YOUNG ECONOMISTS SEMINAR

HRVATSKA NARODNA BANKA
EUROSUSTAV

18th YOUNG ECONOMISTS' SEMINAR
TO THE 31st DUBROVNIK ECONOMIC CONFERENCE

June 5 – 6, 2025, Dubrovnik, Croatia

Konstantin Karsten

Identifying Transition Risk in Sovereign CDS spreads with a high-frequency regulatory instrument

Draft version

Please do not quote

Identifying Transition Risk in Sovereign CDS spreads with a high-frequency regulatory instrument

Konstantin Karsten*†,‡

March 31, 2025

Abstract

This study examines whether sovereign credit risk, as measured by CDS spreads, is influenced by the EU's regulatory actions related to the EU Emissions Trading System (EU ETS). Using a high-frequency approach, I construct three distinct regulatory shock series—announcement, publication, and implementation—and analyze their impact on sovereign risk through local projections across 19 EU countries. The results show that sovereign CDS spreads increase following the announcement of new regulations, but significantly decrease after the publication of all relevant information. This finding suggests that transition risk diminishes once all details of the regulation, including the implementation date, are fully disclosed. The immediate pricing of new information after its publication appears to depend on the regulatory impact of the shock. However, the notable rise in sovereign risk at the point of implementation, despite prior knowledge of the details, warrants further investigation. To ensure the robustness of these findings, I incorporate a carbon emissions measure based on geospatial data, which serves as a common proxy for transition risk. A subsample analysis reveals that the increase in transition risk is more pronounced in countries lagging in their transition efforts. Additionally, the use of a surprise instrument replicates the reaction of the announcement shock, confirming that the surprise component is effectively captured.

Keywords: sovereign CDS spreads, transition risk, EU ETS

*Department of Economics, University of Rostock

†Halle Institute for Economic Research (IWH)

‡konstantin.karsten@uni-rostock.de

1 Introduction

European Union member states face constantly increasing pressure to reduce emissions due to the EU-wide Emissions Trading System (EU ETS) and the growing number of climate policies. To date, little research has been conducted into how the pressure to adapt to new climate policies affects public finances. As public debt per GDP has increased in almost all European countries since the financial crisis (World Bank, 2024), governments have less fiscal space for fiscal policy interventions (Teles and Mussolini, 2014; Aizenman et al., 2019). For example, to support domestic companies in the transition to a low-emission economy. Accordingly, the uncertainty of future regulations can pose a significant risk to a country's financial stability. This risk is usually referred to in the literature as transition risk (Rudebusch, 2021). The aim of this paper is to investigate the impact of increasing transition risk on the credit default risk of governments. The transition risk of new regulations will be assessed using an instrument based on Känzig (2023), to generate three distinct shock series: announcement shocks, publication shocks, and implementation shocks.

To analyze the risk dynamics after an event I use a local projections approach[1] on a panel of 19 EU member states from January 2013 to December 2019, I generate impulse response functions for sovereign CDS spreads. Sovereign CDS spreads can track changes in the credit default risk of governments (Chernov et al., 2020). As baseline specification I use shocks with a high regulatory impact, such as those that lead to distributional effects by altering the number of allowances. Then, I expand the scope in an extended specification to include a broader set of shocks, encompassing smaller ones that may specify technical aspects of regulation implementation or affect only specific industries. I find in my baseline results that the announcement shocks increase the sovereign CDS spreads and increase thereby the sovereign risk. When with the publication shock all information gets available the sovereign CDS spreads decrease significantly cause transition risk in form of policy uncertainty is now lower. The implementation shock increases the sovereign CDS spreads significantly even though all information was already known including the implementation date. Fur-

1. Local projections consist of a series of regressions in which the outcome variable, measured at progressively distant time horizons, is regressed on the intervention either directly if it is randomly assigned, or instrumented if it is not. These regressions are conditioned on a set of controls that can include lags of both the outcome and the intervention, along with other exogenous or predetermined variables (Jordà and Taylor, 2024).

ther research should explore this phenomenon to better understand the underlying dynamics. To the best of my knowledge, local projections have never been applied in this context. Previous literature only used basic panel regressions to analyze the impact of transition risk measures like carbon emissions on sovereign CDS spreads. The use of local projections allows for the examination of how sovereign CDS spreads evolve in the months following a shock, providing insights into the persistence of the shock's impact and, consequently, its economic relevance. The robustness of these findings is confirmed through the inclusion of a carbon emissions measure, one of the most common ways to capture transition risk. Furthermore, a subsample analysis indicates that the increase in transition risk is a general phenomenon, which is more pronounced if the country is in a bad transition state.

The EU ETS is the world's first and largest carbon market, established in 2005 to combat climate change and reduce greenhouse gas emissions cost-effectively. Therefore it is the perfect environment to analyze environmental regulations on a longer time horizon. Operating on a cap-and-trade principle, the EU ETS sets a cap on the total amount of certain greenhouse gases that can be emitted by installations covered by the system. To encourage a continual reduction in overall emissions, the cap is progressively lowered over time (European Commission, 2023). A high-frequency regulatory instrument based on Känzig (2023) is used to measure the transition risk. A completely new approach is the distinction between three different types of events, namely Announcement, Publication and Implementation. These represent the decisive points in the legislative process of the European Union. The EU ETS market should act as transmission cost channel between the regulatory event and the sovereign CDS spread and at the same time evaluate the direction and severity of the regulation.

2 Related Literature

Sovereign CDS spreads are a well-suited measure to reflect changes in sovereign credit and default risk, as shown by Chernov et al. (2020). The objective of this paper is to identify the transition to a low-carbon economy as a significant risk factor for sovereign credit, thereby contributing to the existing body of literature on sovereign CDS. One part of the literature tries to identify risk factors of CDS spreads such as credit rating changes. Longstaff et al. (2011) showed based on the model by Pan and Singleton (2008) that CDS spreads are driven by local and global risk factors, where the latter seems to play the more important role. By the time some factors became established risk factors for sovereign CDS spreads like the domestic and the US stock return, the volatility index (Longstaff et al., 2011) or credit ratings (e.g. Drago and Gallo, 2016; Agiakloglou and Deligiannakis, 2020), which are used as controls in this study. Building up on that, were temporary risk factors like the daily covid-19 infection rates during the pandemic as local risk factors identified (Andrieș et al., 2021; Augustin et al., 2022). Additional Sovereign risk induced by the specific risk factor is more pronounced, if the country is in financial stress (Pallara and Renne, 2019; Andrieș et al., 2021; Augustin et al., 2022). Whereas Hübel (2020) showed that CDS spreads of more sustainable countries are lower. By examining the impact of transition-related regulatory changes on sovereign credit risk, this study aims to expand the understanding of how climate policy and the shift towards sustainability influence sovereign CDS spreads.

In recent years, climate-related risk factors have garnered increased attention from both professionals and researchers, also in the context of public finances. The majority of existing literature has concentrated on physical risks, which encompass the impacts of extreme weather events, natural disasters, and the likelihood of their occurrence (e.g. Bowman et al., 2022; Cevik and Jalles, 2022). For instance, Bachner et al. (2019) illustrate through their model of the Austrian economy the significant financial burden that may fall on public finances if adequate preparations are not made to address the increasing frequency of extreme weather events.

Climate change brings another risk factor, commonly known as transition risk. Multiple studies already examined that the shift to a low carbon and more sustainable economy is a relevant economic factor on the firm level. Transition risk created by carbon policies as an emissions trading system impact the stock market performance of firms (e.g. Bushnell et al., 2013; Jong et al., 2014; Brouwers et al., 2016) and results in higher carbon premia (Bolton and Kacperczyk, 2023). According to Hengge et al. (2023) lead higher carbon prices to negative abnormal returns, which are greater for more carbon-intensive firms. This effect is even stronger for firms outside the EU ETS, indicating that investors account for transition risks tied to the low-carbon shift. Also, the environmental DSGE model by Huang et al. (2021) points out that the introduction of climate policies degrades firms balance sheets which results in a higher default risk. The impact of transition risk caused by climate policies is not limited to polluting sectors as the extended DSGE model by Carattini et al. (2023) indicates.

Fried et al. (2022) show in a dynamic equilibrium model that already the probability of climate policies can lower GDP through two channels. First, climate policy risk reduces expected returns on fossil-based capital, shifting production toward cleaner alternatives. Second, it decreases output by diverting capital from optimal allocations.

In order to prevent the economy of the described potential damages, governments have to act and invest (e.g. Gans, 2012; Zenios, 2022; Lim and Prakash, 2023). As Semieniuk et al. (2020) suggest in the public debt channel of their theoretical model, governments tend to act countercyclically during the transition process. They support failing carbon-intensive industries and bail out financial institutions facing issues like asset revaluation. These actions collectively weaken the government's fiscal capacity. The existing literature demonstrates that transition risk, whether indicated by climate policies or emission levels, can significantly affect the economy and, by extension, public finances. The impact of transition risk on sovereign credit has not been thoroughly explored in existing literature empirically. The only empirical papers to my knowledge are Chaudhry et al. (2020), Collender et al. (2023) and Beirne et al. (2021), which are also the ones most closely related to this study. All three show that different transition risk indicators increase sovereign credit risk, namely carbon emissions, economic rents from natural resources, the share of renewable energy and the ND-Gain index. This paper adds a new and more advanced transition indicator to the existing literature in form of a high-frequency regulatory instrument.

3 Methodology and Data

The aim of this paper is to show not only if transition risk is present in sovereign CDS spreads as previous studies did (e.g. Collender et al., 2023), it should affect the sovereign credit risk dynamics after different types of regulatory shocks. For this reason, will the panel local projections framework based on Jordà (2005) be applied. With Local Projections it is possible to create impulse response functions, which show how an intervention, specifically the regulatory shock series, impacts the average outcome at a future point in time compared to a baseline of no intervention. Empirical economic analysis has increasingly shifted towards the use of longitudinal or panel data, with local projection methods proving particularly effective for managing such data structures. As mentioned in Jordà and Taylor (2024) local projections have several advantages over vector autoregressive models (VAR). Local projections offer a practical solution when full system estimation is challenging due to data limitations or model complexity. They are useful for addressing nonlinearity or state-dependence. Local Projections also simplify estimation of cumulative responses and multipliers. Jordà's method quickly gained popularity as a reliable alternative to VARs to create impulse response functions (e.g. Kilian and Kim, 2011; Plagborg-Møller and Wolf, 2021; Li et al., 2024) and has been successfully applied across various fiscal and monetary policy contexts, including the analysis of fiscal multipliers (Jordà and Taylor, 2016) and economic uncertainty (Aastveit et al., 2017). Estimating a single panel regression is considerably more efficient and straightforward compared to the more complex process of estimating a system of panel regressions, which is required in the case of VARs. As the local projections are not estimated in levels, the commonly debated small sample bias is unlikely to be a concern (Piger and Stockwell, 2023). The local projections framework in differences of this paper is based on the following panel regression model with the 5-year CDS spreads as the dependent variable:

$$CDS_{i,t+h} - CDS_{i,t} = \beta_s Shock_{s,t} + \sum_{j=1}^{4} Controls_{i,t+h-j} + \epsilon_{i,t}$$

5-year sovereign CDS spreads are the most traded maturity, therefore it should reflect any reactions most accurately. The regression model is structured with i representing the individual country, t denoting the current month and j includes the last four lags of each control variable, $h = 1, \ldots, 6$ indicating the horizon of the impulse response, and s specifying the type of shock. This framework allows for the analysis of the temporal effects of different shock types on sovereign credit risk across countries over a six-month horizon. *Shock* contains the three shock series displayed in Figure 1 and 2. The term *Controls* includes besides the lags of the difference in CDS spreads also additional explanatory variables that are based on previous sovereign CDS literature, such as the domestic stock return and the volatility index. Most of them come from the paper by Longstaff et al. (2011) who defined global and local risk factors and can be seen in Table A1 in the appendix with the data source of each control variable. Since transition risk and European law are multinational will this analysis be applied on a panel of 19 members of the European Union.

Unlike physical risk, transition risk is more challenging to detect, as it represents a long-term risk that escalates if government actions are insufficient. Multiple studies suggest that political uncertainty, including the risk associated with the announcement and implementation of new policies, is a significant factor in the pricing of both corporate (Wisniewski and Lambe, 2015) and sovereign CDS spreads (e.g. Pan et al., 2024). In contrast, Boeck et al. (2023) argue that the volatility of sovereign CDS spreads is more closely linked to economic and financial uncertainty than political uncertainty. As previously noted, policy implementation is a key mechanism in driving the transition to a low-carbon economy. There appears to be a meaningful relationship between sovereign CDS spreads and the likelihood of policy implementation. Moreover, carbon emissions have been shown to impact sovereign risk (Chaudhry et al., 2020; Collender et al., 2023) and given that reducing carbon emissions is a central element of the transition process, I will use the implementation of new regulations aimed at lowering carbon emissions as a measure of transition risk for sovereign CDS spreads. For this, I build on the work of Känzig (2023), who identified 126 regulatory shocks to the EU ETS market and quantified their effects through Future Carbon Spot Prices. This approach marks a key distinction from previous studies on transition risk factors and sovereign risk. While much of the existing literature focuses on transition states—such as a country's carbon emissions—and their potential to increase sovereign CDS spreads and credit risk, this paper examines the impact of climate regulations as a shock series, reflecting tangible actions taken to support the transition to a low-carbon economy.

Känzig (2023) developed an instrument, CPSurprise, to capture the effects of European Commission environmental regulations on the EU ETS market. He uses a high-frequency approach to address potential concerns that regulatory decisions in the carbon market may be influenced by broader economic conditions. High-frequency identification is a well-established method for isolating shocks, such as those related to monetary policy (e.g. Kuttner, 2001; Cochrane and Piazzesi, 2002; Gürkaynak et al., 2005; Cesa-Bianchi et al., 2020; Kubota and Shintani, 2022).Ferrara and Guérin (2018) further demonstrated that high-frequency shocks in economic uncertainty can significantly affect lower-frequency economic variables. Cochrane and Piazzesi (2002) employed a similar approach to identify high-frequency shocks, consistent with the method used in both this paper and Känzig (2023). The instrument of Känzig (2023) is calculated as the difference in Future Carbon Emission Prices between the day of the regulatory event and the previous trading day. To account for the fact that prices in the early phases of the EU ETS market often dropped to zero, Känzig (2023) normalized this difference by dividing it by the wholesale electricity price. However, a limitation of the instrument is that the shocks are not homogeneous. Some events reflect significant regulatory decisions by the European Parliament, such as changes in free allocation regulations, while others are merely the implementation of these decisions, which are typically known in advance. The latter type does not represent a surprise shock, as the implementation date is usually anticipated weeks ahead. For example, included Känzig (2023) the 9th of July 2014, the day when the Climate Change Committee agrees on the proposed carbon leakage list for the period 2015-2019 and the 27th of October 2014 when the European Commission adopts the same carbon leakage list for the period 2015-2019, which is not a real surprise shock. On the 1st of January 2015 this regulation entered officially into force. This paper aims to analyze whether transition risk is reflected in sovereign CDS spreads following the announcement of new environmental regulations and to examine how risk dynamics evolve as new information about the regulations is disclosed. To distinguish between these effects, three separate shock series are developed, each corresponding to key stages of European Commission legal acts. The first series captures announcement shocks, which occur when the European Parliament or Commission passes new regulations or regulatory changes. These can be likened to news shocks, as decisions and voting topics are publicly accessible and widely reported in the media. Fried et al. (2022) argue that the high probability of implementing a new climate policy can already affect the economy, but only if the policy is enacted before many investments reach the end of their lifecycle. Additionally, the policy must be stringent enough to significantly reduce investment returns for it to have a meaningful economic impact. Following the decision, it is published in the Official Journal of the European Union, though several weeks may pass between the decision and its official publication. Upon publication, all detailed information regarding the new regulation becomes publicly available. This includes specifics on the timing, scope, and jurisdiction of individual provisions, as well as the official implementation date. Finally, the regulation enters into force, which can only occur after it has been officially published. Also, between the publication and implementation can lay multiple weeks (see Figure 1). Phase III ranges from 2013 to 2019. Therefore, impacts of the financial crisis, the Covid-19 pandemic and changes of phases on the ETS market should not be a concern. The United Kingdom remains included in the sample, as Brexit occurred a year after the analyzed period.

The high-frequency regulatory instrument provides advantages over previous studies by offering a more precise identification of transition risk. Collender et al. (2023), for instance, use carbon emissions, economic rents from natural resources, and the share of renewable energy consumption as indicators of transition risk. Higher carbon emissions, greater economic rents from natural resources, and a lower share of renewable energy consumption are associated with larger sovereign CDS spreads and, consequently, increased sovereign credit risk. These indicators operate on the premise that countries farther from achieving a green economy will face greater costs to complete the transition, leading to elevated sovereign credit risk. Chaudhry et al. (2020) examined sovereign risk in G7 countries using an extreme value theory risk measure, finding that higher carbon emissions are associated with increased sovereign risk, particularly from the most polluting sectors—transportation, electricity, and industry. However, this relationship does not hold uniformly for developing countries, where higher emissions are often linked to heightened economic activity and result in lower CDS spreads (Collender et al., 2023). By incorporating climate regulations, as valued by the EU ETS market, the approach of this paper directly captures cost changes for economies, addressing conflicting results between more and less developed countries, where higher carbon emissions may paradoxically reduce sovereign risk due to their relationship with economic activity. Another method for assessing climate-related risk is through the ND-Gain index, which reflects a country's vulnerability to climate disruptions and its readiness to attract private and public investment for adaptation.[2] According to the ND-Gain based VAR analysis by Beirne et al. (2021), greater vulnerability to direct climate impacts has a stronger effect on sovereign borrowing costs than resilience. However, the ND-Gain index includes numerous climate and economic indicators, not all of which are directly relevant to transition risk, making it difficult to isolate transition risk effects from other factors. Furthermore, the inclusion of multiple economic variables in the original ND-Gain index raises endogeneity concerns, which Kling et al. (2018) address with an adjusted version of the index. Nonetheless, the challenge of clearly identifying transition risk remains. The approach of this paper resolves this issue by directly linking the introduction of regulations to additional transition risk.

A key concern in dividing the legislative process into three distinct shock series is the potential overlap of effects, which could make it difficult to differentiate between them effectively. For this reason, illustrates Figure 1 the number of days between the initial announcement of a regulation when it was effectively approved by the European Commission and the date it entered into force. The timeline of each shock is depicted with two distinct lines: black representing the period before the regulation's

2. For more information on the ND-Gain index, refer to the latest technical report by Chen et al. (2023).

publication in the Official Journal of the European Union, and white denoting the period between publication and enforcement. For visibility purposes, four regulations that took more than 140 days to enter into force after their initial announcement are only partly displayed in the graph. However, these regulations remain included in their full length in the sample for further analysis. On average, it took approximately 83 days for a regulation to be published following its initial announcement (Avg. A to P), and an additional 18 days to implement after publication (Avg. P to I). However, the median values show a significant contrast, with only 13 days between announcement and publication (Med. A to P) and around 2 days for implementation thereafter (Med. P to I). The large discrepancy between the mean and median is attributed to a few lengthy legislative processes, which extended over several months, inflating the average duration. The graph demonstrates that a significant number of regulations take several weeks to enter into force after being approved by a legislative body of the European Union. This time lag provides opportunity to observe varying effects of the same regulation at different stages of its legislative process. Although different legislative stages of the same regulation may occur within the same month, this does not present an issue. The shocks are based on the regulation's impact on carbon futures rather than the specific event days, allowing for distinct effects between the shocks, even if they occur within the same month.

In Figure 2, the three shock series are expressed as either log differences (lower panel) or as absolute differences relative to the country-specific industrial electricity price (upper panel). The dark blue bars represent the announcement shock series, blue represents the publication shock series, and light blue represents the implementation shock series. Positive values indicate an increase in future carbon prices on the day of the shock compared to the previous trading day, while negative values indicate a decrease. The most significant reactions in log differences occurred at the beginning of Phase III of the EU ETS, while the middle of the phase saw relatively fewer notable events. In the final third of Phase III, there was an increase in regulatory events, though none had the same level of impact as those at the start. According to Koch et al. (2016), the EU ETS was less mature in its earlier years, leading to greater uncertainty surrounding new regulations. Since transition risk reflects the uncertainty of upcoming environmental regulations, log differences should, by definition, better capture this uncertainty component compared to absolute measures.

It is important to note that at the start of Phase III in 2013, the cost of emitting a

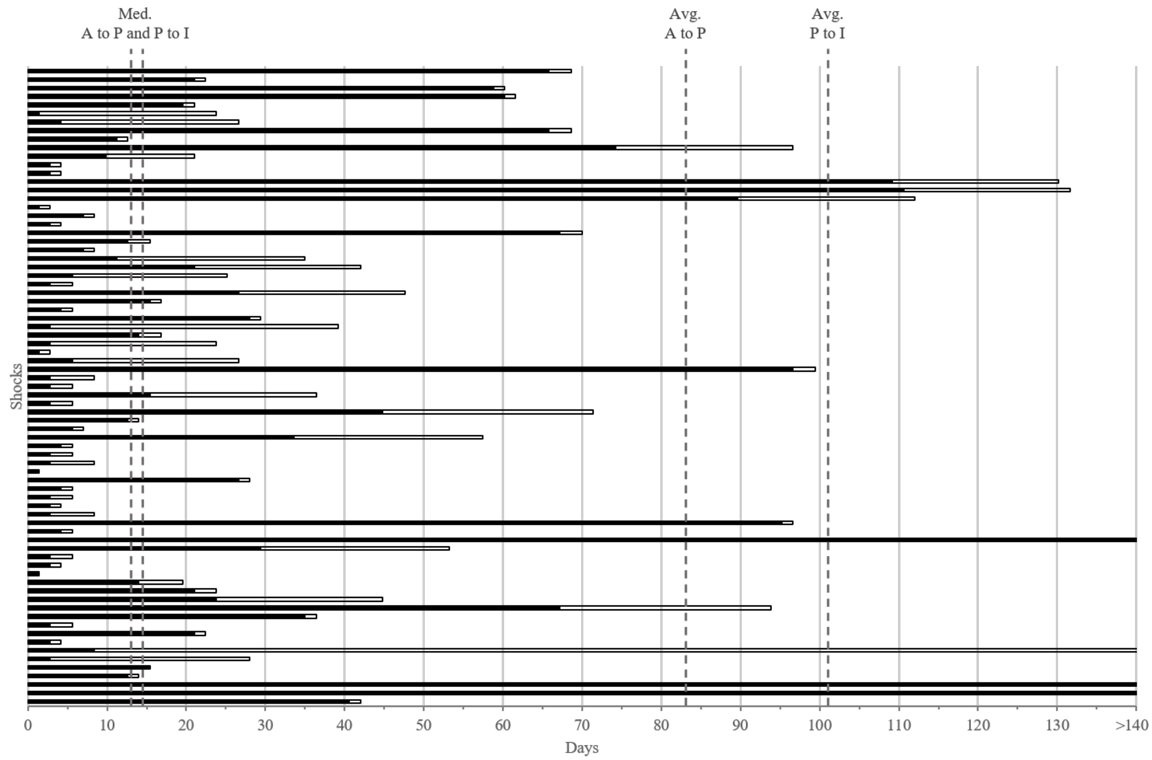

Figure 1: Shock days

ton of CO2 ranged between 6 and 7 Euros, whereas by the end of 2019, it had exceeded 27 Euros. Although reactions were less pronounced later in the phase, the financial impact of these peaks was greater due to the higher carbon prices. For this reason, using the absolute difference may also be a suitable measure. I will include this absolute difference cost-focused measure in an additional subsection following the main results on transition risk. Given that the energy sector is one of the largest emitters, it is advisable to include the electricity price, as suggested by Känzig (2023), as an indicator of the economic cost associated with an increase in the price of CO2. This approach also helps control for the strong log difference reactions observed at the start of Phase III when future carbon prices were low. Thus, the upper panel presents the absolute difference relative to the country-specific industrial electricity price. As the dataset from the International Energy Agency (IEA, 2024) did not include industrial electricity prices for Cyprus, I used a combination of Greek and Turkish industrial electricity prices as proxies. These two countries have the closest economic ties to Cyprus, making them suitable for comparison. The upper panel of Figure 2 highlights that the stronger regulatory shocks are concentrated towards the latter part of Phase III. This revised approach more effectively emphasizes the potential

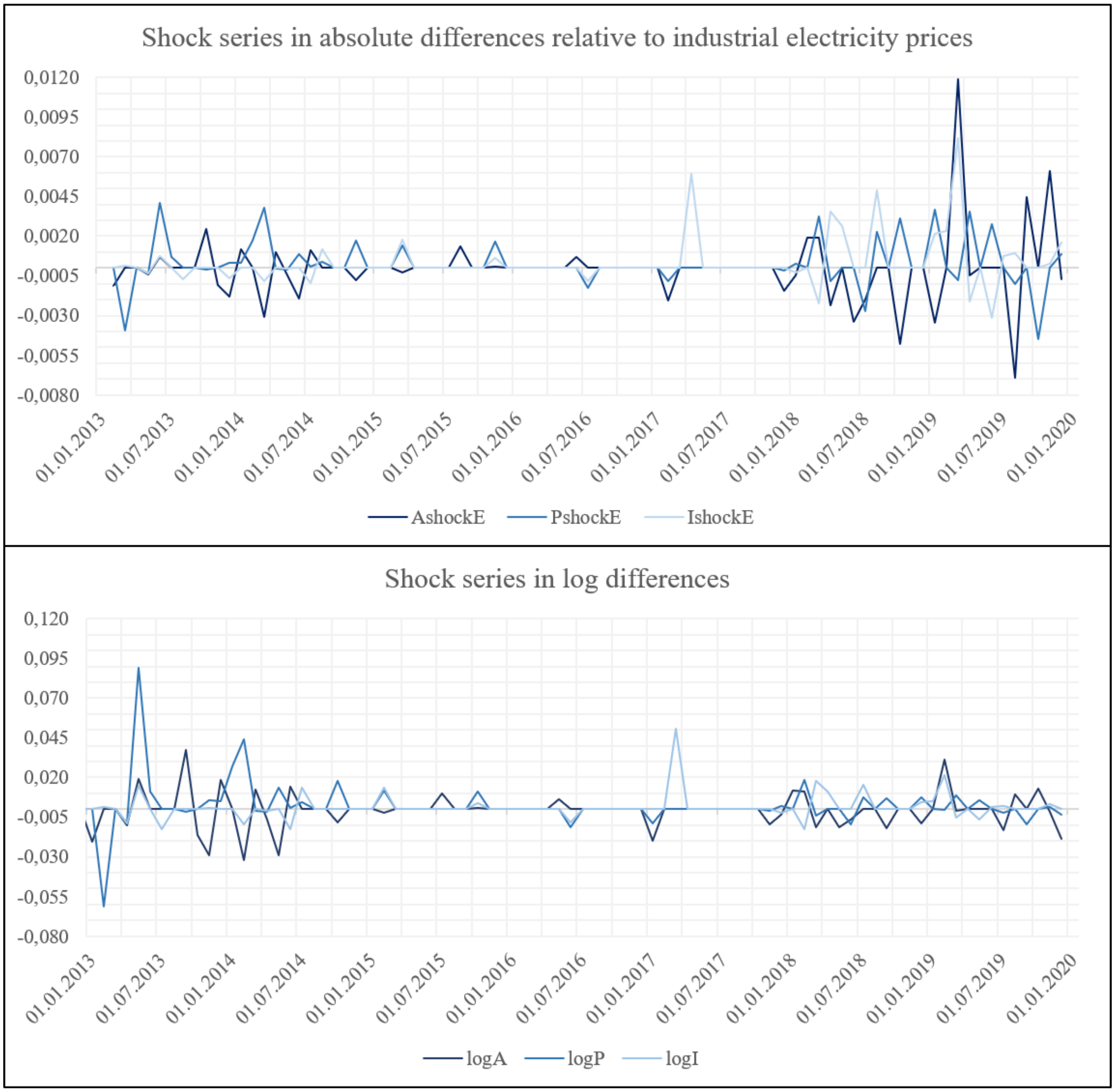

Figure 2: All shocks in absolute differences relative to the industrial electricity price (upper panel) and in log differences (lower panel).

cost impact on economies, as higher carbon prices are presumed to translate directly into increased cost pressures for firms and energy suppliers. On average, when measured in absolute differences relative to industrial electricity prices, the average implementation shock was the largest, followed by the publication shock, while the average announcement shock was negative. In contrast, when using log differences, the average publication shock slightly exceeds the average implementation shock, marking the only significant divergence between the two measures. This discrepancy largely stems from the steep increase in log differences observed at the start of Phase III. Although the average announcement shock was the smallest, it exhibited the highest standard deviation, as seen in Figure 2. The series displayed larger positive and negative shocks that balanced each other out in the average calculation. These findings align with the conclusions of Fan et al. (2017), who assert that the initial announcement of new regulations typically triggers the strongest market reactions in the EU ETS.

4 Results

This section presents and discusses the key findings of the study. Figure 3 displays the impulse response functions of sovereign CDS spreads following the three types of shocks over a six-month horizon, with the baseline model on the left and the extended specification on the right. In the baseline model, sovereign CDS spreads increase immediately after the announcement shocks and significantly after the implementation shocks. The publication shocks result in a significant immediate decrease in sovereign CDS spreads. In the extended specification, both the announcement and implementation shocks lead to significant increases in sovereign CDS spreads, whereas the publication shocks do not result in an immediate decrease. The central question of this paper is whether transition risk significantly affects sovereign CDS spreads. The mean estimates from both specifications indicate that sovereign CDS spreads generally rise following announcement and implementation shocks, reflecting an increase in sovereign credit risk. In the baseline specification, the publication shock leads to a significant reduction in sovereign credit risk for shocks with a large regulatory impact. However, when smaller regulatory impact shocks are included, no significant movement is observed after the publication of regulations, suggesting that the uncertainty introduced by the initial announcement is not fully resolved. This lack of risk reduction may point to the presence of information frictions, particularly for regulations with lower impact. The increase in sovereign CDS

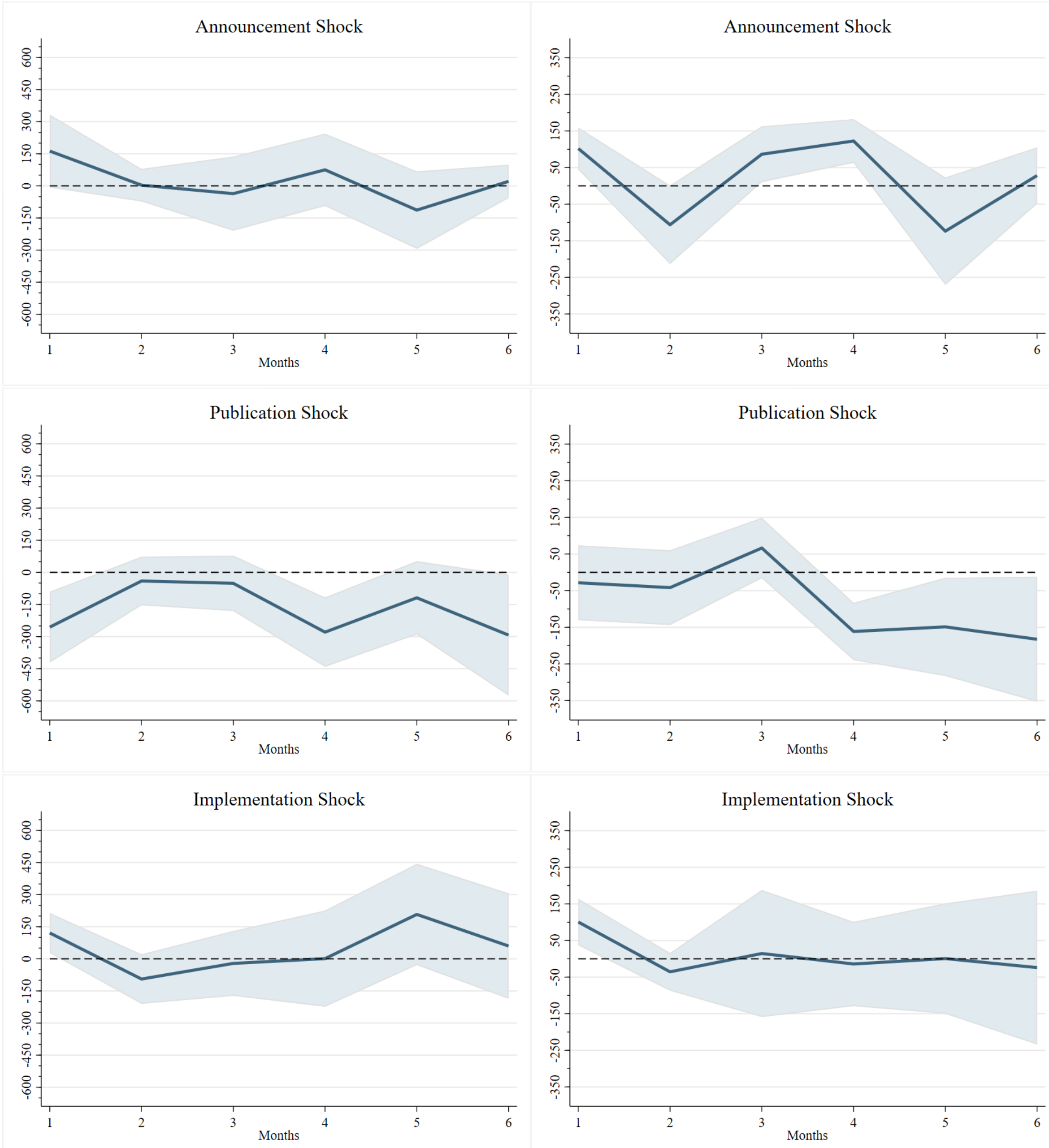

Figure 3: Impulse Response Functions of sovereign CDS Spreads in baseline (left) and extended (right) specification with 90 percent confidence bands.

spreads after both the announcement and implementation shocks suggests that even lower-impact regulations still influence sovereign risk, albeit more subtly. Transition risk is identified during the period between the announcement and publication of regulations, introducing a new risk factor to the literature on sovereign CDS spreads (e.g., Longstaff et al., 2011). The findings align with previous research on how transition states can amplify sovereign risk (e.g., Chaudhry et al., 2020; Collender et al., 2023). The method used in this paper to identify transition risk is based on real political actions rather than the broader context of the green economy transition and its potential threats to government finances. While this approach cannot predict when a sovereign default might occur, it highlights the dynamics of transition risk throughout the legislative process of the European Union, providing insight into how government finances respond to new environmental regulations. This analysis also complements the dynamic equilibrium model by Fried et al. (2022), which shows that even the likelihood of environmental regulations can have economic impacts. Similarly, this study demonstrates that the probability of a strict regulation following an announcement increases sovereign risk.

Cost impact of environmental regulations

As outlined in the methodology section, log differences better capture the uncertainty—and therefore the transition risk—whereas the absolute difference relative to the industrial electricity price more effectively reflects the cost impact that companies face after the introduction of new regulations. The IRFs for the publication and implementation shocks show nearly identical patterns across both specifications. However, the announcement shocks no longer lead to significant increases in sovereign CDS spreads in the absolute difference specification. This suggests that early shocks in Phase III, characterized by large percentage changes, played a crucial role in driving the significance of announcement shocks, which were more prominently captured by log differences. One possible explanation for this result could be the timing of these shocks. Early in Phase III, policy uncertainty was higher, as market participants were unsure how quickly and strictly the new regulations would be implemented. An event study by Koch et al. (2016) suggests that during Phase II and the early part of Phase III, there was a lack of confidence among traders and companies in political actions for reform—and, by extension, the EU ETS as a whole. This distinction becomes even more pronounced when comparing the volatilities of the three shock series between Phase II and Phase III. Volatility, measured in log differences, was significantly higher for all three shock series during Phase II (see Appendix Table A3). The increase in volatility in this period, coupled with uncertainty in political backing and policy consistency, likely contributed to the lack of stable expectations. This, in turn, affected how market participants perceived the long-term effectiveness and viability of the regulatory framework at that time. Uncertainty about future regulations, or transition risk, appears to be a more important driver of sovereign CDS spreads than the higher absolute cost pressures associated with regulatory changes.

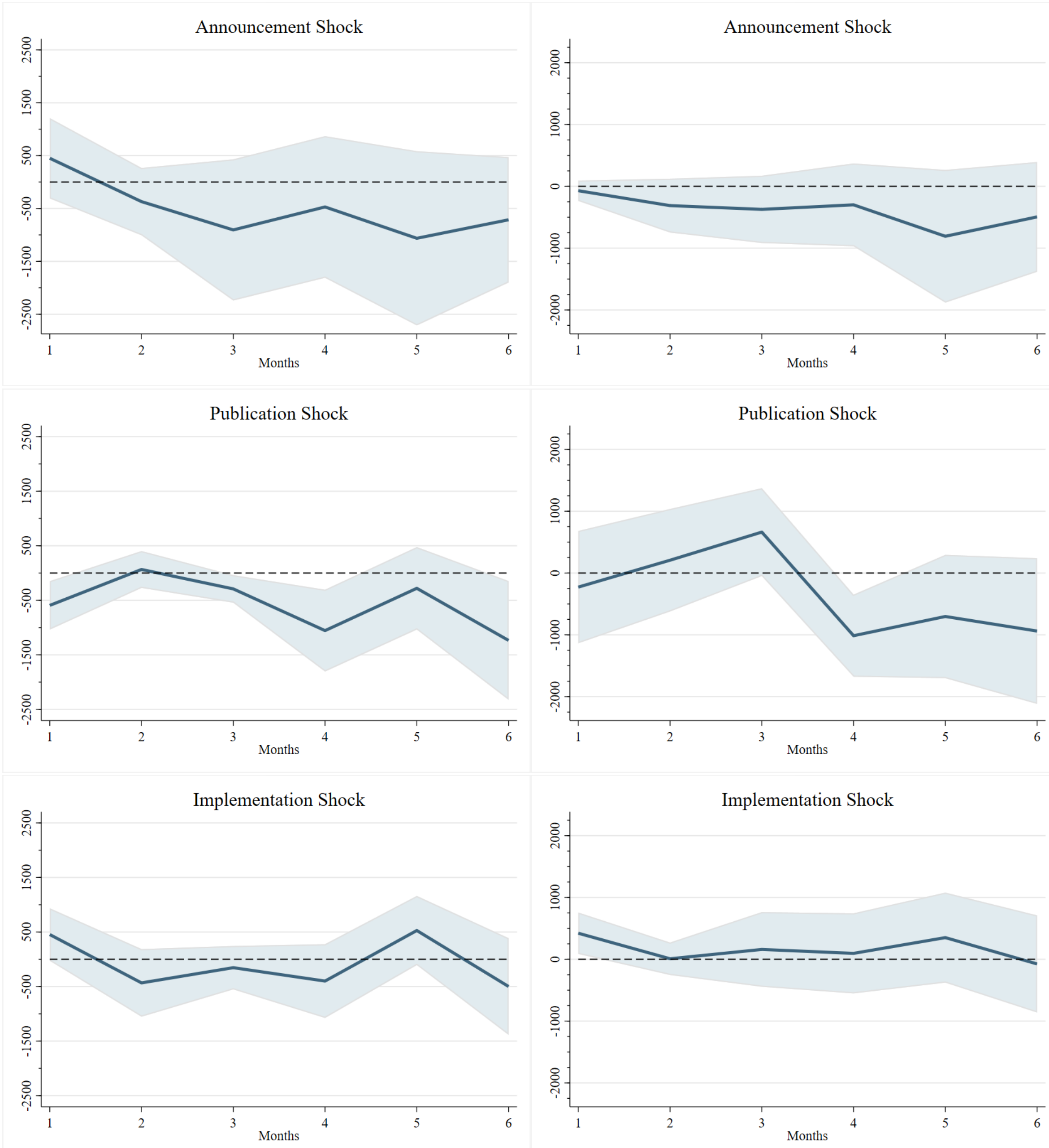

Figure 4: Impulse Response Functions of sovereign CDS Spreads in baseline (left) and extended (right) specification with 90 percent confidence bands.

5 Robustness

The robustness section begins with a sub-sample analysis in Figure 4, focusing on the nine countries with the highest carbon intensity in industrial energy consumption: Cyprus, Slovak Republic, Czech Republic, Ireland, Spain, Belgium, Germany, the United Kingdom, and the Netherlands. The impulse response functions (IRFs) for this sub-sample are similar to those of the full sample. As with the broader analysis, sovereign CDS spreads rise following the announcement and implementation shocks, while the publication shock leads to a significant decrease in spreads in the baseline specification. However, the immediate reactions to the shocks are more pronounced in these high-carbon-intensity countries across all three stages: announcement, publication, and implementation. This suggests that nations with more carbon-intensive industries experience a greater increase in sovereign risk when new environmental regulations are announced. These results align with the transition-state literature (e.g., Collender et al., 2023), which shows that countries lagging in the transition to a low-carbon economy tend to have higher sovereign CDS spreads due to heightened exposure to regulatory changes. This reinforces the conclusion that transition risk is a key factor driving these movements in sovereign CDS spreads. Carbon emissions are frequently utilized as a measure of transition risk, with several studies demonstrating their role in increasing sovereign credit risk (e.g. Chaudhry et al., 2020; Collender et al., 2023). However, one potential concern is that the observed increase in sovereign CDS spreads could be driven by rising carbon emissions rather than regulatory changes. Higher carbon emissions may lead to increased demand for emissions certificates, driving up the cost of emitting a ton of carbon. This raises the question of whether the increase in sovereign CDS spreads is genuinely attributable to regulatory shocks or simply to higher carbon emissions. To address this concern, a measure of country-specific emissions is incorporated into the analysis via an interaction term, capturing the monthly level in carbon emissions. With an interaction model it is possible to distinguish between the regulatory and carbon emission impacts on transition risk. The measure is derived from the Open-Data Inventory for Anthropogenic Carbon dioxide (ODIAC) dataset (Oda and Maksyutov, 2011), published by the National Institute for Environmental Studies in Japan. This geospatial dataset offers several advantages. Its high resolution (1 km x 1 km) allows for precise monitoring of changes in man-made carbon emissions at a monthly level. Furthermore, the dataset provides consistent coverage across regions, ensuring uniformity in measurement and eliminating potential errors caused by varying levels of monitoring infrastructure

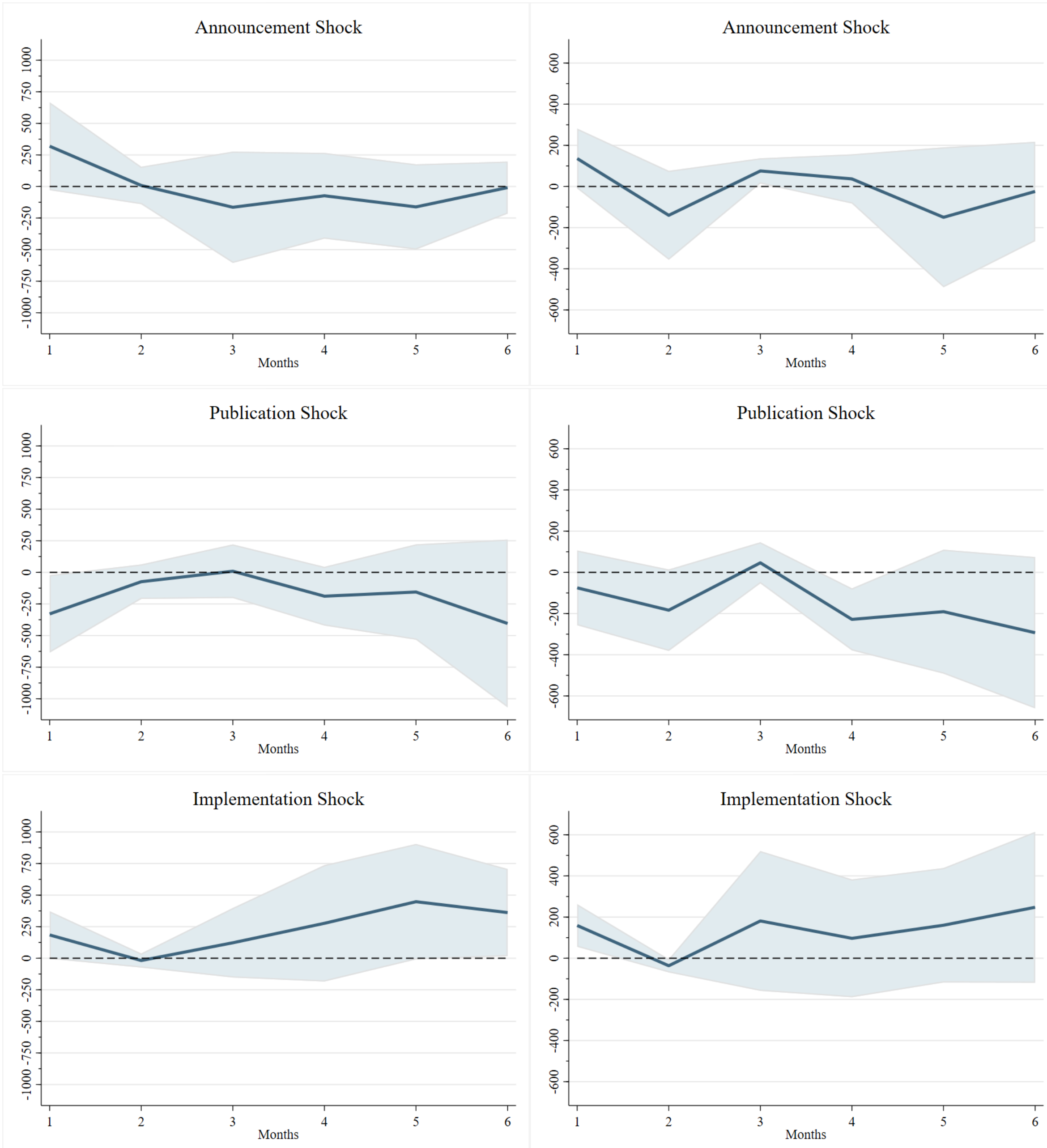

Figure 5: Impulse Response Functions of sovereign CDS Spreads in baseline (left) and extended (right) specification with 90 percent confidence bands and only countries with a high carbon intensity are included.

across countries. To date, such a comprehensive dataset has not been applied in a macroeconomic context of this nature. When the monthly change in carbon emissions is incorporated into the analysis via an interaction model, the impact of the three regulatory shocks on sovereign CDS spreads remains largely unchanged, as shown in Figure 5. This indicates that the observed reactions in sovereign CDS spreads are indeed driven by regulatory changes, rather than fluctuations in country-specific carbon emissions. The carbon emissions level showed a positive but not significant increase in sovereign CDS spreads. The coefficient of the interaction term between the carbon emission level and the implementation shock is positive but insignificant which supports the previous statement that the observed reactions in sovereign CDS spreads are driven by new regulations.

The CPSurprise instrument developed by Känzig (2023) was specifically designed to capture the surprise effect of newly announced regulations. As such, the shape of the impulse response function should closely resemble that of the announcement shock, while differing from the implementation shock. If this similarity holds, it would indicate that the separation of the legal stages successfully isolates the surprise effect, allowing the implementation shock to capture transition risk without interference. As shown in Figure 6, the impulse response function of the CPSurprise shocks on the right mirrors the W-shaped curve of the announcement shock on the left, particularly within the first three months.

6 Conclusion

The analysis concludes that the announcement of new environmental regulations significantly increases transition risk by introducing uncertainty regarding how these regulations will affect economies, and consequently, sovereign risk. This risk is mitigated once all relevant information about the regulation is made publicly available, especially when the regulation has a high regulatory impact. The findings of this paper demonstrate that transition risk is reflected in sovereign CDS spreads when the specifics of the regulation remain unknown. However, the significant rise in sovereign CDS spreads following the implementation date—despite all details being known beforehand—requires further investigation in future research.

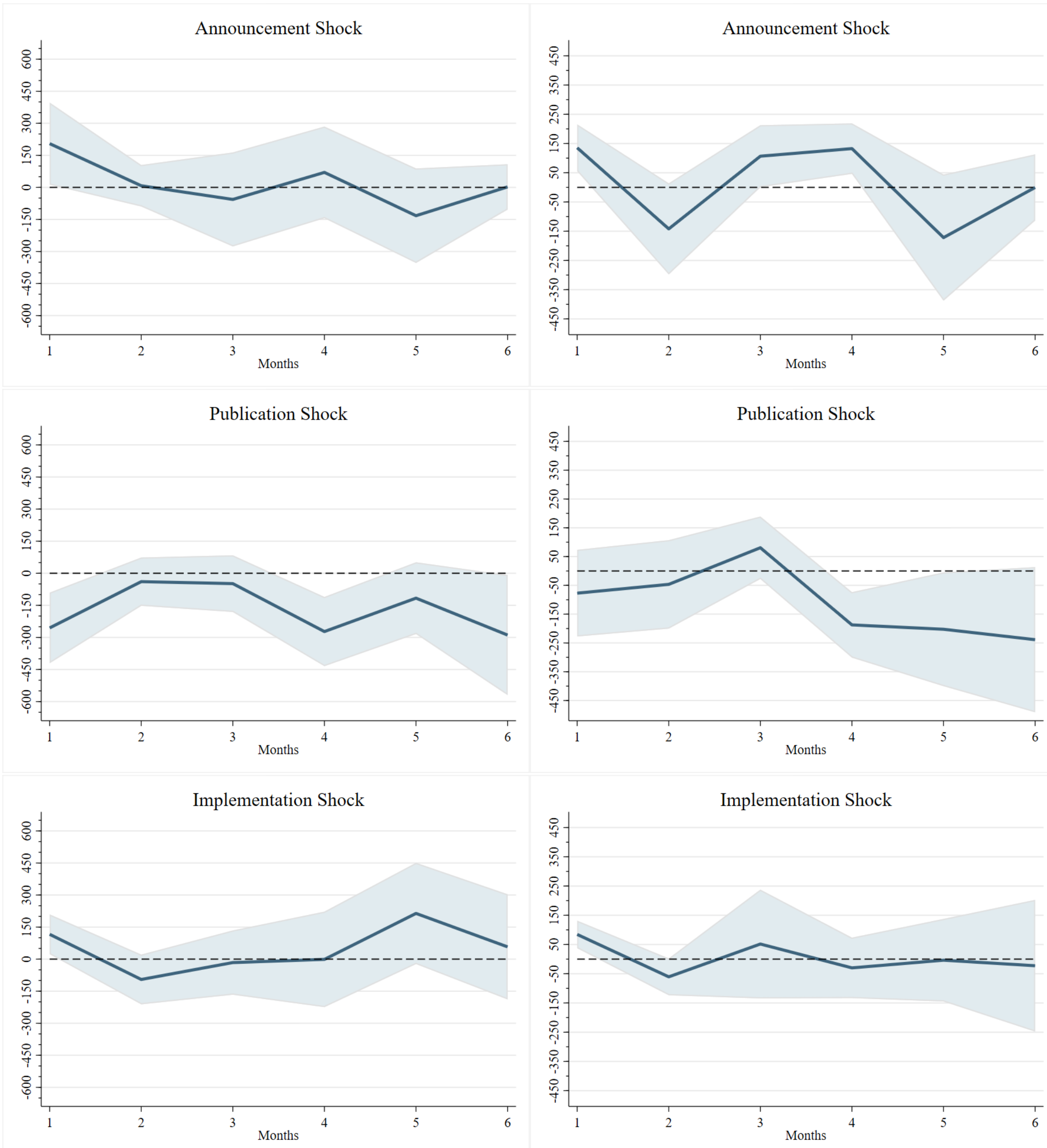

Figure 6: Impulse Response Functions of CDS Spreads after hit by shocks with a high regulatory impact in absolute differences relative to the industrial electricity price (left) and in log differences (right) with the carbon emissions measure in an interaction model.

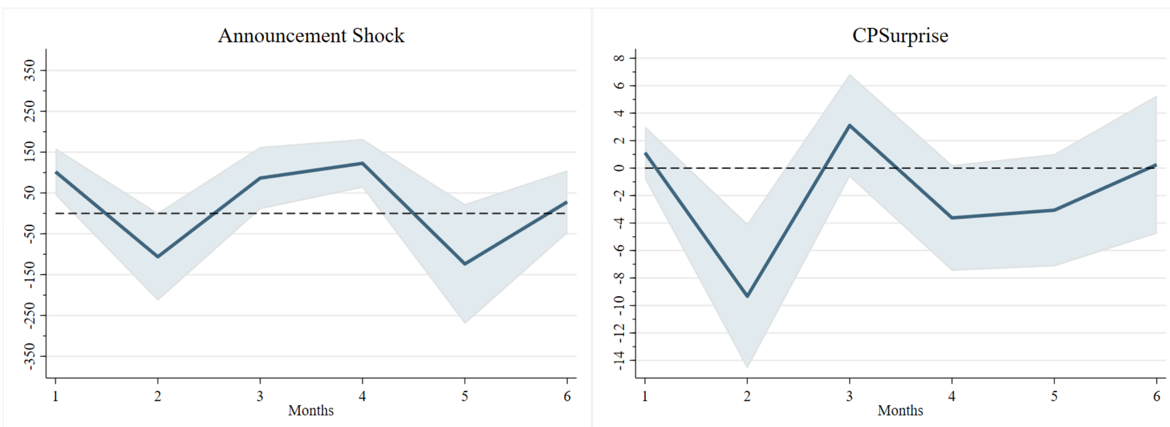

Figure 7: Impulse response functions of sovereign CDS spreads after announcement shocks in log differences (left) and after CPSurprise shocks (right)

References

Aastveit, Knut Are, Gisle James Natvik, and Sergio Sola. 2017. "Economic uncertainty and the influence of monetary policy." *Journal of International Money and Finance* 76 (September): 50–67.

Agiakloglou, Christos, and Emmanouil Deligiannakis. 2020. "Sovereign risk evaluation for European Union countries." *Journal of International Money and Finance* 103.

Aizenman, Joshua, Yothin Jinjarak, Hien Thi Kim Nguyen, and Donghyun Park. 2019. "Fiscal space and government-spending and tax-rate cyclicality patterns: A cross-country comparison, 1960–2016." *Journal of Macroeconomics* 60 (June): 229–252.

Andrieș, Alin Marius, Steven Ongena, and Nicu Sprincean. 2021. "The COVID-19 Pandemic and Sovereign Bond Risk." *The North American Journal of Economics and Finance* 58 (November): 101527.

Augustin, Patrick, Valeri Sokolovski, Marti G. Subrahmanyam, and Davide Tomio. 2022. "In sickness and in debt: The COVID-19 impact on sovereign credit risk." *Journal of Financial Economics* 143.

Bachner, Gabriel, Birgit Bednar-Friedl, and Nina Knittel. 2019. "How does climate change adaptation affect public budgets? Development of an assessment framework and a demonstration for Austria." *Mitigation and Adaptation Strategies for Global Change* 24 (February): 1325–1341.

Beirne, John, Nuobu Renzhi, and Ulrich Volz. 2021. "Feeling the heat: Climate risks and the cost of sovereign borrowing." *International Review of Economics Finance* 76 (November): 920–936.

Boeck, Maximilian, Martin Feldkircher, and Burkhard Raunig. 2023. "A view from outside: sovereign CDS volatility as an indicator of economic uncertainty." *Macroeconomic Dynamics* (November): 1–28.

Bolton, Patrick, and Marcin Kacperczyk. 2023. "Global Pricing of Carbon-Transition Risk." *Journal of Finance* 78 (August).

Bowman, Lera, Dapeng Hu, Mark Hu, Amit Madaan, and Antonio Baldaque da Silva. 2022. "Assessing Climate Change Impact on Sovereign Bonds." *The Journal of Portfolio Management* 48 (September): 98–118.

Brouwers, Roel, Frederiek Schoubben, Cynthia Van Hulle, and Steve Van Uytbergen. 2016. "The initial impact of EU ETS verification events on stock prices." *Energy Policy* 94 (July): 138–149.

Bushnell, James B, Howard Chong, and Erin T Mansur. 2013. "Profiting from Regulation: Evidence from the European Carbon Market." *American Economic Journal: Economic Policy* 5 (November): 78–106.

Carattini, Stefano, Garth Heutel, and Givi Melkadze. 2023. "Climate policy, financial frictions, and transition risk." *Review of Economic Dynamics* 51 (September).

Cesa-Bianchi, Ambrogio, Gregory Thwaites, and Alejandro Vicondoa. 2020. "Monetary policy transmission in the United Kingdom: A high frequency identification approach." *European Economic Review* 123 (April): 103375.

Cevik, Serhan, and João Tovar Jalles. 2022. "This changes everything: Climate shocks and sovereign bonds∗." *Energy Economics* 107 (March): 105856.

Chaudhry, Sajid M., Rizwan Ahmed, Muhammad Shafiullah, and Toan Luu Duc Huynh. 2020. "The impact of carbon emissions on country risk: Evidence from the G7 economies." *Journal of Environmental Management* 265 (July): 110533.

Chen, C, I Noble, J Hellmann, J Coffee, J Murillo, and N Chawla. 2023. *University of Notre Dame Global Adaptation Index Country Index Technical Report.*

Chernov, Mikhail, Lukas Schmid, and Andres Schneider. 2020. "A Macrofinance View of U.S. Sovereign CDS Premiums." *The Journal of Finance* 75 (June): 2809–2844.

Cochrane, John H, and Monika Piazzesi. 2002. "The Fed and Interest Rates—A High-Frequency Identification." *American Economic Review* 92 (April): 90–95.

Collender, Sierra, Baoqing Gan, Christina S. Nikitopoulos, Kylie-Anne Richards, and Laura Ryan. 2023. "Climate transition risk in sovereign bond markets." *Global Finance Journal* 57 (August): 100868.

Drago, Danilo, and Raffaele Gallo. 2016. "The impact and the spillover effect of a sovereign rating announcement on the euro area CDS market." *Journal of International Money and Finance* 67:264–286.

European Commission, EC. 2023. *What Is the EU ETS?* European Commission.

Fan, Ying, Jun-Jun Jia, Xin Wang, and Jin-Hua Xu. 2017. "What policy adjustments in the EU ETS truly affected the carbon prices?" *Energy Policy* 103 (April): 145–164.

Ferrara, Laurent, and Pierre Guérin. 2018. "What are the macroeconomic effects of high-frequency uncertainty shocks?" *Journal of Applied Econometrics* 33 (May): 662–679.

Fried, Stephie, Kevin Novan, and William B. Peterman. 2022. "Climate policy transition risk and the macroeconomy." *European Economic Review* 147 (August): 104174.

Gans, Joshua S. 2012. "Innovation and Climate Change Policy." *American Economic Journal: Economic Policy* 4 (November): 125–145.

Gürkaynak, Refet S, Brian Sack, and Eric Swanson. 2005. "The Sensitivity of Long-Term Interest Rates to Economic News: Evidence and Implications for Macroeconomic Models." *American Economic Review* 95 (February): 425–436.

Hengge, Martina, Ugo Panizza, and Richard Varghese. 2023. "Carbon Policy Surprises and Stock Returns: Signals from Financial Markets." *SSRN Electronic Journal.*

Huang, Bihong, Maria Teresa Punzi, and Yu Wu. 2021. "Do banks price environmental transition risks? Evidence from a quasi-natural experiment in China." *Journal of Corporate Finance* 69 (August): 101983.

Hübel, Benjamin. 2020. "Do markets value ESG risks in sovereign credit curves?" *The Quarterly Review of Economics and Finance* 85 (December).

IEA. 2024. *Energy Prices.* IEA, Paris.

Jong, Thijs, Oscar Couwenberg, and Edwin Woerdman. 2014. "Does EU emissions trading bite? An event study." *Energy Policy* 69 (June): 510–519.

Jordà, Òscar. 2005. "Estimation and Inference of Impulse Responses by Local Projections." *American Economic Review* 95 (February): 161–182.

Jordà, Òscar, and Alan Taylor. 2016. "The Time for Austerity: Estimating the Average Treatment Effect of Fiscal Policy." *The Economic Journal* 126 (February): 219–255.

———. 2024. "Local Projections." *Journal of Economic Literature (forthcoming)* (August).

Känzig, Diego. 2023. "The Unequal Economic Consequences of Carbon Pricing." *Working Paper* (May).

Kilian, Lutz, and Yun Jung Kim. 2011. "How Reliable Are Local Projection Estimators of Impulse Responses?" *Review of Economics and Statistics* 93 (November): 1460–1466.

Kling, Gerhard, Yuen Lo, Victor Murinde, and Ulrich Volz. 2018. "Climate Vulnerability and the Cost of Debt." *SSRN Electronic Journal.*

Koch, Nicolas, Godefroy Grosjean, Sabine Fuss, and Ottmar Edenhofer. 2016. "Politics matters: Regulatory events as catalysts for price formation under cap-and-trade." *Journal of Environmental Economics and Management* 78:121–139.

Kubota, Hiroyuki, and Mototsugu Shintani. 2022. "High-frequency identification of monetary policy shocks in Japan." *The Japanese Economic Review* 73 (January): 483–513.

Kuttner, Kenneth N. 2001. "Monetary policy surprises and interest rates: Evidence from the Fed funds futures market." *Journal of Monetary Economics* 47 (June): 523–544.

Li, Dake, Mikkel Plagborg-Møller, and Christian K. Wolf. 2024. "Local projections vs. VARs: Lessons from thousands of DGPs." *Journal of Econometrics* (March): 105722.

Lim, Sijeong, and Aseem Prakash. 2023. "Does carbon pricing spur climate innovation? A panel study, 1986–2019." *Journal of Cleaner Production* 395 (April): 136459.

Longstaff, Francis A, Jun Pan, Lasse H Pedersen, and Kenneth J Singleton. 2011. "How Sovereign Is Sovereign Credit Risk?" *American Economic Journal: Macroeconomics* 3 (April): 75–103.

Oda, T., and S. Maksyutov. 2011. "A very high-resolution (1 km×1 km) global fossil fuel CO2 emission inventory derived using a point source database and satellite observations of nighttime lights." *Atmospheric Chemistry and Physics* 11 (January): 543–556.

Pallara, Kevin, and Jean-Paul Renne. 2019. "Fiscal Limits and Sovereign Credit Spreads." *SSRN Electronic Journal.*

Pan, Jun, and Kenneth J. Singleton. 2008. “Default and Recovery Implicit in the Term Structure of Sovereign CDS Spreads.” *The Journal of Finance* 63 (September): 2345–2384.

Pan, Wei-Fong, Xinjie Wang, Yaqing Xiao, Weike Xu, and Jinfan Zhang. 2024. “The effect of economic and political uncertainty on sovereign CDS spreads.” *International Review of Economics Finance* 89 (January): 143–155.

Piger, Jeremy, and Thomas Stockwell. 2023. “Differences from Differencing: Should Local Projections with Observed Shocks be Estimated in Levels or Differences?” *SSRN Electronic Journal* (January).

Plagborg-Møller, Mikkel, and Christian K. Wolf. 2021. “Local Projections and VARs Estimate the Same Impulse Responses.” *Econometrica* 89:955–980.

Rudebusch, G.D. 2021. “Climate change is a source of financial risk.” *FRBSF Econ. Lett.* 03:1–6.

Semieniuk, Gregor, Emanuele Campiglio, Jean-Francois Mercure, Ulrich Volz, and Neil R. Edwards. 2020. “Low-carbon transition risks for finance.” *WIREs Climate Change* 12 (October).

Teles, Vladimir K., and Cesar Caio Mussolini. 2014. “Public debt and the limits of fiscal policy to increase economic growth.” *European Economic Review* 66 (February): 1–15.

Wisniewski, Tomasz Piotr, and Brendan John Lambe. 2015. “Does economic policy uncertainty drive CDS spreads?” *International Review of Financial Analysis* 42 (December): 447–458.

World Bank, WB. 2024. *Quarterly Public Sector Debt Database (QPSD).* World Bank.

Zenios, Stavros A. 2022. “The risks from climate change to sovereign debt.” *Climatic Change* 172 (3-4).

Appendix

A List of Variables

Variable	Source
Sovereign CDS spreads (5 year)	Refinitiv
Local Stock Market return	Refinitiv and Yahoo! Finance
Foreign Currency Reserve	Refinitiv and IMF
Global stock return	Yahoo! Finance
Constant maturity treasury rate	FRED St. Louis
Volatility Index (VIX)	Chicago Board Options Exchange
Equity Flow	ICI Investment
Bond flow	ICI Investment

Table A.1: List of Variables

B All regulatory events

Legal Act	Announcement	Publication	Implementation
specifying the administering Member State for each aircraft operator also taking into consideration the expansion of the Union emission trading scheme	01/29/2013	02/11/2013	02/14/2013
cancel all 2012 aviation allowances	04/24/2013	04/25/2013	04/25/2013
registries system	05/02/2013	05/03/2013	05/06/2013

reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change	05/21/2013	06/18/2013	07/10/2013
Aid to non-ferrous metal producers for CO2 costs of electricity	07/17/2013	05/05/2016	//
concerning national implementation measures for the transitional free allocation of greenhouse gas emission allowances	09/05/2013	09/09/2013	//
use of controlled substances as process agents to 1083 metric tonnes per year and limits the emissions from process agent uses to 17 metric tonnes per year	10/10/2013	01/13/2014	//
adjustments to Member States' annual emission allocations for the period from 2013 to 2020	10/31/2013	11/01/2013	11/06/2013
international credit entitlements	11/08/2013	11/11/2013	11/11/2013
auction platform	11/13/2013	11/14/2013	11/15/2013

regards the sectors and subsectors which are deemed to be exposed to a significant risk of carbon leakage	12/18/2013	01/14/2014	//
list of aircraft operators that performed an aviation activity	02/05/2014	02/06/2014	02/11/2014
determine the volumes of greenhouse gas emission allowances to be auctioned in 2013-20	02/25/2014	02/26/2014	02/27/2014
questionnaire for reporting	03/21/2014	03/25/2014	//
fluorinated greenhouse gases and repealing Regulation	04/16/2014	05/20/2014	06/11/2014
transfer of assigned amount units to the Party to the Kyoto Protocol holding account in the registry of Finland	04/16/2014	04/23/2014	//
applying a single global market-based measure to international aviation emissions	04/16/2014	04/30/2014	04/30/2014

technical implementation of the Kyoto Protocol to the United Nations Framework Convention on Climate Change	05/15/2014	06/27/2014	07/22/2014
additional historical aviation emissions and additional aviation allowances to take into consideration the accession of Croatia	06/23/2014	06/24/2014	06/25/2014
submission processes and review of information reported by Member States	06/30/2014	07/11/2014	07/31/2014
list of sectors and subsectors which are deemed to be exposed to a significant risk of carbon leakage	10/27/2014	10/29/2014	//
administering Member State for each aircraft operator	02/09/2015	02/10/2015	02/13/2015
technical implementation of the Kyoto Protocol after 2012	07/13/2015	10/15/2015	10/16/2015
ETS Market stability reserve	10/06/2015	10/09/2015	10/29/2015

allocate greenhouse gas emission allowances free of charge to aircraft operators	05/18/2016	05/19/2016	06/08/2016
instrument to be drawn up within the ICAO bodies and intended to lead to the implementation from 2020 of a single global market-based measure for international aviation emissions	05/30/2016	06/10/2016	06/13/2016
maximum annual amount of allowances constituting the basis for calculating allocations free of charge to installations not covered	01/24/2017	01/25/2017	03/01/2017
European Union and the Swiss Confederation on the linking of their greenhouse gas emissions trading systems	11/10/2017	12/07/2017	//
CCS demonstration projects	11/20/2017	11/22/2017	//
continue current limitations of scope for aviation activities	12/13/2017	12/29/2017	12/29/2017

conclusion of the Agreement between the European Union and the Swiss Confederation on the linking of their greenhouse gas emissions trading systems	01/23/2018	02/16/2018	03/08/2018
Union Registry, LIFE multiannual work programme	02/12/2018	02/13/2018	02/14/2018
enhance cost-effective emission reductions and low-carbon investments	03/14/2018	03/19/2018	04/09/2018
binding annual greenhouse gas emission reductions by Member States from 2021 to 2030	05/30/2018	06/19/2018	07/09/2018
monitoring and reporting of CO2 emissions from and fuel consumption of new heavy-duty vehicles	06/28/2018	07/09/2018	07/31/2018
European Union and the Swiss Confederation on the linking of their greenhouse gas emissions trading systems regarding the adoption of its Rules of Procedure	09/18/2018	09/24/2018	//

governance mechanism energy union	12/11/2018	12/21/2018	12/24/2018
transitional Union-wide rules for harmonised free allocation of emission allowances	12/19/2018	02/27/2019	02/28/2019
verification of data and on the accreditation of verifiers	12/19/2018	12/31/2018	01/02/2019
agreement setting out arrangements for the withdrawal of such a Member State from the European Union	12/19/2018	03/14/2019	03/15/2019
administering Member State for each aircraft operator	02/06/2019	02/12/2019	02/15/2019
determination of sectors and subsectors deemed at risk of carbon leakage for the period 2021 to 2030	02/15/2019	05/08/2019	05/09/2019
Innovation Fund ETS	02/26/2019	05/28/2019	06/18/2019
functioning of the Union Registry	03/13/2019	07/02/2019	07/22/2019
technical implementation of the second commitment period of the Kyoto Protocol	03/13/2019	07/02/2019	07/22/2019

on the proposed citizens' initiative entitled 'A price for carbon to fight climate change'	07/03/2019	07/11/2019	07/22/2019
measures adopted by the International Civil Aviation Organisation for the monitoring, reporting and verification of aviation emissions for the purpose of implementing a global market-based measure	07/18/2019	09/30/2019	10/21/2019
auctioning of allowances with the EU ETS rules for the period 2021 to 2030 and with the classification of allowances as financial instruments	08/28/2019	11/08/2019	11/29/2019
EEA Agreement, on cooperation in specific fields outside the four freedoms	10/24/2019	11/04/2019	//
United Kingdom – Electricity Market Reform: Capacity Mechanism	10/24/2019	03/06/2020	//

auctioning of 50 million unallocated allowances from the market stability reserve for the innovation fund and to list an auction platform to be appointed by Germany	10/30/2019	01/06/2020	01/07/2020
further arrangements for the adjustments to free allocation of emission allowances due to activity level changes	10/31/2019	11/04/2019	11/25/2019
Agreement between the European Union and the Swiss Confederation on the linking of their greenhouse gas emissions trading systems	11/21/2019	12/10/2019	//
European Union Transaction Log to enter changes to the national allocation tables	12/13/2019	02/13/2020	//

Table A.2: All legal acts and corresponding Announcement, Publication and Implementation dates

C Volatility analysis

Volatility	AshockE	PshockE	IshockE	logA	logP	logI
Phase II	0.2064	0.2656	0.1808	0.0119	0.0157	0.0117
Phase III	0.3540	0.2214	0.2698	0.0113	0.0087	0.0099

Table A.3: Standard deviations of all measured shocks in phase II and III.

D Regression tables

D.1 Baseline specification

Month	1	2	3	4	5	6
Announcement Shock	162.68	3.39	-36.19	75.11	-113.25	21.15
	(103.84)	(46.39)	(105.50)	(102.96)	(110.37)	(47.46)
Publication Shock	-255.75**	-40.38	-51.09	-279.11***	-118.75	-292.95*
	(100.73)	(69.03)	(78.90)	(98.71)	(104.28)	(172.12)
Implementation Shock	121.01**	-94.41	-21.33	0.99	207.63	59.93
	(56.73)	(70.58)	(92.38)	(137.01)	(144.23)	(150.14)

Table A.4: Coefficients of the impulse response functions in the baseline specification with the corresponding standard errors in brackets below. The symbols '*', '**', and '***' indicate statistical significance at the 10%, 5% and 1% levels, respectively.

D.2 Extended specification

Month	1	2	3	4	5	6
Announcement Shock	102.08***	-106.21	86.53*	122.69***	-124.00	28.26
	(35.09)	(65.47)	(46.45)	(36.32))	(89.43)	(46.95)
Publication Shock	-28.45	-41.67	66.38	-161.34***	-148.78*	-182.62*
	(62.20)	(62.17)	(50.26)	(47.68)	(81.71)	(103.98)
Implementation Shock	100.60**	-35.47	14.58	-14.04	0.74	-23.92
	(38.80)	(31.36)	(105.80)	(70.19)	(91.95)	(128.14)

Table A.5: Coefficients of the impulse response functions after the shocks in log differences with the corresponding standard errors in brackets below. The symbols '*', '**', and '***' indicate statistical significance at the 10%, 5% and 1% levels, respectively.

D.3 Cost impact of baseline specification

Month	1	2	3	4	5	6
Announcement Shock	450.48	-370.12	-905.66	-470.85	-1063.82	-713.86
	(463.26)	(388.26)	(814.03)	(816.85)	(1004.99)	(723.18)
Publication Shock	-593.26**	65.32	-290.91*	-1055.55**	-279.91	-1235.24*
	(270.74)	(205.89)	(153.91)	(457.26)	(460.76)	(663.74)
Implementation Shock	454.06	-432.69	-153.80	-399.36	527.86	-499.04
	(293.44)	(377.85)	(242.47)	(412.16)	(386.04)	540.38

Table A.6: Coefficients of the impulse response functions baseline specification in absolute differences relative to industrial electricity price with the corresponding standard errors in brackets below. The symbols '*', '**', and '***' indicate statistical significance at the 10%, 5% and 1% levels, respectively.

D.4 Cost impact of extended specification

Month	1	2	3	4	5	6
Announcement Shock	-70.98	-311.92	-372.65	-299.42	-807.90	-494.34
	(100.45)	(265.46)	(331.56)	(408.40)	(654.27)	(541.46)
Publication Shock	-227.60	207.36	662.23	-1013.77**	-702.89	-938.72
	(553.64)	(505.34)	(433.08)	(404.66)	(608.20)	(718.59)
Implementation Shock	421.70**	8.53	159.27	95.79	350.63	-75.34
	(204.20)	(160.01)	(368.28)	(394.96)	(443.88)	(478.93)

Table A.7: Coefficients of the impulse response functions after the shocks in absolute differences relative to industrial electricity price with the corresponding standard errors in brackets below. The symbols '*', '**', and '***' indicate statistical significance at the 10%, 5% and 1% levels, respectively.