Climate Policy, Stranded Assets, and Investors' Expectations

Suphi Sen* Marie-Theres von Schickfus†

Abstract

The goal to keep global warming below 2°C implies that many energy-sector assets are at risk of becoming stranded, as climate policies might render some of their fossil fuel related assets worthless prior to the end of their economic life time. This paper investigates whether and how investors price in stranded asset risk due to climate policy. We exploit the gradual development of a German climate policy proposal aimed at reducing electricity production from coal and analyze its effect on the valuation of energy utilities. We find that investors do care about stranded asset risk, but that they also expect a financial compensation policy for their stranded assets.

Keywords: Stranded assets, climate policy, political economy, utilities.

*ifo Institute - Leibniz Institute for Economic Research at the University of Munich, Poschingerstr. 5, 81679 Munich. Email: sen@ifo.de.

†ifo Institute - Leibniz Institute for Economic Research at the University of Munich, Poschingerstr. 5, 81679 Munich. Email: vonschickfus@ifo.de.

1 Introduction

As early as 2012, global financial services companies drew attention to the risk of coal investments becoming stranded due to the 2°C "carbon budget,"[1] which is the amount of CO_2 that can be emitted to stay below the 2°C goal (Meinshausen et al., 2009). However, the current market valuation of companies owning fossil fuel assets might not be reflecting the stranded asset risk, and this might lead to costly consequences for the whole economy. First, as the capital allocated to fossil fuel assets cannot be directed to clean energy, the misallocation of capital due to delayed disinvestment might render the transition to clean capital more expensive (IPCC, 2014; IRENA, 2017a). Second, "a sudden, unexpected tightening of carbon emission policies could lead to a disorderly re-pricing of carbon-intensive assets and a negative supply shock" (Batten et al., 2016) through changes in energy use and second-round effects in financial markets. Financial institutions such as the Bank of England, the Dutch Central Bank (DNB), the Inter-American Development Bank (IDB), and the European Systemic Risk Board (ESRB) have identified the mispricing of stranded asset risk as a potential systemic risk and threat to financial stability.[2]

Therefore, it is crucial to understand the interaction between investors' expectations and the development of climate policies. Investors' reactions to new policies depend on their prior expectations, which, in turn, are shaped by previous policies. This interaction is central to the current paper: What are investors' priors regarding stranded asset risk, and (how) do these priors change when climate policy proposals are announced? Have investors already priced in expected losses due to the carbon budget, do they only respond to concrete policies, or do they expect

[1] For example, see the report by HSBC on "Coal and Carbon. Stranded Assets: Assessing the Risk," picking up on the 2011 report by the Climate Tracker Initiative on "Unburnable Carbon - Are the World's Financial Markets Carrying a Carbon Bubble?"

[2] See Batten et al. (2016); Schotten et al. (2016); Caldecott et al. (2016); European Systemic Risk Board (2016). To mitigate the risk, the Finance Ministers and Central Bank Governors of the Group of Twenty (G20) requested the Financial Stability Board to create an industry-led Task Force on Climate-Related Financial Disclosures (TCFD, 2017). The private sector is becoming increasingly aware and active as well, with, for example, the rating agency Moody's announcing that it will analyze firms' carbon transition risk in its credit ratings (Moody's, 2016).

to be financially compensated for stranded assets? To answer these questions, we exploit the gradual development of a climate policy proposal in Germany targeting lignite assets and investigate how adjustments of this proposal have affected the market valuation of firms active in electricity production.

We find that investors did not react to announcements of the initial "climate levy" proposal, which was directed at stranding lignite assets by charging an extra fee on carbon emissions (Stage 1). The proposal being turned into a compensation mechanism (Stage 2), paying plant owners for not running their units, did not have a significant effect on stock valuations either. Only, announcements that the compensation mechanism may not go through due to violating state aid rules (Stage 3) resulted in a significant and negative reaction. This suggests that investors have already priced in the stranded asset risk, but with an expectation of a compensation mechanism.

Our analysis starts from the notion that the evolution of climate policies and the expectations of investors are interrelated. First, investors' concern about stranded assets can be influenced by signals they receive. Many climate policies and policy proposals may imply the stranding of fossil assets and thus provide such a signal. For instance, setting a price on CO_2 emissions or imposing a cost on fossil resource extraction[3] can reduce demand, slow down investment in fossil infrastructure, and cause asset stranding. Alternatively, Harstad (2012) has a very different proposal for curbing carbon emissions in the absence of a global climate agreement: "the coalition's best policy is to simply buy foreign deposits and conserve them" - in other words, to compensate fossil asset owners for leaving their reserves unburned. Compensation mechanisms have since been suggested in various contexts, such as to enable an international climate agreement, reduce the cost of emission reductions, prevent carbon leakage, and avoid stranded assets (Harstad, 2012; Peterson and Weitzel, 2014; Collier and Venables, 2014).

[3]For instance, by reducing subsidies or imposing taxes on production, exports, or capital rents (Faehn et al., 2014; Richter et al., 2015; Sinn, 2008).

Second, investors' reactions to such policy signals depend on their prior expectations regarding the likelihood of asset stranding. In fact, they may have already revalued assets downward following information on the carbon budget implied by the Paris Agreement. However, they may find it difficult to translate the general concept of a carbon budget into stranded asset risk for a particular firm or country. In such a case, they would wait for further information on specific climate policies with clear asset stranding implications. Nevertheless, even the announcement of climate policies does not necessarily lead investors to reassess the likeliness of asset stranding. If investors expect a compensation mechanism, they will not react to news on climate policies. There are good reasons for policymakers to opt for compensation policies, and for investors to expect them to do so: policies aimed at stranding assets might result in political friction, for example, due to their potential effects on employment. Therefore, such plans may be met with opposition from affected parties and be amended in the course of the political process.

The policy proposal we investigate provides a convenient empirical setting to disentangle the effects of these different signals and expectations. By tracking the stock market response to different stages of the proposal, we can draw conclusions about investors' prior expectations and how they evolved in the course of the policy's development.

As our baseline estimation strategy, we conduct a short-run event study analysis. More specifically, we investigate whether there are abnormal returns to the assets of three publicly listed energy companies that can be associated with the three stages of the policy proposal.[4] We provide an extensive robustness analysis related to identification of the event effects. First, we conduct placebo tests for the nonevent days just prior to the event days to verify the model's performance in predicting the counterfactual returns. Second, as an alternative to using a market price index to

[4]Short-run event study methodology has been a widely employed approach in identifying how specific events affect asset returns. See MacKinlay (1997) for a comprehensive description of event study methodology.

control for average market conditions, we estimate a synthetic portfolio aiming to produce a counterfactual control unit.[5] These estimations show that our results are not driven by the endogeneity of the market price index to the event shocks. Third, in order to control for industry-wide shocks, we use an energy utility company without any lignite-related assets as the control unit, leading to a difference-in-differences estimation of abnormal returns. Finally, by using a news search engine, we identify a small number of potentially confounding events and verify that our results are not driven by these events.

Related literature. Our paper contributes to the literature on empirical assessments of market reactions to climate policies, often in the form of event studies. Lemoine (2017) and Di Maria et al. (2014) find that market players do act in anticipation of demand-side climate policies. Ramiah et al. (2013) show that stock investors react to announcements of national carbon emission pledges, and Koch et al. (2016) find evidence that regulatory events drove EU ETS allowance prices. In the German power market context, Oberndorfer et al. (2013) investigate the stock market effects of voluntary actions such as the inclusion of firms in a sustainability stock index. However, to date, investor expectations with regard to specific policies directed at stranding assets or to compensation mechanisms have not been studied.

There are few papers investigating empirically how investors price in unburnable carbon risk. Batten et al. (2016) conclude that the announcement of the Paris Agreement in December 2015 had a positive effect on the valuation of renewable energy companies, but no significant effect on fossil fuel companies. Griffin et al. (2015) find that the publication of the Meinshausen et al. (2009) article in *Nature* led to a statistically significant, yet fairly small, reduction in the stock returns of

[5]See Abadie and Gardeazabal (2003) and Abadie et al. (2010) for the synthetic control approach. We apply this approach to the classic short-run event study methodology. See Guidolin and La Ferrara (2007) for a similar approach.

oil and gas firms. They mention several reasons why this effect might be so small. One is investors' expectations with respect to technological developments: this is what Byrd and Cooperman (2016) examine, concluding that investors are aware of the relevance of carbon capture and storage (CCS) in allowing continued carbon use, but that they have already priced in stranded asset risk. A second potential reason is that investors anticipate governments' energy policies, which is what this article examines in detail.

The remainder of the paper is organized as follows. Section 2 describes the development of the specific German policy proposal and the affected companies. In Section 3, we present different scenarios for the empirical analysis with regard to investors' expectations. The empirical methodology is outlined in Section 4. Section 5 presents the main results, and Sections 6 and 7 present the robustness analysis. Section 8 concludes.

2 Policy Background

In this paper, we track investor reactions to each of three steps in the development of a German climate policy proposal known as the "climate levy" (Klimabeitrag), which was first publicly announced in March 2015. This proposal and the way it evolved provides a convenient empirical setting for investigating investor expectations. Each stage in the development of this proposal represents a different event for our analysis. Introduction of the climate levy proposal, which was directed at stranding lignite assets, is the first stage of the policy development. The second stage starts when the proposal was turned into a compensation mechanism. Finally, the proposal enters the third stage with the publication of news that the compensation mechanism is inconsistent with the EU state aid rules. For each of these three events, there are several candidate announcement dates on which the related information might have been publicized, or on which new information might have been released. The stages of the policy development and the potential announcement dates are presented in Table I. In the remainder of this section, we describe the chronological development of the proposal, the affected companies, and the scenarios we test in this setting.

2.1 Development of the Policy Proposal

Stage 1: Climate levy proposal - uncompensated policy. In March 2015, the German Ministry of Economy and Energy presented its first draft of the climate levy legislation. Its main idea is to charge an extra levy on CO_2 emissions from all power generating units older than 20 years whose emissions exceed a certain yearly threshold (a levy-free allowance), with the aim of saving 22 million tons of CO_2. Because the European Emission Trading System (ETS) was not reducing emissions as expected, Germany needed to cut emissions from the electricity sector by that amount in order to reach its national emission reduction targets. The climate levy proposal directly targeted the stranding of assets by focusing on old units and incentivizing nonuse if the allowance is exceeded. Because the excess levy was to be applied independently of technology, the most emission-intensive energy carrier, lignite, would have been the most, or the only, affected one.[6]

German lignite power plants are designed to provide base load electricity, and are all situated next to mines: due to the high transport cost relative to the energy content, lignite is essentially not transported over long distances. Often, operators of lignite power plants are simultaneously the owners and operators of the mines. If the power plant is not run, the fuel next to it is left in the ground. Thus a policy targeting CO_2 emissions from lignite strands the power plant assets as well as their fuel resources.

The climate levy proposal was the first stage of the policy development and we classify this proposal as an "uncompensated policy." Unsurprisingly, the proposal

[6]For the details and implications of the climate levy, see, e.g., Peterson (2015) and Bundesministerium für Wirtschaft und Energie (2015). Lignite provided 24% of German electricity production in 2014.

Table I: Event dates (all in 2015)

No	Date	Events and Announcements
		Stage 1: Climate levy proposal
(1a)	March 20	First news on climate levy draft paper
(1b)	March 26	Climate levy draft presented in parliament
(1c)	May 19	Ministry provides new, less stringent proposal for climate levy
		Stage 2: Security reserve proposal
(2a)	May 23	IG BCE trade union presents proposal of turning lignite plants into capacity reserve
(2b)	May 28[a]	Reports that Ministry is positively considering the IG BCE proposals
(2c)	June 24	Minister: two options on the table, climate levy and security reserve. Coalition summit will decide on July 1
(2d)	July 2	Coalition summit decision on security reserve
		Stage 3: State aid assessments
(3a)	July 23[b]	Academic service of German Parliament assesses security reserve as violating EU state aid rules
(3b)	August 14	Media reports on the service's state aid assessment
(3c)	September 14	European Commission considers state aid procedure

Source: LexisNexis and own research.
[a] Note that events 2a and 2b are very close and may overlap depending on the event window. Moreover, there is a confounding event on June 3, when the Energy Market White Paper was published by the Ministry of Economics and Energy. This white paper does not mention the climate levy or security reserve, but its contents are relevant for all players in the electricity market.
[b] This is the date of the report; it seems that the media reports on August 14 were the first public news on this topic.

sparked protest among industry, trade unions, and politicians.[7] In response, the Ministry presented a new proposal in May 2015, permitting operators to transfer the allowances to other installations, and allowing some flexibility in the levy price. However, this was not enough to placate the levy's opponents.

Stage 2: Security reserve proposal - compensated policy. Only a few days later, the trade union for mining, chemicals, and energy (IG BCE) presented its own proposal, which was to turn six Gigawatts of lignite capacity into a capacity reserve, that is, to take them out of the regular electricity market, pay them for holding capacity ready, and use this capacity only in the case of unexpected shortfalls. This marks the beginning of the second stage of the policy development. Following

[7]While the proposal came from a ministry led by the Social Democrats (SPD), members of their larger coalition partner, the Christian Democrats (CDU), expressed concern about the proposal. Moreover, ministers from the most affected Länder (those with high shares of lignite electricity production - North Rhine-Westphalia, Saxony, Brandenburg, and Saxony-Anhalt) spoke against the policy, regardless of their party affiliation.

IG BCE statements that the Ministry was positively considering this alternative proposal (May 28), reports emerged in various newspapers that the climate levy would not be introduced (June 6). On June 24, Minister Gabriel declared that both options were currently on the table for discussion and that the coalition summit would decide. On July 2, 2015, the federal coalition decided at its energy summit not to introduce the climate levy, but a security reserve (Sicherheitsbereitschaft, literally security readiness[8]), mothballing 2.7 Gigawatts of capacity.[9] The targeted units were equivalent to 13% of installed lignite capacity and were supposed to be compensated for their foregone revenues (to be financed via network fees) until they were gradually phased out of production.

Stage 3: State aid assessments - challenge to the compensation. However, it turned out that the compensation proposal had to overcome another hurdle, which brings us to the third stage. In July 2015, the German Parliament academic service concluded that the security reserve could violate EU state aid rules. On August 14, 2015, *Spiegel online* first reported this state aid assessment, implying that it could cause the security reserve plans to fail. On September 14, the European Commission announced that it was considering a state aid procedure on the security reserve plans. We classify this news as a "challenge to the compensation."

2.2 Companies

We focus on the three publicly listed German companies that were active in the lignite business in 2015: RWE AG, E.ON SE, and EnBW AG.[10] Of these three, RWE was by far the most lignite-intensive electricity producer. The climate levy proposal targeted plants older than 20 years and was intended to be implemented in

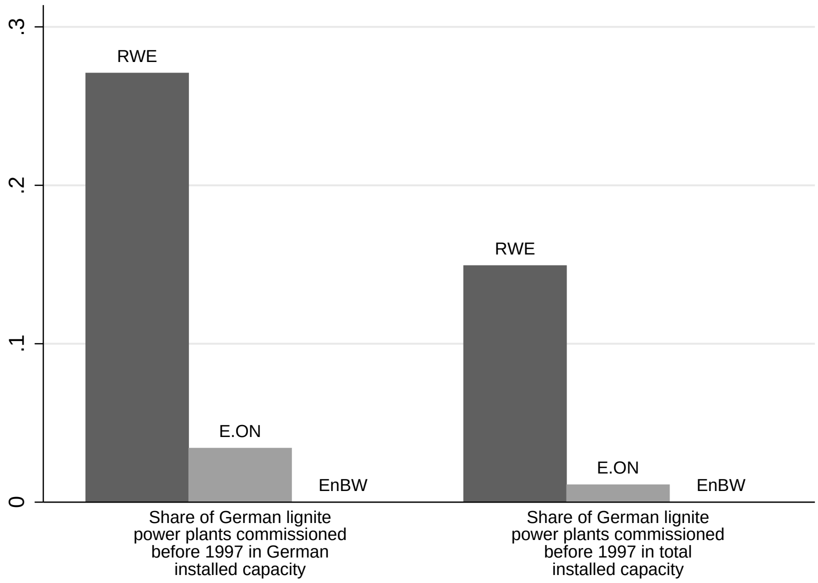
[8]The term "capacity reserve" (Kapazitätsreserve) described another mechanism in the energy market legislation and thus could not be used to describe the mothballing of lignite power plants.

[9]The term "mothballing" is used for power plants (or any other production facilities) that are not in operation, but preserved for potential future use.

[10]Two more firms were operating with lignite: Vattenfall GmbH and Mibrag mbH. As they are not publicly listed, we cannot consider them in the event study.

2017. Figure 1 shows, for each of the companies, the share of German lignite plants commissioned before 1997 in their overall electricity generation capacity (national and worldwide). We see that the climate levy proposal would have affected 27% and 15% of RWE's installed capacity in Germany and worldwide, respectively. For E.ON, the respective shares would have been 3% and 1%. EnBW only holds shares in a plant that was commissioned in 1999 and thus would not have been affected. Moreover, in contrast to RWE, which largely owns the lignite mines next to its plants, E.ON and EnBW operate only the power plants and buy the fuel from a mine operator. Therefore, their stranded asset risk is limited to their power plants, whereas RWE would have had to strand its fossil assets as well.

Figure 1: Lignite capacity affected by climate levy for RWE, E.ON and EnBW, as a share of total installed capacity



Source: Own representation based on Open Power System Data available at `http://data.open-power-system-data.org/conventional_power_plants/`.

While the climate levy proposal did not target specific plants (apart from selecting by age), the security reserve proposal clearly specified the individual plants scheduled for mothballing.[11] Of the three publicly listed companies, only RWE was affected by this bill: two of its units in Frimmersdorf were scheduled to be moth-

[11]See Table VIII in the Appendix for a list of units to be transferred into the security reserve.

balled on October 1, 2017, two units in Niederaußem on October 1, 2018, and one unit in Neurath on October 1, 2019 (the final decommissioning is always scheduled for four years later). Nevertheless, E.ON was impacted by the coalition decision on the security reserve because it implied that the climate levy would not be introduced. All reports related to a potential state aid procedure against the security reserve policy are relevant for all lignite-owning companies because they introduce uncertainty about future policies, but mainly for RWE because its compensation payments are at stake.

3 Scenarios for Investors' Priors and Reactions

By investigating investor reactions to the different events, we can draw conclusions about their initial beliefs corresponding to our research questions. Table 2 outlines possible different combinations of reactions to the three stages; of course, many other combinations are theoretically possible. We concentrate on combinations that we deem plausible in the context of stranded assets, terming them "scenarios."

Table II: Scenarios for investors' priors and reactions

Scenarios		**Reactions to...**		
		Uncompensated policy	Compensated policy	Challenge to compensation
0	Don't care	0	0	0
1	Respond to policies, didn't price in stranded asset risk before	−	+	−
2	Have priced in expected loss, but are surprised by compensation	0	+	−
3	Price in loss and expect compensation	0	0	−

Scenario 0 is no reaction: here, investors simply do not care about stranded asset risk and do not react to any policy proposals or related news. In Scenario 1, the investors' prior is that unburnable carbon per se is not an issue. However, they do care about stranded asset risk induced by specific policies, and react to such news. They are positively surprised by the compensation mechanism and negatively by its challenge. In Scenario 2, investors have already priced in stranded asset risk due to unburnable carbon: for example, they are aware of a nationwide or worldwide emission reduction target and have already considered this overall target in their firm valuation. Therefore, a policy introduced to achieve the target does not impact their valuation of the affected firms. However, the compensation mechanism is unexpected for these investors and they value it positively.[12] When the compensation is challenged, they adjust their valuation downward again. Finally, in Scenario 3, investors do care about stranded asset risk, but they expect to be compensated. When the Ministry announces the uncompensated policy, they do not believe that this will affect the firms economically, and thus show no reaction. The compensation plans are not surprising, either, and investors do not adjust their firm valuation. However, the challenge of the compensation is a surprise, and causes investors to revalue firms downward.

4 Estimation Strategy

As our baseline estimation strategy, we conduct a short-run event study analysis where we investigate whether there are abnormal returns associated with the events.[13] It is worth emphasizing some peculiar aspects of our application in advance. We are interested in the effects of three events. For each event, we have several candidate announcement dates on which the investors might have reacted.

[12]Note that in this case, we would not expect a positive reaction for E.ON: only RWE receives compensation payments and in this scenario investors are not concerned about introduction of the uncompensated policy because they have priced in general unburnable carbon risk.

[13]Throughout the analysis, we use several specifications and identification strategies. To lay out our assumptions about the identification of an event effect and to facilitate comparison among alternative estimators and specifications, we prefer to use a regression based exposition of the short-run event study approach, while we also explain how it is related to the classical exposition with the common test statistics. The classical short run event study methodology was introduced by Fama et al. (1969). See MacKinlay (1997) for a detailed description. Another approach widely used in the literature is a regression-based one. See, for example, Binder (1985a,b). Recent applications in the context of the current paper include Lemoine (2017) and Ramiah et al. (2013).

The effects of the announcements that are related to a single stage of the policy development cannot be considered completely independent: if the investors reacted to an earlier announcement, the later announcements for the same stage will be less likely to have significant effects. For this reason, most of our analysis will be conducted separately for each announcement; only in some cases do we provide the average estimated effects across announcements for brevity of exposition, and refer the reader to the Appendix for individual results. Therefore, in the following subsection, we start by describing our estimation framework for the case of one asset and one announcement. In the subsequent subsection, we describe our approach for the case of more than one announcement and more than one asset, which we mainly employ to estimate the marginal effect of a potential confounding event as a robustness test.

4.1 Baseline Strategy

Estimating cumulative abnormal returns. Consider the following specification to assess the impact of a single event at date T on the returns of a single asset i:

$$r_{it} = X_{it}\beta_i + \sum_{d=-h}^{+h} \gamma_i^d D_t^d + \epsilon_{it}, \tag{1}$$

where r_{it} is the continuously compounded return of the asset at the trading date t, that is, the daily change in the logarithm of asset prices. The normal performance of the asset is predicted by the vector of covariates X_{it}. In the second term, h is the half-width of the event window. Hence the event window spans the $L = 2h + 1$ trading days from $t = T - h$ to $t = T + h$. Define a relative time index $\tau = t - T$ which measures the distance to the event in terms of trading days. The potential effect of the event on the returns is captured by the set of event day dummies, $D_t^d = 1\{d = \tau\}$. The coefficient vectors, β_i and γ_i^d, and the error terms, ϵ_{it}, are asset specific. Initially, assume that $\epsilon_{it} \sim \text{NID}(0, \sigma^2)$, that is, the errors are independent drawings from a normal distribution with mean zero and constant variance.

The idea in Equation (1) is to compare the event-induced abnormal returns (AR) with the normal returns. The normal return, which is an estimate of $\mathrm{E}[r_{it}|X_{it}]$, is the predicted returns given by $\hat{r}_{it} = X_{it}\hat{\beta}$. In this specification, as the event day dummies capture the whole variation in the event window, these observations are not relevant for the estimation of normal returns. Then, the event related abnormal return (AR) is given by $\gamma_i^d = r_{i,T+d} - \mathrm{E}[r_{i,T+d}|X_{i,T+d}]$, and its estimate is the prediction error, given by

$$\hat{\gamma}_i^d = r_{i,T+d} - \hat{r}_{i,T+d}.$$

Assuming that the estimation sample is sufficiently large to ignore sampling error, the prediction variance is equal to σ^2. The null hypothesis, that the event does not have an effect over the event window, is formulated as:

$$H_0\colon \sum_{d=-h}^{h} \gamma_i^d = 0.$$

The sum over the abnormal returns gives the cumulative abnormal return (CAR), which has a variance of $\sum_{d=-h}^{d=h} \sigma^2$ to calculate the usual t-statistics to test the hypothesis.

To interpret the AR as the event effect, the required assumption is that the model is correctly specified such that the predicted returns for the event window are the counterfactual returns to asset i in the absence of the event. The choice of the covariate set is generally motivated by well-known statistical and theoretical models of asset returns that the empirical finance literature deems to perform well. We provide an extensive robustness analysis with respect to this choice. In our baseline estimations, we simply use a constant and a market performance index (the so-called market model), which is generally considered sufficient for short-run event studies.

Estimation window and pseudo tests. Valid inference requires that the normal market performance is uncorrelated with the event-induced abnormal returns. To control for potential feedback from the event to the normal market performance, such as anticipation effects, the common approach is to exclude the event window observation in the estimation of expected returns, which is already the case for the specification in Equation (1). Considering that, in the absence of repeated observations for the event effect, estimated abnormal returns are simply the prediction errors, the natural choice for the estimation window is to use the observations prior to the event window, potentially leaving a gap between the end of the estimation sample and the beginning of the event window. Formally denote the chosen relative distance to the announcement date with k^u such that $k^u > h$. The abnormal returns between $T_j - k^u$ and $T_j - h$ are expected to be insignificant, and can be used to conduct pseudo tests. In other words, we expect the model to perform well for this pseudo window. Modifying Equation (1) to accommodate the choice of the estimation window leads to:

$$r_{it} = X_{it}\beta_i + \sum_{d=-k^u}^{-h-1} \gamma_i^d D_t^d + \sum_{d=-h}^{h} \gamma_i^d D_t^d + \epsilon_{it}. \tag{2}$$

Here, the second term on the right hand side gives the estimated ARs for the pseudo window. By using these estimates, one can calculate an L-days CAR for a date in the pseudo window as if an event has occurred on that date. These pseudo tests can be interpreted as a performance test for the predictions.

Endogeneity of the market price index. The most important threat to identification of the event effect is the presence of other contemporaneous shocks in the event window. There are several ways to control for such potential biases. First, when there is a limited number of assets or announcements, it is feasible to review the news around the event dates. We undertake this approach by using a news search engine and identify a small number of such potential confounding events, which will be discussed in Section 7. Second, the event window should be kept reasonably small to rule out other asset-specific events around the event window. Third, the market model can capture the average effect of market-wide shocks via the market price index. However, the market price index is not a proper counterfactual control unit because the event-affected units might participate in this portfolio, leaving the price index endogenous to the event shock. Also, the weights are not intended to produce a control unit for the affected company, but to reflect the average market conditions. The synthetic control approach allows choosing assets to create a counterfactual portfolio and estimating their weights.[14]

Given the limited number of observations for the event effect (in the absence of repeated event observations), applying a synthetic control approach (Abadie and Gardeazabal, 2003) is an obvious, yet rarely pursued strategy.[15] Its main requirement is to have sufficient observations in the pre-event sample to form a control unit. Extrapolating the outcome variable of the control unit to the event period and comparing it with the observed outcome of the affected units is the idea underlying both the short-run event study approach and the synthetic control approach.[16]

Let $i = 1$ be the company that is hypothesized to be affected by the event. A synthetic control is a weighted average of the units in the so-called donor pool of I units unaffected by the event. Each choice of the vector of weights $W = (w_2, ..., w_{I+1})$ such that $0 \leq w_i \leq 1$ and $w_2 + \cdots + w_{I+1} = 1$ refers to a particular synthetic control. This choice is based on the pre-event characteristics $Z_{i,t<T-k} = \bar{Z}_{it}$. Potentially, one can include the outcome variable as a potential characteristic.

[14] Another approach might be to use a different market index. This approach is less preferable, since our goal is to capture the common shocks in the market that are most relevant for the subject firms.

[15] To our best knowledge, Guidolin and La Ferrara (2007) is one of the few other papers employing such an approach.

[16] Note that Equation (1) can be reformulated as a synthetic control estimation where $X_{it}\hat{\beta}_i$ can be considered the predicted outcome of the control unit. Then, the event effect is tested on the difference between the observed outcome at the event date, r_{iT}, and the extrapolated control outcome to the event date, $X_{iT}\hat{\beta}_{i|T-h-1}$. Indeed, the usual control variable in X_{it}, the market index, is already a weighted average of asset prices in a given market.

That is, we have $\bar{Z}_{it} = [\bar{r}_{it}, \bar{X}_{it}]$. Indeed, Abadie, Diamond, and Hainmueller (2010) argue that matching on pre-event values of outcome variables mitigates the concerns related to unobserved factors in $\bar{Z}_{it}$. Weights can be chosen with the following criteria

$$w_i^* = \arg\min_{w_i} \sum_i v\left(\bar{Z}_1 - \bar{Z}_{i\in I}\right)^2 \text{ st. } 0{\le}w_i{\le}1,\ w_2 + ... + w_{I+1} = 1, \tag{3}$$

where v is a vector of variable-specific weights. For example, in Equation (1), the parameter vector β can be considered a special form of v. The synthetic control estimation of abnormal returns is then given by

$$\gamma_{1t}^d = r_{1t} - \sum_{i\in I} w_i^* r_{it}, \text{ for } t \in [T-h, T+h].$$

We calculate the cumulative abnormal returns as the sum of abnormal returns and apply the usual tests as explained earlier.

In our application, we estimate a synthetic portfolio using DAX30 companies by excluding RWE and E.ON. We base the matching procedure only on the asset returns of these companies.

Controlling for industry-wide shocks. To control for industry-wide shocks, we use EnBW as the control unit, a company in the same industry but without any relevant lignite asset. Therefore, a priori, we do not expect the series of events subject to our analysis to have any effect on EnBW. This gives a difference-in-differences estimate of the abnormal returns by removing biases from industry-wide shocks to returns to asset i.[17] To see this formally, let $i = 1$ denote the company that is hypothesized to be affected by the event, and $i = 2$ denote the control unit. Let the dummy variable $C_i = 1\{i = 1\}$ indicate the treatment group. We have the

[17] In terms of the synthetic control approach, this can be considered as assigning a weight of 1 to EnBW and 0 to all other assets in the donor pool.

following specification:

$$r_{it} = X_{it}\beta_i + \sum_{d=-h}^{h} \delta^d D_t^d + \sum_{d=-h}^{h} \gamma^d D_t^d C_i + \epsilon_{it}. \tag{4}$$

Note that the asset specific intercepts are already included in the parameter vector β to control for differences between the two cross-sectional units over the estimation window. The second term captures the shocks that affect both units. Then $\hat{\gamma}^d$ is the estimated average event effect on firm 1 on an event window day d.

4.2 Other Specifications

Intuitively, the event window should be considered as a bounded time interval. In a single asset - single event case, there is only one observation for each date in the event window, hence the estimated abnormal returns are simply prediction errors. This is the case for Equation (1) as it represents a separate regression for each firm and announcement. When there are repeated observations for the event, in the form of many announcements or assets, it is possible to account for a shift in the conditional mean due to the event shock, or for the intensity of the event effect. While Equation (1) and its variants are our main specifications, we also employ some specifications that utilize the variation in repeated event observations. In the following, we describe our strategy to conduct these estimations.

Repeated observations for the event effect. To account for many announcements, the second term of Equation (1) can be extended to all announcements. This is the approach described in Binder (1985a). Index different announcements with j and denote the corresponding date with T_j. Therefore, $\tau_j = 0$ whenever $t = T_j$, that is, on each announcement date. The event day dummies are modified as $D_t^d = 1\{d = \tau_j \text{ for all } j\}$. For example, $D^{-1} = 1$ when $\tau_j = t - T_j = -1$, which is the case for all dates one day prior to any announcement date. The average abnormal return (AAR) can be estimated by using Equation (1), but with redefined event day dummies. In this case, each event day dummy captures the AAR across announcements for a day in the event window. Therefore, testing H_0 amounts to testing the significance of the average of cumulative abnormal returns (ACAR) over the events. To utilize variation across firms, one can simply impose $\gamma_i^d = \gamma^d$ and/or $\beta_i = \beta$.

In all our estimations, we allow the parameter vector β to be not only firm but also announcement specific. That is, in order to predict the counterfactual returns for each announcement, we employ a different sample around each announcement, and estimate β separately. This is equivalent to using Equations (1) or (2) to estimate the CARs and calculating the ACAR subsequently, as described in MacKinlay (1997). This approach can be represented by a regression model as follows:

$$r_{ijt} = X_{ijt}\beta_{ij} + \sum_{d=-h}^{h} \gamma_i^d D_t^d + \epsilon_{ijt}. \quad (5)$$

Note the unusual indexation of the observations in this specification. Normally, the asset return, covariates, and error term should be uniquely defined by i and t. Indeed, if the normal market performance is estimated from a common sample of firm i's returns for all announcements, one can drop the j index. However, we allow the market structure to differ around announcements. In this case, the effective time index is τ_j, which is uniquely identified by j and t. Similarly, each i and j combination can be considered as a separate cross-sectional unit.

Intensity of the event. In some applications, there is a continuous variable measuring the intensity of the potential event. For example, in one of our robustness analyses, we investigate the effect of a confounding event: in this case, an earnings announcement. In this analysis, the surprise in the earnings announcement is a continuous variable and if the announcement has any effect, it is expected to be correlated with the magnitude of the surprise. Having repeated observations for the event effect allows estimating the marginal abnormal returns due to the surprise.

Denote the intensity of the surprise with s_{ij}. Then, Equation (5) can be modified as follows:

$$r_{ijt} = X_{ijt}\beta_{ij} + \sum_{d=-h}^{h} \gamma_i^d D_t^d s_{ij} + \epsilon_{ijt}. \tag{6}$$

Here γ_i^d is the marginal effect of the surprise. The abnormal return of firm i due to announcement j is calculated as $\gamma_i^d s_{ij}$.

Estimation window with repeated observations for the event effect. As explained earlier, the specification in Equation (1) does not employ any information from the event window to estimate the expected returns. This is a desired property to control for potential feedbacks from the event to the normal market performance. However, this is not the case for Equations (5) and (6) because the event dummies are assumed to be homogeneous across announcements (or firms) and do not partial out the whole variation in the event window.

Therefore, the feedback from the events to the normal market performance has to be taken care of directly by estimating the normal market performance separately from the pre-event observations. The return on a day in the event window is predicted by $\hat{r}_{i,T+d} = \mathrm{E}[r_{i,T+d}|X_{i,T+d}] = X_{ij,T+d}\hat{\beta}_{ij|T-k^u}$, where the estimated parameter vector is conditioned on the available information up to time $T - k^u$. The abnormal return is then given by:

$$\gamma_i^d = r_{i,T+d} - X_{ij,T+d}\hat{\beta}_{ij|T-k^u}. \tag{7}$$

As a result, the prediction of the expected returns does not employ any information from the event window. In this case, the intensity of the event effect is estimated in a second-stage regression by regressing the estimated CARs on the surprise (see MacKinlay, 1997). In all our applications, we exclude the event window observations in estimating the normal market performance.

Table III: Baseline Specification

Half-width of the event windows	$h = 2$
End date of the estimation windows	$T_j - 3$
End date of the estimation windows in pseudo tests	$k^u = 10 \Rightarrow T_j - 11$
Number of observations in the estimation window	90
Error distribution	$\epsilon_{it} \sim \text{NID}(0, \sigma^2)$
Covariate set	Constant, market price index

4.3 Dataset, Baseline Assumptions, and Robustness Analysis

We primarily use data on the three publicly listed German energy utilities in the relevant period: E.ON, RWE, and EnBW. Their stock prices and all other data are from Thomson Reuters Datastream, unless otherwise noted. To calculate market returns, we use the DAX, a performance index consisting of the 30 major German companies trading on the Frankfurt stock exchange, including two of the three companies of interest. For the synthetic control group, we use data on firms in the DAX. Details on other data used in robustness checks are provided in the Appendix.

Our baseline analysis is based on the approach described above. Table III lists our assumptions for the data-generating process we apply in these estimations. In Appendix C, we provide an extensive robustness analysis related to these choices.

5 Baseline Results

We start by presenting the average effect of announcements for each event using the approach described in Section 4.2. The results are presented in Table IV, where each entry refers to the average CAR. Detailed results for each individual announcement can be found in Table IX in the Appendix.

In Table IV, for both RWE and E.ON, only the effects of the announcements related to state aid assessments are significant. That is, investors did not react to the initial climate levy proposal, which was directed at stranding lignite assets by

Table IV: ACAR by the stages of the proposal

Companies	Events		
	Climate levy proposal	Security reserve proposal	State aid assessment
RWE	0.018	0.016	-0.105***
	(0.024)	(0.019)	(0.020)
E.ON	0.014	-0.011	-0.074***
	(0.020)	(0.015)	(0.016)

Notes: This table illustrates the average cumulative abnormal returns of E.ON and RWE from the announcements of each stage of the policy proposal. The event window is the 5 days centered around an announcement. The event window observations are excluded in the estimation of normal market performance. The estimation window is the 90 days just prior to the event window. Standard errors are in parentheses. Significance levels are indicated as * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

charging an extra fee on carbon emissions, or to the following announcements related to the compensation mechanism, that is, paying plant owners for not operating their units. Only the news that the compensation mechanism might not go through due to violating state aid rules seems to have triggered a significant and negative reaction. These results are consistent with Scenario 3 only. That is, investors do price in the stranded asset risk, but with an expectation of compensation.

The heterogeneity in the estimated reactions across the two firms is noteworthy. As illustrated in Table IV, the estimated size of the average effects of the state aid assessment announcements on RWE is much larger than that for E.ON. This could be due to the difference in their share of lignite-related assets, as illustrated in Figure 1.

Having illustrated the general patterns in our findings, we investigate the effects of individual announcements in Table V. We focus on the announcements related to the third stage of the policy development, that is, the impacts of state aid assessments. Corresponding results for the announcements related to other stages are presented in Table IX in the Appendix, where we show that their effects are all insignificant.

The results in Table V indicate that the average estimated effects in Table IV are mainly driven by the CARs during announcements (3b) and (3c): when the media reported on the state aid assessment by Parliament's academic service, and when the

Table V: CAR by the announcements for the state aid assessments

Companies	Announcements		
	(3a)	(3b)	(3b)
RWE	-0.016	-0.132***	-0.143***
	(0.057)	(0.056)	(0.063)
E.ON	0.007	0.003	-0.210***
	(0.054)	(0.054)	(0.057)

Notes: This table presents the cumulative abnormal returns of E.ON and RWE from each announcement in the third stage of the policy proposal. The event window is the five days centered around an announcement. The event window observations are excluded in the estimation of normal market performance. The estimation window is the 90 days just prior to the event window. Standard errors are in parentheses. Significance levels are indicated as * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

EU Commission announced opening the state aid procedure, respectively. Event (3a), the date at which the academic service presented its report to Parliament, seems to have no significant effect on either firm. The insignificant CAR due to this event is in line with our conjecture that this document was not publicly available on that date. Only on the publication dates of the media reports of the assessment do we observe a significant reaction.[18] This pattern is in line with the assumption that investors do not have access to insider information and price in only new information made public via media reports.

According to the results in Table V, both announcement (3b) and (3c) have a significant negative effect on the asset returns of RWE, while E.ON seems to experience a significant CAR only due to announcement (3c). Still, as illustrated in Table IV, the estimated size of the average effect of these announcements is much larger for RWE. The delayed reaction in the case of E.ON might be simply due to heterogeneity in the uncertainty over future profits induced by the challenge to the compensation policy, and hence the inertia in the investors' reaction might be higher for E.ON. We investigate this point in more detail in the next section where we mainly focus on the potential biases due to some confounding events, and show that the difference between the size of the reactions is not large.

[18]The first report on the assessment was published by *Der Spiegel* (event 3b).

6 Robustness of the Model Specification

In Appendix C, we present the results from alternative specifications of the baseline modeling choices set out in Table 3. We show that our results are robust to using a three-day event window, employing other common covariates in the prediction model, and modeling the error term as a GARCH(1,1) process.[19] In this section, however, we focus on analyzing our model's performance in identifying the event effect. We start with conducting pseudo tests by assuming false event windows just prior to our events. This analysis validates our model's performance in predicting the counterfactual returns. Second, we conduct synthetic control estimations to verify that our results are not driven by the endogeneity issue due to the presence of E.ON's and RWE's assets in the DAX30 index.

The results from the pseudo tests are presented in Figure 2. On each graph, the left panel separated by the dashed line is the pseudo-event window, and the right panel is the event window. Each point on a graph refers to the CAR calculated from the abnormal returns on the five days centered around that date.[20] The estimated CARs for date zero (the event date) correspond to the results presented in Table V. The 95% and 99% confidence intervals are indicated with shaded areas.[21]

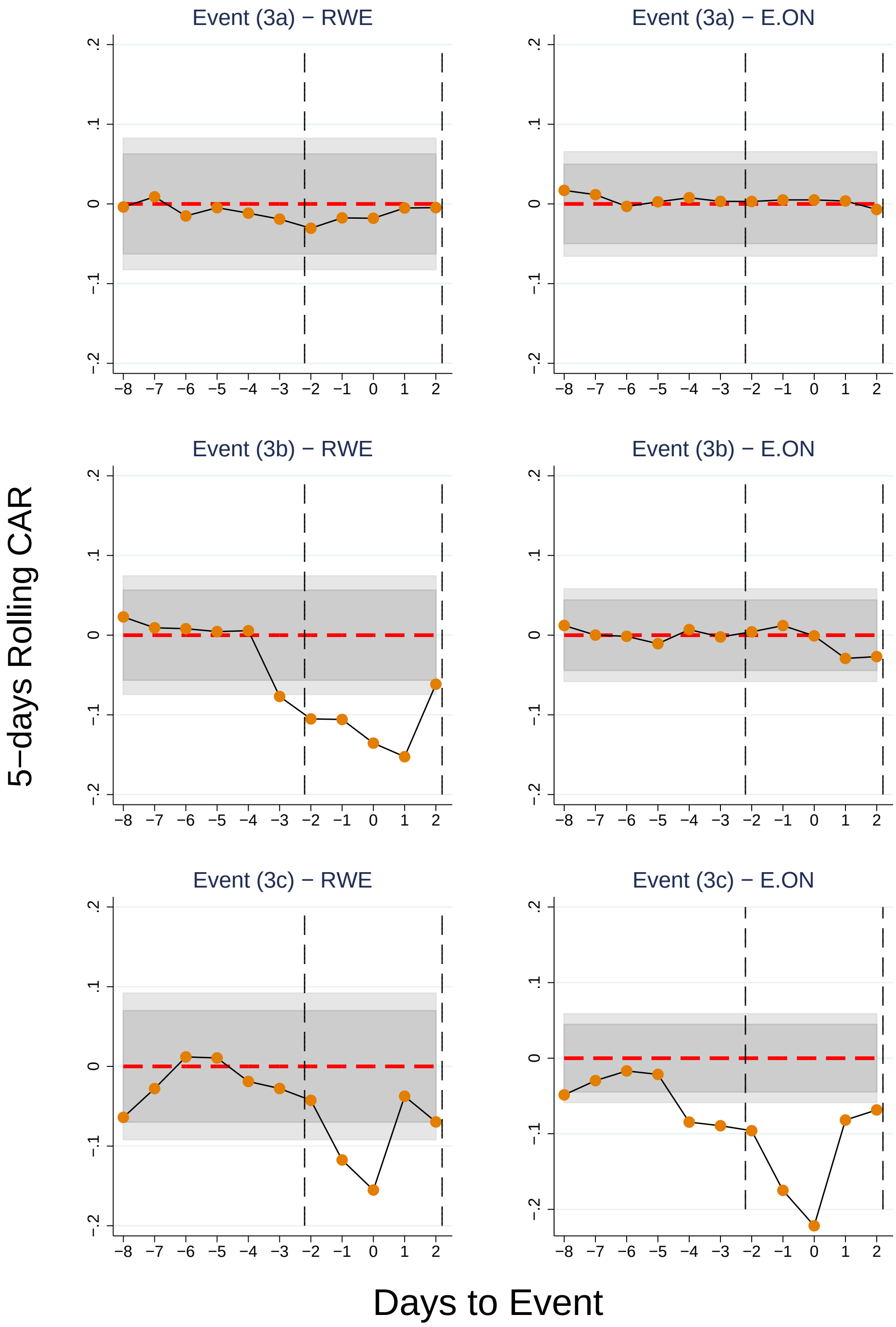
Figure 2 shows that the model performs well in predicting the out-of-sample returns in the pseudo window, thus increasing confidence in our model specification. Furthermore, there seems to be no sign of other events in the pseudo windows that bias the estimated CAR around the event day. For the significant events, the CARs are generally stable and insignificant throughout the pseudo window and gradually become negative and significant in the event windows. The gradual change in the CARs and the presence of significant CARs just before the event window is not

[19]Our results are robust to using 45, 60, and 120 observations for the estimation sample. These results are available upon request.

[20]Corresponding estimated abnormal returns are provided in Figure 9 in the Appendix. See Table IX for the exact size of the estimated CARs and standard errors.

[21]We ignore the sampling uncertainty in the estimation of these confidence bands as their influence is small, as expected. Hence the widths of the confidence bands are constant.

Figure 2: Impact of state aid assessments - CAR over five-day rolling windows



surprising as we use five-day rolling windows. For example, calculation of the five-day rolling CAR on date 3, which is in the pseudo window, employs two abnormal returns from the event window. The observed pattern indicates that the event effects seem to be well captured by the five-day event window.

To control for potential biases due to the endogeneity of the DAX30 index, we perform a synthetic control estimation. The results are presented in Figure 3.[22] While the qualitative results remain the same, the estimated sizes of the CARs are slightly larger. This indicates that the market price index might have been affected by the events subject to our analysis and therefore absorb some of the event effects. However, the size of this bias is very small and negligible for all the events.

7 Confounding Events

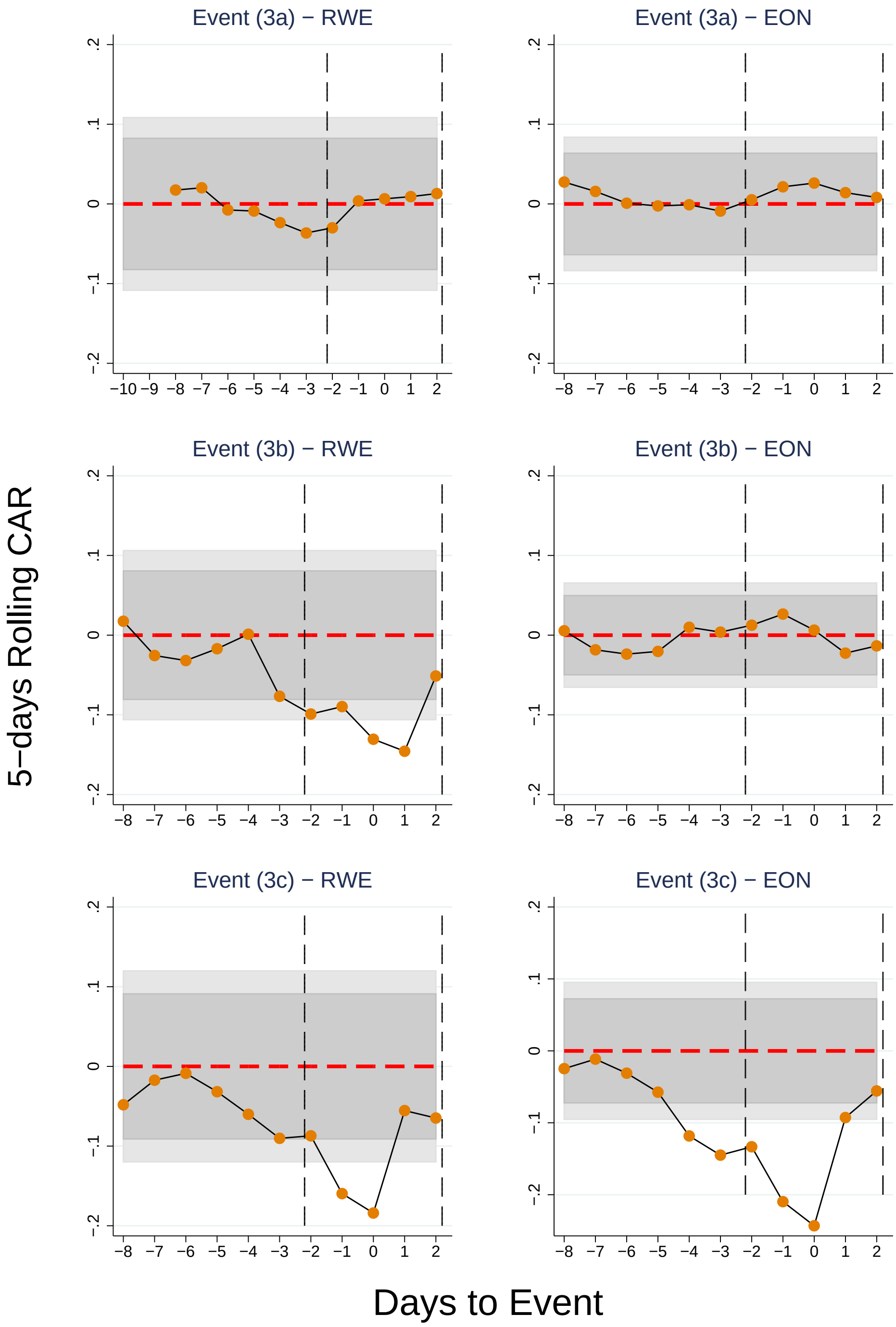
In this section, we control for the presence of confounding events around the announcement dates that might partially or completely drive our baseline results. To detect confounding events, we used a news search engine and conducted a careful review of the news published around the announcement dates of events (3b) and (3c). The search methodology and a summary of all the results are provided in Appendix D. Our search resulted in two news items.

1. Nuclear provisioning assessment. The first news item is around announcement (3c) and is potentially relevant for both RWE and E.ON. On September 10, the first trading date in the event window of announcement (3c), the media reported the results of a study commissioned by the Ministry of Economy and Energy.[23] This study concluded that the energy companies' provisioning for liabilities in connection

[22] See Figure 10 in the Appendix for the corresponding abnormal returns.

[23] See `http://www.spiegel.de/wirtschaft/unternehmen/atomausstieg-fuer-den-atommuell-fehlen-30-milliarden-euro-a-1052869.html`. For an English-language account of the study and its potential implications for the firms' credit ratings, see `https://www.moodys.com/research/Moodys-Nuclear-shutdown-costs-stress-German-power-generators--PR_335268`.

Figure 3: Synthetic control estimations



with nuclear plant decommissioning and waste disposal was insufficient. Although this study did not imply direct political or financial consequences, one could imagine that investors reacted to it.

2. Earnings announcements. Both E.ON and RWE published their quarterly earnings announcements just before announcement (3b) - on August 12 and August 13, respectively. Since the announced earnings are company specific, this event has the potential to induce the patterns in the estimated CARs for announcement (3b).

7.1 Using EnBW as the Control Unit

In this section, we use EnBW, a company from the same industry but without relevant lignite assets, as the single control unit, leading to a difference-in-differences estimation of abnormal returns by removing the effects of common industry-wide shocks. In fact, the nuclear provisioning assessment, one of the potential confounding events discussed above, can be classified as an industry-wide shock. First, the assessment does not target a specific company, but all companies with nuclear power plants. Second, the problem of nuclear waste is relevant not only for RWE and E.ON, but also for EnBW, which has substantial shares of nuclear energy in its generation portfolio.[24] On the other hand, the lignite policy proposal is irrelevant for EnBW, since it does not hold any asset targeted by the proposal. Therefore, if the nuclear provisioning assessment had any effect, it should be reflected in EnBW's asset returns. By using EnBW as a control unit, we can eliminate the influence of common systematic shocks in a general manner.

This approach requires that (i) the events subject to our analysis had no impact on EnBW's asset returns, and (ii) any systematic difference between the affected units and EnBW can be captured by the set of control variables. To assess the validity of EnBW as a control unit, we investigate the model's performance in predicting

[24] According to the firms' annual reports, 23% of EnBW's installed capacity in 2015 was nuclear power plants, compared to 15% for RWE and 28% for E.ON.

Figure 4: Impact of state aid assessments on EnBW

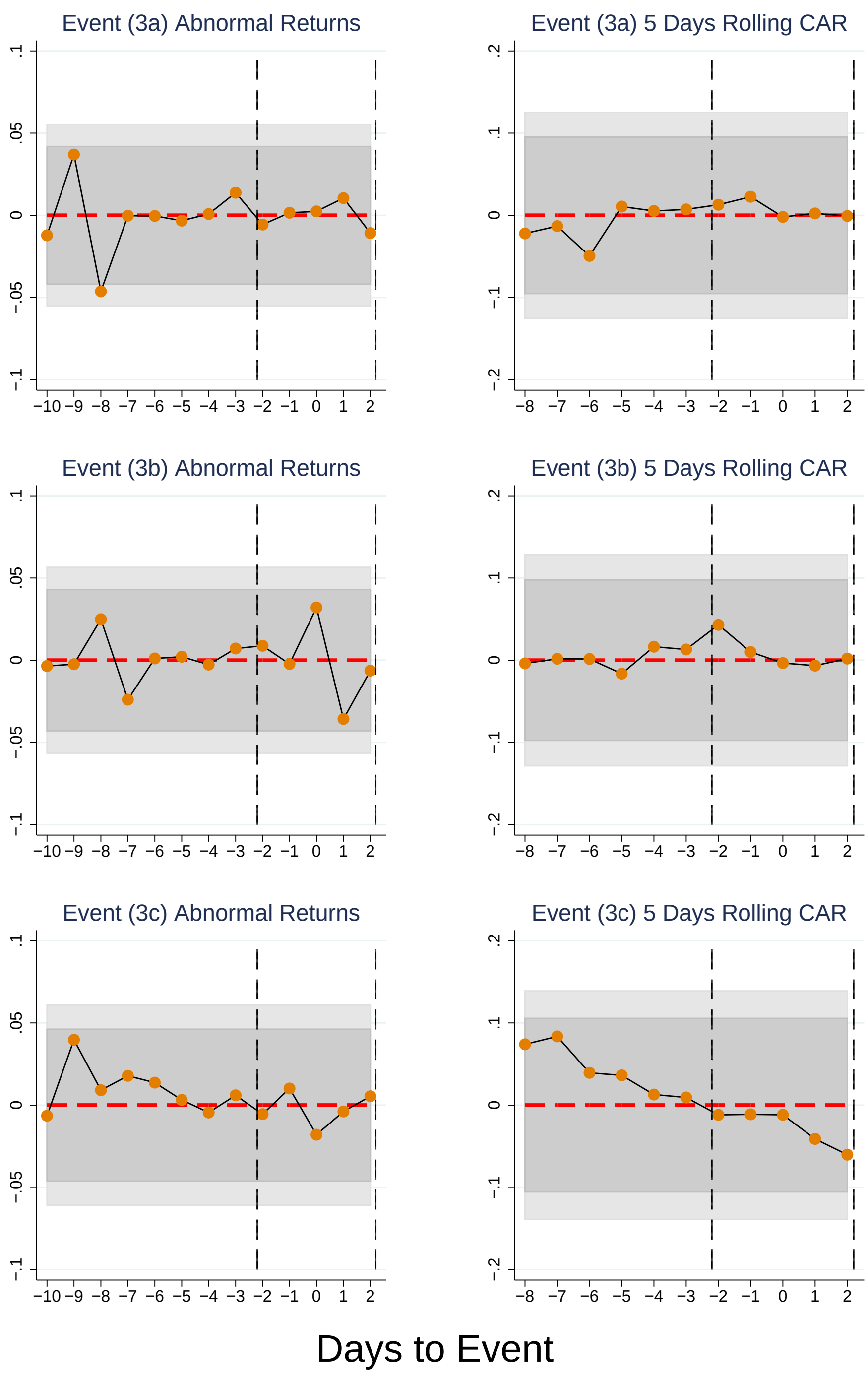
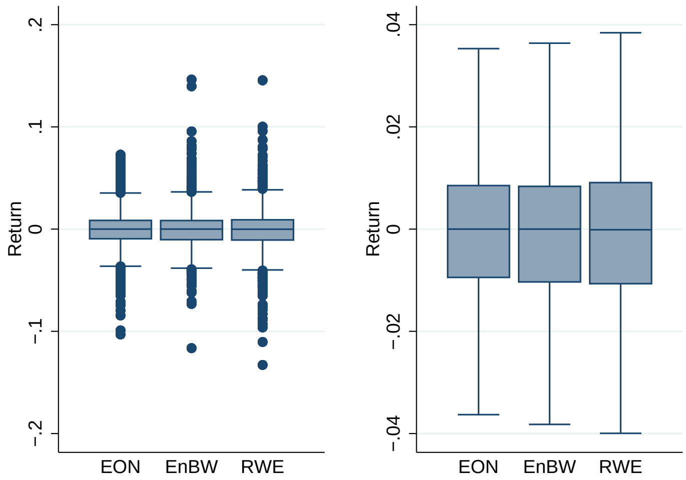


Figure 5: Distribution of the returns

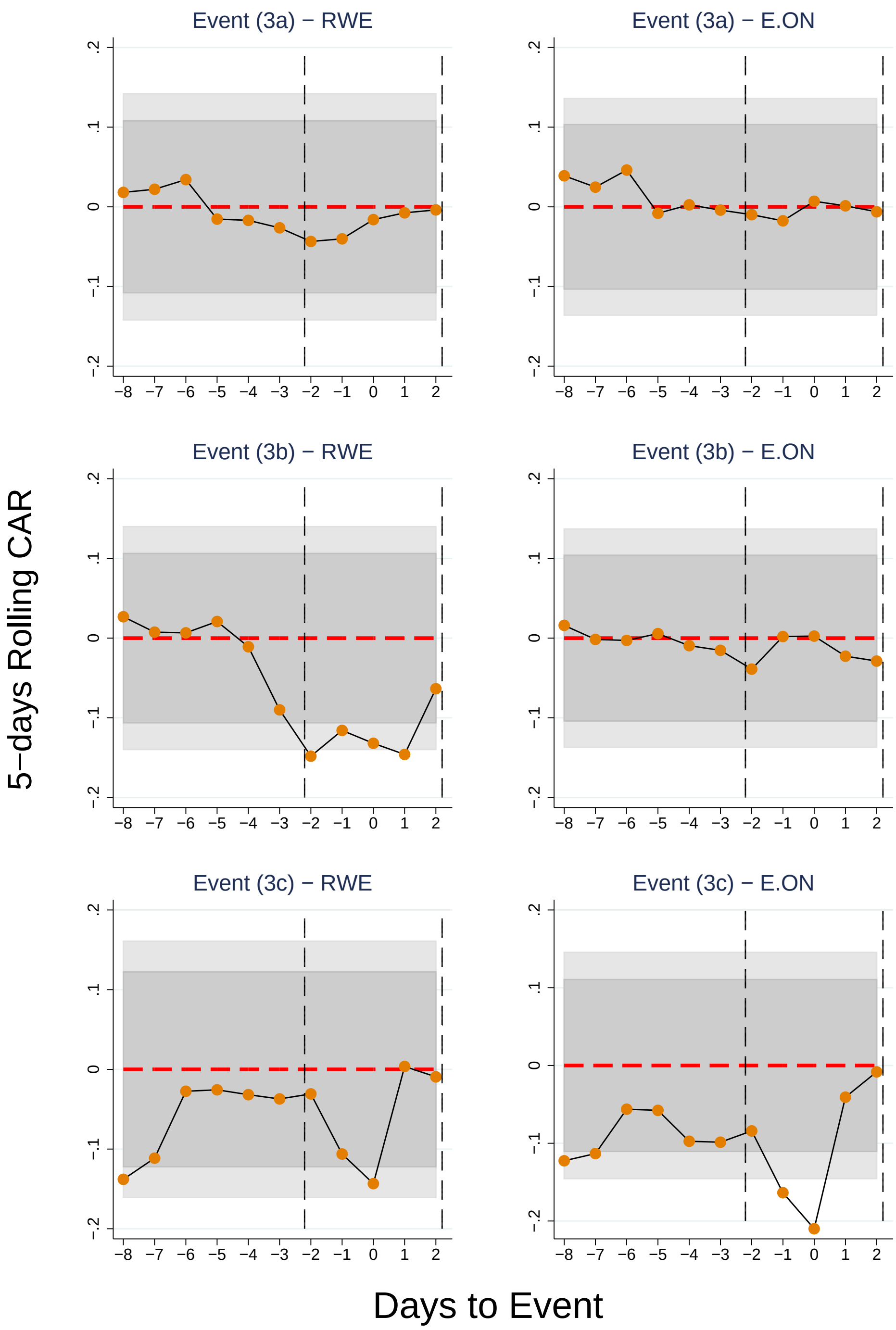


EnBW asset returns and check whether there are significant abnormal returns in the event windows. Figure 4 presents the results. Abnormal returns and corresponding five-day rolling CARs are presented on the left and right panels, respectively.[25] The CARs stay within the 95% percent confidence intervals both in the pseudo and event windows. This confirms the model's out-of-sample performance in predicting EnBW returns. Furthermore, these results are generally in line with the assumption that EnBW was not affected by the policy proposals, and reveal that our baseline estimations are not driven by industry-wide shocks such as the nuclear provisioning assessment. If this event had an effect, we would expect to see some reaction in the asset returns of EnBW.

One concern might be that the results for EnBW are driven by a company-specific characteristic that makes its assets immune to any type of shock. In this case, using EnBW as a control unit would not eliminate the influence of a potential industry-wide shock. Figure 5 illustrates the distribution of the returns for all three companies. The right panel excludes outliers to ease comparison around the center of the distribution. It is clear that the distributions are more or less the same both at the tails and at the center. Therefore, it is not likely that the results for EnBW

[25] Table IX in the Appendix presents the corresponding results.

Figure 6: Estimations by using EnBW as a control unit



are driven by a company-specific characteristic. Hence, using EnBW as a control unit seems a sensible strategy.

The estimation results from using EnBW as the control unit are presented in Figure 6.[26] Despite being slightly less precise, these estimations are generally in line with their baseline counterparts in Figure 2. The size of the estimated CARs for the event windows is close to those in our baseline estimations, indicating that our results are not driven by some industry-level confounding event such as the report on nuclear waste liabilities (see Table XI in the Appendix for details).

7.2 Controlling for Earnings Announcements

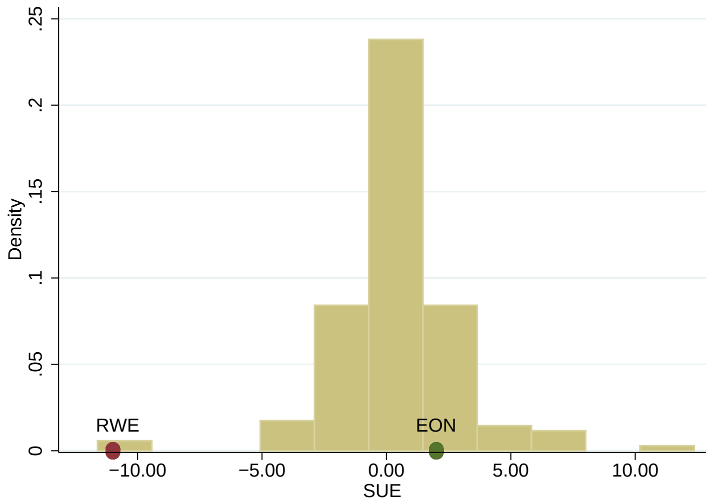
The second news item in our search for confounding events is an earnings announcement just before announcement (3b). The announced earnings are company specific;[27] therefore, their influence on the estimation results cannot be eliminated by using a control unit. In this section, we correct the CARs on the date of announcement (3b) for predicted abnormal returns due to the earnings surprise.

We start by investigating the information content of quarterly earnings announcements for the market valuation of RWE and E.ON. If there is any investor reaction to earnings announcements, it should be due to the departure of announced earnings from investors' prior expectations, namely, the surprise in the information release. We proxy the expected earnings with the quarterly earnings forecasts reported by the Institutional Brokers Estimate System (I/B/E/S), which is the mean of earnings forecasts by many analysts for a large number of firms. Our measure of surprise is the difference between announced earnings (AE) and mean forecasted earnings (MFE) normalized by the standard deviation of the forecasts, namely, standardized unexpected earnings (SUE) provided by the Thomson Reuters Database.

[26]Other related results are presented in Appendix B. See Figure 11 for the corresponding abnormal returns. The estimation tables by events and by announcements are provided in Tables X and XI, respectively.

[27]Note that the content of the earnings announcements is company specific, but their timing is quite close: both RWE's and E.ON's quarterly earnings announcements fall into our event window.

Figure 7: Distribution of SUE



We employ the dataset on quarterly earnings announcements of DAX30 companies in 2015 and 2016. Figure 7 illustrates the distribution of SUEs in our sample. The SUEs for RWE and E.ON within the event (3b) window are indicated by dots. The SUE is small and positive for E.ON; it is negative and substantial for RWE. This pattern has the potential to explain our findings for event (3b).

We estimate the marginal effect of SUE as explained in Section 4.2. We start by estimating the five-day CARs for all the earnings announcements in our sample by excluding the two earnings announcements by E.ON and RWE just before event (3b). Next, we estimate the marginal effect of SUE on the predicted CARs. The results are presented in the first column of Table VI. In the first regression, the effect of SUE on the five-day CARs is insignificant. However, this does not mean that the earnings announcement has no effect. In the following columns, we estimate the marginal effect of SUE on the individual ARs in the event window. Evidently, the only significant impact occurs on the event day. The size of the estimated effects on the days before and after announcement dates is very small. Therefore, the size of the estimated effects on the five-day CARs and the estimated effect on the ARs on the event date are virtually the same.

In the next step, we employ these results to predict the CARs and ARs due to

Table VI: Marginal effect of earnings surprise

	5-Days CAR	AR				
Relative distance		(-2)	(-1)	(0)	(1)	(2)
SUE	0.003	-0.000	0.000	0.003***	-0.000	0.000
	(0.002)	(0.000)	(0.001)	(0.001)	(0.001)	(0.000)
Observations	123	120	120	120	120	120

Notes: Standard errors are in parentheses. Significance levels are indicated as * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table VII: Predicted CAR and AR due to earnings surprise

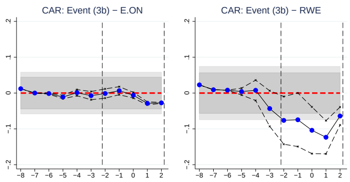
Panel A: Predicted 5-day CARs due to earnings surprise					
Company	Date		Predicted CARs by SUE	95% Confidence Interval	
E.ON	8/12/2015		0.005	-0.002	0.012
RWE	8/13/2015		-0.030	-0.072	0.011

Panel B: Predicted ARs due to earnings surprise					
Company	Date	Relative Distance	Predicted AR by SUE	95% Confidence Interval	
E.ON	8/10/2015	-2	-0.000	-0.002	0.002
	8/11/2015	-1	0.000	-0.003	0.004
	8/12/2015	0	0.005	0.002	0.009
	8/13/2015	1	-0.001	-0.004	0.002
	8/14/2015	2	0.000	-0.001	0.002
RWE	8/11/2015	-2	0.000	-0.009	0.010
	8/12/2015	-1	-0.002	-0.021	0.016
	8/13/2015	0	-0.032	-0.053	-0.010
	8/14/2015	1	0.005	-0.012	0.022
	8/17/2015	2	-0.002	-0.011	0.006

the earnings announcements of E.ON and RWE just before event (3b). The results are presented in Table VII. Panel A shows the predicted CARs by the SUE, and Panel B shows the predicted ARs for each day of the event window. Reflecting the results in Table VI, the predicted CARs due to the SUE are positive and small for E.ON, while they are negative and large for RWE. Panel B shows that the impact of the earnings announcement occurs only on the event day, and the 95% confidence intervals support the estimated sign of the impacts. Other than on the event day, the size of the announcement effect is negligible and insignificant.

We repeat pseudo tests on event (3b) (see Figure 2) by correcting for the effect of

Figure 8: CARs for announcement (3b) corrected for earnings surprise



the earnings announcement. The results are presented in Figure 8. The correction assumes a five-day event window for the earnings announcement. In terms of the relative distance to event 3b, the earnings announcement of RWE happened on date -1, while it is date -2 for E.ON. Therefore, for example, the correction takes place from date -3 to date 1 for RWE. The figure also illustrates the 95% confidence interval for the correction, which refers to the reported confidence intervals in Table VII. The right panel illustrates the corresponding corrected five-day rolling CARs for which the effect of the correction extends beyond the correction window due to the aggregation of ARs across days.[28]

Figure 8 shows that the correction does not have an effect on the results for E.ON. However, the results for RWE change radically. The corrected CAR on the event day (day 0) is not statistically different from the predicted returns as their 95% confidence intervals overlap.

In this section, we designed the analysis to provide an upper bound (in absolute terms) for the effect of event (3b) on RWE's returns. For example, if the corrections were applied to the estimations with EnBW as the control unit, or if the results were assessed by using a 99% confidence interval, our conclusion that this event is insignificant would be supported. We therefore conclude that neither RWE nor E.ON were affected by event (3b). These results suggest that the reaction to the state aid assessments is solely due to announcement (3c), and the total size of the difference between the reactions for RWE and E.ON is not as drastic as implied by

[28]The corresponding corrected ARs are presented in Table 12 in Appendix B.

the baseline results.

8 Conclusion

We analyze the stock market effects of a German climate policy aimed at stranding fossil assets. We exploit the fact that the proposal underwent three stages. It started as a "climate levy" increasing the CO_2 price for power plants older than 20 years and was subsequently turned into a compensation mechanism paying individual lignite-fired power plants for phasing out. In the third stage, the adoption of the compensation mechanism policy was challenged based on the possibility that it may violate EU state aid rules.

We test the effects of news about the different policy stages on three German utility companies with different exposure to stranded asset risk (RWE: high exposure, E.ON: some exposure, EnBW: no exposure). We find no significant reactions to the first and second stages, but a significant and negative reaction to the third stage for RWE and E.ON. Our evidence suggests that compensation mechanisms are expected and thus priced in the valuation of firms. This implies that investors do care about stranded asset risk, but because of the expectation of compensation, they do not believe that they will be financially affected - neither by general unburnable carbon risk nor due to specific policy proposals implying the stranding of assets. Only the challenge of the compensation changes their beliefs.

Stranded asset risk is relevant for the energy sector and beyond. Most fossil energy assets are long-lived; they usually require a large initial investment, but have relatively low operating costs. Such long-term investments have the potential to "lock in" carbon-intensive technologies for a long time (Erickson et al., 2015). Calculations by IEA (2013) and Pfeiffer et al. (2016) conclude that the "2 degree capital stock" will already be reached in 2017. Investments in fossil capacities after 2017 are inefficient: they lead to "both larger carbon lock-ins and higher short term emissions that need to be compensated by deeper emissions cuts in the long run" (IPCC, 2014), increasing the cost of climate change mitigation. Moreover, in order to achieve emission cuts in such a scenario, fossil assets need to be stranded. IEA (2013) provides a conservative estimate that the energy industry faces sunk costs of \$ 120 billion due to fossil fuel plants being retired early, even if action to achieve the 2°C goal starts in 2012. For a scenario of delaying climate action until 2030 (and using a different methodology), IRENA (2017a) estimates stranded assets of \$ 1.9 trillion in electricity generation, and an additional \$ 7 trillion in upstream energy infrastructure (mostly oil production). This is approximately equivalent to 3.5% of global wealth, and implies a risk not just for the obviously affected energy industry facing sunk costs: international organizations, financial institutions and regulators are increasingly concerned about the "transition risk" of climate policy, especially about a sudden re-pricing of assets.[29]

Of course, a sudden devaluation of energy companies will occur only if expectations were not adjusted in accordance with the risk of asset stranding. Given energy companies' size and interrelation with the rest of the economy, policymakers may regard energy companies as "too big to fail." For this and other political economy reasons,[30] policymakers may opt for compensation policies, and investors may expect them to do so. Compensations, then, are almost a self-fulfilling prophecy: if they are expected, they will be necessary in order to avoid larger shocks.[31] It is therefore essential for policymakers and researchers alike to understand the interaction between policy making and investors' expectations when designing climate policies aimed at fostering a transition to clean capital. A credible commitment to non-compensation, combined with a clear pathway toward clean capital, may be a way to avoid macro shocks as well as costly compensation payments.

[29]Cf., e.g., European Systemic Risk Board (2016); Caldecott et al. (2016); IRENA (2017b); Batten et al. (2016); Banque de France (2015); Baron and Fischer (2015).

[30]See Jenkins (2014) for an overview of political economy constraints on climate policy.

[31]Batten et al. (2016) use a similar argument referring to the potential time inconsistency of government policies in the context of stranded assets. They do not consider compensations, however, but only distinguish between a "low carbon equilibrium" and a "high carbon equilibrium."

References

Abadie, A., Diamond, A., and Hainmueller, J. (2010). "Synthetic Control Methods for Comparative Case Studies: Estimating the Effect of California's Tobacco Control Program." *Journal of the American Statistical Association*, *105*(490), 493–505.

Abadie, A., and Gardeazabal, J. (2003). "The Economic Costs of Conflict: A Case Study of the Basque Country." *American Economic Review*, *93*(1), 113–132.

Banque de France (2015). *Assessment of Risks to the French Financial System.* Paris: Banque de France.

Baron, R., and Fischer, D. (2015). *Divestment and Stranded Assets in the Low-Carbon Transition.* OECD, background paper for the 32nd round table on sustainable development edn., http://www.oecd.org/sd-roundtable/papersandpublications/Divestment%20and%20Stranded%20Assets%20in%20the%20L carbon%20Economy%2032nd%20OECD%20RTSD.pdf.

Batten, S., Sowerbutts, R., and Tanaka, M. (2016). "Let's talk about the weather: The impact of climate change on central banks." *Bank of England Staff Working Paper*, *603*.

Binder, J. J. (1985a). "Measuring the effects of regulation with stock price data." *The RAND Journal of Economics*, 167–183.

Binder, J. J. (1985b). "On the use of the multivariate regression model in event studies." *Journal of Accounting Research*, 370–383.

Bundesministerium für Wirtschaft und Energie (2015). "Der Nationale Klimaschutzbeitrag Der Deutschen Stromerzeugung. Ergebnisse Der Task Force "CO2-Minderung"." Tech. rep., Berechnungen: Öko-Institut e.V. &

Prognos AG, http://phasenpruefer.info/wp-content/uploads/2015/03/Vorschlag-Klimaschutzbeitrag-Kraftwerke.pdf.

Byrd, J. W., and Cooperman, E. S. (2016). "Investors and Stranded Asset Risk: Evidence from Shareholder Responses to Carbon Capture and Sequestration (CCS) Events." SSRN Scholarly Paper, Social Science Research Network, Rochester, NY.

Caldecott, B., Harnett, E., Cojoianu, T., Kok, I., and Pfeiffer, A. (2016). *Stranded Assets: A Climate Risk Challenge*. Washington, D.C.: Inter-American Development Bank (IDB).

Collier, P., and Venables, A. J. (2014). "Closing Coal: Economic and Moral Incentives." *Oxford Review of Economic Policy*, *30*(3), 492–512.

Di Maria, C., Lange, I., and van der Werf, E. (2014). "Should We Be Worried about the Green Paradox? Announcement Effects of the Acid Rain Program." *European Economic Review*, *69*, 143–162.

Erickson, P., Kartha, S., Lazarus, M., and Tempest, K. (2015). "Assessing carbon lock-in." *Environmental Research Letters*, *10*(8), 084023.

European Systemic Risk Board (2016). "Too late, too sudden: Transition to a low-carbon economy and systemic risk." *Reports of the Advisory Scientific Committee*, *6*.

Faehn, T., Hagem, C., Lindholt, L., Maeland, S., and Rosendahl, K. E. (2014). "Climate Policies in a Fossil Fuel Producing Country - Demand Versus Supply Side Policies." *SSRN Scholarly Paper*.

Fama, E. F., Fisher, L., Jensen, M. C., and Roll, R. (1969). "The Adjustment of Stock Prices to New Information." *International Economic Review*, *10*(1), 1–21.

Griffin, P. A., Jaffe, A. M., Lont, D. H., and Dominguez-Faus, R. (2015). "Science and the stock market: Investors' recognition of unburnable carbon." *Energy Economics*, *52*, 1–12.

Guidolin, M., and La Ferrara, E. (2007). "Diamonds Are Forever, Wars Are Not: Is Conflict Bad for Private Firms?" *American Economic Review*, *97*(5), 1978–1993.

Harstad, B. (2012). "Buy Coal! A Case for Supply-Side Environmental Policy." *Journal of Political Economy*, *120*(1), 77–115.

IEA (2013). *Redrawing the Energy-Climate Map - World Energy Outlook Special Report*. Paris: OECD/IEA Publishing.

IPCC (2014). *Climate Change 2014 Mitigation of Climate Change: Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

IRENA (2017a). *Chapter 3 of Perspectives for the Energy Transition – Investment Needs for a Low-Carbon Energy System*. Abu Dhabi: International Renewable Energy Agency (IRENA).

IRENA (2017b). *Stranded Assets and Renewables: How the Energy Transition Affects the Value of Energy Reserves, Buildings and Capital Stock*. Abu Dhabi: International Renewable Energy Agency (IRENA).

Jenkins, J. D. (2014). "Political economy constraints on carbon pricing policies: What are the implications for economic efficiency, environmental efficacy, and climate policy design?" *Energy Policy*, *69*, 467–477.

Keller, A. (2010). "Competition Effects of Mergers: An Event Study of the German Electricity Market." *Energy Policy*, *38*(9), 5264–5271.

Koch, N., Grosjean, G., Fuss, S., and Edenhofer, O. (2016). "Politics matters: Regulatory events as catalysts for price formation under cap-and-trade." *Journal of Environmental Economics and Management*, *78*, 121–139.

Lemoine, D. (2017). "Green Expectations: Current Effects of Anticipated Carbon Pricing." *Review of Economics and Statistics*, *99*(3).

MacKinlay, A. C. (1997). "Event studies in economics and finance." *Journal of Economic Literature*, *35*(1), 13–39.

Meinshausen, M., Meinshausen, N., Hare, W., Raper, S. C. B., Frieler, K., Knutti, R., Frame, D. J., and Allen, M. R. (2009). "Greenhouse-Gas Emission Targets for Limiting Global Warming to 2 °C." *Nature*, *458*(7242), 1158–1162.

Moody's (2016). "Environmental Risks: Moody's To Analyse Carbon Transition Risk Based On Emissions Reduction Scenario Consistent with Paris Agreement." Tech. rep., Moody's Investor Service, New York.

Oberndorfer, U., Schmidt, P., Wagner, M., and Ziegler, A. (2013). "Does the Stock Market Value the Inclusion in a Sustainability Stock Index? An Event Study Analysis for German Firms." *Journal of Environmental Economics and Management*, *66*(3), 497–509.

Peterson, S. (2015). "Clash between national and EU climate policies: The German climate levy as a remedy?" *Kiel Policy Brief*, *92*.

Peterson, S., and Weitzel, M. (2014). "Reaching a climate agreement: Do we have to compensate for energy market effects of climate policy?" *Kiel Working Paper*, *1965*.

Pfeiffer, A., Millar, R., Hepburn, C., and Beinhocker, E. (2016). "The '2°C Capital Stock' for Electricity Generation: Committed Cumulative Carbon Emissions from the Electricity Generation Sector and the Transition to a Green Economy." *Applied Energy*, *179*, 1395–1408.

Ramiah, V., Martin, B., and Moosa, I. (2013). "How Does the Stock Market React to the Announcement of Green Policies?" *Journal of Banking & Finance*, *37*(5), 1747–1758.

Richter, P. M., Mendelevitch, R., and Jotzo, F. (2015). "Market Power Rents and Climate Change Mitigation: A Rationale for Coal Taxes?" *Beiträge zur Jahrestagung des Vereins für Socialpolitik 2015: Ökonomische Entwicklung - Theorie und Politik - Session: International Trade II*, *B08-V1*.

Schotten, G., van Ewijk, S., Regelink, M., Dicou, D., and Kakes, J. (2016). "Time for Transition: An exploratory study of the transition to a carbon-neutral economy." *De Nederlandsche Bank Occasional Studies*, *14*(2).

Sinn, H.-W. (2008). "Public Policies against Global Warming: A Supply Side Approach." *International Tax and Public Finance*, *15*(4), 360–394.

TCFD (2017). "Recommendations of the Task Force on Climate-related Financial Disclosures." Tech. rep., Task Force on Climate-related Financial Disclosures.

Appendix

(Intended for online publication)

A Phase-Out Plan for Security Reserve

Table VIII: Phase-out schedule

Operator	**Name of unit**	**Nameplate capacity**	**Date of mothballing**	**Date of decommissioning**
Mibrag	Buschhaus	352 MW	Oct 1, 2016	Sep 30, 2020
RWE	Frimmersdorf P	284 MW	Oct 1, 2017	Sep 30, 2021
	Frimmersdorf Q	278 MW	Oct 1, 2017	Sep 30, 2021
	Niederaußem E	295 MW	Oct 1, 2018	Sep 30, 2022
	Niederaußem F	299 MW	Oct 1, 2018	Sep 30, 2022
	Neurath C	292 MW	Oct 1, 2019	Sep 30, 2023
Vattenfall	Jänschwalde F	465 MW	Oct 1, 2018	Sep 30, 2022
	Jänschwalde E	465 MW	Oct 1, 2019	Sep 30, 2023

Source: State Aid Decision Text (SA.42536), Closure of German Lignite Plants: Letter to the Member State. Available at `http://ec.europa.eu/competition/state_aid/cases/261321/261321_1762503_157_2.pdf`.

B Further Results from the Estimations in the Main Text

This section provides further details on the baseline estimations. Table IX presents the CARs under the baseline specification, separately for each event. The event-specific results confirm the observation from the aggregate effect by event category: no single event in categories 1 and 2 has a significant effect on asset returns. Figures 9, 11, and 10 present the abnormal returns leading to the results in Figures 2, 6, and 3, respectively. Tables X and XI are the estimation results from using EnBW as the control unit. Figure 12 presents the corresponding ARs leading to the corrected CARs for the earnings announcements.

Table IX: CARs by announcement: Baseline specification

Stages	Announcements	Companies		
		E.ON	RWE	EnBW
Climate levy proposal	1a	0.040	0.033	-0.004
		(0.029)	(0.034)	(0.040)
	1b	-0.011	0.004	-0.014
		(0.030)	(0.035)	(0.040)
	1c	0.005	-0.002	0.007
		(0.028)	(0.036)	(0.043)
Security reserve proposal	2a	-0.029	-0.004	0.014
		(0.027)	(0.034)	(0.044)
	2b	-0.028	-0.033	0.017
		(0.027)	(0.033)	(0.044)
	2c	-0.013	-0.002	-0.007
		(0.028)	(0.031)	(0.049)
	2d	-0.007	0.012	0.011
		(0.027)	(0.030)	(0.050)
	2e	-0.021	0.001	-0.095
		(0.051)	(0.070)	(0.054)
	2f	0.024	0.114	0.011
		(0.051)	(0.070)	(0.054)
State aid assessment	3a	0.004	-0.020	-0.001
		(0.025)	(0.032)	(0.052)
	3b	-0.000	-0.135***	-0.004
		(0.022)	(0.028)	(0.051)
	3c	-0.220***	-0.150***	-0.017
		(0.024)	(0.038)	(0.051)

Notes: This table presents the cumulative abnormal returns of all companies due to each announcement. The event window is the five days centered around an announcement. The event window observations are excluded in the estimation of normal market performance. The estimation window is the 90 days just prior to the event window. Standard errors are in parentheses. Significance levels are indicated as * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

C Robustness to Baseline Specification Choices

Table XII is comparable to Table IX, but reduces the event window from five days to three days around the event. This decreases the size of the coefficients, but does not alter significance levels. We are therefore confident that our baseline specification

Table X: ACARs by the stages of the proposal: EnBW as the control unit

Companies	Stages of the proposal		
	Climate levy proposal	Security reserve proposal	State aid assessment
RWE	0.027	0.023	-0.096***
	(0.038)	(0.028)	(0.034)
E.ON	0.023	-0.004	-0.066**
	(0.035)	(0.025)	(0.033)

Notes: This table presents the average cumulative abnormal returns of RWE and E.ON for each stage of the proposal. The event window is the five days centered around an announcement. The event window observations are excluded in the estimation of normal market performance. The estimation window is the 90 days just prior to the event window. Standard errors are in parentheses. Significance levels are indicated as * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

of five days does well in capturing the full event effects.

In Tables XIV and XV, we provide results based on an extended covariate set. This means that we estimate Equation 1 by not only using a constant and the DAX index as explanatory variables, but we add two more covariates to the vector X_{it}. To take into account specificities of energy stocks, we control for oil prices following Keller (2010) and Griffin et al. (2015). We use the crude oil spot price of Brent, FOB. To control for the opportunity costs of investment on a given date, we include the risk-free rate of return, namely, the German three-month government bond benchmark rate. The results are almost indistinguishable from the baseline specification.

Table XVI presents the results from using a GARCH(1,1) model for the error terms. The entries with "na." indicate convergence failure. Results from successful estimations are in line with our baseline results.

D Confounding Events Investigation

This section presents details on the search for potential confounding events around announcements (3b) and (3c). We conducted a search for English- and German-language news in LexisNexis for the five-day window (working days) around each of these announcements, filtering by company name (RWE or E.ON, respectively).

Table XI: CARs by announcement: EnBW as the control unit

Stages	Announcements	Companies	
		E.ON	RWE
Climate levy proposal	1a	0.044	0.037
		(0.050)	(0.055)
	1b	0.003	0.018
		(0.050)	(0.055)
	1c	-0.002	-0.008
		(0.050)	(0.056)
Security reserve proposal	2a	-0.043	-0.018
		(0.051)	(0.056)
	2b	-0.046	-0.050
		(0.051)	(0.054)
	2c	-0.006	0.004
		(0.056)	(0.057)
	2d	-0.019	0.001
		(0.055)	(0.055)
	2e	0.074	0.096
		(0.076)	(0.089)
	2f	0.013	0.103
		(0.075)	(0.091)
State aid assessment	3a	0.005	-0.019
		(0.055)	(0.057)
	3b	0.004	-0.131***
		(0.054)	(0.056)
	3c	-0.203***	-0.133***
		(0.057)	(0.063)

Notes: This table presents the cumulative abnormal returns of all companies due to each announcement. The event window is the three days centered around an announcement. The event window observations are excluded in the estimation of normal market performance. The estimation window is the 90 days just prior to the event window. Standard errors are in parentheses. Significance levels are indicated as * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

We restricted the search to business news in newswires and press releases to avoid a large number of news items appearing multiple times. Still, we were faced with a large number of very diverse news items in the event window for each firm.

We therefore manually categorized the news items according to their content and counted the number of news items on a specific topic in the given event window. We then assessed, based on content and press coverage, whether the news topics could be relevant drivers for the stock performance we observe in our event window. When we identified a potential company-specific confounding event for announce-

Table XII: ACARs by the stages of the proposal: Three-day event window

Companies	Stages of the proposal		
	Climate levy proposal	Security reserve proposal	State aid assessment
RWE	0.014	0.017	-0.064***
	(0.019)	(0.014)	(0.015)
E.ON	0.011	-0.006	-0.035***
	(0.015)	(0.011)	(0.011)
EnBW	0.012	-0.007	-0.001
	(0.023)	(0.015)	(0.023)

Notes: This table illustrates the average cumulative abnormal returns of E.ON, RWE, and EnBW from the announcements of each stage of the policy proposal. The event window is the three days centered around an announcement. The event window observations are excluded in the estimation of normal market performance. The estimation window is the 90 days just prior to the event window. Standard errors are in parentheses. Significance levels are indicated as * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

ment (2b), we performed robustness analyses (see Section 7.2 for robustness checks on earnings announcements). For announcement (3c), we are more concerned with news that affects both RWE and E.ON, and thus performed robustness analyses for the case of a potential industry confounding event. Here we identified the nuclear provisioning issue as outlined in Section 7.1. LexisNexis provides a good overview of important issues around the event dates, but it was essential to complement this with own research on the events identified as potentially confounding. For instance, we found that the German business newspaper *Handelsblatt* was the first to report on the nuclear provisioning report on September 11; however, the first news items in LexisNexis mentioning this in the context of RWE appear on September 15.

Tables XVII, XVIII, XIX, and XX present the main news topics and numbers of news items on these topics for each company and each event window.

Table XIII: CARs by announcement: Three-day event window

Stages	Announcements	Companies		
		E.ON	RWE	EnBW
Climate levy proposal	1a	0.013	0.000	0.020
		0.022	0.026	0.033
	1b	(0.009)	(0.029)	(0.004)
		0.022	0.027	0.031
	1c	(0.010)	(-0.002)	(0.015)
		0.022	0.027	0.033
Security reserve proposal	2a	-0.022	-0.002	0.024
		(0.023)	(0.028)	(0.033)
	2b	0.002	-0.012	-0.002
		(0.022)	(0.027)	(0.033)
	2c	-0.020	0.003	-0.025
		(0.021)	(0.024)	(0.035)
	2d	0.005	0.026	-0.003
		(0.021)	(0.023)	(0.037)
	2e	-0.030	-0.025	-0.048
		(0.035)	(0.046)	(0.042)
	2f	0.028	0.110	0.016
		(0.038)	(0.052)	(0.040)
State aid assessment	3a	0.001	-0.004	0.014
		(0.020)	(0.025)	(0.038)
	3b	-0.010	-0.109***	-0.006
		(0.018)	(0.022)	(0.039)
	3c	-0.096***	-0.079***	-0.012
		(0.018)	(0.028)	(0.042)

Notes: This table presents the cumulative abnormal returns of all companies due to each announcement. The event window is the three days centered around an announcement. The event window observations are excluded in the estimation of normal market performance. The estimation window is the 90 days just prior to the event window. Standard errors are in parentheses. Significance levels are indicated as * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Figure 9: Abnormal returns in the pseudo tests

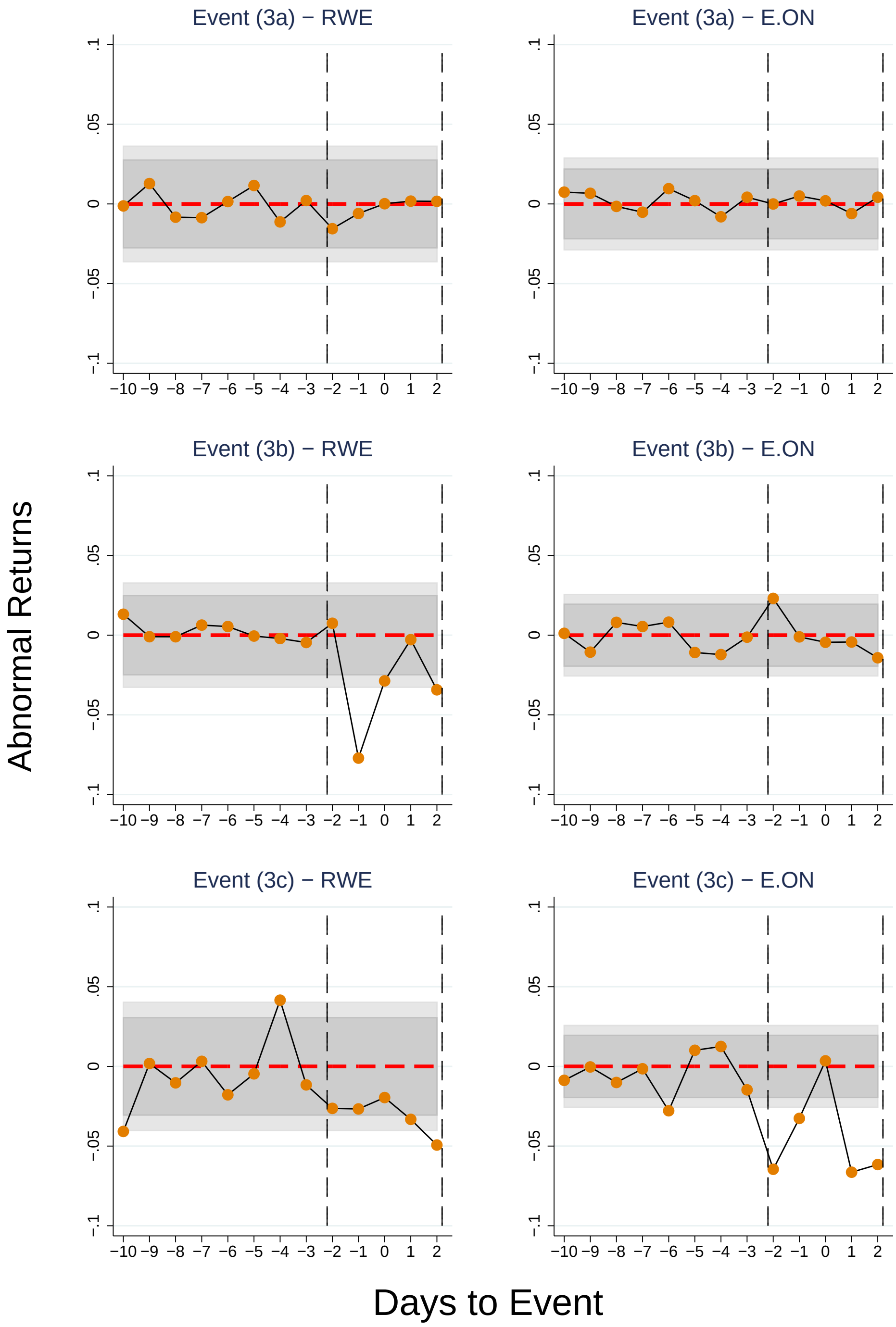


Figure 10: Abnormal returns from the synthetic control estimations

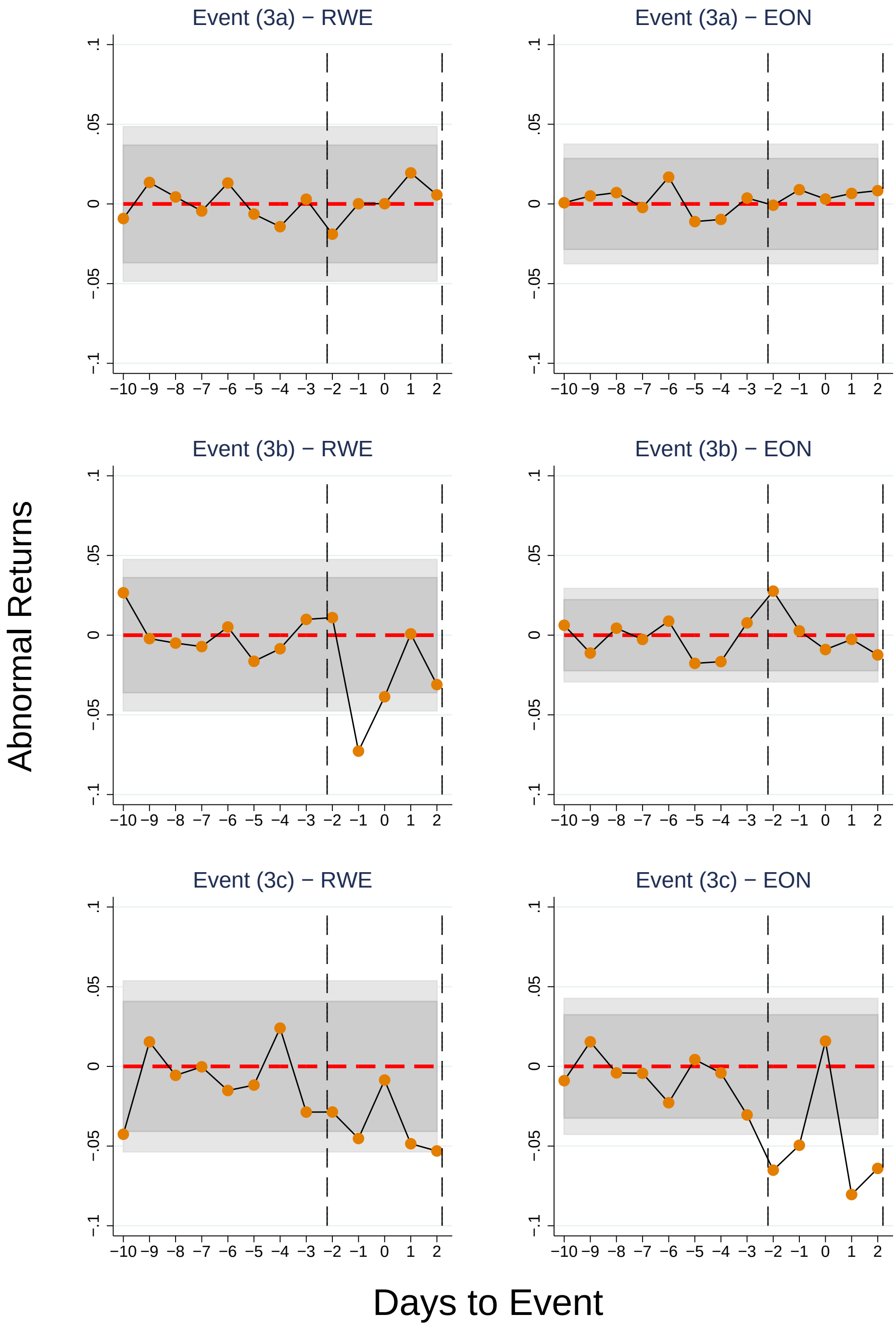


Figure 11: Abnormal returns from using EnBW as a control unit

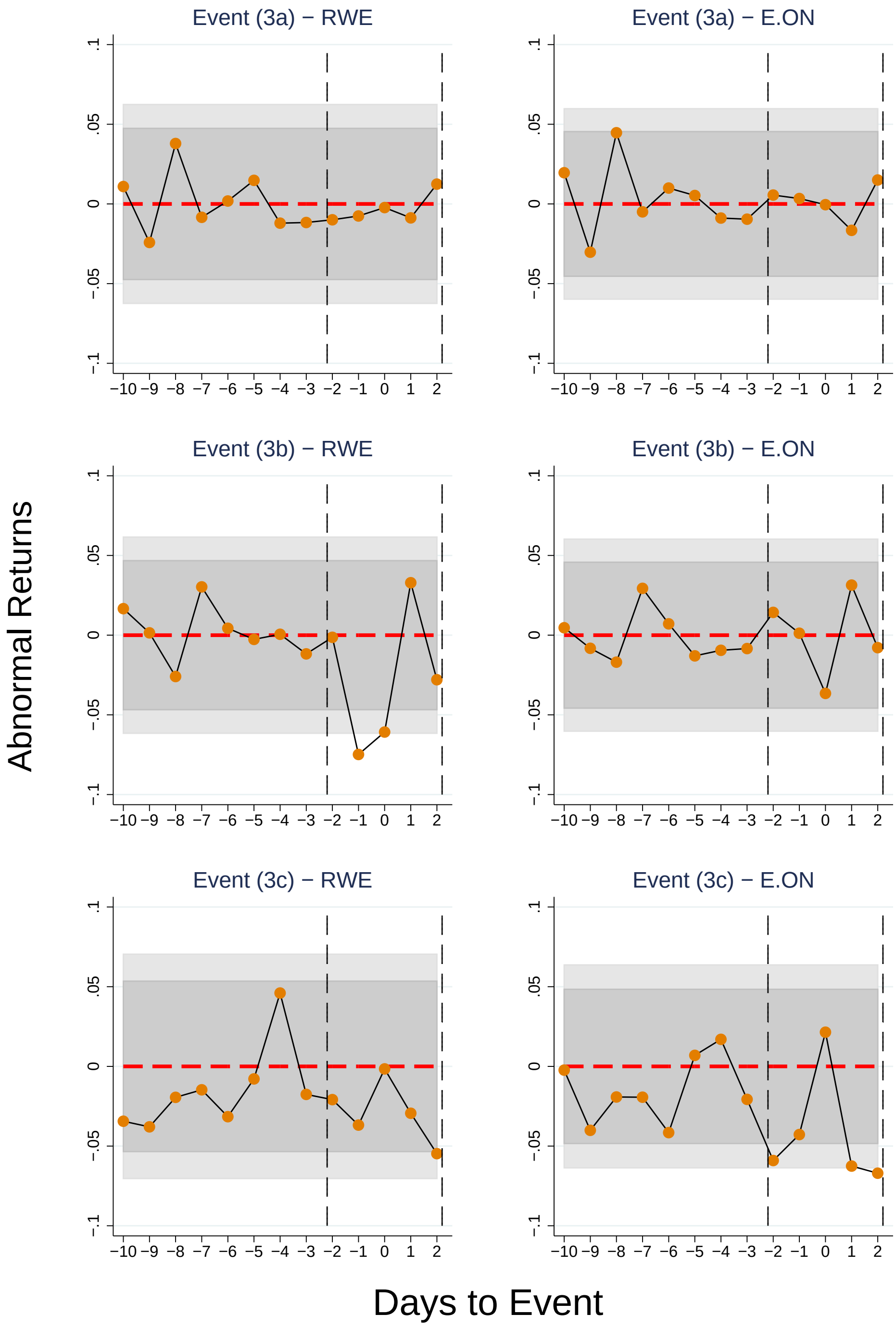


Figure 12: ARs for announcement (3b) corrected for earnings surprise

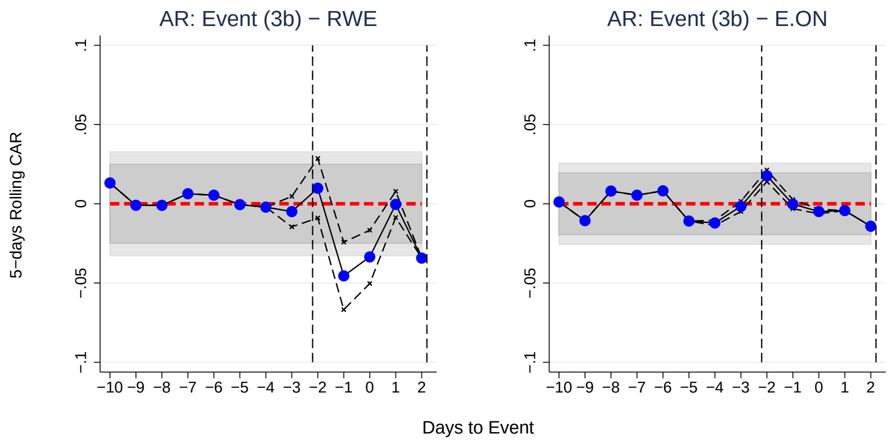


Table XIV: ACARs by the stages of the proposal: Extended covariate set

Companies	Stages of the proposal		
	Climate levy proposal	Security reserve proposal	State aid assessment
RWE	0.021	0.013	-0.087***
	(0.025)	(0.019)	(0.021)
E.ON	0.021	-0.014	-0.071***
	(0.020)	(0.014)	(0.017)
EnBW	-0.010	-0.009	-0.000
	(0.030)	(0.020)	(0.033)

Notes: This table illustrates the average cumulative abnormal returns of E.ON, RWE, EnBW from the announcements of each stage of the policy proposal. The event window is the five days centered around an announcement. The event window observations are excluded in the estimation of normal market performance. Normal market performance is predicted by a constant, returns to market price index, oil prices, and a risk free rate of interest. The estimation window is the 90 days just prior to the event window. Standard errors are in parentheses. Significance levels are indicated as * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table XV: CARs by announcement: Extended covariate set

Stages	Announcements	Companies		
		E.ON	RWE	EnBW
Climate levy proposal	1a	0.037	0.029	-0.003
		(0.028)	(0.034)	(0.043)
	1b	-0.009	0.008	-0.013
		(0.029)	(0.035)	(0.040)
	1c	0.006	0.001	0.007
		(0.029)	(0.035)	(0.042)
Security reserve proposal	2a	-0.022	0.001	0.015
		(0.029)	(0.036)	(0.043)
	2b	-0.026	-0.029	0.017
		(0.029)	(0.036)	(0.043)
	2c	-0.013	-0.002	0.001
		(0.027)	(0.031)	(0.046)
	2d	-0.010	0.012	0.008
		(0.027)	(0.030)	(0.049)
	2e	-0.019	0.001	-0.092
		(0.046	(0.061)	(0.055)
	2f	0.024	0.111	0.011
		(0.050)	(0.068)	(0.052)
State aid assessment	3a	0.005	-0.018	-0.002
		(0.026)	(0.033)	(0.050)
	3b	-0.001	-0.135***	-0.003
		(0.023)	(0.029)	(0.051)
	3c	-0.222***	-0.155***	-0.012
		(0.023)	(0.036)	(0.054)

Notes: This table presents the cumulative abnormal returns of all companies due to each announcement. The event window is the three days centered around an announcement. The event window observations are excluded in the estimation of normal market performance. Normal market performance is predicted by a constant, returns to market price index, oil prices, and a risk-free rate of interest. The estimation window is the 90 days just prior to the event window. Standard errors are in parentheses. Significance levels are indicated as * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table XVI: CARs by announcement: GARCH(1,1)

Stages	Announcements	Companies		
		E.ON	RWE	EnBW
Climate levy proposal	1a	0.037	-0.001	0.028
		(0.029)	(0.041)	(0.036)
	1b	-0.009	-0.013	0.008
		(0.029)	(0.040)	(0.035)
	1c	na.	0.004	na.
		na.	(0.047)	na.
Security reserve proposal	2a	-0.011	0.013	na.
		na.	(0.045)	na.
	2b	-0.021	0.015	na.
		(0.029)	(0.039)	na.
	2c	-0.012	-0.003	-0.010
		(0.028)	(0.052)	(0.032)
	2d	-0.010	0.006	0.005
		(0.028)	(0.048)	(0.030)
	2e	-0.015	-0.105	-0.006
		(0.061)	(0.078)	(0.077)
	2f	0.022	0.002	0.107
		(0.039)	(0.092)	(0.100)
State aid assessment	3a	na.	-0.006	na.
		na.	(0.041)	na.
	3b	na.	-0.008	-0.137***
		na.	(0.053)	(0.049)
	3c	-0.224***	-0.016	-0.162***
		(0.029)	(0.041)	(0.075)

Notes: This table presents the cumulative abnormal returns of all companies due to each announcement. The event window is the three days centered around an announcement. The event window observations are excluded in the estimation of normal market performance. Normal market performance is predicted by a constant and returns to a market price index, by using a GARCH(1,1) model for the error terms. The estimation window is the 90 days just prior to the event window. Standard errors are in parentheses. Significance levels are indicated as * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table XVII: Type and number of company-related news around event 3b, RWE

Topic	**Wed 12/08**	**Thu 13/08**	**Fri 14/08**	**Mon 17/08**	**Tue 18/08**
Earnings announcements (EA), financials	1	9		1	
Background on EA, company strategy	2	6			
Voting rights announcements		4			
Investments of company		2		5	3
Personnel appointments					2
Other					2

Source: Own summary based on LexisNexis, German- and English-language newswires and press releases, filtered by date and company name. “Other” includes local activities such as Czech gas management and local protests.

Table XVIII: Type and number of company-related news around event 3b, E.ON

Topic	**Wed 12/08**	**Thu 13/08**	**Fri 14/08**	**Mon 17/08**	**Tue 18/08**
Earnings announcements (EA), financials	7				
EA and background, company strategy	16	6			
E.ON Russia financials	7	15		1	
E.ON UK financials	1	1	2	1	1
Voting rights announcements	5				
Investments of company	5		2		
Other	2			4	2

Source: Own summary based on LexisNexis, German- and English-language newswires and press releases, filtered by date and company name. “Other” includes local activities such as the opening of a plant, school visits, public relation activities related to a wind farm, etc., or the mentioning of E.ON in news about other firms. News items from Saturday and Sunday are assigned to the following Monday.

Table XIX: Type and number of company-specific news around event 3c, RWE; industry-wide news in bold

Topic	Thu 10/09	Fri 11/09	Mon 14/09	Tue 15/09	Wed 16/09
Tendering and contracting	6		4		
Issues with power plant permissions	4	1	1	2	
Personnel issues	1	4			
Background on past stock performance		4	1		
Pending lawsuits		6	4		
Local operations & PR		6		1	
General industry news (gas supply)			**4**	**2**	
Nuclear provisioning Germany				**1**	**7**
Other		1	1	3	2

Source: Own summary based on LexisNexis, German- and English-language newswires and press releases, filtered by date and company name. News items from Saturday are assigned to the following Monday. "Pending lawsuits" relates to a gas procurement conflict where RWE may need to pay a penalty, for part of which the company already booked provisions. "Issues with power plant permissions" involve wind farm projects (new proposal after rejection) and a coal-fired power plant (court ruling that permit is upheld). "General industry news on gas supply" is a report on Iran as a potential new gas supplier for Europe. While this news is relevant industry-wide, we would expect it to have a positive impact on returns, if any.

Table XX: Type and number of company-specific news around event 3c, RWE; industry-wide news in bold

Topic	Thu 10/09	Fri 11/09	Mon 14/09	Tue 15/09	Wed 16/09
Tendering and contracting		2			
Obligatory notifications on stocks and securities	3				
Nord-Stream pipeline	16	4	3		
E.ON's record low & background info on restructuring	10				
Stock market update mentioning E.ON	2	1	3		
Local customer relations and projects		2	6	3	2
General industry news (gas supply)			**1**	**3**	**1**
Nuclear provisioning Germany		**1**		**3**	
Other	1	1	2	1	

Source: Own summary based on LexisNexis, German- and English-language newswires and press releases, filtered by date and company name. News items from Saturday are assigned to the following Monday. "Nord-Stream pipeline" refers to business news over the shareholders' agreement on the pipeline, as well as political concerns voiced by Slovakia and Ukraine (calling the project "anti-European"). "E.ON's record low" on stock markets was recorded on September 10 and is why E.ON appeared in several general stock market updates. In background information, it was attributed to an unexpected announcement related to E.ON's company reorganization: In splitting the company into "clean" E.ON and "dirty" Uniper, E.ON would keep its nuclear business and the related liabilities. This decision is also relevant for the subsequent reaction of E.ON's shares to the nuclear provisioning assessment. "General industry news on gas supply" is a report on Iran as a potential new gas supplier for Europe. While this news is relevant industry wide, we would expect it to have a positive impact on returns, if any.