DISCUSSION PAPER SERIES

IZA DP No. 5896

How Policy Changes Affect Shareholder Wealth: The Case of the Fukushima Daiichi Nuclear Disaster

André Betzer
Markus Doumet
Ulf Rinne

August 2011

Forschungsinstitut
zur Zukunft der Arbeit
Institute for the Study
of Labor

How Policy Changes Affect Shareholder Wealth: The Case of the Fukushima Daiichi Nuclear Disaster

André Betzer
University of Wuppertal

Markus Doumet
University of Mannheim

Ulf Rinne
IZA

Discussion Paper No. 5896
August 2011

IZA

P.O. Box 7240
53072 Bonn
Germany

Phone: +49-228-3894-0
Fax: +49-228-3894-180
E-mail: iza@iza.org

IZA Discussion Paper No. 5896
August 2011

ABSTRACT

How Policy Changes Affect Shareholder Wealth: The Case of the Fukushima Daiichi Nuclear Disaster*

This paper analyzes how policy changes affect shareholder wealth in the context of environmental regulation. We exploit the unique and unexpected German reaction to the Fukushima Daiichi nuclear disaster, which involved the immediate shutdown of almost half of Germany's nuclear reactors while safety checks were carried out, and a three-month moratorium on extending the lives of others. Using the event study methodology, our findings indicate a wealth transfer from nuclear energy companies to renewable energies companies in Germany. We moreover find that the joint market capitalization of these firms has decreased, but the amount of this combined decrease is small. Substantial heterogeneity in the shareholder wealth effects across European countries can be linked to different nuclear energy policies. The shareholder wealth of nuclear and conventional energy companies in the United States has been unaffected.

JEL Classification: Q48, Q54, G38

Keywords: electric power, nuclear power, green economy, earthquake, tsunami, event study, environment

Corresponding author:

Ulf Rinne
IZA
P.O Box 7240
53072 Bonn
Germany
E-mail: rinne@iza.org

* We would like to thank Anne C. Gielen, Simon Jäger, Peter Limbach and participants at the IZA Internal Seminar for helpful comments and suggestions. We would also like to thank Daniela Geppert and Martin Schletter for their excellent research assistance. All remaining errors are our own.

Yet after Hiroshima, Einstein remarked,
"If I knew they were going to do this, I would have become a shoemaker!"
Scientific American (2004)

1 Introduction

Maybe the German Chancellor Dr. Angela Merkel—who holds a doctorate in physical (quantum) chemistry—had similar thoughts after the shocking events in Japan in March 2011 as Albert Einstein had after the first nuclear bomb hit Hiroshima. In any case, she has clearly changed her mind at some point since 1998 when she wrote in *Science*: "An honest consideration of our options indicates that we cannot afford to discontinue peaceful use of nuclear energy" (Merkel, 1998). Such a change of her mind would explain Germany's unique and unexpected, but yet determined reaction to Fukushima to immediately shutdown almost half of the country's nuclear power plants and to introduce a three-month moratorium on extending the lives of others. The reaction marked yet another change in Germany's nuclear policy; this time, however, the change came overnight and without change of government.

The German reaction may appear very forceful and courageous—or even panic, but it is nevertheless in line with a trend of "going green". There is an increasing move towards renewable energy in recent years, at least in the European Union. Whereas non-binding targets had little effect, the directive 2009/28/EC for the promotion of renewable energy includes binding goals which are to be reached in the 27 Member States by 2020 (European Union, 2009). Yet, about 80% of the energy production in the EU comes from conventional sources of energy and about 14% from nuclear energy (Diekmann, 2009).

Despite this trend towards renewable energy, and despite all political efforts, there is a fundamental debate and a growing literature about the actual costs and benefits of "going green." The trade-off between environment and competitiveness is at the core of this debate (Porter and van der Linde, 1995; Palmer et al., 1995). However, the underlying question whether environmental regulation might actually promote growth has not been answered satisfactorily yet.[1] There is some consensus in the literature that the relationship between economic growth and environmental quality is inversely U-shaped. For example, Grossman and Krueger (1995) analyze indicators of air and water quality in a cross section of countries and find that after an initial phase of deterioration, economic growth is followed by a subsequent phase of improvement in environmental quality. But there is also evidence for a large heterogeneity across countries.[2]

[1] See, e.g., Brock and Taylor (2005) for a survey of the theoretical and empirical literature on the relationship between economic growth and the environment.

[2] See, e.g., Choi et al. (2010) who study the relationship between carbon dioxide emissions and

The dramatic and shocking events that took place in Japan in March 2011 provide us with the opportunity to shed further light on the question whether environmental regulation might promote economic growth. We exploit the unique and unexpected German reaction to the Fukushima Daiichi nuclear disaster, which involved the immediate shutdown of almost half of Germany's nuclear power plants while safety checks were carried out, and a three-month moratorium on extending the lives of others. Only a couple of months earlier the same government had reverted the shutdown strategy of previous governments. We expect that the reversal of nuclear policy affects German energy companies differently. Whereas nuclear energy companies can be expected to lose shareholder wealth, companies in the "green economy" supposedly gain from this decision. We are able to compare the magnitude of these two effects. We also investigate the shareholder wealth effects on European energy companies, and more specifically on competitors in France, Italy, Switzerland and Austria. These firms may on the one hand be affected by the German reaction (e.g., as potential suppliers of electricity to Germany); on the other hand, they may be affected by their own country's reaction—if there was a policy change.

The earthquake and the subsequent tsunami hit Japan unexpectedly, and similarly unexpected was the reaction of the German government to these events. This allows us to apply a methodology which is typically used in the finance literature. Using the event study approach, we measure the impact of the German reaction on shareholder wealth of energy companies in different sectors. There are a few studies in the finance literature assessing the effects of nuclear disasters on stock prices, such as the impact of the incident at Three Mile Island in March 1979 (Bowen et al., 1983; Hill and Schneeweis, 1983), of the Chernobyl disaster in April 1986 (Fields and Janjigian, 1989; Kalra et al., 1993), and also of the recent accident in Japan (Ferstl et al., 2011). However, our paper focuses on the impact of policy changes in response to the recent accident and specifically explores the unique German reaction. The nuclear disaster is the exogenous trigger for any policy change. We also add to the debate about the costs and benefits of "going green." This discussion gains importance as renewable sources of energy appear more and more as a valuable alternative to conventional sources. Our paper is therefore, both in terms of methodology and research question, related to Fisher-Vanden and Thorburn (2011) who assess the shareholder wealth effects of membership in voluntary environmental programs. In terms of methodology, related applications of the event study approach include Card and Krueger (1995) who assess the quantitative impacts of increases in the minimum wage on employer profits, Brown et al. (2004) who examine the market effects of the Terrorism Risk Insurance Act of 2002 in the United States, and Lin (2011) who measures the impact of immigration on employer profits.[3]

---

economic growth (and openness) using time series data from China, Korea and Japan.

[3] See Snowberg et al. (2011), and references therein, for event studies in political economy.

If markets respond rationally to new information and the stock market accurately reflects the firms' value, the event study approach provides a direct measure of how shareholder wealth is affected by unanticipated interventions. Yet, "event studies have even fallen out of favor in their traditional strongholds: economics and finance" (Snowberg et al., 2011, p.1). The reasons for this decline include the choice of the event window, the assignment of a prior probability, and the presence or absence of other confounding events (Snowberg et al., 2011). Our study, however, does not suffer from any of these problems. On the contrary, we argue that Germany's reversal of nuclear policy is an ideal case to apply the event study methodology. Our results appear robust to the choice of the event window and the prior probability of our event was overwhelmingly judged as being zero. Furthermore, confounding events that could eventually bias our findings are not very important because our focus primarily lies on the immediate market responses.

Our results indicate that shareholder wealth has been significantly affected by the German reaction in response to the Fukushima Daiichi nuclear disaster. We find the expected opposing effects on nuclear energy companies and companies in the "green economy." Whereas the cumulative average abnormal returns amount to –3.50% in the German nuclear and conventional energy industry, the shareholder wealth in the renewable energies sector has increased by 17.89% during the period of 20 trading days after the earthquake in Japan. In terms of market capitalization, these effects translate into a decrease of about € 2.1 billion in the nuclear and conventional energy industry, and a gain of roughly € 1.9 billion for renewable energy companies. When we investigate whether European firms in the same sectors outside Germany could benefit from the German reaction, we find cumulative average abnormal returns of 0.71% in the European nuclear energy industry. This seems relatively small, but in terms of market capitalization it corresponds to a non-negligible increase of about € 5.9 billion. Furthermore, we find substantial heterogeneity in the shareholder wealth effects across European countries which can be linked to different nuclear energy policies and policy responses. For instance, we present evidence for substantial wealth gains of Austrian conventional energy companies that are likely caused by the German policy change.

The remainder of this paper is organized as follows. Section 2 describes the series of events in Japan and policy reactions in Europe in March 2011, which we exploit in our analysis. We particularly emphasize the German reaction to these events and argue that the reaction was both unique and unexpected. Against this background, we derive hypotheses for our empirical analysis. Section 3 provides a description of the event study methodology, of the data and our sample of firms, and of our event period. Section 4 presents our empirical results. Section 5 investigates the robustness of our results by analyzing the United States as a "placebo" test. Finally, Section 6 concludes.

2 Background: Fukushima and Beyond

This section describes the shocking events in Japan that took place in early March 2011 as well as the subsequent policy reactions in European countries. We emphasize Germany's reversal of its nuclear energy policy. We argue that this unexpected policy change provides an ideal case to apply the event study methodology.

2.1 The Fukushima Daiichi Nuclear Disaster in Japan

Japan was shaken by a major earthquake on March 11, 2011. When the 9.0 magnitude earthquake hit at 2:26pm, all three operating reactors at the Fukushima Daiichi nuclear power plant went into automatic shutdown. The earthquake additionally destroyed the external power supply of the plant, so emergency power generators provided the electricity for the cooling system. When the subsequent tsunami hit the Japanese east coast where the Fukushima Daiichi nuclear power plant is situated, it took these backup generators and the operators had to switch to battery power. External mobile power generators could not be connected. As pressure and temperature levels kept rising, the Japanese Prime Minister Naoto Kan declared the nuclear emergency status at 7:03pm. The Japanese government announced an evacuation zone of 3 kilometers around the power plant at 9:00pm.

On March 12, 2011 at 7:55pm, the Japanese Prime Minister announced that a hydrogen explosion had occurred at the Fukushima Daiichi nuclear power plant. The evacuation zone was extended to a radius of 20 kilometers around the power plant. On March 13, 2011 excessive radiation levels were reported and officials were quoted that a nuclear meltdown could be underway at one of the reactors and that a meltdown was "highly possible" at another (Washington Post, 2011). On March 20, 2011 the Japanese government announced the permanent shutdown of the the Fukushima Daiichi nuclear power plant.

In sum, more than 80,000 people have been evacuated from around the power plant. Radioactive materials have been detected in tap water as far away as Tokyo, as well as in agricultural products. There was, however, no immediate policy reaction in Japan. The Prime Minister only gradually changed his view. On July 13, 2011 he said that Japan should reduce and eventually eliminate its dependence on nuclear energy (New York Times, 2011).

2.2 The Unique and Unexpected German Reaction

Whereas there was no immediate policy reaction in Japan, the German government announced only three days after the events in Japan to immediately shutdown almost half of the country's nuclear power plants. The reaction marked yet another change in Germany's nuclear policy. This time, however, it was not possible to anticipate such a change. Our analysis explores the Fukushima Daiichi nuclear disaster as the exogenous trigger for the unexpected policy change in Germany.

Germany's energy policy has seen important changes in the attitudes towards the peaceful use of nuclear energy. Importantly, a shutdown strategy for Germany's nuclear reactors had already been enacted when the Atomic Energy Law (*Atomgesetz*) came into force on January 1, 2002. The social democratic-green coalition of Chancellor Gerhard Schröder had scheduled a stepwise phase-out of nuclear power plants until 2022–2025.[4] This shutdown strategy was basically reverted—or, more precisely, it was delayed—on December 14, 2010 by the conservative-liberal coalition of Chancellor Dr. Angela Merkel. On that day, an amendment to the Atomic Energy Law came into force which specified an extension of the life-span of nuclear reactors by 12 years on average.[5]

Against this background, the government's reaction to the shocking events in Japan was unexpected and marked yet another change in Germany's nuclear policy. The German government announced on March 14, 2011 at 4:05pm the immediate shutdown of almost half of Germany's nuclear power plants while safety checks were carried out, and a three-month moratorium on extending the lives of others. The moratorium and the decision to shutdown seven of the country's 17 nuclear reactors (i.e., those reactors that that went online before 1981) were confirmed in a press conference on the next day after a meeting with the federal states' governments. After expert commissions had debated on these issues and had made recommendations, the German Parliament passed another amendment to the Atomic Energy Law on June 30, 2011. According to this amendment, the country will phase all nuclear reactors out by 2022 (Deutscher Bundestag, 2011).

Germany's energy market is dominated by four large energy suppliers: E.ON, EnBW, RWE, and Vattenfall. These companies possess nearly 75% of all conventional power plant capacity and most of the power grid (Traber et al., 2011). Furthermore, all 17 nuclear power plants which were active before the Fukushima Daiichi nuclear disaster were operated by these four firms. We therefore expect a direct impact of the German reaction on these companies' shareholder wealth.

2.3 Reactions in Selected European Countries

We argue that Germany's reaction to the Fukushima Daiichi nuclear disaster is unique in international comparison. Only Switzerland's reaction was relatively similar, but it

[4]Note that the Atomic Energy Law did not specify a precise end date. Based on calculations of a usual operation period of 32 years, it specified how much energy a nuclear power plant was allowed to produce before being closed down.

[5]The life-span of older reactors was extended by 8 years and that of younger reactors by 14 years.

did not involve the immediate shutdown of existing nuclear reactors. The Swiss Federal Councillor Doris Leuthard announced on March 14, 2011 that plans for building three additional nuclear reactors were stopped. Moreover, safety checks on the existing nuclear reactors were announced on that day.

In stark contrast, France did not reconsider its nuclear energy policy. On the contrary, the country is still planning to expand its nuclear energy production. In response to the German reaction, the French President Nicolas Sarkozy said on June 7, 2011: “The decision of the Germans? I’m not criticizing. (...) If they close their plants, they must be replaced. We will be a candidate for selling them electricity...” (China Daily, 2011). If investors share this view, French nuclear and conventional energy companies may gain shareholder wealth in the aftermath of Germany’s reversal of its nuclear energy policy. France derives more than 75% of its electricity from nuclear energy, and the country is the world’s largest net exporter of electricity.

Italy has no nuclear power plants. The country shutdown its last two nuclear rectors after the Chernobyl disaster in 1986. On March 24, 2011 the Council of Ministers of Italy approved a moratorium on the future construction of nuclear power plants. These plans to reverse Italy’s policy and to re-engage in nuclear energy were ultimately stopped by a referendum on June 13, 2011.

Similarly, Austria has no nuclear power plants. Since 1999, “nuclear-free Austria” is part of the country’s constitution. The share of renewable energies in Austria’s energy production was 73.3% in 2009 (BMWFJ, 2011). However, Austria has been a net importer of electricity—also from Germany. Austrian power plant operators were nevertheless quoted that they expect increasing electricity prices after the German reaction, and that this would lead to higher profits and may also lead to the utilization of previously unused power plant capacity (e.g., of gas-fired power plants). If investors share this view, Austrian energy companies may gain shareholder wealth in the aftermath of Germany’s reversal of its nuclear energy policy.

2.4 Hypotheses on Shareholder Wealth Effects

In this section we derive hypotheses which are tested in our empirical analysis. These hypotheses focus on the shareholder wealth effects of policy changes in reaction to the Fukushima Daiichi nuclear disaster. Our main emphasize is on the German reaction and its impact on German energy companies in different sectors as well as on their European competitors.

Our first hypothesis is that we expect a negative impact on Germany’s nuclear energy companies. Germany’s reversal of its nuclear energy policy should *ceteris paribus* be associated with lower future profits of the four firms operating nuclear reactors in Germany. Compared to the situation before the Fukushima Daiichi nuclear disaster, the life-span of nuclear reactors was substantially shortened. For example, almost half of the country's reactors were immediately shutdown.

Second, we expect a positive impact on Germany's renewable energies companies. This includes firms operating in different sectors of the "green economy," i.e., firms that generate electricity from renewable energies as well as companies that develop the related equipment (e.g., wind-powered turbines or photovoltaic cells). The German reaction should *ceteris paribus* increase demand for the products and services of these companies. Renewable energies are the sources of electricity that will, at least in the medium run, have to replace nuclear energy. Whereas coal and gas-fired energy may replace nuclear energy in the short run, a further move towards renewable energies appears inevitable in the medium run because carbon dioxide emission targets are to be met.

Third, the relative magnitude of the impacts on Germany's nuclear energy companies and on Germany's renewable energies companies is an empirical question. We have no *a priori* expectation whether the two effects cancel each other out, or if one of the two effects dominates the other. One possible scenario could be that other European energy companies (nuclear and/or conventional electricity producers) step in and deliver electricity to Germany in the future. If this is the case, the negative impact on the shareholder wealth of German nuclear energy companies may exceed the positive impact on German renewable energies companies.

Fourth, we similarly have no clear-cut *a priori* expectation about the shareholder wealth effects on rivals in other European countries at the aggregate level. As outlined above, the initial situation before the Fukushima Daiichi nuclear disaster was very different in European countries, and similarly different were the European countries' policy reactions. The overall effect at the aggregate European level is therefore an empirical question. The German reaction may have furthermore triggered some uncertainty about other countries' policy responses, and investors may have increasingly viewed similar reactions to the German reaction as likely.

Fifth, we expect heterogeneous shareholder wealth effects on competitors when we separately analyze selected European countries because nuclear energy policies and policy reactions substantially vary across countries. For example, the Swiss reaction to the Fukushima Daiichi nuclear disaster was relatively similar to the German reaction. We therefore expect similar shareholder wealth effects on Swiss nuclear energy companies. On the other hand, the French government did not reconsider its nuclear energy policy. Hence, we do not expect negative shareholder wealth effects in France. On the contrary, if the French President is right and French nuclear energy companies are candidates for selling electricity to Germany, these companies may experience positive shareholder wealth effects. Similar gains may result for Austrian companies for the reasons stated above.

3 Empirical Approach

In this section, we first describe the event study methodology and highlight important methodological challenges and their solutions. Second, we present the data and our sample of firms as well as the event period that we investigate in this study.

3.1 Event Study Methodology

We measure the impact of the German reaction to the events in Japan on shareholder wealth using the event study methodology. In this framework, abnormal returns are the crucial measure to assess the impact of a given event. The general idea of this measure is to isolate the event's effect from any other general movements of the market. The abnormal return of firm i on event date τ is defined as the difference of the realized return and the expected return given the absence of the event:

$$AR_{i,\tau} = R_{i,\tau} - E[R_{i,\tau}|Q_{i,\tau-1}] \tag{1}$$

The expected return (henceforth referred to as normal return) is unconditional on the event, but conditional on a separate information set (e.g., past returns). This implies that the event study methodology will only yield reliable results if the event of interest contains unanticipated information. In contrast to most event studies on regulatory or legislative changes that are likely to suffer from anticipation effects (at least to some extent), we can rule out the presence of such effects in our case. The earthquake hit Japan unexpectedly, and similarly unexpected was the reaction of the German government to these events.

To measure normal returns, we follow Brown and Warner (1985) and apply the market model:

$$\varepsilon_{i,\tau} = R_{i,\tau} - (\alpha_i + \beta_i R_{m,\tau}) \tag{2}$$

where $\varepsilon_{i,\tau}$ is the abnormal return of firm i on day τ and $R_{m,\tau}$ is the return of the market portfolio on day τ. The coefficients α_i and β_i in equation (2) are OLS estimates obtained from regressions of firm i's daily returns on the market portfolio (and a constant) over a period of 200 trading days ending 21 days before our first event.

Daily average abnormal returns are then calculated for each day of the event period as the arithmetic mean of contemporary market model residuals:

$$AAR_\tau = \frac{1}{N}\sum_{i=1}^{N} \varepsilon_{i,\tau} \tag{3}$$

where N is the total number of firms in the sample.

The cumulative average abnormal return from τ_1 to τ_2 is given by:

$$CAAR_{\tau_1,\tau_2} = \sum_{\tau=\tau_1}^{\tau_2} AAR_\tau \tag{4}$$

We test the statistical significance of (daily and cumulative) average abnormal returns applying a cross-sectional t-test and the standardized residuals test suggested by Patell (1976). Additionally, we apply the standardized cross-sectional residuals test introduced by Boehmer et al. (1991). This test is robust towards event-induced variance increases that potentially bias the other two tests. But in case of any non-normality in abnormal returns, the former three parametric tests are poorly specified. We therefore additionally apply the Corrado (1989) rank test in its modified form suggested by Corrado and Zivney (1992).

The standard event study methodology and hypothesis tests rely on the assumption of i.i.d. distributed market model residuals. However, this assumption is most likely violated in our case since the events of interest occur during the same calendar time period for all firms, and these firms are in the same industry (the energy industry). Binder (1985a,b) surveys the literature of the event parameter approach which addresses the problem of contemporaneous correlation in market model residuals. The first step is to parameterize individual abnormal returns by the inclusion of dummy variables in equation (2):

$$R_{i,\tau} = \alpha_i + \beta_i R_{m,\tau} + \sum_{t=\tau_1}^{\tau_2} \delta_{i,t} D_t + \varepsilon_{i,\tau} \tag{5}$$

where D_t equals one during the event period of interest and zero otherwise.

Instead of an OLS estimation of each firm's market model equation, the system of market model equations is jointly estimated applying Zellner's (1962) famous seemingly unrelated regressions approach (henceforth referred to as SUR):

$$\begin{bmatrix} R_{1,\tau} = \alpha_1 + \beta_1 R_{m,\tau} + \sum_{t=\tau_1}^{\tau_2} \delta_{1,t} D_t + \varepsilon_{1,\tau} \\ \vdots \\ R_{i,\tau} = \alpha_i + \beta_i R_{m,\tau} + \sum_{t=\tau_1}^{\tau_2} \delta_{i,t} D_t + \varepsilon_{i,\tau} \\ \vdots \\ R_{N,\tau} = \alpha_N + \beta_N R_{m,\tau} + \sum_{t=\tau_1}^{\tau_2} \delta_{N,t} D_t + \varepsilon_{N,\tau} \end{bmatrix} \tag{6}$$

The joint estimation of the system of market model equations yields abnormal return estimates and standard errors which are numerically equivalent to the estimates derived from OLS regressions of the individual equations. Thus, there are no efficiency gains from using the SUR estimator. The advantage of SUR over OLS lies in the construction of hypothesis tests. The null hypothesis of no average abnormal returns can be tested in this framework by testing linear constraints on the coefficients $\delta_{i,t}$ while explicitly allowing for contemporaneous correlation in the error terms. A single parameter restriction is then sufficient to mimic the null hypothesis of the previously introduced tests:

$$\frac{1}{N}\sum_{i=1}^{N}\delta_{i,t} = 0 \qquad (7)$$

Although different test statistics are available to test joint hypotheses in the SUR framework, most statistics suffer from poor small sample properties and are biased against the null hypothesis.[6] We therefore only apply a standard Wald-Test.

In addition to abnormal returns we compute abnormal trading volume applying a simple constant mean methodology. The average daily trading volume for each individual firm is estimated over the period of 200 trading days ending 21 days before our first event. Following Brav and Gompers (2003) we correct for outliers by setting values outside the 99% quantile to the median value. Assuming semi-strong form market efficiency we expect that the abnormal trading volume is close to zero over the pre- and post-event period, but that it significantly increases during the event period.

3.2 Data, Sample Selection, and Event Period

In this section, we provide a description of the sample and event date selection process. To quantify the impact of the Fukushima Daiichi nuclear disaster and the subsequent unique German reaction, we consider the four large energy suppliers dominating the German market as well as renewable energies companies since we expect opposite effects on these firms' profitability. Without the consideration of the EU's and Switzerland's major electricity utilities and listed renewable energies companies we cannot sufficiently prove the uniqueness of the German reaction. Moreover, we would neglect potential wealth transfers due to a change in the competitiveness of German energy companies caused by the substantial shift in Germany's nuclear policy in response to the Fukushima Daiichi nuclear disaster.

To identify nuclear and conventional energy companies, we apply the following criteria throughout our analysis. First, we only consider listed companies that are domiciled in the respective country. Second, we include companies whose last annual financial statement reports that at least 50% of their turnover is from nuclear and/or conventional electricity generation. We consider oil, gas and coal as conventional sources of energy.

[6] See Binder (1985b) for a detailed discussion of the various tests.

In the German case, we identify three companies out of the four major energy companies as listed companies that are domiciled in Germany: RWE, E.ON, and EnBW. The fourth company, Vattenfall, is a private company fully owned by the Swedish state. We therefore restrict our analysis of German nuclear and conventional energy companies to the former three companies.[7] Note that Vattenfall did not operate any of the seven nuclear reactors that were immediately shutdown after the Fukushima Daiichi nuclear disaster.

We use the constituents of the DAX Subsector All Renewable Energies Index to identify companies operating in the "green economy." According to the index rules of the Deutsche Boerse Group, this index captures all listed companies generating electricity from renewable energies as well as companies that develop the related equipment (e.g., wind-powered turbines, photovoltaic cells, biogas plants). The index (as of February 2011) consists of 38 members. We exclude two companies that are listed, but not domiciled in Germany. Furthermore, we exclude one company that has an insufficient number of observed returns over the estimation window.[8]

We moreover consider the EU's and Switzerland's major electricity utilities, i.e., nuclear and conventional energy companies, as well as listed renewable energies companies. Our sample therefore additionally includes companies domiciled in France, UK, Italy, Spain, Austria, Switzerland, the Benelux, and Nordic countries. These countries' energy sectors are not directly affected by the German reaction, but potentially benefit from a permanent shutdown of the German nuclear reactors. The subsample of major electricity utilities consists of 13 companies. Additionally, we identify 25 listed companies operating in the "green economy" whose business activities are comparable to the constituents of the DAX Subsector All Renewable Energies Index.[9]

Before we can test the impact of the Fukushima Daiichi nuclear disaster and of the German reaction on shareholder wealth, we need to identify the events that possibly contain substantial new information. The events that comprise our event window are listed in Table 1. We define the day of the terrible earthquake and the subsequent tsunami in Japan (March 11, 2011) as "day zero" for our analysis.

Table 1 about here

The estimation period for the regression of the market model equations is based on a period of 200 trading days ending 21 days before day zero. The stock mar-

[7] We also perform our analysis when we additionally exclude EnBW. The share of their stocks in free float is relatively low, but our results remain virtually the same.

[8] Since renewable energies companies potentially suffer from non-synchronous trading, we additionally estimate the market model applying the Scholes and Williams (1977) approach. Our results are robust towards the choice of the estimation method.

[9] We follow the categorization of the STOXX Europe Sector indices using the *Industry Classification Benchmark, ICB* to identify appropriate and comparable companies.

ket and accounting data for this study were obtained from ThomsonReuters Datastream.[10] We use the CDAX Index to estimate the market model's parameters for each company of both German subsamples. The CDAX Index is an equal-weighted index that reflects the price developments of all German listed companies across the major market segments Prime Standard and General Standard. Parameter estimations for the two remaining subsamples are based on the Stoxx Europe 600 Index that represents companies with large, intermediate and small market capitalization in the European countries included in our sample.

4 Results

After the tsunami hit the Japanese coast on March 11, 2011 (Friday), the Japanese Prime Minister declared the nuclear emergency status. Germany's reversal of its nuclear policy was announced on March 14, 2011 (Monday), i.e., on the next trading day. These events were completely unexpected by financial markets. Hence, the following event study results focus solely on the market reactions of share prices on March 11, 2011 ($\tau = 0$), on March 14, 2011 ($\tau = 1$), and during the subsequent time period of 20 trading days.

4.1 Shareholder Wealth Effects in Germany

Table 2 and Figure 1 show the market impact of the Japanese disaster and of the German policy reaction on the German nuclear and conventional energy industry as well as on the German renewable energies industry. We do not observe an immediate reaction on the day of the earthquake, but it comes at no surprise that the event day abnormal return (AAR_1) is highly significant at the 1% level and amounts to –3.27% for the three major German nuclear and conventional energy companies RWE, E.ON, and EnBW. In addition, the market reaction of the 35 constituents of the DAX Subsector All Renewable Energies Index on this event day is positive, highly significant at the 1%-level, and adds up to 11.62%. These figures corroborate our first two hypotheses and furthermore indicate that financial markets incorporate the new information released by the Japanese and German governments very quickly.

Table 2 and Figure 1 about here

Table 2 and Figure 2 also take a closer look at the actual wealth gains and losses the events under scrutiny have caused. For this purpose, we analyze the evolution of total shareholder wealth, measured by the market capitalization, of the three

[10]Daily stock and index returns are calculated applying the concept of total shareholder return.

major German nuclear and conventional energy companies as well as of the German renewable energies companies.

Figure 2 about here

Column 7 of Table 2 shows that a total value of € 4.405 billion is lost on the event day in the German nuclear and conventional energy sector. In contrast, the total wealth gains in the renewable energies sector amount to € 1.105 billion on that day. These results indicate that although we observe substantially higher abnormal returns for the renewable energies industry compared to the abnormal returns in the nuclear and conventional energy sector, the total shareholder wealth gains in the renewable energies sector do not compensate for the huge losses in the nuclear and conventional energy sector.

To investigate this further, we also look at the cumulative average abnormal returns ($CAAR_{\tau_1,\tau_2}$) in both industries over different post-event time periods. The empirical pattern described above on the event day remains virtually the same if we look at the post-event period up to 20 trading days after the event. Therefore, we can infer that the market is semi-strong form efficient as all information is already captured in security prices on the event day.

Table 3 about here

In Table 3, we observe the following significantly negative cumulative average abnormal returns in the German nuclear and conventional energy industry in the aftermath of the Fukushima Daiichi nuclear disaster: $CAAR_{1,10}$ = –3.86%; $CAAR_{1,20}$ = –3.50%. During the 20 trading days after the German reaction to the Japanese events, a total shareholder value of € 2.078 billion is destroyed in the nuclear and conventional energy industry. On the other hand, cumulative average abnormal returns in the German renewable energies increase over time and are significantly positive at conventional levels in all sub-periods: $CAAR_{1,10}$ = 17.51%; $CAAR_{1,20}$ = 17.89%. Over the total post-event period the shareholder wealth gains in the renewable energies sector amount to € 1.887 billion.

In summary, the above presented German results on the impact of the Fukushima Daiichi nuclear disaster and of the German policy response in the aftermath suggest a wealth transfer from the nuclear and conventional energy industry to the renewable energies sector. The combined wealth effect of both industries in Germany is negative and amounts to € 0.191 billion over the entire post-event period of 20 trading days.

An additional question is whether anybody else benefits from the German reaction. To answer this question, we investigate the policy and market reactions in the nuclear and conventional energy industry as well as in the renewable energies industry in other European countries, and in particular in countries which are in geographic proximity to Germany. Firms located in these countries could potentially provide the electricity that Germany would need in case its own electricity supply would not be sufficient in the future.

4.2 Shareholder Wealth Effects in Europe

First, we look at the industries' reaction in Europe as a whole. Table 4 and Figure 3 exhibit the abnormal returns and the evolution of the market capitalization during the event period of 20 trading days for major European electricity utilities and renewable energies firms. The average abnormal return of the German competitors in the nuclear and conventional energy industry on the event day ($\tau = 1$) is significant and slightly negative with –0.86%. The total loss in shareholder value amounts to € –5.567 billion on that day. The market reaction of the German competitors in the European renewable energies sector is insignificant and adds up to 1.26% which represents a total wealth gain of € 663 million.

Table 4 and Figure 3 about here

We also investigate in more detail the European market reactions in both industries over different post-event time periods (up to 20 trading days after the event). It seems likely that only during the course of the post-event period, it becomes clear if the German competitors in the nuclear industry benefit from the decision of the German government, or if they lose due to the fact that European governments in general reassess their nuclear energy strategies.

Table 5 depicts the cumulative average abnormal returns in the post-event period in the European nuclear and conventional energy industry as well as in the renewable energies industry. All cumulative average abnormal returns in the different sub-periods for the nuclear and conventional energy firms are slightly positive and insignificant, suggesting that there seems to be no impact of the Fukushima Daiichi nuclear disaster on the European nuclear and conventional energy industry as a whole ($CAAR_{1,10}$ = 0.90%; $CAAR_{1,20}$ = 0.71%). However, over the entire post-event period the industry gains in total € 5.924 billion in terms of market capitalization.

The effect on the European (ex-Germany) renewable energies sector is predominantly insignificant. Although the effects for a period of 10 trading days are significant, they diminish over time and become insignificant if measured over the entire event period of 20 trading days. Whereas their German competitors experience a shareholder gain of € 1.887 billion during the entire event period, the European (ex-Germany) renewable energies sector gain € 1.102 billion in the aftermath of the Fukushima Daiichi nuclear disaster.

Table 5 about here

Overall, the European market reaction (ex-Germany) to the events in Japan is predominantly insignificant. However, the European competitors of the German major electricity utilities experience a total shareholder wealth gain of € 5.924 billion over the event period of 20 trading days. This indicates a wealth transfer from the German nuclear and conventional energy industry not only to the German renewable energies sector (€ 1.887 billion), but also to the European nuclear and conventional energy industry. Moreover, we find a substantial abnormal trading volume for the European energy companies after the event. This indicates that investors react to the new and unanticipated information in some way. It may be the case that opposing effects for companies in different countries cancel each other out at the aggregate European level.

To investigate whether such opposing effects are present, we analyze in a next step the market reactions separately in selected European countries. Heterogenous impacts may be present due to different policy reactions in these countries.

4.3 Shareholder Wealth Effects in Selected European Countries

Figure 4 displays the shareholder wealth effects in four European countries.[11] We observe heterogeneous effects across France, Italy, Switzerland and Austria, which can be linked to the countries' reactions, energy policies and other interventions.

Figure 4 about here

French firms in the nuclear and conventional energy industry exhibit a significantly negative average abnormal return of –2.11% on the day of the German reaction. This negative impact increases over time; and the cumulative average abnormal returns amount to –5.56% over the entire post-event period of 20 trading days. These results are likely related to the French uncertainty in the aftermath of the nuclear disaster. On the one hand, the French President Nicolas Sarkozy assured that "Japan's nuclear crisis would not change French policy on nuclear power" (Bloomberg; March 17, 2011), but on the other hand the French nuclear regulator regarded "reactor safety (as) fairly satisfactory" (Bloomberg; March 30, 2011).

We observe only a small positive reaction on the event day for Austrian companies (0.91%). However, the Austrian market reaction of conventional energy firms becomes substantially positive as well as statistically and economically significant afterwards ($CAAR_{1,10}$ = 15.59%; $CAAR_{1,20}$ = 15.68%). These figures indicate that investors expect Austrian conventional energy firms to benefit from the German policy reaction and corroborate our hypothesis stated above.

[11]Detailed results and hypothesis tests for these countries are available from the authors.

The stock price reaction of Swiss conventional energy companies is significantly negative and in the longer run even stronger than that of their German counterparts. On the event day we observe a significant negative abnormal return of –3.82%. Over the entire post-event period of 20 trading days, cumulative average abnormal returns remarkably increase and amount –15.98%. This is both statistically and economically significant. This result confirms our hypothesis about shareholder wealth effects in Switzerland in the aftermath of the Fukushima Daiichi nuclear disaster, even though the magnitude of the effects is unexpectedly large.

The share price of Italian conventional energy firms hardly reacted in the aftermath of the Japanese events and the German reaction (0.22% on the event day; $CAAR_{1,20}$ = –0.92%). This comes as no surprise as Italy has no nuclear power plants.

In summary, the above results show that the market has heterogeneous expectations about which country's nuclear and/or conventional energy industry will gain or lose in the aftermath of the German reaction. We observe that Austrian conventional energy firms seem to benefit from the German reaction, Italian firms seem to be unaffected, and Swiss and French firms seem to lose.

5 Robustness Check: United States

To assess the robustness of our empirical results, we investigate the shareholder wealth effects on nuclear and conventional energy companies in the United States. This analysis can be viewed as a "placebo" test assessing the validity of our approach as the United States did not reconsider their energy policy in the aftermath of the Fukushima Daiichi nuclear disaster. Furthermore and importantly, we are not aware of any channel through which the reaction of the German government could have affected the shareholder wealth of United States' energy companies. We therefore expect no effect in this part of our analysis.

After the shocking events in Japan, the United States did not reconsider their nuclear energy policy. In a press briefing of the White House on March 14, 2011—the day when the German government announced the policy change—the Deputy Secretary of Energy, Dan Poneman, said that "each event as it occurs is taken into account, but we do not sort of change from day to day our overall approach to the desire to diversify our overall energy posture" (The White House, 2011). The United States' government continued to take the same stance during the subsequent weeks, although it announced a comprehensive safety review by the Nuclear Regulatory Commission (NRA) for the country's 104 operating nuclear reactors on March 23, 2011. One week later (March 30, 2011), the President of the United States, Barack Obama, assured in his "Energy Security Speech" that nuclear energy has important potential for increasing the country's electricity without adding carbon dioxide to the atmosphere—subject to rigorous safety standards. The results of the comprehensive safety review by the NRA were published on May 13, 2011. The review did not find any problems at nuclear reactors in the United States that would threaten their safety. In sum, there are no events that we expect to result in substantial shareholder wealth effects on nuclear and conventional energy companies in the United States.

To assess whether this is indeed the case, we apply the same methodology as before. We also apply the same sample selection criteria as before. Our sample therefore consists of nuclear and conventional energy companies which are listed and domiciled in the United States. Each firm's last annual financial statement reports that at least 50% of its turnover is from nuclear and/or conventional electricity generation. As before, we consider oil, gas and coal as conventional sources of energy. Figure 5 and Table 6 display the resulting shareholder wealth effects on these companies.

Figure 5 and Table 6 about here

The immediate market reaction of the United States' conventional energy industry is negative, but it is neither economically nor statistically significant on the event day (–0.42%). We find that cumulative average abnormal returns become insignificant for longer event windows, and they additionally change from negative to positive values ($CAAR_{1,20}$ = –1.53%; $CAAR_{1,30}$ = –0.85%; $CAAR_{1,40}$ = 1.88%). As hypothesized above, the shareholder wealth of nuclear and conventional energy companies in the United States appears unaffected in the aftermath of the Fukushima Daiichi nuclear disaster. This finding confirms the validity of our approach.

6 Conclusions

This paper analyzes the shareholder wealth effects on electricity companies in Germany and in Europe in the aftermath of the Fukushima Daiichi nuclear disaster. The unique and unexpected German reaction to the shocking events in Japan allows us to apply the event study methodology. Although it appears that event studies are under-used and on the decline even in their traditional fields of application (economics and finance, see Snowberg et al., 2011), we can rule out the problems this approach typically suffers from. Most importantly, we can exclude any anticipation effects as the probability of such an event was overwhelmingly judged as being essentially zero—or, in the words of Taleb (2007), the event came close to discovering a "black swan." Similarly unexpected was the German reaction. Only a couple of months earlier, the same government had basically reverted the shutdown strategy of the previous governments. The change in Germany's nuclear energy policy that we explore thus came literally overnight.

From a conceptual point of view, our results indicate that in our case, new information is immediately priced in the stock markets. Our results show a remarkably strong effect on our event day; and this effect generally persists throughout the entire event period. This is not very common in event studies and makes us confident that the German reaction indeed represents an unanticipated intervention. Although this is a prerequisite for the event study approach to generate unbiased results, it nevertheless appears to be rarely fulfilled in this manner.

From a policy-oriented point of view, our findings indicate that the German reaction has resulted in a wealth transfer from nuclear energy companies to renewable energies companies. We moreover find that the joint market capitalization of German firms in both sectors has decreased, but the amount of this combined decrease is small. We moreover detect non-negligible effects on nuclear energy companies in other European countries. Importantly, the latter effects exhibit a substantial degree of heterogeneity across countries, which can be linked to the respective nuclear energy policies. One noticeable exception is probably the case of France. In stark contrast to "popular wisdom" (put forward for instance by the French President Nicolas Sarcozy), investors in the stock markets do not seem to value the perspective that French nuclear reactors may export electricity to Germany in the future. Alternatively, they attach a relatively low probability to such a scenario. However, investors appear to share the view of Austrian power plant operators who were quoted that they expect increasing electricity prices, the utilization of previously unused power plant capacity, and higher profits. Our results indicate substantial wealth gains of Austrian firms that are very likely caused by the German policy change.

Our paper therefore highlights important economic impacts of the nuclear disaster in Japan which are channeled through the unique and unexpected German reaction to these shocking events. However, we want to clearly point out the limitations of our analysis. First, we focus on shareholder wealth effects. Therefore, we disregard—at least in principle—the social benefits of the German reaction. Such positive effects which are not incorporated in our outcome measure may include reductions in morbidity or premature mortality, increased land values after the cleanup of hazardous waste sites, or any other social benefit associated with the shutdown of nuclear power plants (Palmer et al., 1995). For example, employment effects may also result. We are not able to investigate these dimensions at this stage. This does, however, not rule out that such effects may be present. Second, and related to the previous point, our analysis only considers the short-term shareholder wealth effects of the German reaction. At this point in time, we are agnostic about the long-term effects. In general, these effects on German firms are uncertain because they may for example react with strategic partnerships to rivals in other European countries (e.g., joint ventures such as RWE in the Netherlands) and, more generally, with increased international cooperation. German firms may also have increased incentives to invest in "green" technology, and such investments can have important effects in the long run. Third, our paper does not explicitly analyze the effects of "going green" on electricity prices, carbon dioxide emissions, or the security of energy supplies.[12] These factors are only included in our analysis in as far as they are priced in the stock markets. Fourth, we only consider the shareholder wealth effects on listed companies. This has the drawback that our results for renewable energies companies are likely lower bounds as many of this sector's companies are small- and medium-sized firms which are not (yet) listed on the stock market.

Despite of these limitations, our study shows that "going green" is not necessarily associated with substantially large detrimental effects for the economy. Although we find evidence for a wealth transfer from nuclear and conventional energy companies to renewable energies companies in Germany, these two opposing effects cancel each other almost completely out. The overall loss in terms of the joint market capitalization of companies who are affected by Germany's policy change is relatively small. One should, however, be cautious when generalizing from this result. It is very likely related to the specific German context. For example, renewable energies have been subsidized in Germany for quite some time and there are already a number of established companies operating in this sector of the country's economy. Germany was therefore relatively well prepared for the reversal of its nuclear energy policy. Nevertheless, the abrupt phase-out in response to the Fukushima Daiichi nuclear disaster could not be expected.

[12]Kemfert and Traber (2011) investigate these dimensions for Germany.

References

Binder, J. (1985a). Measuring the Effects of Regulation with Stock Price Data. *RAND Journal of Economics 16*, 167–183.

Binder, J. (1985b). On the Use of the Multivariate Regression Model in Event Studies. *Journal of Accounting Research 23*, 370–383.

BMWFJ (2011). Energiestatus Österreich 2011. Bundesministerium für Wirtschaft, Familie und Jugend (Österreich).

Boehmer, E., J. Musumeci, and A. B. Poulson (1991). Event-Study Methodology under Conditions of Event-Induced Variance. *Journal of Financial Economics 30*(2), 253–272.

Bowen, R. M., R. P. Castanias, and L. A. Daley (1983). Intra-Industry Effects of the Accident at Three Mile Island. *Journal of Financial and Quantitative Analysis 18*(1), 87–111.

Brav, A. and P. Gompers (2003). The Role of Lockups in Initial Public Offerings. *Review of Financial Studies 16*, 1–29.

Brock, W. A. and M. S. Taylor (2005). Economic Growth and the Environment: A Review of Theory and Empirics. In P. Aghion and S. N. Durlauf (Eds.), *Handbook of Economic Growth*, Volume 1, Chapter 28, pp. 1749–1821. Elsevier.

Brown, J. R., J. D. Cummins, C. M. Lewis, and R. Wei (2004). An Empirical Analysis of the Economic Impact of Federal Terrorism Reinsurance. Working Paper 04–04, The Wharton Financial Institutions Center.

Brown, S. J. and J. B. Warner (1985). Using Daily Stock Returns: The Case of Event Studies. *Journal of Financial Economics 14*(1), 3–31.

Card, D. and A. B. Krueger (1995). *Myth and Measurement: The New Economics of the Minimum Wage*, Chapter 10: How Much Do Employers and Shareholders Lose?, pp. 313–354. Princeton, NJ: Princeton University Press.

China Daily (2011). Sarkozy Sees Opportunities in German Exit of Nuclear Energy. June 8, 2011.

Choi, E., A. Heshmati, and Y. Cho (2010). An Empirical Study of the Relationships between CO2 Emissions, Economic Growth and Openness. IZA Discussion Paper 5304, Institute for the Study of Labor (IZA), Bonn.

Corrado, C. J. (1989). A Nonparametric Test for Abnormal Security-Price Performance in Event Studies. *Journal of Financial Economics 23*(2), 385–396.

Corrado, C. J. and T. L. Zivney (1992). The Specification and Power of the Sign Test in Event Study Hypothesis Tests Using Daily Stock Returns. *Journal of Financial and Quantitative Analysis*, 465–478.

Deutscher Bundestag (2011). Entwurf eines Dreizehnten Gesetzes zur Änderung des Atomgesetzes. Drucksache 17/6070, Deutscher Bundestag, 17. Wahlperiode.

Diekmann, J. (2009). Renewable Energy in Europe: Strong Political Will Required for Ambitious Goals. Weekly Report 36, 242–250, German Institute for Economic Research (DIW Berlin), Berlin.

European Union (2009). Directive 2009/28/EC. The European Parliament and the Council.

Ferstl, R., S. Utz, and M. Wimmer (2011). The Effect of the Japan 2011 Disaster on Nuclear and Alternative Energy Stocks Worldwide: An Event Study. Working Paper.

Fields, M. A. and V. Janjigian (1989). The Effect of Chernobyl on Electric-Utility Stock Prices. *Journal of Business Research 18*(1), 81–87.

Fisher-Vanden, K. and K. S. Thorburn (2011). Voluntary Corporate Environmental Initiatives and Shareholder Wealth. *Journal of Environmental Economics and Management* (forthcoming).

Grossman, G. M. and A. B. Krueger (1995). Economic Growth and the Environment. *The Quarterly Journal of Economics 110*(2), 353–377.

Hill, J. and T. Schneeweis (1983). The Effect of Three Mile Island on Electric Utility Stock Prices: A Note. *Journal of Finance 38*(4), 1285–1292.

Kalra, R., G. V. Henderson Jr., and G. A. Raines (1993). Effects of the Chernobyl Nuclear Accident on Utility Share Prices. *Quarterly Journal of Business and Economics 32*(2), 52–77.

Kemfert, C. and T. Traber (2011). The Moratorium on Nuclear Energy: No Power Shortages Expected. *DIW Economic Bulletin* (1), 3–6.

Lin, C. (2011). Give Me Your Wired and Your Highly Skilled: Measuring the Impact of Skilled Immigration on Employers and Shareholders. IZA Discussion Paper 5754, Institute for the Study of Labor (IZA), Bonn.

Merkel, A. (1998). The Role of Science in Sustainable Development. *Science 281*(5375), 336–337.

New York Times (2011). Japan Premier Wants Shift Away From Nuclear Power. July 14, 2011, page A6 (New York edition).

Palmer, K., W. E. Oates, and P. R. Portney (1995). Tightening Environmental Standards: The Benefit-Cost or the No-Cost Paradigm? *Journal of Economic Perspectives 9*(4), 119–132.

Patell, J. M. (1976). Corporate Forecasts of Earnings Per Share and Stock Price Behavior: Empirical Tests. *Journal of Accounting Research 14*(2), 246–274.

Porter, M. E. and C. van der Linde (1995). Toward a New Conception of the Environment-Competitiveness Relationship. *Journal of Economic Perspectives 9*(4), 97–118.

Scholes, M. and J. Williams (1977). Estimating Betas from Nonsynchronous Data. *Journal of Financial Economics 5*, 309–327.

Scientific American (2004, September). Einstein = Man of Conscience^2. *Scientific American 291*, 10.

Snowberg, E., J. Wolfers, and E. Zitzewitz (2011). How Prediction Markets Can Save Event Studies. IZA Discussion Paper 5640, Institute for the Study of Labor (IZA), Bonn.

Taleb, N. N. (2007). *The Black Swan: The Impact of the Highly Improbable*. Random House.

The White House (2011). Press Briefing by Press Secretary Jay Carney, Nuclear Regulatory Commission Chairman Greg Jaczko and Deputy Secretary of Energy Dan Poneman. Office of the Press Secretary (March 14, 2011).

Traber, T., C. Kempfert, and J. Diekmann (2011). German Electricity Prices: Only Modest Increase Due to Renewable Energy expected. Weekly Report 6, 37–46, German Institute for Economic Research (DIW Berlin), Berlin.

Washington Post (2011). Japanese Nuclear Plants' Operator Scrambles to Avert Meltdowns. March 13, 2011.

Zellner, A. (1962). An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias. *Journal of the American Statistical Association 57*, 348–368.

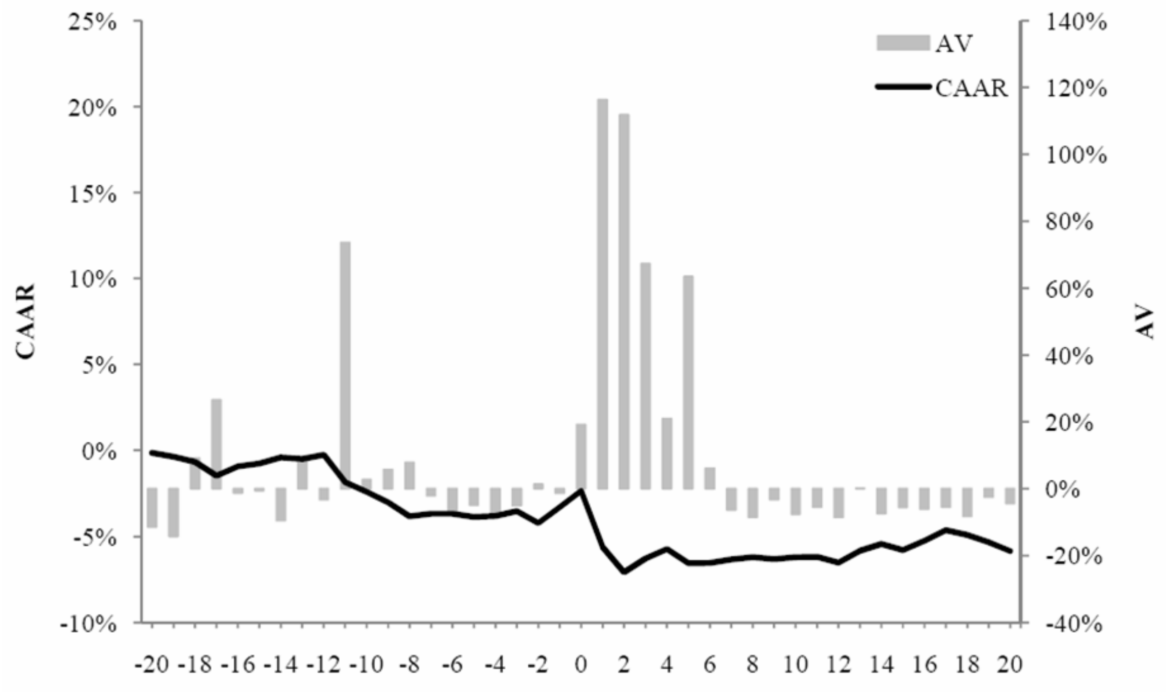
Table 1: Important Events in Selected Countries.

Date	Event Time	Japan	Germany	Other Countries
2/11/2011	–20			
2/14/2011	–19			
...	...			
2/24/2011	–11		RWE releases annual financial statement	
...	...			
3/4/2011	–5			
3/7/2011	–4			
3/8/2011	–3			
3/9/2011	–2			
3/10/2011	–1			
3/11/2011	0	Earthquake and tsunami in Japan, Prime Minister declares nuclear emergency status		
3/14/2011	1	Reports of excessive radiation levels, nuclear meltdown being underway	Germany calls independent inquiry to study nuclear plant future and sets three month moratorium for nuclear extension	Switzerland stops plans for three additional nuclear reactors and announces safety checks on existing reactors
3/15/2011	2		German pre-1980 nuclear plants to be halted, Merkel says	
3/16/2011	3			
3/17/2011	4		Merkel against closing all nuclear power plants in Germany; German nuclear moratorium is legal, Merkel says	Nicolas Sarkozy assures that Japan's nuclear crisis would not change French nuclear energy policy
3/18/2011	5			
3/21/2011	6	Japanese government announces permanent shutdown of Fukushima Daiichi nuclear power plant		
3/22/2011	7			
3/23/2011	8			
3/24/2011	9			Italy approves a moratorium on the future construction of nuclear power plants
3/25/2011	10			
3/28/2011	11		Merkel says her personal view of nuclear power has changed after Fukushima	
3/29/2011	12		FDP in favor of leaving eight German nuclear power plants closed	
3/30/2011	13			French nuclear regulator regards reactor safety as fairly satisfactory
3/31/2011	14			
4/1/2011	15		Merkel's coalition to close eight nuclear power plants	
4/4/2011	16			
4/5/2011	17			
4/6/2011	18			
4/7/2011	19			
4/8/2011	20			

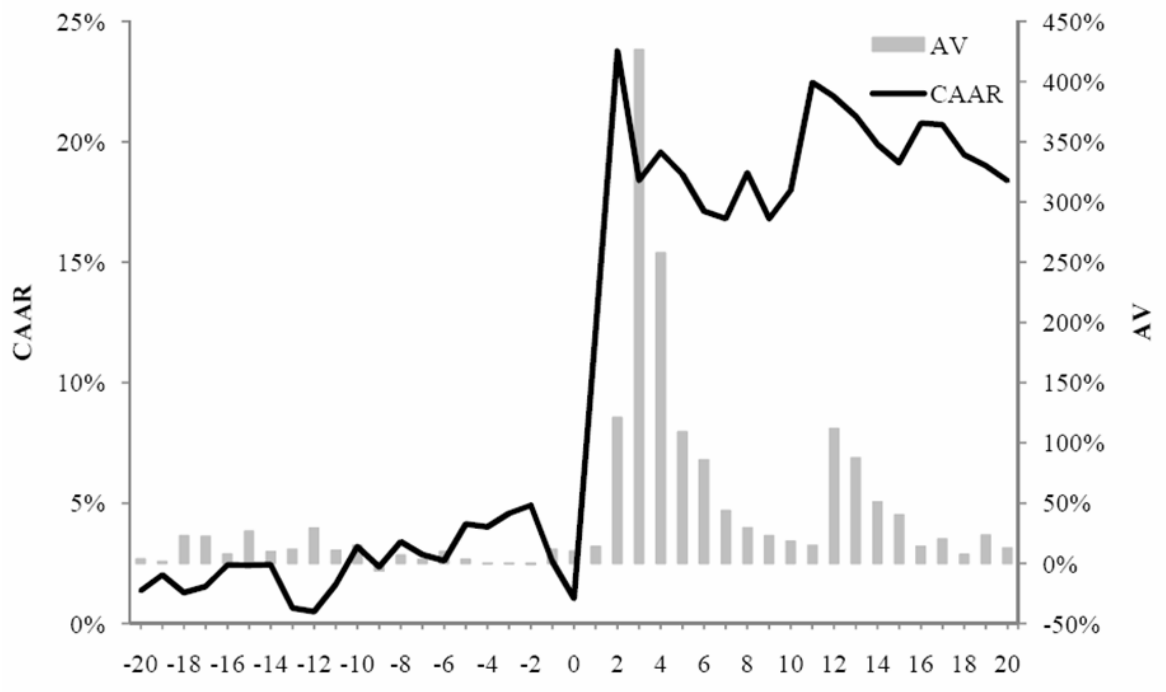
Source: Authors' illustration.

Figure 1: Cumulative Average Abnormal Returns and Abnormal Trading Volume, Germany.

(a) Nuclear/Conventional Energy Companies



(b) Renewable Energies Subsample



Notes: The abnormal return is calculated using the market model as the normal return. Abnormal volume is calculated as described in Brav and Gompers (2003).

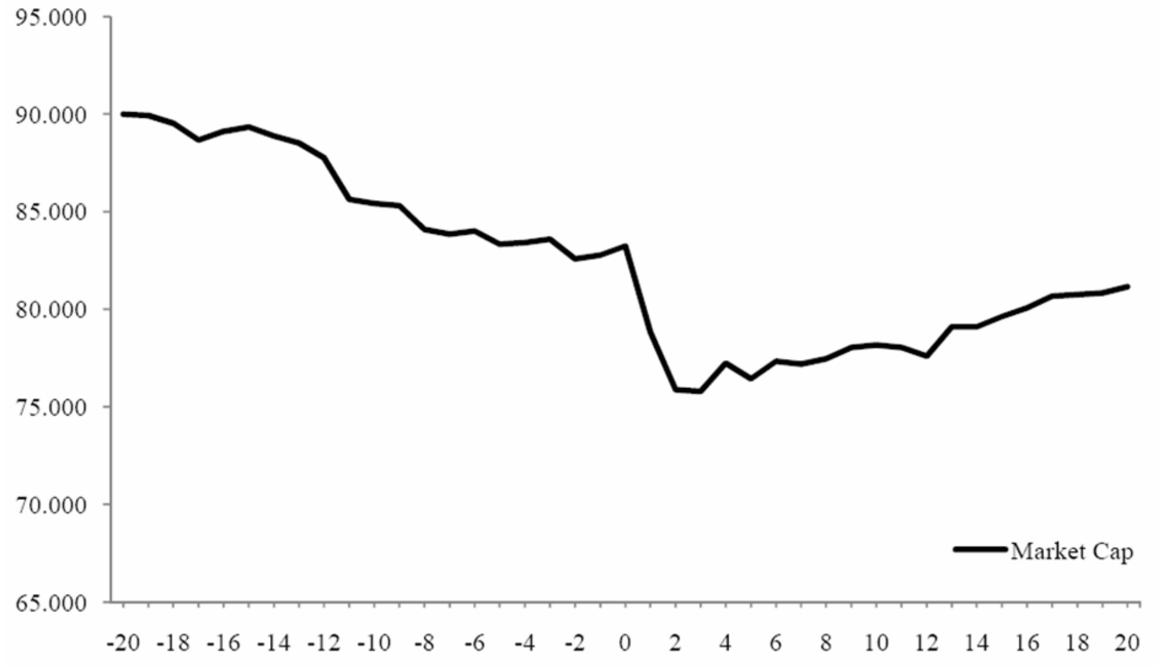
Table 2: Cumulative/Daily Average Abnormal Returns and Aggregate Market Capitalization, Germany.

Event Time	**Nuclear/Convent. Energy Companies**			**Renewable Energies Subsample**			**Total**
	$CAAR_{-20,\tau}$	AAR_{τ}	$MCAP_{\tau}$	$CAAR_{-20,\tau}$	AAR_{τ}	$MCAP_{\tau}$	$MCAP_{\tau}$
–20	–0.1490%	–0.1490%	89,982.07	1.3616%	1.3616%	8,908.37	98,890.44
–19	–0.3709%	–0.2219%	89,918.92	2.0115%	0.6498%	9,051.17	98,970.09
–18	–0.6629%	–0.2920%	89,525.07	1.2792%	–0.7322%	9,048.30	98,573.37
–17	–1.4769%	–0.8140%	88,659.04	1.5302%	0.2509%	9,176.39	97,835.43
–16	–0.9341%	0.5428%	89,102.00	2.4256%	0.8955%	9,316.68	98,418.68
–15	–0.7547%	0.1794%	89,329.58	2.4102%	–0.0155%	9,460.78	98,790.36
–14	–0.4106%	0.3441%	88,862.51	2.4463%	0.0361%	9,317.73	98,180.24
–13	–0.5044%	–0.0938%	88,518.75	0.6352%	–1.8111%	9,204.02	97,722.77
–12	–0.2594%	0.2450%	87,758.07	0.4872%	–0.1480%	8,996.61	96,754.68
–11	–1.8483%	–1.5889%	85,633.61	1.6110%	1.1238%	9,077.87	94,711.48
–10	–2.4024%	–0.5541%	85,416.55	3.1897%	1.5787%	9,260.86	94,677.41
–9	–3.0157%	–0.6133%	85,309.79	2.3517%	–0.8380%	9,217.60	94,527.39
–8	–3.8225%	–0.8068%	84,085.51	3.3938%	1.0421%	9,142.44	93,227.95
–7	–3.6810%	0.1414%	83,843.99	2.8568%	–0.5370%	9,003.00	92,846.99
–6	–3.6734%	0.0076%	84,009.62	2.5985%	–0.2583%	8,896.96	92,906.58
–5	–3.8614%	–0.1879%	83,331.82	4.1262%	1.5277%	8,925.61	92,257.43
–4	–3.8015%	0.0598%	83,415.40	4.0032%	–0.1230%	8,798.54	92,213.94
–3	–3.5270%	0.2745%	83,585.30	4.5635%	0.5604%	8,871.90	92,457.20
–2	–4.2174%	–0.6903%	82,571.00	4.9051%	0.3415%	8,839.83	91,410.83
–1	–3.3078%	0.9096%	82,766.06	2.5608%	–2.3442%	8,616.41	91,382.47
0	–2.3539%	0.9539%	83,231.94	1.0430%	–1.5178%	8,416.16	91,648.10
1	–5.6217%	–3.2677%	78,827.13	12.1129%	11.0699%	9,521.60	88,348.73
2	–7.0874%	–1.4657%	75,873.72	23.7698%	11.6569%	10,256.50	86,130.22
3	–6.2843%	0.8031%	75,786.22	18.3865%	–5.3833%	9,396.45	85,182.67
4	–5.7460%	0.5384%	77,233.01	19.5699%	1.1834%	9,823.80	87,056.81
5	–6.5578%	–0.8118%	76,438.29	18.6309%	–0.9390%	9,620.87	86,059.16
6	–6.5369%	0.0209%	77,332.28	17.1087%	–1.5222%	9,755.63	87,087.91
7	–6.3333%	0.2036%	77,188.91	16.7993%	–0.3094%	9,589.50	86,778.41
8	–6.2039%	0.1294%	77,455.41	18.7127%	1.9134%	9,881.01	87,336.42
9	–6.3251%	–0.1212%	78,043.31	16.8067%	–1.9060%	9,802.30	87,845.61
10	–6.2137%	0.1115%	78,167.95	17.9848%	1.1781%	9,934.62	88,102.57
11	–6.1904%	0.0233%	78,035.58	22.4525%	4.4677%	10,533.71	88,569.29
12	–6.5220%	–0.3316%	77,596.46	21.8639%	–0.5886%	10,460.72	88,057.18
13	–5.8226%	0.6994%	79,097.19	21.0533%	–0.8106%	10,491.54	89,588.73
14	–5.4345%	0.3881%	79,098.43	19.8918%	–1.1615%	10,502.55	89,600.98
15	–5.7859%	–0.3515%	79,622.80	19.1213%	–0.7705%	10,467.07	90,089.87
16	–5.2448%	0.5412%	80,064.23	20.7715%	1.6502%	10,635.38	90,699.61
17	–4.6424%	0.6023%	80,665.15	20.7004%	–0.0711%	10,592.22	91,257.37
18	–4.9136%	–0.2712%	80,746.92	19.4648%	–1.2356%	10,502.98	91,249.90
19	–5.3447%	–0.4311%	80,831.93	19.0114%	–0.4534%	10,416.45	91,248.38
20	–5.8529%	–0.5082%	81,153.66	18.3759%	–0.6355%	10,303.38	91,457.04

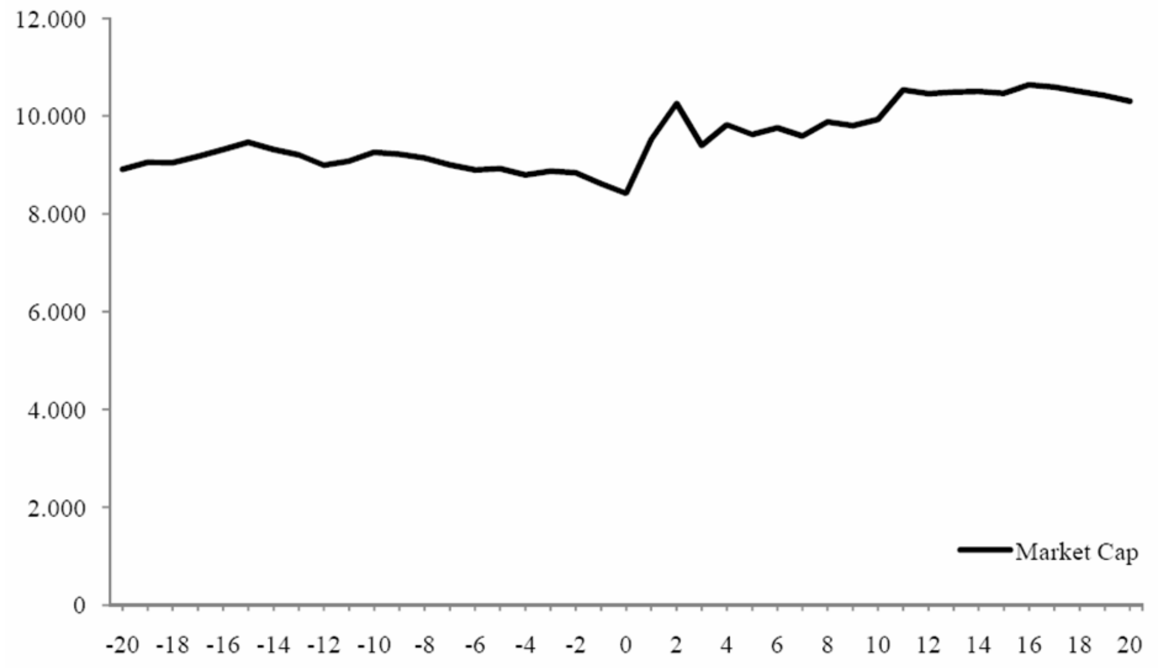
Notes: Aggregate market capitalization in € million. For companies with multiple class of stock we report the consolidated market capitalization.

Figure 2: Daily Market Capitalization, Germany.

(a) Nuclear/Conventional Energy Companies



(b) Renewable Energies Subsample



Notes: For companies with multiple class of stock we report the consolidated market capitalization.

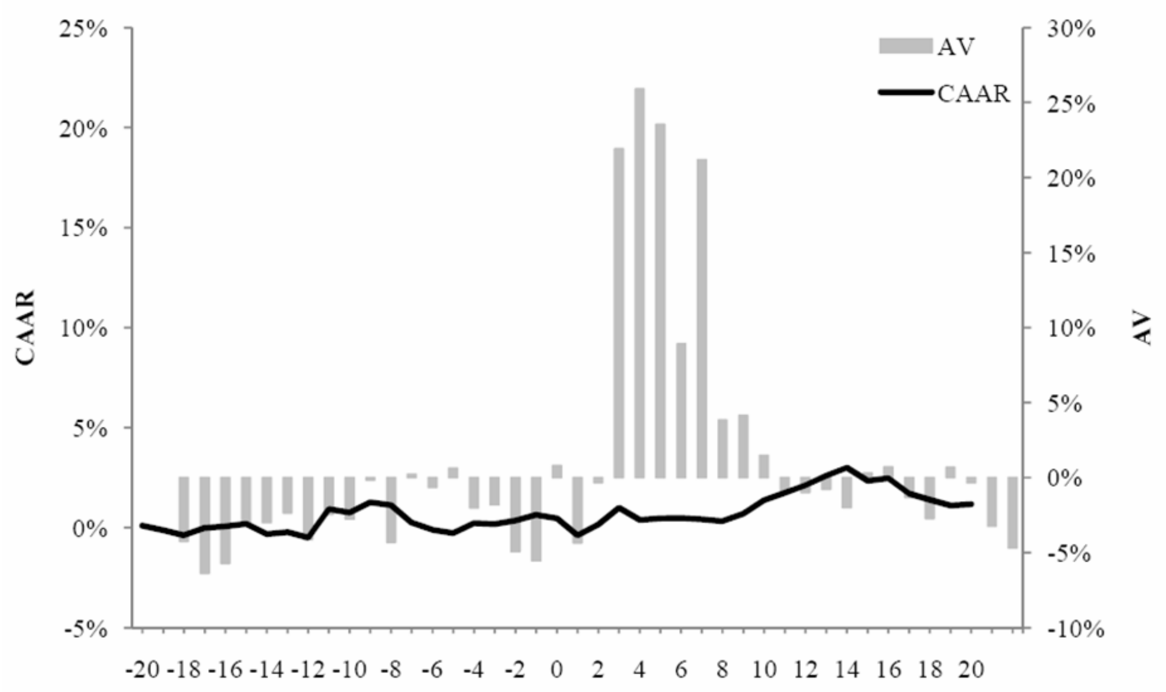
Table 3: Cumulative Average Abnormal Returns and Related Test Statistics, Germany.

	$CAAR_{\tau_1,\tau_2}$	+/–	t-Test	Patell Z	Boehmer et al.	Corrado Rank	Wald (SUR)
Panel A: Nuclear/Conventional Energy Companies							
(0;0)	0.95%	2:1	1.6329*	1.8780*	1.0032	1.2521	1.74
(1;1)	–3.27%	0:3	–2.1612**	–6.1855***	–2.0674**	–1.8665*	19.95***
(0;10)	–2.91%	0:3	–2.2925**	–1.6343*	–2.1326**	—	—
(0;20)	–2.55%	1:2	–1.0043	–0.5744	–0.9219	—	—
(1;10)	–3.86%	0:3	–2.0875**	–2.3080*	–2.0440**	—	—
(1;20)	–3.50%	0:3	–1.7778*	–1.0086	–2.5171**	—	—
Panel B: Renewable Energies Subsample							
(0;0)	–1.52%	14:21	–2.3430**	–2.5815***	–1.7339*	–1.1624	2.24
(1;1)	11.07%	29:6	5.2629***	22.2902***	5.6717***	4.2028***	142.00***
(0;10)	16.06%	26:9	3.6390***	9.6775***	4.8911***	—	—
(0;20)	16.43%	27:8	3.4502***	7.6831***	4.9978***	—	—
(1;10)	17.51%	26:9	4.0835***	10.8170***	5.2925***	—	—
(1;20)	17.89%	27:8	3.9129***	8.3447***	5.3840***	—	—

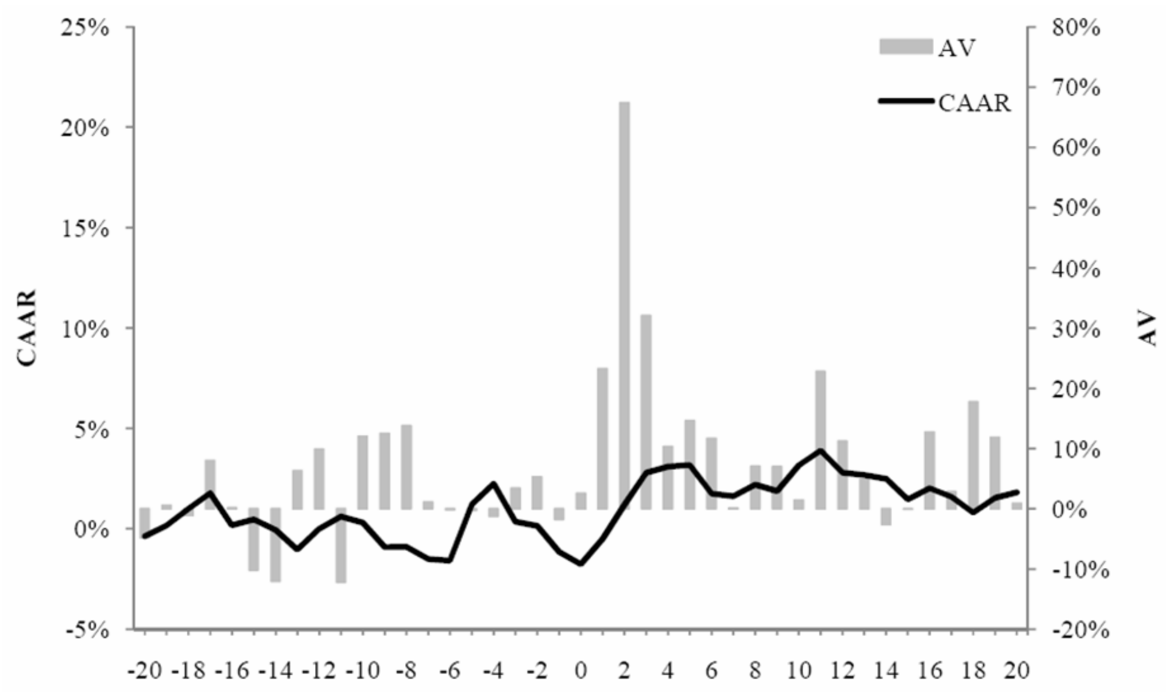
*** significant at 1%; ** significant at 5%; * significant at 10%.

Figure 3: Cumulative Average Abnormal Returns and Abnormal Trading Volume, Europe (ex Germany).

(a) Nuclear/Conventional Energy Companies



(b) Renewable Energies Subsample



Notes: The abnormal return is calculated using the market model as the normal return. Abnormal volume is calculated as described in Brav and Gompers (2003).

Table 4: Cumulative/Daily Average Abnormal Returns and Aggregate Market Capitalization, Europe (ex Germany).

Event Time	Nuclear/Convent. Energy Companies (EU)			Renewable Energies Subsample (EU)			Total (EU)
	$CAAR_{-20,\tau}$	AAR_τ	$MCAP_\tau$	$CAAR_{-20,\tau}$	AAR_τ	$MCAP_\tau$	$MCAP_\tau$
–20	0.0991%	0.0991%	279,850.60	–0.3674%	–0.3674%	9,976.82	289,827.42
–19	–0.1290%	–0.2281%	280,090.83	0.1537%	0.5211%	10,102.62	290,193.45
–18	–0.3881%	–0.2591%	279,411.83	0.9903%	0.8366%	10,098.34	289,510.17
–17	–0.0135%	0.3747%	281,635.20	1.7744%	0.7842%	10,100.76	291,735.96
–16	0.0655%	0.0789%	284,194.55	0.1694%	–1.6051%	10,035.60	294,230.15
–15	0.1868%	0.1214%	283,292.24	0.4726%	0.3032%	10,054.05	293,346.29
–14	–0.3128%	–0.4996%	279,340.76	–0.0692%	–0.5417%	9,930.37	289,271.13
–13	–0.2277%	0.0850%	277,209.67	–1.0376%	–0.9685%	9,962.28	287,171.95
–12	–0.4910%	–0.2633%	274,310.16	–0.0074%	1.0302%	9,826.11	284,136.27
–11	0.9291%	1.4202%	277,494.66	0.6097%	0.6171%	9,902.01	287,396.67
–10	0.7526%	–0.1765%	279,695.21	0.3051%	–0.3045%	10,194.58	289,889.79
–9	1.2633%	0.5107%	282,606.01	–0.9063%	–1.2114%	10,388.89	292,994.90
–8	1.1244%	–0.1390%	278,877.27	–0.9042%	0.0021%	10,157.36	289,034.63
–7	0.2453%	–0.8791%	275,712.65	–1.5047%	–0.6005%	10,104.02	285,816.67
–6	–0.1157%	–0.3610%	275,505.13	–1.5948%	–0.0901%	10,074.76	285,579.89
–5	–0.2668%	–0.1511%	273,206.34	1.1969%	2.7918%	9,993.83	283,200.17
–4	0.2236%	0.4905%	272,024.49	2.2479%	1.0510%	10,021.62	282,046.11
–3	0.1727%	–0.0510%	272,807.85	0.3485%	–1.8994%	9,997.16	282,805.01
–2	0.3478%	0.1751%	272,927.44	0.1443%	–0.2042%	10,155.17	283,082.61
–1	0.6361%	0.2883%	271,069.76	–1.1483%	–1.2926%	9,941.50	281,011.26
0	0.4704%	–0.1657%	268,812.97	–1.7566%	–0.6084%	9,772.70	278,585.67
1	–0.3867%	–0.8571%	263,246.28	–0.4996%	1.2571%	10,436.15	273,682.43
2	0.1586%	0.5453%	259,949.82	1,1815%	1.6811%	10,559,57	270,509.39
3	0.9977%	0.8391%	258,489.20	2.7937%	1.6122%	10,472.62	268,961.82
4	0.3920%	–0.6057%	261,732.04	3.1033%	0.3095%	10,766.77	272,498.81
5	0.4732%	0.0812%	261,119.44	3.1774%	0.0741%	11,012.93	272,132.37
6	0.4896%	0.0163%	267,775.35	1.7476%	–1.4298%	10,800.46	278,575.81
7	0.4242%	–0.0654%	267,822.74	1.6216%	–0.1260%	10,735.59	278,558.33
8	0.3202%	–0.1041%	269,662.52	2.1924%	0.5708%	10,892.16	280,554.68
9	0.6847%	0.3645%	272,291.93	1.8774%	–0.3150%	11,050.03	283,341.96
10	1.3698%	0.6852%	272,091.22	3.1637%	1.2863%	11,144.35	283,235.57
11	1.7323%	0.3625%	272,942.83	3.8935%	0.7298%	11,663.95	284,606.78
12	2.1124%	0.3801%	275,262.99	2.7922%	–1.1013%	11,450.16	286,713.15
13	2.5996%	0.4872%	279,650.86	2.6860%	–0.1062%	11,659.23	291,310.09
14	2.9956%	0.3960%	278,100.75	2.4837%	–0.2023%	11,711.81	289,812.56
15	2.3387%	–0.6569%	278,301.97	1.4597%	–1.0240%	11,630.53	289,932.50
16	2.4652%	0.1265%	279,599.94	2.0278%	0.5680%	11,780.07	291,380.01
17	1.7042%	–0.7610%	276,655.80	1.5874%	–0.4404%	11,401.56	288,057.36
18	1.4015%	–0.3026%	275,089.85	0.8071%	–0.7803%	11,248.02	286,337.87
19	1.1150%	–0.2865%	273,185.23	1.5465%	0.7394%	10,880.59	284,065.82
20	1.1788%	0.0638%	274,736.49	1.8096%	0.2632%	10,874.73	285,611.22

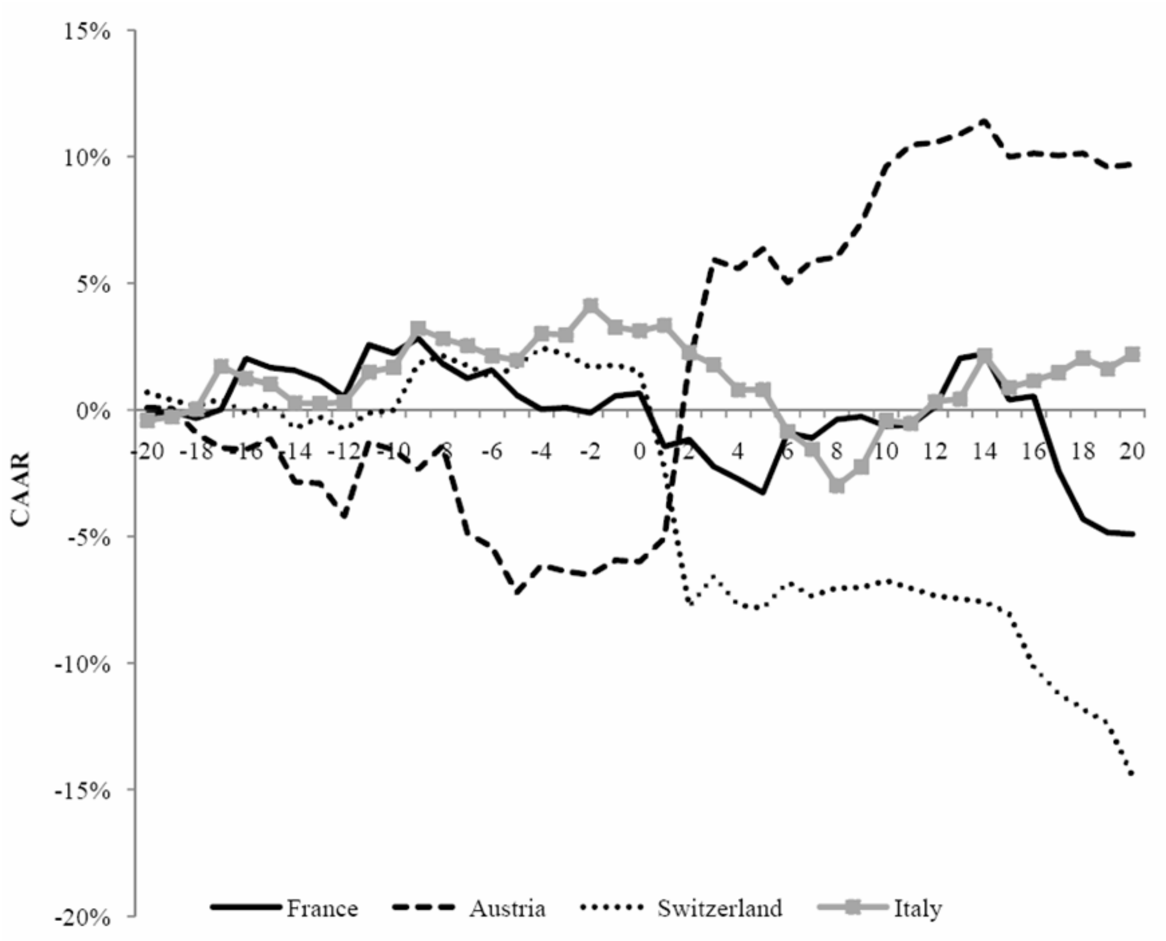
Notes: Aggregate market capitalization in € million. For companies with multiple class of stock we report the consolidated market capitalization.

Table 5: Cumulative Average Abnormal Returns and Related Test Statistics, Europe (ex Germany).

	$CAAR_{\tau_1,\tau_2}$	+/–	t-Test	Patell Z	Boehmer et al.	Corrado Rank	Wald (SUR)
Panel A: Nuclear/Conventional Energy Companies (Europe ex Germany)							
(0;0)	–0.17%	6:7	–0.6165	–0.5320	–0.3932	–0.3354	0.56
(1;1)	–0.86%	5:8	–1.1604	–2.8060***	–1.1853	–1.0697	1.05
(0;10)	0.73%	7:6	0.2932	0.7270	0.3336	—	—
(0;20)	0.54%	8:5	0.1591	0.6840	0.3062	—	—
(1;10)	0.90%	7:6	0.3615	0.9307	0.4086	—	—
(1;20)	0.71%	8:5	0.2068	0.8198	0.3563	—	—
Panel B: Renewable Energies Subsample (Europe ex Germany)							
(0;0)	–0.61%	12:13	–0.5582	–0.2673	–0.1516	–0.9099	0.38
(1;1)	1.26%	18:7	1.2460	2.7993**	1.5005	2.3294***	1.70
(0;10)	4.31%	16:9	1.9401**	2.3051**	2.0369**	—	—
(0;20)	2.96%	16:9	0.7808	1.0573	0.9456	—	—
(1;10)	4.92%	16:9	2.1789**	2.5022**	2.2027**	—	—
(1;20)	3.57%	15:10	0.8444	1.1431	0.8840	—	—

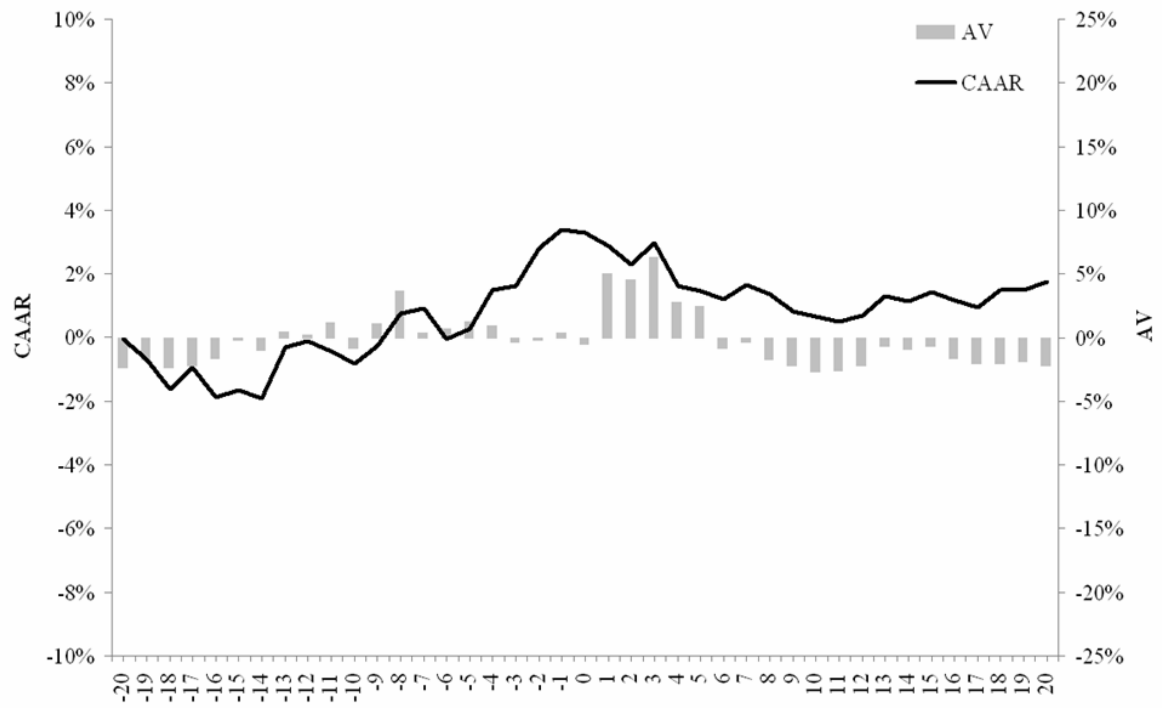
*** significant at 1%; ** significant at 5%; * significant at 10%.

Figure 4: Cumulative Average Abnormal Returns of European (ex Germany) Nuclear/Conventional Energy Companies by Country.



Notes: The abnormal return is calculated using the market model as the normal return.

Figure 5: Cumulative Average Abnormal Returns and Abnormal Trading Volume, Nuclear/Conventional Energy Companies in the United States.



Notes: The abnormal return is calculated using the market model as the normal return.

Table 6: Cumulative Average Abnormal Returns and Related Test Statistics, Nuclear/Conventional Energy Companies in the United States.

	$CAAR_{\tau_1,\tau_2}$	+/–	t-Test	Patell Z	Boehmer et al.	Corrado Rank	Wald (SUR)
(0;0)	–0.08%	7:16	–0.4469	–0.8353	–0.6647	–0.3815	0.41
(1;1)	–0.42%	9:14	–1.5518	–2.6854***	–1.6371	–0.6159	1.83
(0;10)	–2.73%	3:20	–3.5959***	–4.7438***	–4.3985***	—	—
(0;20)	–1.62%	7:16	–1.7733*	–2.2015**	–2.3818**	—	—
(0;30)	–0.93%	8:15	–0.9018	–1.3815	–1.7436*	—	—
(0;40)	1.80%	12:11	1.3214	0.8780	1.0456	—	—
(1;10)	–2.65%	3:20	–3.8508***	–4.7112***	–4.5261***	—	—
(1;20)	–1.53%	7:16	–1.8743*	–2.0691**	–2.3611**	—	—
(1;30)	–0.85%	8:15	–0.8849	–1.2518	–1.6554*	—	—
(1;40)	1.88%	14:9	1.5026	1.0210	1.2847	—	—

*** significant at 1%; ** significant at 5%; * significant at 10%.