Distant Event, Local Effects? Fukushima and the German Housing Market*

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Abstract. The Fukushima Daiichi accident in Japan in March 2011 caused a fundamental change in Germanys energy policy which led to the immediate shut down of nearly half of its nuclear power plants. Using data from Germanys largest internet platform for real estate and employing a difference-in-differences approach, we find that Fukushima reduced house prices near nuclear power plants that were in operation before Fukushima by almost 5%. House prices near sites that were shut down right after the accident even fell by 9.7%. Our results suggest that economic reasons are of prime importance for this observed fall in house prices.

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1 Introduction

On 11 March 2011, Japan was struck by a devastating earthquake and tsunami, which led to a major accident at the Fukushima Daiichi nuclear power plant operated by Tokyo Electric Power Company (TEPCO). This accident brought nuclear safety to the forefront of global attention. Nowhere, however, not even in Japan itself, did the Fukushima Daiichi accident have such repercussions on public opinion and energy policy as in distant Germany. Following mass anti-nuclear protests across Germany and a historic defeat in a state election in Baden-Württemberg, Germany's coalition government closed eight of the country's 17 nuclear power plants (henceforth, NPPs) in August 2011.[1] Scrapping a recent decision of its own to extend the life of nuclear reactors by an average of 12 years, the government also declared the phasing out of Germany's remaining nine NPPs by 2022, a decision that made Germany the biggest economy to announce plans to give up nuclear energy.[2]

The impact of the Fukushima accident on Germany's energy policy is manifest. However, the Fukushima accident, and the U-turn in Germany's nuclear energy policy it caused, is likely to have an effect also on local economies in Germany. Plant closures and the nuclear phase-out might harm employment and reduce local business tax revenues in regions with NPPs. Such adverse economic effects, which

[1]The year 2011 saw the permanent retirement of 13 reactors in the world. Twelve of these retirements were due to the Fukushima Daiichi accident in Japan – four at the Fukushima Daiichi plant itself and eight in Germany. The thirteenth reactor was an old reactor in the United Kingdom (43-year-old Oldbury nuclear power station reactor 2). At the end of 2011, there were 435 reactors in operation worldwide, 2% less than at the beginning of the year (International Atomic Energy Agency, 2012).

[2]After the Fukushima Daiichi accident, Japan decided to phase out its NPPs until the end of the 2030s. The new government under prime minister Shinzo Abe, however, announced to re-start those NPPs that pass new and stricter security standards. Other countries, such as Belgium, Italy and Switzerland have re-evaluated their nuclear programs (International Atomic Energy Agency, 2012). Switzerland decided in May 2011 to not extend operation times of existing NPPs anymore and to ban the construction of new reactors. The first Swiss NPP will presumably close in 2019, the last in 2034. In Italy, a referendum held in June 2011 stopped plans of the Berlusconi-led government to build a new NPP, thereby keeping Italy non-nuclear. Italy's four NPPs had been closed following a referendum in 1987. In Belgium, plans to extend remaining operation times of the country's two oldest NPPs were scrapped in July 2012, and the two NPPs are now scheduled to close in 2015. The last Belgian NPP will close in 2025.

take time to fully unfold, have in fact been frequently discussed in the local and national press.[3] The decision to phase out nuclear energy has also reduced the actual risk of a nuclear fall-out in German regions that host a NPP facility. Both (expected) direct local economic effects and changes in local exposure to the risk of a nuclear accident through plant closures or cuts in the remaining maximum operation times of NPPs should be reflected in local house prices. For residential property is both a durable consumption good and an asset whose present value depends both on current and future conditions in a locality.

This paper uses data on individual house offers from Germany's largest internet platform for real estate to investigate the effect of Fukushima on the German housing market. Our empirical analysis compares the prices of houses located close to NPP sites with the prices of houses located further away from such sites before and after the Fukushima accident (*difference-in-differences* approach). We find that prices for real estate in the vicinity of NPPs that were in operation before Fukushima fell by almost 5% after Fukushima. House prices near sites that were shut down permanently right after the accident even fell by 9.7%. In contrast, Fukushima had no effect on house prices near NPP sites that were inactive at the time of the accident.

Our main identifying assumption for a causal interpretation of our results is that conditional on controls, among them a large set of individual house characteristics, house prices in treatment and control regions would have followed the same trend in the absence of Fukushima. We corroborate this identifying assumption in various ways. For example, we show that pre-Fukushima trends in prices did not differ statistically between houses close to and further away from a NPP site. We also show that our results do not change when we restrict the estimation sample to a more homogeneous set of regions (e.g., by excluding house offers from urban districts).

Our study relates to an extensive literature that has investigated the effects of undesirable facilities on local housing markets, such as fossil fuel plants (Davis,

[3]For instance, the German weekly magazine *Der Spiegel* wrote in its online edition on 2 June 2011: "The nuclear phase-out puts strain on local municipalities: Eight NPPs are closed lightning fast. As a consequence, the municipalities will lose millions in business taxes." And the *Südhessen Morgen*, a local newspaper, wrote on the situation in the Hessian town of Biblis: "The closing down of the nuclear power plant is a major blow for Biblis. [...] It will lead to significant losses of purchasing power and to distortions on the housing market."

2011; Blomquist, 1974), nuclear power plants (Nelson, 1981; Gamble and Downing, 1982; Folland and Hough, 2000), hazardous waste sites and waste incinerators (Gayer et al., 2000; Greenstone and Gallagher, 2008; Kiel and McClain, 1995), and major infrastructure projects, such as airports, railroads, or highways (Anselin and Lozano-Gracia, 2008; Caruthers and Clark, 2010; Cho et al., 2008; Cohen and Coughlin, 2008; Debrezion et al., 2007; Hughes and Sirmans, 1992). Our study contributes to this literature in several ways. First, our study is one of the first large-scale studies of NPPs, and, to the best of our knowledge, the first large-scale study of NPPs outside the US. Second, it is also one of the first studies to analyze the closure of a facility. Since the opening of a facility may trigger important adjustment processes, with households sorting across neighborhoods (Davis, 2011), the closure of a facility might not just reverse the effect of its opening.[4] Third, our setting precludes anticipation effects that may otherwise complicate the identification of the effects of a site closure or opening. Potential house buyers or sellers could neither anticipate the Fukushima accident nor the subsequent change in Germany's energy policy. Moreover, the availability of house-level data from before and after the Fukushima Daiichi accident allows us to more forcefully control for differences between locations with and without a NPP site.

Our setting has the unique feature that it permits us to study the response of real estate prices to a distant event that did not in any physical way affect the estate. The radiation released by the Fukushima Daiichi accident in Japan did not have a measurable impact on the environment in Germany, and neither did the Tsunami that caused this accident. In recent work, Fink and Stratmann (2013) study the effect of the nuclear accident in Fukushima on house prices in the United States. Using zip-code level data on the median value of single-family houses before and after Fukushima, the authors find that house values in regions within a 25-mile radius of a NPP site appreciated slightly after Fukushima. This finding is at odds

[4] Kiel and McClain (1995) show that the effect on property prices of an incinerator is not constant over time but varies over the siting process and the operation time of the facility. However, the authors do not consider the closure of the incinerator. Currie et al. (2013), in their analysis of the effect of toxic industrial plants on the housing market, distinguish explicitly between plant openings and plant closures. They find that the effects of plant opening and closures are roughly symmetric, with plant closures increasing and plant openings decreasing house prices.

with the hypothesis that house prices in the vicinity of NPP sites may have suffered because residents updated their nuclear risk perceptions after the Fukushima Daiichi accident. Other than in Germany, no NPP in the United States was closed and none suffered a reduction in its remaining operation time.

The paper proceeds as follows. Section 2 provides background information on Germany's NPP sites, and reviews the chronology of government responses and changes in Germany's energy policy following the nuclear accident in Japan. It also discusses potential mechanisms through which the Fukushima Daiichi accident and the resulting change in Germany's nuclear energy policy may have affected housing prices near German NPPs. Section 3 describes the real estate data and the identification strategy we use in our empirical analysis. This section also provides summary statistics, disaggregated by distance to NPP sites, on basic amenities of property that is offered for sale prior to and after the Fukushima Daiichi accident. Section 4 presents and discusses our regression results. Section 5 concludes.

2 Background

2.1 Fukushima and German Energy Policy: A Chronology of Events

When the Tohoku earthquake and Tsunami struck Japan on 11 March 2011, there were 15 NPPs in operation at ten sites in Germany (see Figure 1 for their location in Germany).[5] Another two NPPs, Brunsbüttel and Krümmel, had been inoperative for several years[6] without a final decision to close them permanently.

Only three days after the Tsunami in Japan, the German federal government announced a 3-month nuclear moratorium that took immediate effect. During the moratorium, the seven oldest NPPs (incl. the already inoperative NPP Brunsbüttel)

[5] One of these NPPs, Biblis-B, had been disconnected from the grid two weeks before Fukushima for regular inspection scheduled for 25 February 2011 to 22 May 2011 (Deutsches Atomforum, 2012).

[6] NPPs Brunsbüttel and Krümmel had shut down in the summer of 2007. Brunsbüttel has remained inoperative ever since, while Krümmel has resumed operation only for a short time in June 2009 (Department of Nuclear Safety, 2011, 2012).

were temporarily shut down within three days of the government's announcement (see Table A-1 in the Appendix). On 22 March 2011, the government set up two commissions, one to assess security standards at German NPPs (the so-called *Reaktorsicherheitskommission*), and one to inquire into the risk of atomic energy that the German population was still willing to bear after the Fukushima Daiichi accident (the so-called *Ethikkommission*).

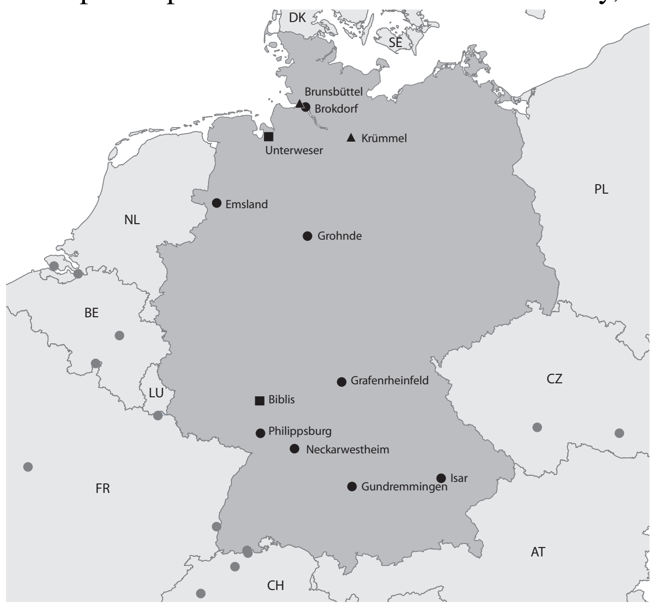
Despite these initiatives, the ruling Christian Democratic Party of Chancellor Merkel suffered a historic defeat in the state election in Baden-Württemberg on 27 March 2011. After ruling the state since its foundation in 1952, the Christian Democrats were ousted from office by a coalition of Social Democrats and Greens. The Greens, which traditionally oppose nuclear energy, scored their all-time best state election result, and their top candidate became the first green leader of a German state (*Ministerpräsident*). Commentators agreed that the Fukushima accident had significantly influenced the election result.[7] In the eyes of many voters, the accident had proved wrong the pro-nuclear energy policy of the federal coalition government of the Christian Democratic Party and the Liberal Democratic Party, which only half a year earlier had extended remaining operation times of the existing NPPs in Germany.[8]

On 30 May 2011, shortly after the two commissions had issued their final reports, the German federal government announced that it would permanently shut down all seven NPPs that had been temporarily shut down under the moratorium. The government also decided to permanently close the notoriously accident-stricken NPP Krümmel, which had already been inoperative since the summer of 2007. In addition, the government also reversed its previous decision to extend the operation times of the nine remaining NPPs. The German parliament approved these measures by great majority on 30 June 2011 in the 13th Amendment to the Atomic Energy Act (*13. Gesetz zur Änderung des Atomgesetzes*). Taking effect on 6 August

[7] See, for instance, the online comments in *Die Zeit* ("Die Wahl der Spätentscheider") or *Rheinische Post* ("Fukushima 21: Das waren keine normalen Wahlen") on 28 March 2011.

[8] The Christian Democrats and the Liberals had already announced plans to extend the operation times of existing NPPs during their campaign for the national election in September 2009. After a lengthy discussion about the exact terms of the extensions, the coalition parties agreed on 5 September 2010 that the operation times of NPPs should be increased by an average of 12 years per reactor. The corresponding law was approved by the German parliament on 28 October 2010.

FIG. 1: Nuclear power plant sites in and close to Germany, March 2011



Note: Foreign nuclear power plant (NPP) sites are marked by grey dots and without name. German NPP sites are marked by black dots, triangles, or squares and with name. Black dots indicate operating NPP sites that were not (fully) closed after Fukushima (Brokdorf, Emsland, Grohnde, Grafenrheinfeld, Philippsburg, Neckarwestheim, Gundremmingen, and Isar), black squares indicate operating NPP sites that were (fully) closed after Fukushima (Unterweser, Biblis), and black triangles indicate non-operating NPPs at the time of the Fukushima accident (Brunsüttel, Krümmel), all of which were closed after Fukushima.

2011, the seven moratorium NPPs and NPP Krümmel lost their operating license (see Table A-1). None of these eight NPPs had been re-connected to the grid after the moratorium expired in mid-June. The last NPP in Germany will now close in 2022. Most Germans either welcomed the government decision (44%) or considered the closure date for the last NPP as even ”too late” (31%) (Infratest dimap, 2011b).

2.2 Fukushima and the German Housing Market: Theoretical Considerations

The nuclear disaster at Fukushima, and the change in Germany’s energy policy it caused, might have large effects on local housing markets near German NPPs. Real estate is an immobile durable consumption good and asset. House prices therefore depend on local economic conditions and amenities – and on their future development. Fukushima and the nuclear phase-out in Germany might affect German house prices through two channels: first, by affecting local economies, and second, by changing the actual and perceived risk of nuclear energy. We discuss both channels in turn.

Consider the economic channel first. For several reasons, the nuclear phase-out in Germany is likely to have adverse effects on local economies near NPP sites.[9] First, NPPs are usually important local employers. The German electric utilities company *RWE*, for instance, used to employ around 700 workers at the NPP site in the small Hessian town of Biblis. Subcontractors employed another 300 workers at the site. All in all, the NPP Biblis provided work for almost 1000 workers – in a town of just 9000 inhabitants. Ten months after NPP Biblis was closed, RWE announced that it would reduce employment at the site from 645 to 470 workers by the end of 2012 (RWE AG, 2012). Another 50 of its workers, along with the great majority of workers from subcontracting firms, had already left the site by that time. Many of the remaining 500 workers will for now continue working at the site. Regular inspections in the post-operation period and the dismantling of the NPP in the future still require specialized staff. The employment effects of the nuclear phase-out will therefore not materialize at once, not even at sites which were closed immediately. Second, the closure of a NPP might not only reduce labor demand at the site itself but also in the region more broadly. In regular intervals, usually once a year, large-scale renewal and maintenance work takes place at NPP sites. The maintenance work, which often lasts for several weeks, requires many external engineers and assembly operators to work at the site in addition to the regular work force. These external workers often stay in local hotels and eat in local restaurants. The closure of a NPP is therefore likely to hurt also the local hotel and restaurant industry. Finally, the nuclear phase-out will also reduce business tax

[9] There are numerous newspaper articles on the adverse effects of site closures on local economies. See, for instance, the online articles in *Frankfurter Rundschau* on 2 October 2012 (”Eine Stadt sucht ihre Zukunft”) or in *Kreiszeitung Wesermarsch* on 10 March 2012 (”Beschäftigte hoffen auf Rückbau”).

revenues, the most important source of revenue for local municipalities.[10] Deteriorating local economic conditions are likely to be reflected in falling house prices. In the short run, effects might be strongest in regions in which a NPP site was closed immediately. But even in regions where only the operation time of the local NPP was reduced, house prices might fall if people anticipate adverse economic effects to materialize in the future.

The second channel through which Fukushima might affect local housing markets is through its effect on the perceived and actual risk of nuclear energy. After Fukushima, people might perceive nuclear energy to be more risky than before the accident and therefore might be less willing to live close to a NPP. Right after the accident, the majority of Germans (70%) thought that a severe nuclear accident comparable to that in Japan could also happen in Germany (Infratest dimap, 2011a); and the share of those in favor of a nuclear phase-out increased to 71%, up from 62% in August 2010. Even the German chancellor Angela Merkel, a trained physicist, explained the change in Germany's energy policy by a change in her assessment of the risk of nuclear energy. In a parliamentary speech on 9 June 2011, she stated that "[b]efore Fukushima, I accepted the residual risk of nuclear energy because I was convinced that this risk will not materialize in a high-tech country with high security standards [...] Fukushima made us aware of the fact that even in a high-tech country such as Japan, the risk of nuclear energy cannot be controlled with certainty."[11] If Fukushima has indeed increased the perceived risk of nuclear energy, people might be less willing to live close to a NPP. This should ceteris paribus cause house prices to fall. However, the political decision to phase out nuclear energy has reduced the actual life span of NPPs and even led to the immediate closure of two NPP sites (Biblis, Unterweser). The phase-out has therefore reduced the actual risk of a nuclear accident. This should ceteris paribus increase the relative attractiveness of houses in the vicinity of NPPs.[12] Whether the positive

[10] In, Biblis, for instance, the NPP accounted for more than 50% of local business tax revenues (see *Spiegel Online*, "Ende der AKW-Ära: Atomausstieg kostet Kommunen Millionen", 1 June 2011).

[11] Translation by the authors. The speech can be accessed in German on http://www.bundesregierung.de/Content/DE/Bulletin/2011/06/59-1-bk-regerkl-bt.html.

[12] As house prices reflect both the present and the future risk of a nuclear disaster, house prices may not only appreciate near NPPs which were closed but also near NPPs that only saw a reduction in their remaining maximum operation time.

effect on house prices (through a reduced actual risk) or the negative effect (through an increased perceived risk) prevails is unclear. However, the overall risk effect is likely to be positive near NPPs that were closed immediately after Fukushima. After all, local residents no longer life near an operating NPP, and increases in their risk perceptions of operating NPPs are therefore no longer relevant for their housing decisions.[13]

Summarizing the above, the Fukushima accident is likely to decrease local house prices near German NPPs if the accident increased the perceived risk of nuclear energy. The nuclear phase-out, which followed the accident, is also likely to decrease house prices if the phase-out adversely affects local economies. The phase-out, however, also tends to increase local house prices by reducing the actual risk of a nuclear disaster through site closures and cuts in maximum remaining operating times. A priori, therefore, the overall effect on house prices near German NPPs is ambiguous. As discussed above, the relative importance of changes in risk perceptions, in risk exposure and in economic conditions will differ between sites that were closed right after the accident and those that were not. In the empirical analysis, we will exploit regional variation in sites closures to gauge the respective importance of these different causal pathways.

3 Empirical Strategy and Data

3.1 Empirical Strategy

To identify the effect of the Fukushima Daiichi accident on the prices of houses located next to a NPP site, we apply a difference-in-differences (DiD) approach by estimating variants of hedonic price functions of the following type:

$$
\begin{aligned}
Y_{ijt} &= \alpha + X_i\beta + \gamma NPP_i + \zeta Fukushima_t + \delta(NPP_i \times Fukushima_t) + D_j + D_t \\
&\quad + \varepsilon_{ijt} \qquad (1)
\end{aligned}
$$

[13]Admittedly, NPPs carry some risk for their environment even after they are closed. For instance, fuel rods still have to be cooled in the immediate post-operation period, as they would melt otherwise.

where Y_{ijt} is the log asking price of property i in region j in month t, X_i is a vector of house characteristics, NPP_i is a dummy for property located in the vicinity of a NPP site, and $Fukushima_t$ is a dummy for the time period after the Fukushima Daiichi accident. D_j is a full set of region dummies, D_t a full set of time dummies, and ε_{ijt} is an error term.

The treatment effect of interest is δ. It captures differences in the pre- to post-Fukushima change in the average price of houses located next to and further away from a NPP site. The vector X_i controls for observable property characteristics and therefore also for changes in the composition of offered houses over time. Property characteristics include age (and its square), a dummy for property still under construction, living space (and its square), base area (and its square), and a dummy for detached houses. In our baseline specification, the NPP_i dummy is equal to one if a house is located within 5km of a NPP site (we analyze the effect on houses further away than 5km in additional regressions). The dummy captures time-invariant mean level differences in the price of houses located in the vicinity of NPP sites. D_j controls for time-invariant differences in housing prices between small regional units. In our baseline specification, we define these regional units on the zip-code level, of which there are 10,559 in our estimation sample. If not noted otherwise, standard errors are clustered at this regional level. Finally, the full set of month dummies D_t controls for country-wide changes in house prices over time.

Potential buyers and sellers in the German housing market could not anticipate the Fukushima accident and the subsequent change in Germany's energy policy. We can therefore rule out anticipation effects and hence that the treatment (Fukushima) had an effect on housing prices in the pre-treatment period. The main identifying assumption of our difference-in-differences approach is that conditional on controls, prices of houses located close to and further away from a NPP site would have followed the same trend in the absence of Fukushima. We corroborate this identifying assumption by a series of robustness and specification checks. In particular, we test for differences in pre-Fukushima trends between houses in treatment and control regions, add regional time trends and exclude urban areas to increase the homogeneity of the analyzed regions. In additional robustness checks, we also add additional property-to-NPP distance measures to see how quickly any potential

Fukushima effect levels off with distance, use municipality and county instead of zip-code fixed effects, and confine the estimation sample to new offers only. Finally, we also test whether the treatment effect differs between operating NPP sites that were shut down post Fukushima and NPP sites that were not. Exploiting regional variation in sites closures allows us to to gauge the respective importance of the different causal pathways (changes in risk perceptions, in risk exposure and in economic conditions) we discussed in Section 2.2 that may underlie observed associations between changes in houses prices and closeness of property to NPP sites.

3.2 Data and Descriptive Statistics

For our analysis, we use monthly house price data provided by the commercial internet platform *ImmobilienScout24*, Germany's leading online property broker.[14] Data on individual house prices and house characteristics stem from property offers that individuals place on this platform.[15] The data set covers a large part of the housing supply in Germany and, given its large sample size, is therefore suitable for the analysis of regional house prices (Bauer et al., 2013). The data set provides information on property characteristics and the exact geocode of each property. *ImmobilienScout24* only records asking but no transaction prices. This can be a potential drawback, especially if the difference between asking and transaction prices varies systematically with property amenities or characteristics of localities. However, in a recent analysis for rural areas in the German state of Rhineland-Palatinate, Dinkel and Kurzrock (2012) show that while asking prices on *ImmobilienScout24* do exceed actual transaction prices by an average of 15%, asking price premiums do not vary systematically with either house or neighborhood characteristics.

[14]See http://www.immobilienscout24.de/. Bauer et al. (2013) provide a detailed description of the data.

[15]Fees for posting an offer on *ImmobilienScout24* depend on posting duration (two weeks, one month, three months), the type of real estate offered (e.g. houses or flats), and the type of offer (for sale, for rent). Postings can be modified anytime during purchased posting time. Posting durations are automatically extended (and additional fees payable) if purchased posting time expires and individuals have not deactivated their posting beforehand. Individuals are reminded by *ImmobilienScout24* of pending expiration deadlines.

Our estimation sample consists of single-unit houses that were offered for sale between March 2007 and March 2013. We exclude house offers for which information on property characteristics is missing. We also exclude observations with very unusual property characteristics.[16] Moreover, we drop March 2011 offers from our estimation sample, as this month saw the accident at Fukushima (on 11 March). Finally, we also exclude the 731 observations of houses that are located within 5km from the French NPP of Fessenheim or the Swiss NPP of Leibstadt.[17] After these restrictions, the total sample consists of an unbalanced panel of 6,513,165 offers for 1,643,316 houses.

Table 1 provides summary statistics for sale offers prior to and after the Fukushima accident for houses located at least 5 km and less than 5 km away from a NPP site (see columns (1) and (5), and (4) and (8)). Average offer prices increased pre- to post-Fukushima both for houses within 5 km of a NPP site (+8,358 Euro) and for houses located more than 5 km away from a NPP site (+3,388 Euro). The difference of these two differences, i.e. the unconditional difference-in-difference (DiD) estimate, is 4,969 (see column (9) of Table 1). This suggests that Fukushima had a small positive effect on house prices near NPP sites. The unconditional DiD estimate, however, is not statistically different from zero (standard errors are clustered at the zip code level). The same holds for the unconditional DiD in log prices (+4.4%), the dependent variable of our regression analysis. However, the descriptives also suggests that the change in house prices near operating NPPs differed greatly from the change in house prices near non-operating NPPs. Prices near the NPP sites of Brunsbüttel and Krümmel that were already inactive before the Fukushima disaster increased by almost 29,000 Euro after Fukushima (see columns

[16]We exclude houses with a reported base area of less than 50 or more than 10,000 square meters, houses with a reported living space of less than 25 or more than 500 square meters, and houses with an asking price of less than 1,000 or more than 10 Mio. Euro. Furthermore, we exclude houses with more than 11 rooms and houses that are older than 200 years.

[17]The Fessenheim NPP is located in north-eastern France, little more than 1 km away from the French-German border. It is the oldest NPP in France that is still in operation. In September 2012, the French president Francois Hollande announced that the Fessenheim NPP will be closed by the end of 2016. Hollande had promised the closure of this sites already during his election campaign in early 2012. The Leibstadt NPP is located in northern Switzerland, right at the Swiss-German border. It is the youngest NPP in Switzerland. The exact closing date of the NPP is still under discussion but current plans schedule the closure for 2034.

(3) and (7)). In contrast, prices near operating NPPs fell by nearly 2,000 Euro (columns (2) and (6)). It is therefore important to distinguish in the regression analysis between house prices near operating and non-operating NPPs and the effect that Fukushima had on their respective development.

TABLE 1: SUMMARY STATISTICS BY DISTANCE TO NPP SITE, BEFORE AND AFTER FUKUSHIMA

	Before Fukushima				After Fukushima				DiD
	Distance to next NPP < 5 km			≥ 5 km	Distance to next NPP < 5 km			≥ 5 km	
	all	operating	non-operating		all	operating	non-operating		[(5) – (1)]– [(8) – (4)]
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Price (Euro)	217,811	234,142	177,907	264,472	226,169	232,338	206,790	267,860	4,969
	[103,331]	[110,292]	[69,292]	[193,098]	[115,572]	[118,500]	[103,516]	[220,733]	(8,286)
Log Price (Euro)	12.189	12.264	12.008	12.315	12.199	12.231	12.101	12.281	0.044
	[0.463]	[0.459]	[0.420]	[0.571]	[0.006]	[0.520]	[0.013]	[0.653]	(0.035)
Age (years)	33.015	31.045	37.827	29.203	41.009	40.301	43.232	36.776	0.422
	[30.591]	[31.238]	[28.387]	[30.006]	[32.384]	[32.931]	[30.504]	[32.587]	(1.504)
In construction (%)	3.676	4.616	1.380	5.089	2.278	2.949	0.173	3.926	-0.234
	[18.818]	[20.983]	[11.669]	[21.977]	[14.922]	[16.918]	[4.152]	[19.421]	(1.274)
Living space (m^2)	146.128	150.176	136.240	152.709	152.559	155.072	144.662	156.432	2.707
	[50.241]	[51.157]	[46.475]	[55.577]	[52.720]	[52.722]	[51.942]	[59.334]	(3.192)
Base area (m^2)	703.277	656.734	816.999	730.196	740.270	679.978	929.679	810.717	-43.527
	[694.189]	[653.171]	[773.846]	[777.039]	[751.970]	[618.390]	[1045.826]	[871.418]	(37.988)
Detached house (%)	27.852	27.885	27.773	33.319	25.299	26.081	22.842	29.250	1.515
	[44.829]	[44.845]	[44.793]	[47.136]	[43.475]	[43.911]	[41.994]	[45.491]	(2.690)
Observations	14,717	10,443	4,274	4,571,491	7,198	5,460	1,738	1,919,759	6,513,165

NOTE: Columns (1) to (8) show the mean of each variable for property located within or outside a 5 km range of a NPP site. Among the property within the 5 km range, we further distinguish between property near sites that were operating before Fukushima and those that were not (NPPs Brunsbüttel, Krümmel). Averages are calculated for the pre-Fukushima period March 2007 to February 2011 and for the post-Fukushima period April 2011 to March 2013. Standard deviations are reported in square brackets (columns (1) to (8)). Standard errors clustered at the zip code level are reported in round brackets (column (9)).

Finally, Table 1 also shows that there exist some pronounced differences in property characteristics between houses in treatment and control regions. Houses near NPP sites, and especially those near the non-operating sites of Brunsbüttel and Krümmel, tend to be considerably cheaper. They are also older and of smaller base area. Moreover, houses near NPP sites are less often under construction and less frequently a detached property. These differences in levels exist both before and after Fukushima. Unconditional DiD estimates reported in column (9) of Table 1, however, suggest that Fukushima had no statistically significant effect on average property characteristics of houses offered near NPP sites.

4 Results

4.1 Main Results

The starting point of our regression analysis is the unconditional DiD estimate of the effect that Fukushima had on log house prices near NPP sites (see column (9) of Table 1). We reproduce this unconditional DiD estimate of $+4.4\%$ in column (1) of Table 2. In a regression framework, we obtain this estimate by estimating equation (1) without property characteristics, region and month fixed effects. After adding time dummies and zip code fixed effects to our regression, we estimate a treatment effect of -2.5% (column (2)). The effect, however, is not statistically significant. We next add property characteristics to account for potential changes in the composition of offers over time (column (3)). The coefficient estimate of the treatment effect changes only slightly to -3.2% but is now measured much more precisely (and statistically significant at the 10% level). The estimate suggests that Fukushima decreased house prices near German NPPs by 3.2% relative to house prices further away from NPPs.

So far, our regression analysis may mask important differences in the treatment effect on houses near operating and non-operating NPPs. The NPP sites of Brunsbüttel and Krümmel had already been inoperative for several years before Fukushima (but retained the possibility to be re-connected to the grid in the future). Therefore, house prices in the vicinity of the two non-operating plants might already have reflected the possibility of a permanent closure before Fukushima. Consequently, columns (4) and (5) of Table 6 report separate treatment effects for houses near operating and non-operating NPPs. Specification (4) does not control for property characteristics, while specification (5) does.

The differences are striking. Fukushima appears to have had no effect on house prices near non-operating NPPs. This result is consistent with the conjecture that local house prices near these sites already reflected the possibility of a permanent site closure. House prices near NPPs that were operating before Fukushima, in contrast, declined markedly. The most elaborate specification (5) suggests that asking prices of houses in the vicinity of an operating NPP site fell by 4.8% after the Fukushima accident. Therefore, real estate offered in the vicinity of operating NPP sites suffered a marked relative devaluation. In our further analysis, we use specification (5) as our baseline. For the sake of brevity, we will also henceforth not report the (always insignificant) effects on houses near non-operating NPPs, but concentrate instead on the effect that Fukushima had on houses near operating NPPs.

The effects of the Fukushima accident on the housing market in Germany need not be confined to real estate within 5 km of an operating NPP site. If they are not, our control group of houses located at least 5 km away from a NPP site may be contaminated. To assess this possibility, we consider four further specifications. Column (1) of Table 3 reports treatment effects both for houses located less than 5 km from a NPP site and for houses located 5-10 km from a NPP site. The control group now consists of houses located at least 10 km away from a site. Reassuringly, the treatment effect for houses in the immediate vicinity of a NPP remains at -4.8%. In contrast, houses located 5 to 10 km from a NPP site experienced only a small, and weakly statistically significant, decrease in their offer price (-1.8%). The treatment effect falls further when we consider property in locations even more distant from a NPP site: to -1.1%, -0.9% and -0.9% for house located 10-15 km, 15-20 km and 20-25 km, respectively, from a NPP site (see columns (2) to (4); the control group always consists of houses located further away than the farthest distance category). These findings suggest that the impact of Fukushima on house prices in Germany was confined to real estate in the immediate vicinity of NPP sites. Our choice of a 5 km cutoff for NPP_i therefore appears adequate. In what follows, we will maintain this threshold to define property within close range of NPP sites.

TABLE 2: MAIN REGRESSION RESULTS

	(1)	(2)	(3)	(4)	(5)
Treatment effect:					
NPP<5km × Post-Fukushima	0.044 (0.035)	-0.025 (0.032)	-0.032^{*} (0.018)		
operat. NPP<5km × Post-Fukushima				-0.051^{**} (0.025)	-0.048^{***} (0.016)
non-operat. NPP<5km × Post-Fukushima				0.048 (0.066)	0.015 (0.029)
Month dummies	no	yes	yes	yes	yes
Zip code fixed effects	no	yes	yes	yes	yes
Property characteristics	no	no	yes	no	yes

NOTES: The endogenous variable is the log of the nominal house price posted. All regressions include a dummy for the post-Fukushima period. Regressions in columns (1) to (3) include a NPP dummy that indicates whether a house on offer is located within 5 km from a NPP site. In columns (4) and (5), we instead add separate NPP dummies for house near NPPs that were operating and non-operating right before the Fukushima accident. Property characteristics include age (and its square), a dummy for property still under construction, living space (and its square), base area (and its square), and a dummy for detached houses. The estimation sample comprises sales offers for single-unit detached and terraced houses posted on the internet platform ImmobilienScout24 in the months March 2007 to March 2013 (March 2011 offers are excluded). The sample size is $6,513,165$ (offer × month observations). The number of zip-code-level regional clusters is $10,559$. ***, **, * denote statistical significance at the 1%, 5%, and 10% level. Standard errors are clustered at the zip code level.

TABLE 3: TREATMENT EFFECTS BY DISTANCE TO NPP SITES

	(1)	(2)	(3)	(4)
Treatment effects:				
operating NPP $<$ 5km $\times$ Post-Fukushima	-0.048***	-0.049***	-0.049***	-0.049***
	(0.016)	(0.016)	(0.016)	(0.016)
5km $\leq$ operating NPP $<$ 10km $\times$ Post-Fukushima	-0.018*	-0.018*	-0.019*	-0.019**
	(0.009)	(0.009)	(0.009)	(0.009)
10km $\leq$ operating NPP $<$ 15km $\times$ Post-Fukushima		-0.010	-0.011	-0.011
		(0.009)	(0.009)	(0.009)
15km $\leq$ operating NPP $<$ 20km $\times$ Post-Fukushima			-0.008	-0.009
			(0.007)	(0.007)
20km $\leq$ operating NPP $<$ 25km $\times$ Post-Fukushima				-0.009
				(0.006)

NOTES: The endogenous variable is the log of the nominal house price posted. The NPP dummies indicate whether a house on offer is located within 5 km, between 5 and 10 km, 10 and 15 km, 15 and 20 km or 20 and 25 km from a NPP site that was operating right before the Fukushima accident. Apart from these alternative distance measures and their respective interactions with the post-Fukushima dummy, property characteristics considered in these regressions are identical to those in Table 2. All regressions again include month dummies and zip-code fixed effects. Sample size in all regressions is $6,513,165$ (offer $\times$ month observations) and the number of zip-code-level regional clusters is $10,559$. ***, **, * denote statistical significance at the 1%, 5%, and 10% level. Standard errors are clustered at the zip code level.

4.2 Robustness Checks

The key assumption for our difference-in-differences estimator to be unbiased is that asking prices of the treatment group (houses located within 5 km of an operating NPP site) and control group (houses located at least 5 km from a NPP site) would have followed the same time trend in the absence of the Fukushima accident. We corroborate this assumption in two ways. First, we restrict the estimation sample to a more homogeneous set of regions for which differential time trends are less likely. Second, we control for regional time trends and test directly for differentials trends between treatment and control regions.

The estimation results on various restricted estimation samples are reported in Table 4. Column (1) reproduces–from column (5) of Table 2–the treatment effect for houses near operating NPPs of our baseline specification. In columns (2) and (3), we restrict the estimation sample to property offers within 50 km and 25 km, respectively, of NPP sites.[18] For property offers within 50 km of NPP sites, the estimated treatment effect (-5.2%) turns out to be very close to our baseline estimate of -4.8%; and for property offers within 25 km of NPP sites, it shrinks only slightly in absolute magnitude to -4.3% (see columns (2) and (3) of Table 4).[19] As a further check, we exclude all offers from Germany's 25 largest cities.[20] Again, the estimated treatment effect (now -4.0%) differs only little from our baseline estimate (see column (4)). Excluding urban city districts from the estimation sample (column (5)), or cities with more than 100,000 inhabitants (column (6)), also only reduces somewhat the magnitude of the estimated treatment effect.

[18]In these restricted estimation samples, property offers from East Germany (which has no NPP sites) are virtually zero, and the share of property offers from bigger cities is significantly reduced. 14.8% of all observations in our unrestricted estimation sample are from East Germany (including Berlin). This figure falls to 0.2% and 0.1% if we restrict the estimation sample to property offers within 50 km and 25 km, respectively, of NPP sites. 12.6% (6.1%) of all observations in our unrestricted estimation sample are from Germany's 25 (5) largest cities. This figure falls to 9.7% (4.7%) if we restrict the estimation sample to property offers within 50 km of NPP sites. It falls further to 4.0% (1.4%) if we restrict the estimation sample to property offers within 25 km of NPP sites.

[19]We also ran regressions in which we considered only offers within 5 km or outside 50 km (25 km) of a NPP site. The estimated treatment effect of -4.9% (-5.1%), however, again hardly differs from our baseline estimate.

[20]Each of these cities has more than $250,000$ residents. Four cities have more than one million inhabitants (Berlin, Hamburg, Munich, Cologne).

We next control for regional time trends and test directly for differentials trends between treatment and control regions (see Table 5). First, we add a linear time trend and its interaction with our NPP dummy to the set of regressors. As shown in column (1) of Table 5, however, there is no evidence that linear price trends differed between real estate close to NPP sites and real estate further away from such sites. Our point estimate of the treatment effect also remains negative, large, and statistically significant (-6.8%). In an alternative specification (see column (2)), we add 98 linear time trends at the two-digit zip code level to the set of regressors. The estimated treatment effect of -4.6%, however, hardly differs from our baseline estimate of -4.8%. We next add three leads of the treatment effect to the regression specification. Specifically, we interact dummies for the months 1-12, 13-24, and 25-36 before the Fukushima Daiichi accident with the NPP dummy. Reassuringly, all three leads of the treatment effect are statistically insignificant (see column (3) of Table 5). We thus find no evidence that offer prices of the treatment and control group followed different trends before the Fukushima Daiichi accident. Moreover, the treatment effect remains statistically significant at -4.5%. The lack of evidence for a differential pre-Fukushima trend also suggests that the September 2010 decision of the government to extend maximum remaining operation times of German NPPs had no effect on real estate prices in the vicinity of NPP sites. Finally, we explore whether the treatment effect changed over time after the treatment. For this purpose, we split the post-Fukushima estimation sample in two periods of twelve months each. The results in column (4) suggest that the treatment effect changed little over the two periods (-4.5% vs. -5.1%). Finally, we add lead and lag indicators at the same time (see column (5)). The results, however, are virtually unchanged. Figure 2 illustrates the findings of this regression graphically.

TABLE 4: ROBUSTNESS CHECKS I: REGIONAL AND POPULATION-BASED RESTRICTIONS ON ESTIMATION SAMPLE

	(1)	(2)	(3)	(4)	(5)	(6)
Treatment effect:						
operating NPP $<$ 5km $\times$						
Post-Fukushima	-0.048***	-0.052***	-0.043***	-0.040**	-0.038**	-0.036**
	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
Estimation sample:						
Property $<$ 50km from NPP	no	yes	no	no	no	no
Property $<$ 25km from NPP	no	no	yes	no	no	no
Excl. 25 most populous cities	no	no	no	yes	no	no
Excl. city districts	no	no	no	no	yes	no
Excl. cities $>$ 100k residents	no	no	no	no	no	yes
Observations	6,513,165	1,972,134	579,333	5,693,814	5,205,559	5,236,289

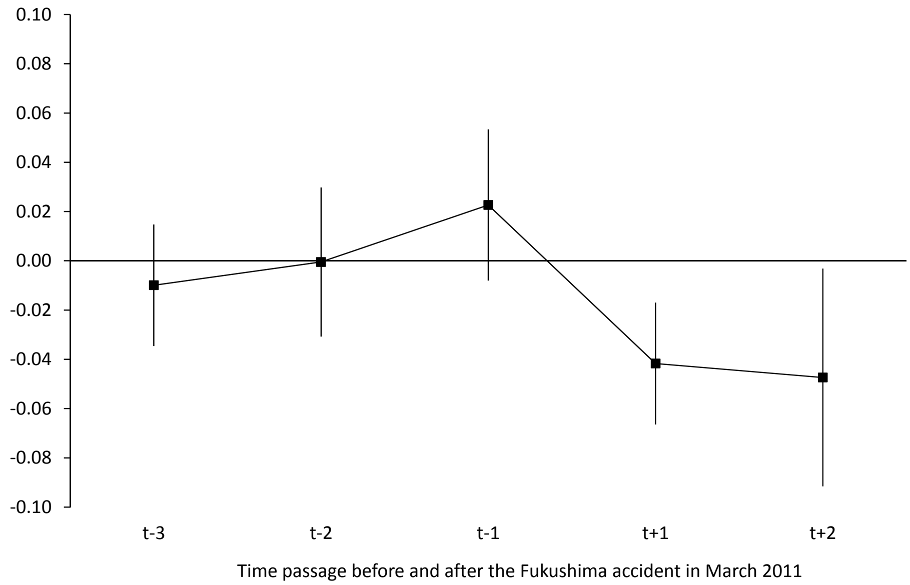
NOTES: The endogenous variable is the log of the nominal house price posted. To ease comparison, column (1) reproduces – from column (5) of Table 2 – the treatment effect of our baseline specification. The NPP dummy indicates whether a house on offer is located within 5 km from a NPP site that was operating right before the Fukushima accident. All regressions include time, NPP and post-Fukushima dummies, zip-code fixed effects, and property characteristics (see notes to Table 2). Estimates reported in columns (2) to columns (6) are based on restricted estimation samples. Column (2) reports estimates for property within 50km of a NPP site, and column (3) for property within 25km of a NPP site. Column (4) estimates are based on a restricted estimation sample that excludes property offers from the 25 most populous cities in Germany. The estimation sample for column (5) excludes property from city districts, and the estimation sample for column (6) excludes property from cities with more than 100,000 inhabitants. The number of zip-code level regional clusters is 10,559 in specification (1), 3,445 in specification (2), 1,141 in specification (3), 9,531 in specification (4), 8,951 in specification (5), and 8,990 in specification (6). ***, **, * denote statistical significance at the 1%, 5%, and 10% level. Standard errors are clustered at the zip code level.

TABLE 5: ROBUSTNESS CHECKS II: LINEAR TIME TRENDS, TREATMENT LEADS AND LAGS

	(1)	(2)	(3)	(4)	(5)
Lags:					
NPP $<$ 5km $\times$ Post-Fukushima	-0.068***	-0.046***	-0.045**		
	(0.023)	(0.015)	(0.020)		
NPP $<$ 5km $\times$ Fukushima$_{t+2}$				-0.051**	-0.047*
				(0.023)	(0.027)
NPP $<$ 5km $\times$ Fukushima$_{t+1}$				-0.045***	-0.042***
				(0.012)	(0.015)
Leads:					
NPP $<$ 5km $\times$ Fukushima$_{t-1}$			0.023		0.023
			(0.019)		(0.019)
NPP $<$ 5km $\times$ Fukushima$_{t-2}$			-0.0005		-0.0005
			(0.018)		(0.018)
NPP $<$ 5km $\times$ Fukushima$_{t-3}$			-0.010		-0.010
			(0.015)		(0.015)
Time Trend:					
NPP dummy $\times$ linear time trend	0.001				
	(0.001)				
Zip-code level linear time trends	no	yes	no	no	no

NOTES: The endogenous variable is the log of the nominal house price posted. The NPP dummy indicates whether a house on offer is located within 5 km from a NPP site that was operating right before the Fukushima accident. All regressions include time, NPP and post-Fukushima dummies, zip-code fixed effects, and property characteristics (see notes to Table 2). Compared to our baseline specification in column (5) of Table 2, specification (1) adds a linear time trend and its interaction with the NPP dummy to the set of regressors. Specification (2) adds 98 linear time trends at two-digit zip code levels to the set of regressors. In specifications (3) and (5), the NPP dummy is interacted with time dummies that divide the 48 months period before Fukushima in four periods of one year each. In specifications (4) and (5), the NPP dummy is interacted with time dummies that divide the 24 months period after Fukushima in two periods of one year each. Sample size in all regressions is $6,513,165$ (offer $\times$ month observations) and the number of zip-code-level regional clusters is $10,559$. ***, **, * denote statistical significance at the 1%, 5%, and 10% level. Standard errors are clustered at the zip code level.

FIG. 2: GRAPHICAL REPRESENTATION OF TREATMENT LEADS AND LAGS



Notes: Plotted estimates are from column (5) of Table 5. The point estimates are marked by a dot. The vertical bands indicate the 90% confidence interval of each estimate.

We also conduct several other tests to assess the robustness of our main finding. The results of these tests are reported in Table A-2 in the Appendix. First, we restrict the estimation sample to those sales offers that are newly posted (inflow sample) instead of considering all offers in a given month (stock sample). The price of new offers may respond more quickly to changes in local (dis-)amenities and may therefore more accurately reflect changes in local conditions. Excluding old offers leaves us with $1,549,717$ observations, a fourth of our overall sample size, but does not change our estimate of the treatment effect (see column (2) of Table A-2). As an alternative robustness check, we limit the estimation sample to the last monthly offer price recorded for a property, as this price arguably more closely proxies the final sales price. Again, however, we find a significant negative treatment effect (not shown). Second, we drop all observations from the four-month period March to June 2011. Restricting the estimation sample in this way provides for a clear divide between sales offers before Fukushima (March 2007 to February 2011) and sales offers after the post-Fukushima change in Germany's energy policy (July 2011 to March 2013). With the parliament's decision on 30 June 2011, future operating and closure times of individual NPPs were fixed and any uncertainty on the future of individual NPPs resolved. The estimate of the treatment effect, however, is also not affected by this change in the estimation sample (column (3)). Third, we use municipality fixed effects instead of zip code region fixed effects. The use of these political-administrative clusters, which are more numerous than zip code regions ($14,264$ instead of $10,559$ in our baseline estimation sample), again does not change our results markedly (column (4)). The same holds true if we use district fixed effects, i.e., larger political-administrative regional clusters (column (5)).

4.3 Causal Pathways and Heterogenous Treatment Effects

We have shown that Fukushima had a sizeable negative effect on house prices near NPPs that were operating at the time of the disaster. In principle, this negative effect can be explained by two factors (see Section 2.2). First, the nuclear power phase-out in Germany has/is expected to have negative effects on local economies. Second, people might perceive the risk of a nuclear accident to be greater after Fukushima than before the disaster. The relative importance of these two channels, however, should differ between sites that were closed right after the accident and those that were not. On the one hand, adverse economic effects should, at least in the short run, be larger near sites that were closed completely (and we will later in this section provide evidence that this is indeed the case). On the other hand, increases in the perceived risk of nuclear energy should be less relevant (if relevant at all) near closed sites. If the negative effect of Fukushima on house prices was mainly due to economic reasons, we would therefore expect the effect to be larger near NPP sites that were closed after the accident. If, in contrast, the negative effect of Fukushima was mainly due to updated risk assessments, we would expect the effect to be smaller near closed sites.

In an additional regression, we therefore distinguish not only between houses near non-operating and operating NPPs, but also among the latter group between houses near sites that were closed and that were not closed after Fukushima. The results of this regression are reported in column (2) of Table (6) (column (1) reproduces our previous result on the treatment effect for houses near operating and non-operating NPPs). As evident, Fukushima decreased the price of houses located near NPP sites that were operating before Fukushima but closed after the accident by as much as 9.7%. In contrast, the fall in prices is considerably smaller (-3.4%) for houses near operating sites that were not closed after the accident. Finally, and as already shown, Fukushima did not have a statistically significant effect on house prices near NPP sites that were inactive at the time of the accident.

TABLE 6: HETEROGENOUS TREATMENT EFFECTS: TREATMENT EFFECTS BY CLOSURE TYPE

	(1)	(2)
Treatment effects:		
Operating NPP $<$ 5km $\times$ Post-Fukushima	-0.048*** (0.016)	
Operating NPP, closed $<$ 5km $\times$ Post-Fukushima		-0.097*** (0.024)
Operating NPP, not closed $<$ 5km $\times$ Post-Fukushima		-0.034* (0.018)
Non-operating NPP $<$ 5km $\times$ Post-Fukushima	0.015 (0.029)	0.015 (0.029)

NOTES: The endogenous variable is the log of the nominal house price posted. The NPP dummies indicate whether a house on offer is located within 5 km from a NPP site that was either operating or not operating before the Fukushima accident. Among the operating NPP sites, we further distinguish between those sites that were fully closed after Fukushima and those that were not. All regressions include time dummies, the respective NPP dummies, property characteristics, and zip-code fixed effects. Sample size in all regressions is $6,513,165$ (offer $\times$ month observations) and the number of zip-code-level regional clusters is $10,559$. ***, **, * denote statistical significance at the 1%, 5%, and 10% level. Standard errors are clustered at the zip code level.

The results suggest that economic reasons are of prime importance for the deterioration of offer prices in the vicinity of NPP sites. In fact, municipalities with a NPP already feel the negative effects of the nuclear phase-out, especially if their NPP site was closed right after Fukushima. Table 7 provides estimates from simple DiD regressions that compare pre- to post-Fukushima changes in economic outcomes of municipalities with and without a NPP. Specifically, we regress, at the municipality level, economic outcomes on NPP dummies that indicate whether a municipality has a NPP, on a dummy for the post-treatment period and on interaction terms. We distinguish between municipalities with NPPs that were i) operating before Fukushima and closed thereafter, ii) operating before Fukushima and not closed thereafter, and iii) non-operating before Fukushima. For each economic outcome, we use two observations per municipality: the latest available observation before the Fukushima accident and the most recent observation available after the accident (see the bottom two rows of Table 7).[21]

Between June 2010 and June 2012, employment fell by 2.6% in municipalities with a NPP site that was closed after Fukushima relative to municipalities without a NPP (see column (1) of Table 7). No such effect can be observed for municipalities with a NPP that was already inactive before Fukushima and for municipalities with a NPP that is still in operation. Furthermore, we find that between February 2011 and November 2013, unemployment increased by as much as 10.6% in municipalities that saw their NPP site closed after Fukushima (see column (2)). The difference to the unemployment trend in municipalities without a NPP is smaller for municipalities with a NPP site that is still in operation (4.6%), and is not statistically significant for municipalities with a NPP that was already inactive before Fukushima. The closure of reactors after Fukushima also severely affected overnight stays at local hotels, which regularly accommodate engineers and assembly operators from subcontracting firms (see column (3) of Table 7). Overnight stays in Stadland, the municipality that hosts the closed NPP site of Unterweser, decreased from 21,041 in 2010 to 17,754 in 2012. Data for Biblis, the second site which was closed after Fukushima, are missing, but reports from local newspapers suggest that the local hotel and restaurant industry already suffers greatly from the closure.[22] Negative effects on overnight stays are also visible, but considerably smaller, for municipalities with NPP sites that are still operating. Finally, we find that between 2010 and 2012 business tax revenues declined by 323 Euros per capita in municipalities with a NPP site that was closed after Fukushima (relative to the change in municipalities without a NPP). The magnitude of this decline is considerable, given that the two municipalities of Biblis and Stadland received business tax revenues of just 421

[21] Data on employment and unemployment come from the German employment agency, data on overnight stays and business tax revenues come from the statistical offices of the German Länder.

[22] See, for instance, the online article in *Frankfurter Rundschau* on 2 October 2012 (”Eine Stadt sucht ihre Zukunft”).

Euros per capita in 2010. However, the results on business tax revenues should be taken with some caution, as revenues fluctuate strongly from year to year.

TABLE 7: OTHER OUTCOMES: DID ESTIMATES AT MUNICIPALITY LEVEL

	(1)	(2)	(3)	(4)
	Dependent variable			
Municipality with...	Employment (in logs)	Un-employment (in logs)	Overnight stays (in logs)	Business tax revenues per capita
operating NPP, closed × Post-Fukushima	-0.026***	0.106**	-0.243***	-0.323*
	(0.010)	(0.041)	(0.011)	(0.191)
operating NPP, not closed × Post-Fukushima	-0.001	0.046*	-0.090***	-0.166
	(0.002)	(0.024)	(0.029)	(0.436)
non-operating NPP, closed × Post-Fukushima	-0.015	-0.016	-0.035	-0.101
	(0.009)	(0.031)	(0.089)	(0.068)
Pre-treatment period	June 2010	Feb 2011	2010	2010
Post-treatment period	June 2012	Nov 2013	2012	2012
Observations	16,665	15,986	5,615	16,678

NOTES: The endogenous variable is the log of total employment (column (1)), the log of total unemployment (column (2)), the log of the number of overnight stays (column (3)), and business tax revenues per capita in 1,000 Euros (column (4)) of a municipality. Employment is measured at the place of work. The three NPP dummies indicate whether a municipality has a NPP site that i) was operating before Fukushima and was closed thereafter, ii) was operating before Fukushima and was not closed thereafter, and iii) was non-operating before Fukushima. Regressions include dummies for municipalities with a NPP, a dummy for the respective post-treatment period, and interaction terms. Each regression uses data for one pre- and one post-treatment period. The sample consists of all municipalities in West Germany, for which data is available. Data on overnight stays are not available for the following four municipalities with a NPP: Brockdorf, Biblis, Grafenrheinfeld, Grundremmingen. ***, **, * denote statistical significance at the 1%, 5%, and 10% level. Standard errors are clustered at the municipality level. All regressions are weighted by a municipalities' population on 31 December 2010.

Taken together, the results suggest that the nuclear phase-out has already significant negative economic effects on municipalities with a NPP – and especially on those municipalities with NPP sites that were closed after Fukushima. The results reported in Table 7 are therefore consistent with the conclusion drawn from our analysis of treatment heterogeneity by closure type. Adverse economic effects appear to be the prime causal pathway by which the Fukushima accident caused a fall in the price of real estate in the vicinity of NPPs in Germany.

5 Conclusion

The nuclear accident at Fukushima on 11 March 2011 caused a fundamental change in Germany's energy policy. Within days of the accident, the German government decided to temporarily close eight of 17 nuclear reactors. In June 2011, the government made the closure permanent, and also declared the phasing out of Germany's remaining nine NPPs by 2022. This paper shows that the nuclear disaster in distant Japan – and the U-turn in Germany's energy policy it caused – has large adverse effects on house prices near German NPPs. Using data from Germany's largest internet platform for real estate, we show that house prices near NPPs that were operating at the time of the Fukushima disaster fell by almost 5% after the disaster.

We argue that adverse economic effects of the nuclear phase-out are the prime reason for the observed fall in houses prices. NPP sites do not only employ a considerable number of workers. They also benefit local subcontracting firms, increase local overnight stays, and generate business tax revenues. The unexpected nuclear phase-out is therefore likely to have adverse effects on local economies, and we show that these effects are already noticeable in regions where a NPP site was closed immediately after the accident. Consequently, we also expect the decrease in house prices to be largest near such sites. Consistent with this conjecture, we find that house prices near NPP sites that were shut down after Fukushima fell by as much as 10% after the accident.

Our analysis suggests that the longer-term effects of Fukushima on local house prices near (former) NPP sites will largely depend on how successful local economies will adjust to the nuclear phase-out. Future research can fruitfully explore this issue. Furthermore, the U-turn in Germany's energy policy caused by the Fukushima accident will require the construction of additional wind, geothermal, and solar power production capacity, as well as of supportive infrastructure, such as reservoir power stations and long-distance transmissions lines. The opening of plants and facilities in the next years will provide ample opportunities to study also the effects of such plants and facilities on local economies.

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TABLE A-1: NUCLEAR POWER PLANTS (NPPS) AND NPP SITES IN GERMANY

	NPP name	NPP site	NPP state	NPP in operation (March 2011)	Post-Fukushima NPP shut down: temporary[1]	permanent[2]	NPP background/technical features: operating since[3]	reactor type	capacity (MWe)
1.	Biblis-A	1	HE	yes	yes	2011/08/06	1974	PWR	1,225
2.	Biblis-B	1	HE	yes	yes	2011/08/06	1976	PWR	1,300
3.	Brokdorf	2	SH	yes	no	2021/12/31	1986	PWR	1,480
4.	Brunsbüttel[4]	3	SH	no	yes	2011/08/06	1976	BWR	806
5.	Emsland	4	NI	yes	no	2022/12/31	1988	PWR	1,400
6.	Grafenrheinfeld	5	BY	yes	no	2015/12/31	1981	PWR	1,345
7.	Grohnde	6	NI	yes	no	2021/12/31	1984	PWR	1,430
8.	Gundremmingen-B	7	BY	yes	no	2017/12/31	1984	BWR	1,344
9.	Gundremmingen-C	7	BY	yes	no	2021/12/31	1984	BWR	1,344
10.	Isar-1	8	BY	yes	yes	2011/08/06	1977	BWR	912
11.	Isar-2	8	BY	yes	no	2022/12/31	1988	PWR	1,485
12.	Krümmel[4]	9	SH	no	no	2011/08/06	1983	BWR	1,402
13.	Neckarwestheim-1	10	BW	yes	yes	2011/08/06	1976	PWR	840
14.	Neckarwestheim-2	10	BW	yes	no	2022/12/31	1988	PWR	1,400
15.	Philippsburg-1	11	BW	yes	yes	2011/08/06	1979	BWR	926
16.	Philippsburg-2	11	BW	yes	no	2019/12/31	1984	PWR	1,468
17.	Unterweser	12	NI	yes	yes	2011/08/06	1978	PWR	1,410

NOTE: [1] Temporary shut downs during the 3-month moratorium were announced on 14 March 2011 and took effect within three to four days. [2] The German federal government announced on 30 May 2011 the list of NPPs that were to be closed permanently and the remaining operation times of NPPs that were to remain active. All of the NPPs that were temporarily shut down during the moratorium had to shut down permanently. These measures took effect on 6 August 2011. None of the NPPs temporarily shut down during the moratorium, and neither Brunsbüttel and Krümmel, resumed operation between the end of the moratorium in mid June and 6 August 2011. [3] Date of initial criticality (Department of Nuclear Safety, 2011). [4] NPPs Brunsbüttel and Krümmel had been inactive since the summer of 2007, except for one short-time operation of Krümmel in June 2009 (Department of Nuclear Safety, 2011, 2012). BW=Baden-Wuerttemberg, BY=Bavaria, HE=Hesse, NI=Lower Saxony, SH=Schleswig Holstein. BWR=Boiling water reactor. PWR=Pressurised water reactor.

TABLE A-2: ROBUSTNESS CHECKS III: NEW OFFERS, PRE- AND POST-MORATORIUM PERIOD, REGIONAL CLUSTERS

	(1)	(2)	(3)	(4)	(5)
Treatment effect:					
NPP $<$ 5km $\times$ Post-Fukushima	-0.048***	-0.049**	-0.049***	-0.051***	-0.051***
	(0.016)	(0.019)	(0.018)	(0.016)	(0.019)
Type of offers	all	new offers	all	all	all
Sample incl. 04-06/2011	yes	yes	no	yes	yes
Regional fixed effects	zip code	zip code	zip code	municipality	district
Observations	6,513,165	1,549,717	6,275,778	6,513,165	6,513,165

NOTES: The endogenous variable is the log of the nominal house price posted. To ease comparison, column (1) reproduces–from column (5) of Table 2–the treatment effect of our baseline specification. The NPP dummy indicates whether a house on offer is located within 5 km from a NPP site that was operating right before the Fukushima accident. All regressions include time, NPP and post-Fukushima dummies, regional fixed effects, and property characteristics (see notes to Table 2). Column (2) reports estimates for a restricted estimation sample, in which only sales offers are considered that are newly posted in a given month (inflow sample). Column (3) reports estimates for a restricted sample, in which all observations from the four-month period March to June 2011 are dropped. Columns (4) and (5) report results when using municipality and district fixed effects, respectively, instead of zip code fixed effects. The number of zip-code level regional clusters is 10,559 in specification (1), 10,349 in specification (2), and 10,549 in specification (3). The number of municipality level regional clusters in specification (4) is 14,264 and the number of district level regional clusters in specification (5) is 418. ***, **, * denote statistical significance at the 1%, 5%, and 10% level. Standard errors are clustered at the level of the regional fixed effects.