate. Previous research explicitly examines how stock markets respond to climate policies. For instance, [Monasterolo and De Angelis \(2020\)](#) scrutinize market reactions to

the 2015 Paris Agreement, while [Bauer et al. \(2023\)](#) investigate market responses to the Inflation Reduction Act, which represents the most significant climate policy action undertaken in the US. Additionally, [Hengge et al. \(2023\)](#) demonstrate that green stocks in the EU outperform brown stocks subsequent to a carbon policy surprise —defined similarly as in this study—in a sample spanning from 2011 to 2021.

To assess whether international market expectations indeed change in response to a EU carbon policy shock, potentially leading to a reduction in greenhouse gas (GHG) emissions, I utilize the S&P 500 Integrated Oil & Gas index to represent brown stocks and the NASDAQ index to proxy green technology. While the selection of the S&P 500 Integrated Oil & Gas index is straightforward, no green stock indices are available dating back to 2000, which marks the beginning of our sample period used in the Vector Autoregression (VAR) analysis⁷. Therefore, as an alternative, I utilize the NASDAQ index, given that many firms associated with advanced technologies are listed on the NASDAQ. Nonetheless, I also examine the impact of carbon pricing on six green stock market indices and five brown indices in an event study setup.

Figure 6 shows the impulse response function of the two stock indices. Once again, the black line represents the point estimate, while the shaded areas denote the corresponding confidence bands. The negative response of the S&P Integrated Oil & Gas index and the positive response of the NASDAQ index indicate that markets indeed anticipate climate change will assume a more prominent role in policymaking or, at the very least, in the economic performance of companies. This incentivizes firms to reduce their carbon emissions to garner favorability among investors, thereby explaining the decline in GHG emissions outside of Europe. Furthermore, Figure B.1 presents the results of the counterfactual exercise similar to the one previously discussed, revealing qualitatively and quantitatively very similar outcomes. This further supports the idea that these stock market movements are influenced by expectations about future climate policies rather than current economic performance.

To demonstrate that these results are not contingent on the specific indices utilized, and considering the imperfect substitution of the NASDAQ for a green stock index, I employ an event study approach to examine the effect of a carbon policy surprise on six green and five brown stock market indices. Formally, I estimate the following local projections for every stock market index i :

$$y_{t+h}^i - y_{t-1}^i = \alpha_h^i + \beta_h^i CPSurprise_t + \theta_{h,1}^i (y_{t-1}^i - y_{t-2}^i) + \dots + \theta_{h,p}^i (y_{t-1}^i - y_{t-p+1}^i) + \epsilon_{t+h}^i \quad (5)$$

⁷Since the number of variables is potentially already at the upper limit, I include the stock market indices rather than oil prices and the European stock market index.

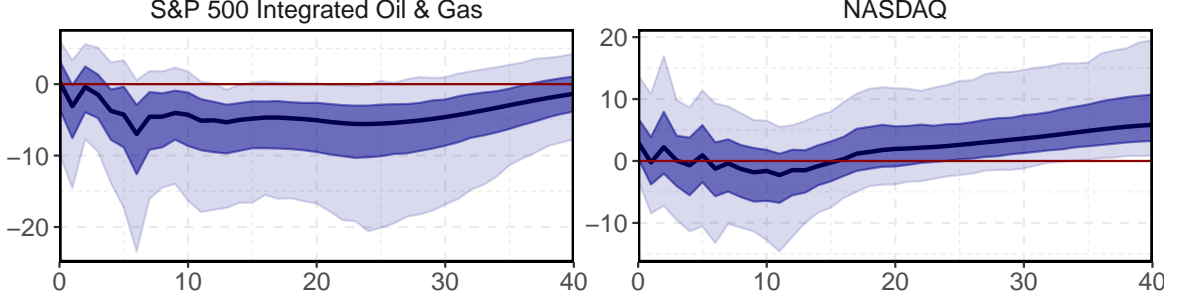


Figure 6: Stock Market Reactions to a Carbon Policy Shock

Notes: This figure displays the impulse responses of the two stock market indices to a carbon policy shock, estimated by incorporating these variables into the VAR model rather than oil prices and the European stock market index. The solid line represents the point estimate, while the dark and light shaded areas indicate the 68% and 90% confidence intervals, respectively.

where y_t^i denotes the log of the stock market index of interest at time t , h is the horizon in months, $CPSurprise_t$ is the carbon policy surprise series and β_h^i is the coefficient of interest. We control for $p = 3$ lags.

Figure 7 illustrates the percentage change of green and brown stock indices following a carbon policy surprise. In particular, we observe a substantial divergence in the returns of green and brown stocks after such an event. Importantly, these results remain robust across different indices used, bolstering the earlier findings obtained from the VAR setup. Additionally, Figure B.2 in Appendix B. demonstrates that the results are not only economically significant but also statistically robust.

Overall, the results of both the Vector Autoregression (VAR) and the event study suggest that expectations regarding future climate policies or the economic performance of brown and green firms undergo substantial shifts following a carbon policy surprise. This alteration in expectations serves as a plausible transmission channel, explaining, at least partly, the observed reduction in greenhouse gas (GHG) emissions following a carbon policy surprise.

Climate policies. While stock market indices provide insight into agents' expectations regarding future climate action, we further investigate the presence of a *Brussels Effect* by estimating changes in climate action policy stringency indices. For this analysis, I use the OECD Climate Actions and Policies Measurement Framework (CAPMF), the most comprehensive internationally harmonized climate mitigation policy database. The CAPMF tracks 130 policy variables aggregated into key climate actions and policies from 1990 to 2022 for 49 countries, including OECD members, partner countries, and the EU as a block (Nachtigall et al., 2022). It offers measures of policy stringency, defined as the extent to which policies incentivize emissions

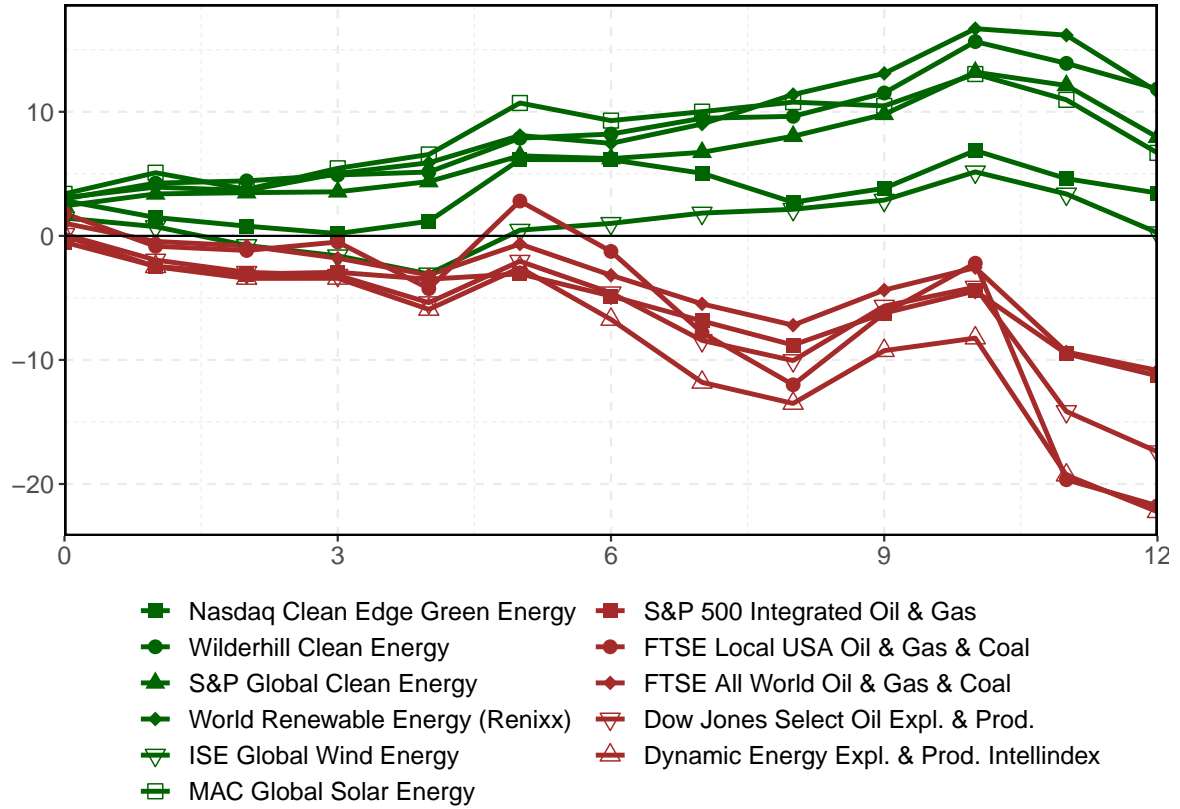


Figure 7: Stock Market Reactions to a Carbon Policy Surprise Estimated Using Local Projections

Notes: Impulse response functions to a carbon policy shock estimated using local projections. The lines represent the point estimates of the stock indices.

reductions, along with average stringency values and the number of adopted policies across various sectors and policy areas. In the following analysis, I make a distinction between different building blocks: sectoral policies, cross-sectoral policies, and international policies. The main difference between these blocks lies in their scope and application: sectoral policies are targeted at specific economic sectors or sources of emissions, cross-sectoral policies address emissions across multiple sectors without being confined to one, and international policies involve commitments that span national borders, requiring coordination and cooperation among multiple countries to address global climate challenges. I estimate the impact on the policy stringency index for countries outside of the EU.

While I used the carbon policy surprise series directly when estimating effects on stock market indices, for this analysis I utilize the carbon policy shock retrieved from the monthly external instrument VAR (see Figure C.1), since policy stringency indices are only available on an annual basis. This approach addresses the challenges of using high-frequency surprises

with low-frequency data. As discussed by [Stock and Watson \(2018\)](#) and emphasized by [Känzig \(2023\)](#), aggregating high-frequency surprises to lower frequencies can complicate estimation due to their small and sparse nature, resulting in a low signal-to-noise ratio ([Nakamura and Steinsson, 2018](#)). By estimating shocks at a higher frequency (i.e. in a monthly external instrument VAR), where the signal-to-noise ratio is stronger, and subsequently aggregating to the annual level, we improve the power of our analysis (also see e.g. [Hensel et al., 2024](#)). This method enables us to accurately capture the dynamic causal effects of EU carbon pricing on annual climate policy stringency indices. Formally we estimate the following panel local projections for the three different building blocks of the indices:

$$y_{t+h}^{i,c} - y_{t-1}^{i,c} = \alpha_h^{i,c} + \beta_h^i CPShock_t + \theta_{h,1}^i (y_{t-1}^{i,c} - y_{t-2}^{i,c}) + \dots + \theta_{h,p}^i (y_{t-1}^{i,c} - y_{t-p+1}^{i,c}) + \epsilon_{t+h}^i \quad (6)$$

where $y_t^{i,c}$ the stringency index for policy i and country c at time t , h is the horizon in years, $CPShock_t$ is the carbon policy shock series extracted from the monthly VAR and summed up to annual frequency and β_h^i is the coefficient of interest. Lastly, $\alpha_h^{i,c}$ are the country fixed effects. We control for $p = 3$ lags.

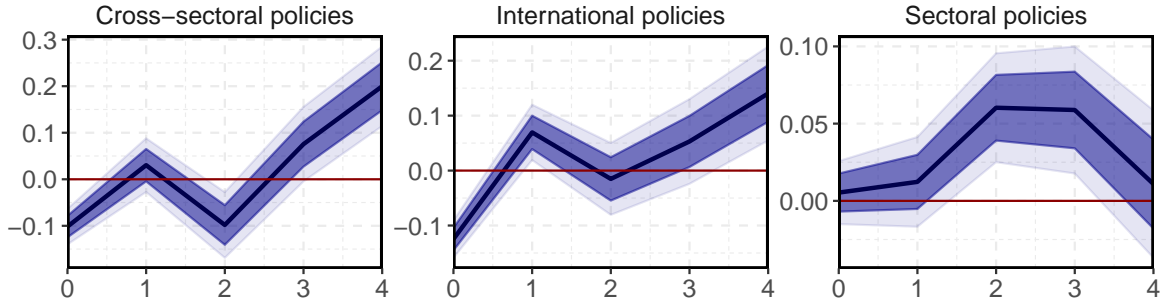


Figure 8: Policy Stringency Index Reactions to a Carbon Policy Shock Estimated Using Local Projections

Notes: Impulse response functions to a carbon policy shock estimated using local projections. The solid line represents the point estimate, while the dark and light shaded areas indicate the 68 and 90 percent confidence intervals, respectively. Standard errors are corrected for autocorrelation using [Newey and West \(1987\)](#) standard errors.

Figure 8 shows the response of the climate policy stringency indices after a carbon policy shock. We clearly see, that across the different categories that climate policies outside of Europe get more stringent after an carbon policy shock. This further supports the notation of a *Brussels Effect* when it comes to the EU ETS and therefore could explain the decline in greenhouse gas emissions outside of Europe.

6 Region specific effects

While aggregate effects do not indicate evidence of carbon leakage, it is possible that such leakage could manifest in individual regions, masked by the aggregation. As carbon prices rise, the potential for leakage in these regions could intensify. Therefore, assessing whether economic and climate spillovers are already occurring in specific regions with unique characteristics can provide valuable insights into possible future leakage dynamics in these areas.

Advanced and Emerging Economies. We begin by examining spillovers to advanced economies (excluding the Euro Area) and emerging economies. Figure 9 presents the impulse response functions of industrial production and greenhouse gas (GHG) emissions for these two groups. The black line represents the aggregate point estimate, while the shaded area depicts the associated confidence intervals. The Vector Autoregression model is estimated separately for each group.

For industrial production, advanced economies excluding the Euro Area display relatively muted but consistently negative responses. Emerging economies, however, exhibit more pronounced and persistently negative reactions across all horizons. These patterns suggest that EU carbon policy shocks do not deliver economic benefits to either group.

GHG emissions in both advanced and emerging economies show negative responses, aligning with the global aggregate. Notably, there is no evidence of carbon leakage to emerging economies, as their emissions decline consistently following an EU carbon policy shock. Similarly, advanced economies outside the Euro Area experience a decline in emissions, albeit less pronounced. These findings highlight the effectiveness of carbon pricing in reducing emissions globally without generating adverse spillovers that compromise environmental goals. These findings are further validated through a counterfactual analysis, similar to the one presented earlier, as illustrated in Figure B.3.

A Closer Look at Emerging Economies. The results so far are encouraging from a climate policy perspective. However, the analysis has been conducted at relatively broad aggregation levels. To provide a more granular perspective, we also examine the smallest possible aggregation group for emerging economies. This additional analysis is particularly relevant given early theoretical research on carbon leakage from the EU Emissions Trading System. For instance, Babiker (2005) projected significant economic gains and high carbon leakage to certain emerging economies, such as China.

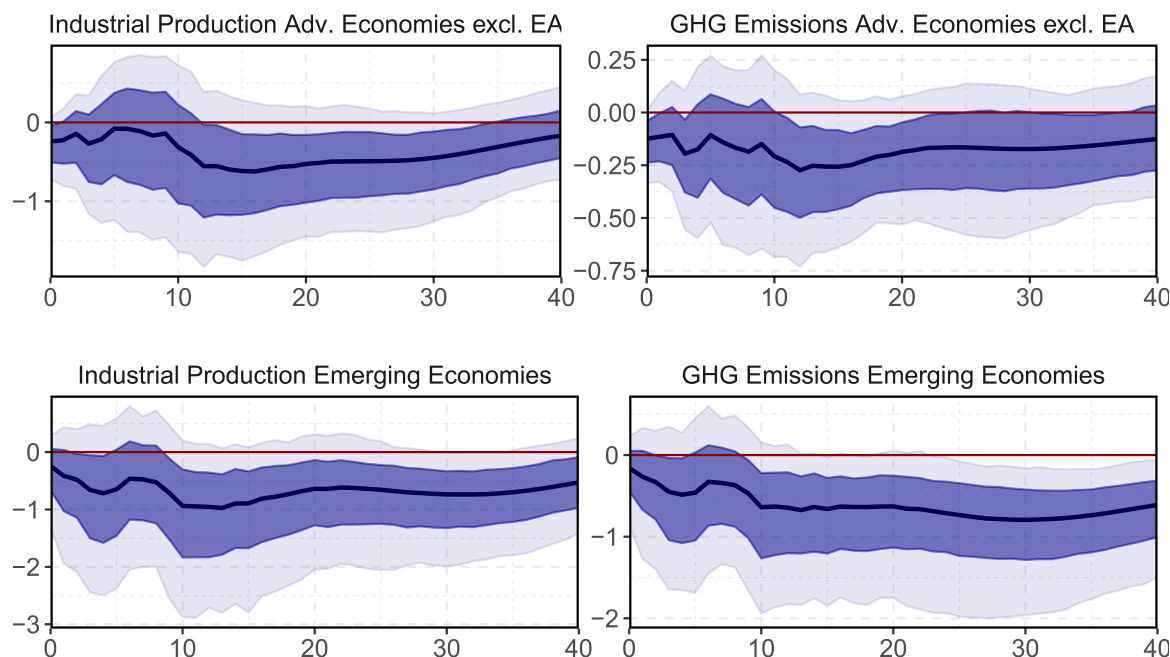


Figure 9: Impulse Responses to a Carbon Policy Shock for Emerging and Advanced Economies

Notes: Impulse responses to a carbon policy shock, normalized to increase CPI energy by 1 percent upon impact. The solid line represents the point estimate, while the dark and light shaded areas indicate the 68 and 90 percent confidence intervals, respectively.

Figure 10 illustrates the regional responses to a carbon policy shock. Notably, no region experiences economic benefits, reaffirming the conclusion that there are no economic beneficiaries from EU carbon pricing. Most regions show a decline in GHG emissions, with the notable exception of the Eastern Europe/CISS region, which exhibits short-term carbon leakage. Interestingly, China demonstrates a significant decline in emissions, contrary to prior ex-ante theoretical predictions.

While these findings generally support the effectiveness of EU carbon pricing in reducing emissions, the observed short-term carbon leakage in the Eastern Europe/CISS region underscores that leakage remains a concern. Moreover, [Känzig et al. \(2024\)](#) demonstrate that broader EU climate policies have contributed to carbon leakage in parts of Africa. Understanding why certain regions experience increases in GHG emissions while most show declines is critical to addressing the underlying dynamics of carbon leakage. Again, these findings are further validated through a counterfactual analysis, similar to the one presented earlier, as illustrated in Figure B.4.

Additionally, it is essential to determine whether high carbon prices exacerbate non-linear leakage dynamics and to identify the factors driving these divergent responses. Although a

detailed exploration of these issues is beyond the scope of this paper, they represent crucial areas for future research, given their significant implications for the effectiveness and long-term sustainability of carbon pricing policies.

7 Conclusion

This paper investigates the global economic and climate spillovers of the European Union Emissions Trading System. Using exogenous variations in EU carbon prices identified through a carbon policy surprise series, I analyze the dynamic effects of carbon policy shocks on greenhouse gas emissions and economic activity. The findings show that an increase in carbon prices within the Euro Area leads to a significant and sustained reduction in GHG emissions, albeit with short-term economic costs, such as higher prices and increased unemployment, aligning with recent literature.

Crucially, the analysis extends beyond the EA, demonstrating a global reduction in GHG emissions following EU carbon price increases, with no evidence of carbon leakage. However, the global climate impacts are less pronounced compared to the EA, and no region emerges as an economic beneficiary of EU carbon pricing. Through Structural Scenario Analysis, I show that the reduction in GHG emissions is not solely driven by decreased industrial production. Instead, the evidence suggests that carbon policy shocks serve as signals of future climate policies, influencing market expectations, investor behavior, and policy frameworks—suggesting a manifestation of the *Brussels Effect*.

Region-specific analyses reveal largely consistent responses across regions, with the notable exception of the Eastern Europe/CISS region, where short-term carbon leakage is observed. This highlights the complexity of global carbon policy impacts and underscores the need to better understand region-specific leakage dynamics.

Overall, the findings affirm the effectiveness of the EU ETS in reducing GHG emissions while highlighting the broader economic and climate spillovers. Future research should aim to unravel the mechanisms behind these spillovers and assess the implications of carbon leakage, particularly as rising carbon prices could amplify both leakage risks and economic impacts globally.

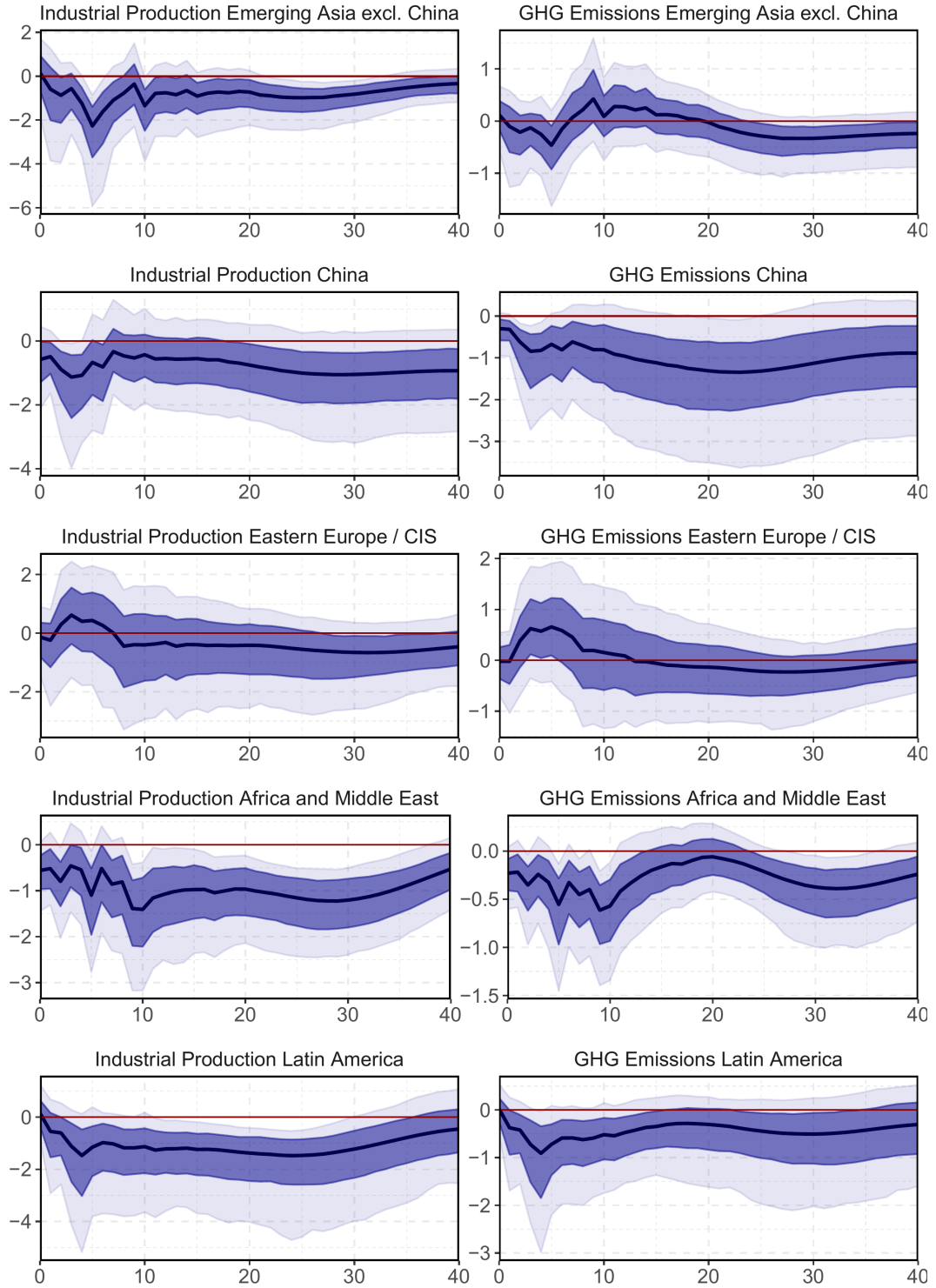


Figure 10: Impulse Responses to a Carbon Policy Shock for Emerging Economies Regions

Notes: Impulse responses to a carbon policy shock, normalized to increase CPI energy by 1 percent upon impact. The solid line represents the point estimate, while the dark and light shaded areas indicate the 68 and 90 percent confidence intervals, respectively.

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A. Data

In Appendix A., I provide further details on the data, the sources and construction of variables.

Table A.1: Variable Information

Variable	Description	Source
Variable for the VAR		
Consumer Price Index (CPI)	Consumer Price Index for all items	Eurostat for Europe and Ha et al. (2023) for rest of the world
Consumer Price Index Energy (CPI Energy)	Consumer Price Index for energy items	Eurostat
Industrial Production	Industrial Production Index	CPB World Trade Monitor
Greenhouse Gas Emissions	Total greenhouse gas emissions (kt of CO2 equivalent)	Climate Watch via Worldbank
Unemployment rate	Harmonised Unemployment Rate	Eurostat
Brent Crude Oil	Crude Oil Prices: Brent - Europe	FRED
Global Brent Crude Oil	Crude Oil Prices: Brent - World	FRED
Global price of Energy	Benchmark prices which are representative of the global market	FRED
Stock Market	EURO STOXX 50	Bloomberg
Global Stock Market	MSCI World	Bloomberg
Two-Year Interest Rate	Two-year government bond yield	ECB
NASDAQ	NASDAQ Composite Index	Bloomberg
S&P 500 Integrated Oil & Gas	S&P 500 sub-index for integrated oil and gas	Bloomberg
Variable for the event studies		
Nasdaq Clean Edge Green Energy	Clean energy index tracking companies in the green energy sector	Bloomberg
Wilderhill Clean Energy	Clean energy index focused on companies innovating for cleaner energy	Bloomberg
S&P Global Clean Energy	Clean energy index covering global clean energy companies	Bloomberg
World Renewable Energy (Renixx)	Index tracking global renewable energy companies	Bloomberg
ISE Global Wind Energy	Index tracking companies in the global wind energy sector	Bloomberg
MAC Global Solar Energy	Index tracking companies in the global solar energy sector	Bloomberg
FTSE Local USA Oil & Gas & Coal	Index covering US-based oil, gas, and coal companies	Bloomberg
FTSE All World Oil & Gas & Coal	Index covering global oil, gas, and coal companies	Bloomberg
Dow Jones Select Oil Expl. & Prod.	Index focusing on oil exploration and production companies	Bloomberg
Dynamic Energy Expl. & Prod. Intellindex	Index for energy exploration and production companies	Bloomberg
Climate Policies: Cross-sectoral	Measures of policy stringency, defined as the extent to which policies incentivize emissions	OECD; Nachtigall et al. (2022)
Climate Policies: International	Measures of policy stringency, defined as the extent to which policies incentivize emissions	OECD; Nachtigall et al. (2022)
Climate Policies: Sectoral	Measures of policy stringency, defined as the extent to which policies incentivize emissions	OECD; Nachtigall et al. (2022)

The analysis begins by constructing a unified dataset of all variables and aggregating the data to various regional levels. As documented in [Ebregt et al. \(2016\)](#), individual industrial production indices are not publicly available for all countries, and only aggregated data for specific regions can be accessed. To address this limitation, metadata is matched to identify the countries corresponding to each region, and this information is linked to the GHG emissions and consumer price index (CPI) data. Only countries with complete time series data for the period 2000–2019 are included in the dataset to ensure consistency and reliability.

The CPI data is seasonally adjusted using the X-13ARIMA-SEATS method to remove seasonal effect. For the aggregation of GHG emissions, the total emissions for each year are summed across all countries within a given region. In contrast, the aggregation of CPI indices requires weighting based on the relative economic importance of each country within the region. This weighting follows the methodology employed by the International Monetary Fund, which uses the world share of purchasing power parity (PPP)-adjusted GDP to assign appropriate weights.

The aggregated regional CPI and industrial production indices are subsequently used as explanatory variables for temporal disaggregation of GHG emissions using the Chow-Lin method (see e.g. [Sax and Steiner \(2013\)](#)). In the case of Europe, the energy component of the CPI is included as an explanatory variable. For other regions, this component is often unavailable; however, the results are robust to this limitation. Analyses indicate that the findings remain consistent even when only industrial production is used as an explanatory variable for the temporal disaggregation.

Figure [A.1](#) presents the transformed data as incorporated into the VAR model for the main analysis.

B. Additional Results

Appendix [B.](#) presents supplementary figures that provide further insights into the main analysis. Figures [B.1](#) and [B.2](#) illustrate the reactions of green and brown stock market indices to carbon policy shocks, confirming that market expectations about future climate policies play a significant role. Finally, Figure [B.3](#) and Figure ?? details the individual country responses of GHG emissions to a carbon policy shock, highlighting the heterogeneity across non-EA OECD and BRICS countries.

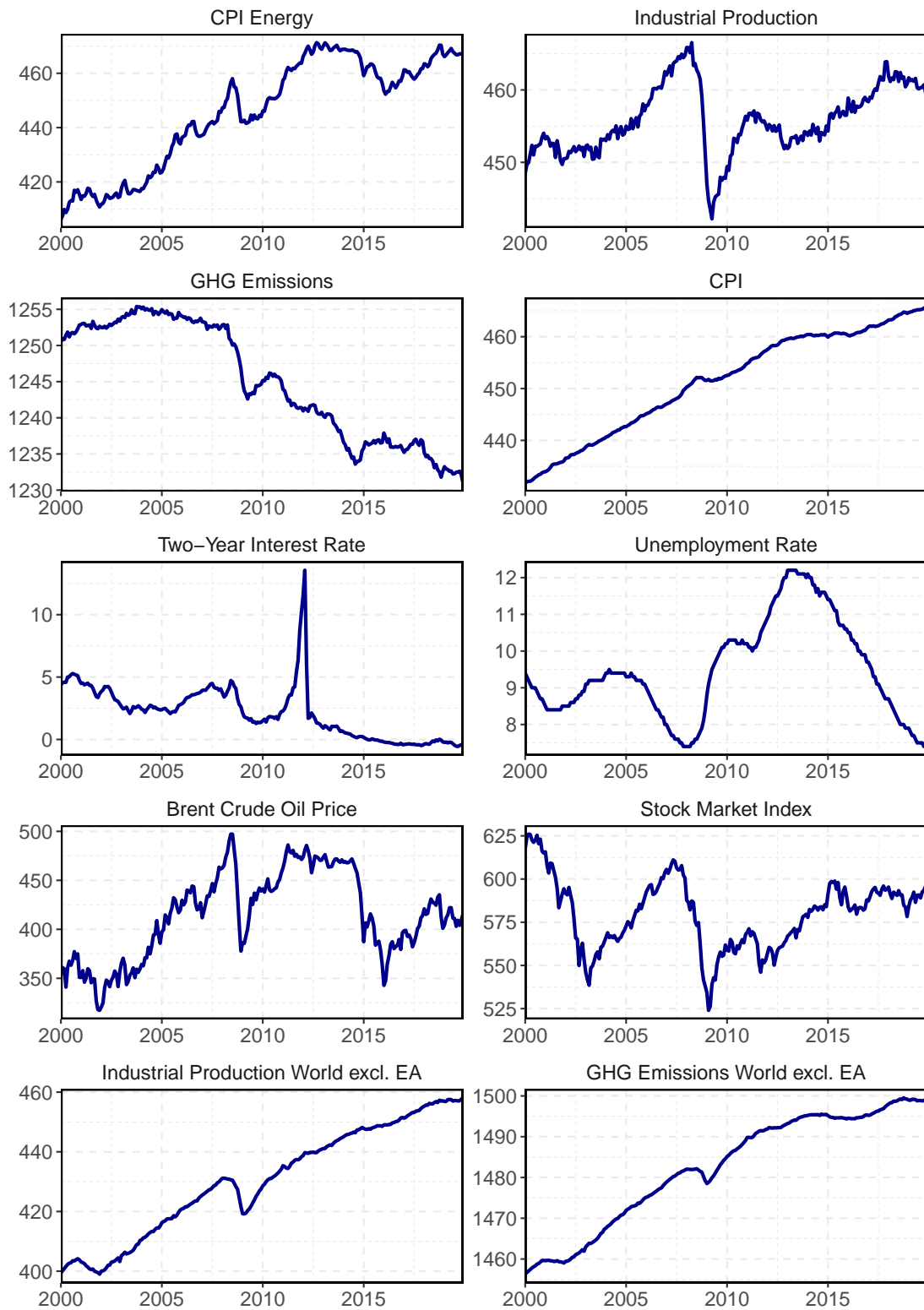


Figure A.1: Transformed Data Used in the VAR Model

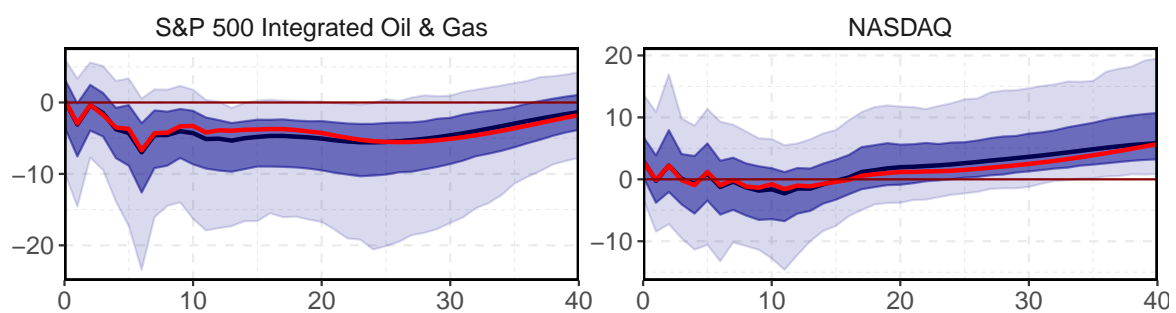


Figure B.1: Stock Market Reactions to a Carbon Policy Shock and the Counterfactual

Notes: This figure displays the impulse responses of the two stock market indices to a carbon policy shock, estimated by incorporating these variables into the small VAR model. The solid line represents the point estimate, while the dark and light shaded areas indicate the 68% and 90% confidence intervals, respectively. The red line illustrates the counterfactual impulse response function, assuming no change in EA industrial production following the carbon policy shock.

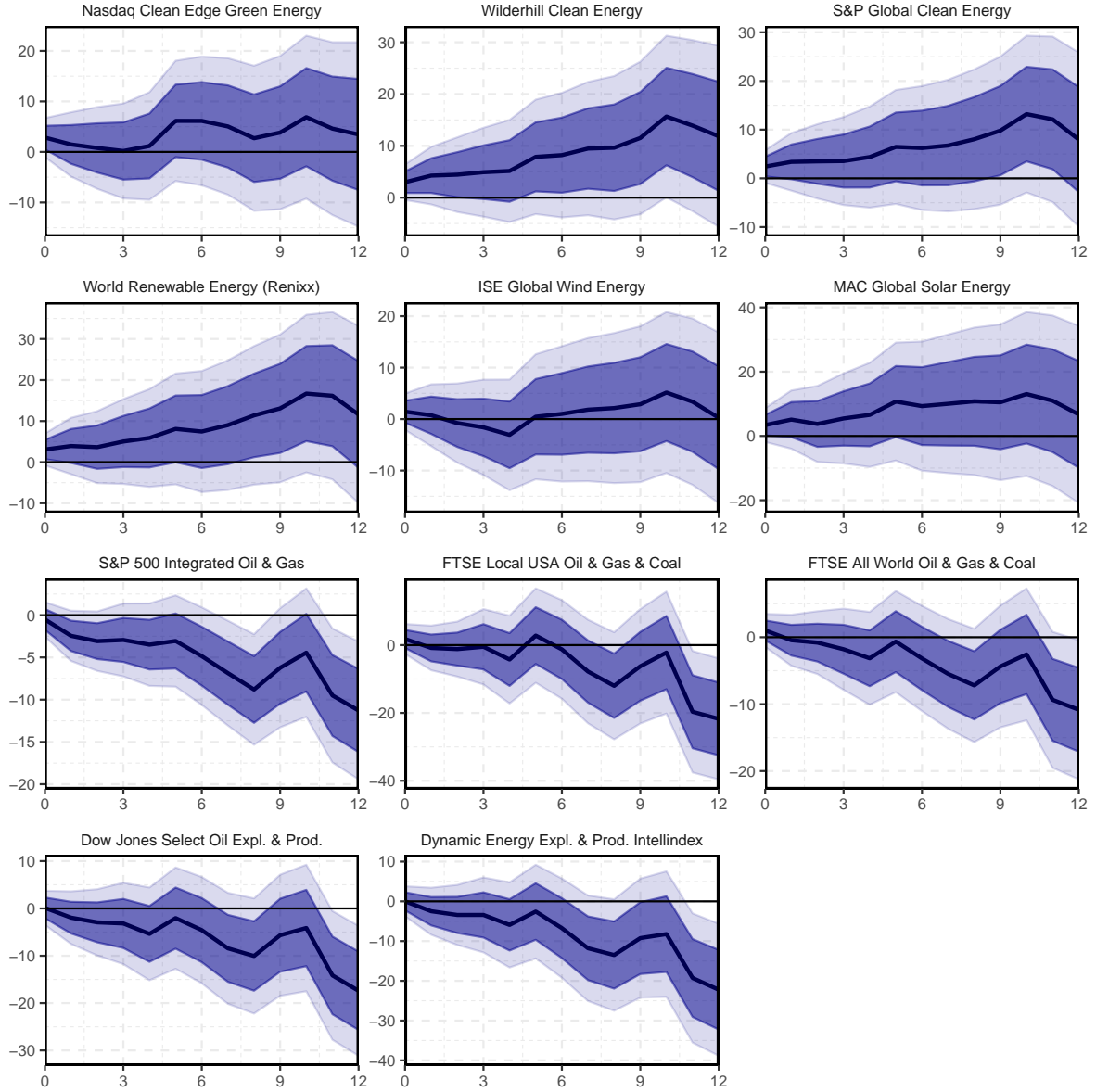


Figure B.2: Stock Market Reactions to a Carbon Policy Surprise Estimated Using Local Projections

Notes: Impulse response functions to a carbon policy shock, estimated using local projections. The black line represents the point estimate, while the shaded area indicates the corresponding 68% and 90% confidence interval, estimated using Eicker-Huber-White heteroskedasticity-robust standard errors.

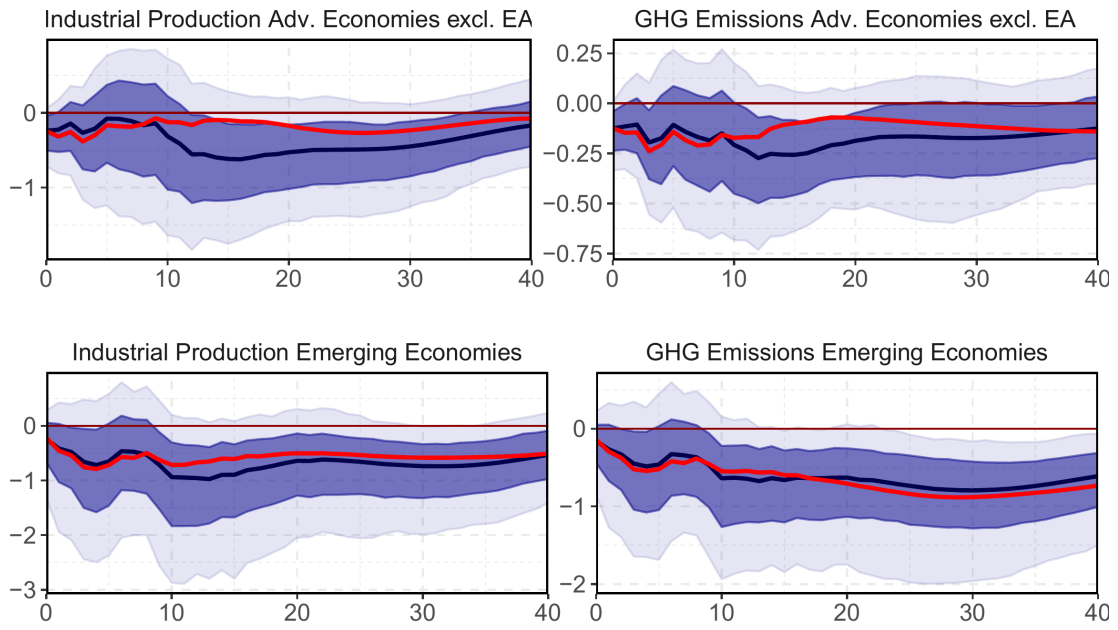


Figure B.3: Impulse Response of GHG emissions to a Carbon Policy Shock and the Counterfactual

Notes: Impulse response of GHG emissions to a carbon policy shock, normalized to increase CPI energy by 1 percent upon impact. The solid line represents the point estimate, while the dark and light shaded areas indicate the 68 and 90 percent confidence intervals, respectively. The red line illustrates the counterfactual impulse response function, assuming no change in EA industrial production following the carbon policy shock.

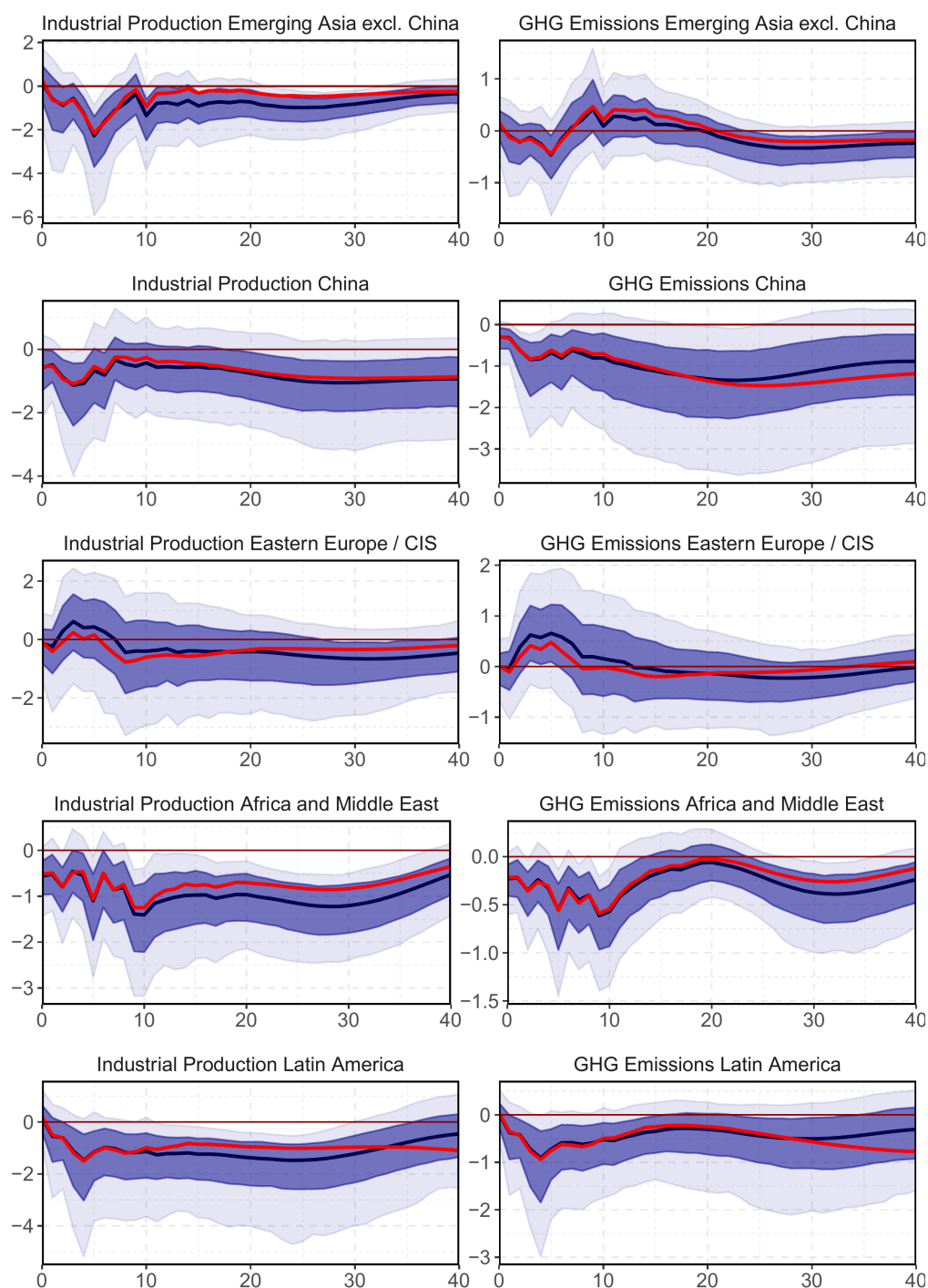


Figure B.4: Impulse Response of GHG emissions to a Carbon Policy Shock and the Counterfactual

Notes: Impulse response of GHG emissions to a carbon policy shock, normalized to increase CPI energy by 1 percent upon impact. The solid line represents the point estimate, while the dark and light shaded areas indicate the 68 and 90 percent confidence intervals, respectively. The red line illustrates the counterfactual impulse response function, assuming no change in EA industrial production following the carbon policy shock.

C. Robustness

Appendix C. includes robustness checks to validate the findings of the main analysis. Figure C.1 compares the impulse response functions obtained from an external instrument VAR and the baseline internal instrument VAR, showing consistent results across both methods. Figure C.2 presents the impulse response functions from VAR model with global oil prices and a global stock index instead of European ones, demonstrating that the findings are not overly sensitive to the variables included. Figure C.3 explores the effects of different lag lengths on the impulse response functions, confirming that the results are stable across various lag structures. Overall, these robustness checks reinforce the reliability and validity of the main conclusions.

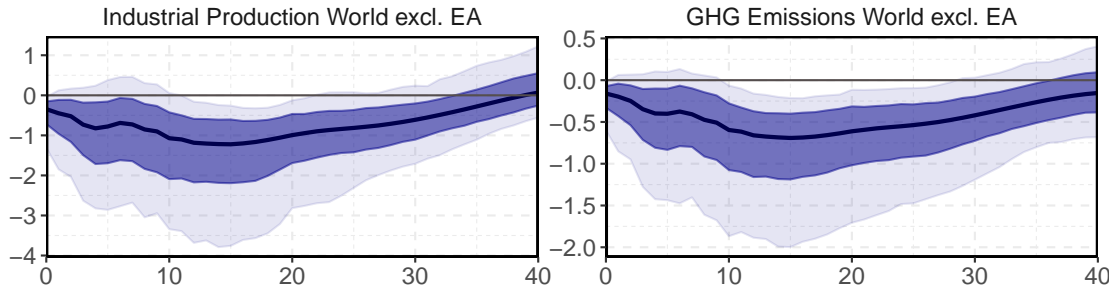


Figure C.1: Impulse Responses to a Carbon Policy Shock; External Instrument VAR

Notes: Impulse responses to a carbon policy shock, normalized to increase CPI energy by 1 percent upon impact. The solid black line represents the point estimate, while the dark and light shaded areas indicate the 68% and 90% confidence intervals for the external instrument VAR.

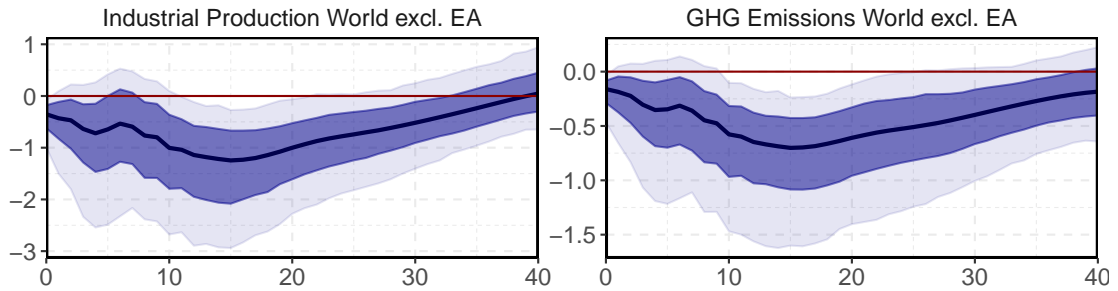


Figure C.2: Impulse Responses to a Carbon Policy Shock; With Global Oil and Stock Prices

Notes: Impulse responses to a carbon policy shock, normalized to increase CPI energy by 1 percent upon impact. The black solid line represents the point estimate, while the dark and light shaded areas indicate the 68 and 90 percent confidence intervals, for the baseline VAR. Global Brent Crude Oil prices and a global stock market index are used instead of European ones.

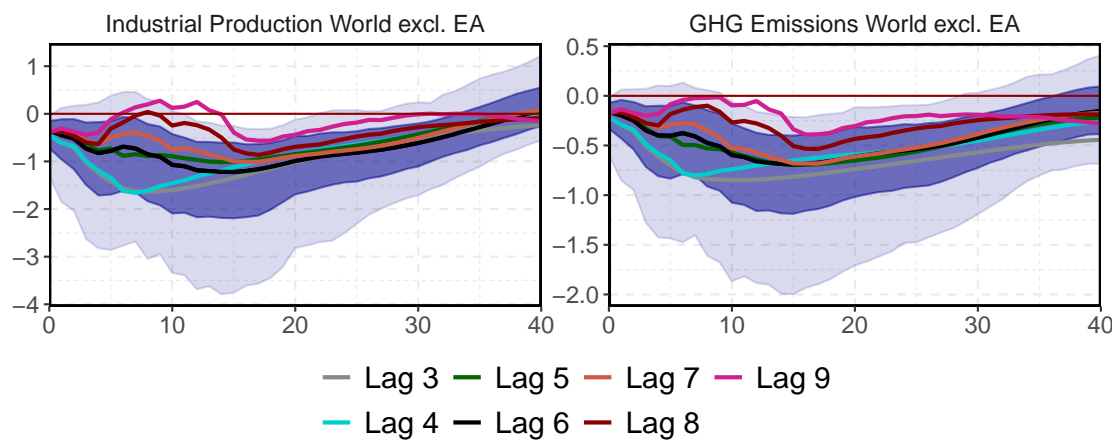


Figure C.3: Impulse Responses to a Carbon Policy Shock; Different Lag Lengths

Notes: Impulse responses to a carbon policy shock, normalized to increase CPI energy by 1 percent upon impact. The black solid line represents the point estimate, while the dark and light shaded areas indicate the 68 and 90 percent confidence intervals, for the baseline VAR. The colored lines show the point estimates for different lag lengths.

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Assessing the Global Impact of EU Carbon Pricing: Economic and Climate Spillovers

Abstract

This paper explores the global economic and climate spillovers of the European Union Emissions Trading System (EU ETS), leveraging exogenous variations in carbon prices identified through a carbon policy surprise series. Findings reveal that higher EU carbon prices lead to significant and sustained reductions in greenhouse gas (GHG) emissions, both within the Euro Area (EA) and globally, with no evidence of carbon leakage. Structural Scenario Analysis confirms that these reductions are driven by energy efficiency improvements rather than solely by declines in industrial production. The results highlight the transmission of the shock through the Brussels Effect, where EU carbon policies influence global standards, evidenced by stricter carbon policies abroad and shifts in investor behavior favoring green industries. Furthermore, no region benefits economically from EU carbon pricing. Overall, the EU ETS proves effective in reducing emissions without being undermined by carbon leakage.

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