Environmental risk and the anchoring role of local amenities[*]

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Abstract

We analyse the anchoring role of local amenities following a news shock on environmental risk. Using an exhaustive registry of housing transactions in England and Wales between 2007 and 2014, we identify the impact of changes in perceived environmental risk by comparing property prices near nuclear facilities to those further away before and after the Fukushima nuclear accident. The local price drop is long-lived and amounts to 3.5%. There is significant heterogeneity, mostly driven by the nature of local production amenities. At-risk areas with highly-mobile labour structure undergo a more substantial price decrease after the catastrophe. This heterogeneity is consistent with the existence of large equilibrium adjustments, only mitigated by persistent local amenities. Such finding is further supported by the long-term patterns of residential flight after the opening of nuclear plants—a gradual rise in deprivation is only observed in at-risk neighbourhoods where labour is mobile.

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Hazardous risk may affect property prices in the vicinity of at-risk facilities (Davis, 2011; Muehlenbachs et al., 2015). A direct effect derives from the agents' valuation of environmental risk. This valuation effect may be amplified through consumption and production externalities, and the associated equilibrium adjustments. For instance, richer residents may have higher willingness-to-pay for environmental quality; thus, they may avoid zones at risk, followed by productive industries and other endogenous amenities (e.g., high-quality schools). This paper exploits a pure "news shock" about environmental risk and analyses the anchoring role of local amenities, in order to untangle the direct effect on environmental valuation and the indirect effects resulting from externalities and equilibrium adjustments.

We isolate a rare experiment which strongly affected beliefs about nuclear risk and was not accompanied by any other changes in the institutional environment. This experimental variation is the Fukushima nuclear accident (FNA)—the largest nuclear accident after the Chernobyl disaster—and its perception in the United Kingdom.[1] Given the large uncertainty about the risk related to nuclear facilities, agents should markedly revise their priors in the rare event of a catastrophe (Benoît and Dubra, 2013), leading to a local decrease in housing valuation.[2] In the wake of the initial news shock, however, housing prices should also incorporate anticipated medium-run adjustments occurring through residential sorting and the relocation of production. In order to isolate these effects, we use spatial heterogeneity in local amenities and identify the price response as a function of the extent to which local amenities and the local production structure are "immobile" or subject to large relocation frictions.

Using an exhaustive registry of housing transactions between 2007 and 2014 in England and Wales, we identify the impact of the Fukushima accident on nuclear-risk beliefs from a comparison of at-risk neighbourhoods with safer ones in a difference-in-differences specification.[3] Our hedonic analysis proceeds in two steps. In the first step, we quantify the average and distributional impacts on local housing markets. The housing price decrease in the wake of the Fukushima catastrophe is estimated to be around 3.5%. The effect differs across quantiles of the price distribution: there

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[1] Alvin M. Weinberg, a nuclear physicist who pioneered reactor design, wrote after the Chernobyl accident, "*a nuclear accident anywhere is a nuclear accident everywhere*" (Weinberg, 1986).

[2] Our empirical design exploits major uncertainty about the environmental risk related to nuclear facilities. This observation is supported by Poortinga et al. (2013) and Smith and Michaels (1987), documenting the shift in public support for nuclear energy before and after the Fukushima accident and Chernobyl. Another example of such revision is Gallagher (2014), who provides evidence that more flood insurance was taken up following floods in the US.

[3] In order to capture the extent to which a neighbourhood may be affected by a nuclear incident, we rely on the Fukushima-Daiichi evacuation area and define a 20 km at-risk zone around each UK nuclear site (Japanese Government, 2011).

is a compression of the distribution in treated zones with a large price decrease for the top decile (7% against 0% for the lowest decile). Moreover, the effect is persistent throughout the post-Fukushima period, and is observed across a variety of specifications, e.g., controlling for time-invariant heterogeneity and differential trends along observable characteristics, and using the neighbourhoods of large coal or gas-fired plants as a control group.

In the second step, we explore how local amenities may anchor neighbourhood composition and mitigate the price effect of the treatment. We find that natural or man-made consumptive amenities (e.g., natural parks, schools) explain little of the treatment heterogeneity across neighbourhoods. Instead, the presence of immobile production amenities markedly mitigates the price drop in at-risk neighbourhoods. We proxy the extent to which local production is mobile by combining census data on the jobs of residents with measures of job mobility in various industries. This definition of "immobile" productive amenities both captures high relocation costs due to physical infrastructure (e.g., capital-intensive factories) and rigidities associated with labour demand (e.g., industries with low job turnover). Our interpretation is similar to that of Lee and Lin (2018), in which complementarity between consumption and amenities governs the sorting of richer residents into high-amenity locations. Environmental risk triggers flight among some residents, which in turn affects local communities through peer effects (Durlauf, 1996, 2004), agglomeration effects (Glaeser et al., 2001), or preference-based segregation (Schelling, 1971; Anas, 1980; Card et al., 2008). With forward-looking individuals, the current price would incorporate part of these future equilibrium adjustments in population and amenities. Along this process, immobile amenities may anchor neighbourhood composition and moderate these dynamics.[4] In our context, the most relevant of such factors is found to be labour demand.

The previous finding is further supported by the analysis of long-term dynamics following the opening of plants in the 1970s.[5] From 1971 to 2011, population decreased in the vicinity of nuclear plants and the share of low-skilled workers significantly increased, suggesting a flight of richer residents. These effects are however entirely concentrated in at-risk areas with mobile production amenities.

Our findings provide insights about two major policy issues. They first highlight the (negative) neighbourhood impact of nuclear risk, even in a historically-supportive

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[4] We also find some supporting evidence that the price decrease is smaller in areas with larger moving costs—either proxied by the number of children per family or the difficulty to relocate in a safer neighbourhood within the same commuting area.

[5] Detailed data on neighbourhood composition in the aftermath of Fukushima are not yet available. In addition, were these data available, population changes could only be detectable in the middle or long run given the spatial mobility in England and Wales.

environment (Poortinga et al., 2013). The nuclear technology is expected to play an important role in the transition to low-carbon energy in the United Kingdom and across the World, and such expansion must be accepted by local communities. We show a non-negligible impact of the revision of priors about industrial risk following a remote nuclear accident (Huang et al., 2013). As in Gibbons et al. (2016) with the fracking technology, it indicates uncertainty about industrial risk. Targeted objective information campaigns could help refine and anchor beliefs of the local population.[6] Our findings also characterise the role of local amenities in mitigating endogenous neighbourhood dynamics following local shocks. Dispersion in environmental amenities does generate segregation in the long run (Heblich et al., 2016; Lin, 2017) and may partly explain regional inequalities. Evidence suggests that nuclear facilities are disamenities, despite their effect on local employment and tax revenues. We find that the provision of (production) amenities may reduce the risk of residential flight and migration of businesses in areas with low environmental amenities and could thus counteract the widening of spatial inequalities. This result sheds light on a new role of place-based policies: they may mitigate future local shocks, and not only compensate for past shocks as stressed in the literature (Glaeser and Gottlieb, 2008; Kline and Moretti, 2014; Neumark and Simpson, 2015).

The estimation of the overall impact of industrial risk on local communities presents a challenge. Hedonic analyses of housing market are often contaminated by omitted variation. A local increase in industrial risk perception—either because of plant openings or because of rare and salient events—is often accompanied by policy adjustments, such as compensation targeted towards at-risk populations or the premature closure of hazardous facilities. The neighbourhood response to extreme events is identified absent such policy effects. Many elements—policy response, local spillovers but also insurance coverage, risk preferences or the functioning of housing markets—influence the hedonic response to increased environmental risk, which could explain the ambiguous findings of the economic literature (see among others Bléhaut, 2014; Boes et al., 2015; Fink and Stratmann, 2015; Zhu et al., 2016; Ando et al., 2017; Bauer et al., 2017; Tanaka and Zabel, 2018, for industrial risk).[7] The United Kingdom offers an interesting context as it is one of the rare countries hav-

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[6] Due to data limitations, we cannot study how market reactions vary with environmental issues awareness. We find no evidence that residents incorporate the technological characteristics of the closest nuclear plant (e.g., past accidents or the technology of reactors) when revising their beliefs, and the response to Fukushima does not depend on the local influence of the UK Green Party.

[7] Even in the absence of residential sorting, local spillovers, and policy adjustments, the neighbourhood response to the Fukushima incident remains a combination of (i) a shift in risk perception, (ii) the valuation of such risk, and (iii) the housing market response to the shift in housing demand. Using our hedonic approach, we do not separately identify the contribution of these different fundamentals.

ing shown "*continued loyalty*" towards nuclear power (Ramana, 2013)—notably by committing to the renewal of its nuclear plant fleet after the catastrophe. Moreover, safety regulations were not modified in response to the event. More generally, we find no evidence of any changes in policies that could have a specific impact on neighbourhoods close to nuclear plants, such as governmental grants targeted toward these areas or changes in transportation infrastructure (LeRoy and Sonstelie, 1983; Baum-Snow, 2007). We can thus interpret our estimates as being only triggered by a change in the perception of environmental risk.[8] This interpretation stands in stark contrast with the German experience where nuclear power ambitions were considerably scaled down after the Fukushima accident: residents revised their beliefs about a premature shutdown of nuclear facilities anticipating large employment effects (Bauer et al., 2017).

This paper contributes to two distinct strands of the literature. First, the research contributes to the hedonic price literature whose interest is in the amenity value of environmental factors. Recent papers have estimated the impact on residential sorting and housing prices of the following environmental (dis)amenities: shale gas wells (Muehlenbachs et al., 2015; Gibbons et al., 2016), hazardous waste sites (Gayer, 2000; Greenstone and Gallagher, 2008), coal-fired power plants (Davis, 2011), wind farms (Gibbons, 2014), industrial pollution (Davis, 2004; Chay and Greenstone, 2005; Currie et al., 2015) and nature and wilderness (Gibbons et al., 2014).[9] Our main contribution to this literature is (i) to document large spatial treatment heterogeneity, (ii) to relate this heterogeneity to the local distribution of immobile amenities in at-risk areas, and (iii) to validate this interpretation by looking at neighbourhood composition in the long run, as in Depro et al. (2015); Heblich et al. (2016); Lin (2017). The anchoring role of immobile productive amenities, to-

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[8] The life extension of most operational reactors in the United Kingdom was confirmed in December 2012, which did not come as a surprise and was not contested by major political parties. Overall, we find no evidence that future closure and their associated employment effects drive our estimates: we do not find significant price fluctuations in at-risk neighbourhoods around the announcement of December 2012; we do not find differential effects across nuclear sites with different local employment shares; we find a non-negligible price decrease around nuclear waste facilities—which were not susceptible to closure and exerted no direct economic externalities on neighbouring communities.

[9] We relate closely to the specific strand investigating the cost of industrial risk in an hedonic framework, as in Gamble and Downing (1982); Folland and Hough (1991); Clark et al. (1997); Olsen and Wolff (2013); Bléhaut (2014); Boes et al. (2015); Fink and Stratmann (2015); Zhu et al. (2016); Ando et al. (2017); Bauer et al. (2017); Tanaka and Zabel (2018). Our experimental design relies on a news shock, as in Gayer (2000); Mastromonaco (2015), and the main experimental variation used as a news shock is a far-distant accident. Domestic accidents trigger other effects besides changes in risk perception, including the disruption of the local economy (Nelson, 1981; Gamble and Downing, 1982; Tanaka and Managi, 2016; Kawaguchi and Yukutake, 2017) and changes in risk preferences (Hanaoka et al., 2018).

gether with (local) support for nuclear energy, may explain the variation in hedonic prices of nuclear risk observed across countries. In the UK, the government's commitment to nuclear power limited uncertainty about the future closure of hazardous facilities, in contrast with the institutional settings used in Boes et al. (2015); Fink and Stratmann (2015); Zhu et al. (2016); Ando et al. (2017); Bauer et al. (2017); Tanaka and Zabel (2018).

Second, our paper contributes to the literature on the dynamics of spatial inequalities (Lee and Lin, 2018) and investigates the interaction of a random amenity shock with the presence of other amenities. In contrast to Lee and Lin (2018), however, we focus on an observed exogenous shock and uncover productive amenities and the rigidity of the local productive structure as the main anchoring factors (rather than natural permanent amenities, such as oceans, mountains and lakes). We find a compression of the price distribution in at-risk neighbourhoods on average, with an outmigration of richer households, largely mitigated by the presence of immobile industries. This effect is consistent with the existence of complementarities between amenities and consumption. In the long run, the environmental disamenity induces a flight of residents, mostly due to the outmigration of higher-skilled workers (as in Banzhaf and Walsh, 2008). Again, this effect depends on the presence of immobile amenities (i.e., rigid labour demand in our context). This finding generally relates to the literature studying the link between (a) population density or neighbourhood composition, and (b) production amenities (see Glaeser, 1998, for a review) or consumptive ones (Glaeser et al., 2001; Couture, 2013). The spillovers governing residential sorting and the relocation of production could relate to homophilous preferences (Schelling, 1971; Anas, 1980; Card et al., 2008), peer effects within neighbourhoods (Durlauf, 1996, 2004), the endogenous supply of amenities (see for instance Fernandez and Rogerson, 1996, with school quality) or neighbourhood spillovers on firm productivity (see Haskel and Martin, 1993, in the UK context).

The remainder of this paper is structured as follows. Section 1 discusses the context. In Section 2, we describe the data sources and the empirical strategy. Sections 3 and 4 present our main findings, exploring first the average impact of the Fukushima accident and second identifying treatment heterogeneity along local amenities. Section 5 briefly concludes.

1 Context

In this section, we briefly describe the main experimental variation exploited in the paper, i.e., the Fukushima accident and its media treatment. We then discuss its impact in the United Kingdom. In Appendix B, we provide a more complete description of the media treatment by local newspapers, the state of the nuclear fleet in England and Wales, and the policy discussions in the United Kingdom as compared to the rest of the world.

The Fukushima nuclear accident On March 11, 2011, a major tsunami triggered by the Great East Japan earthquake hit the Fukushima-Daiichi nuclear plant (FNP), leading to a failure of coolant systems and large radioactive leakages due to equipment damage. This accident was given the highest level (Level 7) on the classification of the International Nuclear Event Scale, a level then only attained by the Chernobyl accident, as the accident required countermeasures to protect the public. The Japanese government responded by defining several zones: a *restrictive* area, 20 kilometres from the damaged plant, where evacuation was compulsory; an *evacuation-prepared* area between 20 and 30 kilometres, where residents were advised to stay indoors; and additional at-risk areas, where cumulative radiation might breach a safety threshold (20 millisieverts per year). In total, 150,000 residents were evacuated because of the Fukushima catastrophe (Japanese Government, 2011; Hasegawa, 2013). In July 2012, the Fukushima Nuclear Accident Independent Investigation Commission revealed that the regulatory institutions had overestimated the capacity of power stations to resist such an earthquake and tsunami and found that The Tokyo Electric Power Company (TEPCO) had failed to take adequate preventive measures.[10]

The incident raised concerns regarding the safety of all nuclear power stations across the world, particularly because the Japanese system was considered as one of the safest. For instance, all countries with nuclear power announced inspections of their facilities (World Energy Council, 2012). The Fukushima accident had a massive impact on public support for nuclear power in Japan (Poortinga et al., 2013) and other producers of nuclear power, often leading to immediate policy adjustments or uncertainty about the continuation of existing nuclear programmes (Davis, 2012; World Energy Council, 2012). Only a small group of those countries unequivocally announced the continuation of their nuclear program in the aftermath of the accident, including South Korea, Russia and the UK (see Appendix B for a discussion of post-Fukushima policies around the world).

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[10] Following the accident, a large number of TEPCO executives were identified as former independent supervisors and the same conflicts of interest were detected in European countries. See "System bred TEPCO's cosy links to watchdogs", *The Financial Times*, April 20, 2011, and "Fukushima spin was Orwellian", *The Guardian*, July 1, 2011.

Impact in the United Kingdom In this subsection, we first describe the characteristics of the nuclear fleet and discuss the aftermath of the catastrophe in the United Kingdom (or more specifically, England and Wales, due to data limitations).

The nuclear fleet in England and Wales included 15 operational nuclear reactors in 2010. With four additional reactors in Scotland, nuclear power accounted for about 16% of domestic electricity generation in the UK (IEA, 2011). All operational reactors—but one—were based on UK-specific technologies (Magnesium Non Oxidizing—Magnox—, or the Advanced Gas-cooled Reactor), whereas the Fukushima-Daiichi reactors were based on the second most common design of electricity-generating nuclear reactor in the world, the Boiling-Water Reactor (BWR). An overall assessment of risk inherent in each nuclear design is difficult as their merits in terms of safety depend on the accidents that are considered, the plant size and their vulnerability to surrounding hazards. However, the average nuclear plant in our sample is much smaller and newer than the Fukushima-Daiichi plant, and natural hazards, e.g., earthquakes, are much less frequent. Nuclear risk around Fukushima-Daiichi was probably higher than in at-risk neighbourhoods of England and Wales (see Web Appendix B).

In principle, the extent to which residents in England and Wales should have revised their beliefs about nuclear risk following Fukushima should account for similarities to and differences with the Japanese nuclear context, e.g., the respective regulatory institutions, reactor designs, and plant vulnerabilities to natural and man-made hazards. In practice, however, hypothetical scenario exercises are difficult to evaluate, even for seasoned experts.

General public attitudes to nuclear power were found to be stable in the wake of Fukushima (Poortinga et al., 2013).[11] Anti-nuclear protests were mostly confined to anti-nuclear activists with limited apparent support from the rest of the population, contrary to Germany, Italy, Japan and, to some extent, France.[12]

As a consequence of the general support for nuclear power, the UK confirmed its pre-Fukushima plans of reinforcing the nuclear fleet and transitioning to next-generation power plants. This position clearly contrasted with that of many OECD countries, showing "*continued loyalty*" to nuclear power (Ramana, 2013). For in-

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[11] Citizens were "*willing to accept the building of new nuclear power stations if it would help to tackle climate change*", which does not necessarily imply that they were comfortable with having nuclear plants in their immediate neighbourhood.

[12] In January 2012, only 300 anti-nuclear protesters marched against plans to build a new nuclear power station at the Wylfa site. In February 2012, about seven protesters set up camp in an abandoned farm on the site of the proposed Hinkley Point C nuclear power station. On March 10, 2012, a year after the Fukushima nuclear disaster, a few hundred anti-nuclear campaigners formed a symbolic chain around the Hinkley Point, Wylfa, and Heysham sites.

stance, Chris Huhne, then Secretary of State for Energy and Climate Change, criticised European leaders for their haste in stopping nuclear development and reaffirmed the government support for nuclear power after the release of the Office for Nuclear Regulation Interim Report on the Fukushima accident (Weightman, 2011): "*Having considered your findings, I see no reason why the UK should not proceed with our current policy: that nuclear should be part of the future energy mix [...].*". In June 2011, the government confirmed the list of eight sites—all adjacent to existing nuclear plants—deemed suitable to host new reactors by 2025 (see Table 1). In February 2012, *Electricité de France* (EDF) applied to extend the life of all its Advanced Gas-cooled Reactors (AGRs), with the first two approvals granted in December 2012. In addition, the construction of two Evolutionary Pressurised Reactors (EPRs) at the Hinkley Point site received the go-ahead in March 2013. In short, there was no premature shutdown of power plants or even the slightest expectation about a premature phase-out of operational plants.

This *general* support for nuclear power in the United Kingdom should not prevent *local* communities near nuclear facilities from adjusting their perception of nuclear risk (a *risk-perception* effect). Local residents should update their beliefs about nuclear hazards, leading to a downward shift in housing demand. The overall support for nuclear power provides, however, assurance on the permanence of nuclear power plants in their neighbourhood. Nuclear facilities also generate large economic spillovers in the local neighbourhood through the variety of services contracted by the power plant or their employees, or through local tax revenues. This *employment* effect may play a significant role in the wake of Fukushima (as in Germany, see Bauer et al., 2017). Our context is thus useful in that it neutralises direct fluctuations in this *employment* effect.[13] Further deterioration in local economic prospects could only result from the *risk-perception* effect and the indirect equilibrium responses of residential sorting and local production. In Section 3, we provide empirical support for stable employment effects.

2 Data sources and empirical strategy

This section describes our data sources, the main identification strategy, and provides important descriptive statistics. Appendix B presents a comprehensive description of the data.

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[13] Theoretically, the UK government could have compensated local communities for their (increased) perceived exposure to nuclear risk, making these areas more attractive in absolute terms for households with a low valuation of safety. Again, the absence of any such policy response or discussion in parliament (see Appendix B) reduces concerns about this potential *policy* effect.

2.1 Data sources

Nuclear power plants and nuclear waste sites The two major sources of potential radioactive contamination in England and Wales are nuclear power plants and nuclear waste sites. As they represent different types of possible contamination, we distinguish nuclear waste sites from nuclear power plants and estimate their effect on housing markets separately.

In March 2011, 19 operational reactors over 10 nuclear plants could threaten neighbourhoods in England, Wales and Scotland (Figure 1). The country also had 10 closed plants at that time. In Table 1, for each active and inactive plant, we report information on their installed capacity, the number of operating reactors, the date their commercial operations started, the date of their (expected) closure, their technology, and their exact location (Department of Energy & Climate Change and the International Atomic Energy Agency PRIS database). Appendix B provides additional information on their different technologies, and the safety of these reactors. We also collect data on the number of workers employed in each nuclear site from the plant operator website (EDF) and a list of historical accidents (e.g., cracks). Interestingly, accidents do not only concern active plants but also closed ones, typically registered as nuclear waste sites.

Radioactive wastes come from three main sources in the UK: the generation of electricity in nuclear plants, military nuclear programmes and the usage of radioactive materials in industry, medicine, and research. They are classified into three categories according to the nature and quantity of radioactivity they contain and their heat-generating capacity. High Level Wastes (HLW) are wastes with high levels of radioactivity and they require advanced facilities due to heat generation. Intermediate Level Wastes (ILW) are highly radioactive but do not require cooling devices. Low Level Wastes (LLW) are low in radioactivity, and no advanced storage facilities are needed. In Appendix Table B2, we document the packaged volume for each waste category, the location, and the site owners of each of the 44 radioactive waste sites in the United Kingdom. Overall, these sites are in 34 distinct locations, about half of those being decommissioned or operational nuclear power plants. We also collect data on the radioactivity concentration, material composition, treatment and packaging, and waste source of each site (2010 UK Inventory Radioactive Waste of the Department of Energy & Climate Change and Nuclear Decommissioning Authority).

Housing data Our main empirical analysis draws on Land Registry transaction data between January 2007 and December 2014. Under the Land Registration Act

2002 and the Land Registration Rules 2003, Land Registry registers all sales and changes in ownership rights (mortgage, lease or right of way) in England and Wales. The transaction data are exhaustive but only a few characteristics are recorded, i.e., price, postcode, type of property (e.g., flat, terraced house, detached house), and whether the property was built during the past 10 years.

We also rely on another data source based on new mortgages issued by Nationwide—the second largest mortgage company in the UK—between January 2007 and December 2013. The Nationwide dataset includes a wide range of controls for property characteristics (e.g., the construction date, the number of bedrooms, bathrooms, garages, size in square meters, and heating facilities) but only accounts for 15% of sales. We use the Nationwide data to clean for property-specific characteristics and their possible correlation with the treatment. We provide a more detailed description of this dataset in Appendix B.

Our baseline analysis collapses transactions at the Lower Super Output Area (LSOA) × month level.[14] A LSOA is a Census unit comprising between 400 and 1,200 households. We choose this unit (i) to match Census data, and (ii) to restrict the number of observations while keeping disaggregated and consistent geographical units. For the period January 2007–December 2014, we record the number of transactions, their average price, and the total value of transactions for each LSOA and in each month, which yields about 1,700,000 observations.

Neighbourhood characteristics We collect data on neighbourhoods to study how the housing market reaction to a shock varies alongside neighbourhood characteristics, such as local productive and consumptive amenities. These data are also used to verify that variation in housing demand between neighbourhoods before and after the accident is not due to price trends which correlate with specific neighbourhood features around nuclear plants.

First, we gather information on general socio-economic and demographic characteristics of households. From the 2011 UK Census, we construct measures of housing quality, average age, number of schooling years, ethnic and religious compositions, share of migrants, the number of children per household, the unemployment rate, and whether the LSOA is urban or rural. In addition, we use a deprivation index—*The English Indices of Deprivation 2010*, constructed by the Social Disadvantage Research Centre at the University of Oxford—which summarizes different forms of deprivation related to income, crime, barriers to housing and services, living envi-

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[14] We use individual transaction data only in quantile regressions to study the change in the within-LSOA property price distribution.

ronment, education, health and disability, and employment.

Second, we collect data on productive amenities that could anchor households to specific LSOAs. Using a representative sample of workers with data on job history for 50 years after World War II, Booth et al. (1999) document job mobility across industries. Workers in the UK change jobs more often in industries such as (light) manufacturing, distribution and finance, and some occupations—managers, professionals, clerks, and the self-employed—have slightly higher turnover rates. From the 1971 and 2011 Censuses, we measure the share of high-mobility industries and high-mobility occupations based on Booth et al. (1999) for all LSOAs both in 1971 and in 2011. From the 2011 Census, we also compute the percentage of co-workers living in an *at-risk* LSOA as a proxy for the average cost of moving away from a nuclear site while continuing to work in the same LSOA.

Third, we collect data on consumptive amenities at the LSOA level, such as public services, schools, national parks, and historical heritage sites. This data is obtained from overlaying maps of LSOAs with (i) the Point of Interest (POI) data provided by the Ordnance Survey, (ii) listing data from the National Heritage List for England (NHLE), (iii) historical pollution data and past presence of coal-burning factories (Heblich et al., 2016), SO_2 concentration measured by the Department for Environment, Food and Rural Affairs (DEFRA). We also construct a set of basic topographic indicators for each LSOA (average elevation, minimum and maximum elevations, latitude, longitude, distance and orientation with respect to the closest nuclear plant).

2.2 Empirical strategy

In order to capture the extent to which a neighbourhood is threatened by a nuclear incident, we rely on the Fukushima-Daiichi evacuation process and define a potential 20-kilometre evacuation zone around each nuclear site in England and Wales.[15] Letting T_i denote the baseline treatment, where LSOAs are indexed by i, we set $T_i = 1$ for all LSOAs whose centroid is within the potential evacuation zone of any active nuclear power plant and we set $T_i = 0$ for all LSOAs whose centroid is within a range of 20–100 kilometres from any active nuclear power plant but not in a poten-

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[15] The evacuation process was abundantly discussed in the media. See Ian Sample and Tania Branigan's article, "Fukushima nuclear plant blast puts Japan on high alert", *"[Japanese] authorities are evacuating tens of thousands of residents living within a 12-mile (20-kilometre) radius of the Fukushima-Daiichi plant."*, *The Guardian*, March 12, 2011. We also consider alternative definitions of treated and control areas using alternative bandwidths, buffer zones between these areas, or allowing for a continuous treatment.

tial evacuation zone.[16] Figure 1 displays these evacuation and control zones for all nuclear plants and Figure 2 illustrates the treatment construction, especially when their zones of influence overlap. Importantly, we associate each LSOA—treated or not—to the closest nuclear plant and clean the estimation from any fluctuations across the large neighbourhoods of nuclear plants.

We estimate the hedonic price response to nuclear risk in a difference-in-differences specification, where January 2007–March 2011 is the pre-catastrophe period ($\mathbb{1}_{t<\tau} = 0$, and t is a month × year) and April 2011–December 2014 is the post-catastrophe period ($\mathbb{1}_{t>\tau} = 1$).[17] Specifically, we estimate the following equation:

$$p_{izt} = \beta_0 + \beta_1 T_i \times \mathbb{1}_{t>\tau} + \beta_2 T_i + \beta_3 \mathbf{X}_i \times \mathbb{1}_{t>\tau} + \beta_4 \mathbf{X}_i + \delta_{zt} + \varepsilon_{izt}, \tag{1}$$

where i indexes the LSOA, z indexes the zone of influence of a nuclear plant (defined with respect to the closest nuclear plant) and t is the month × year. p_{izt}, the dependent variable, is either the average price, the volume of transactions, or the number of transactions (all in natural logarithms). In the baseline specification, the vector $\mathbf{X}_i$ includes transaction characteristics (new, tenure, type: flat, terrace, semi-detached, detached) and the LSOA deprivation score. δ_{zt} is a set of zone-of-influence × month fixed effects that account for changes in the housing market over time in the larger neighbourhood of each nuclear plant. In another baseline specification, we also add LSOA fixed effects in order to reduce noise related to time-invariant unobserved characteristics.

We also consider the following variations around the baseline specification. We allow output areas with different ex-ante ecological awareness (proxied by votes for the Green Party in 2010), different population characteristics (type of accommodation, high/medium/low education levels, occupational structure) to have different pre- and post-catastrophe impacts on the outcome variable. We vary the treatment definition, notably restricting the control group $T_i = 0$ to LSOAs whose centroid is within a hypothetical evacuation zone of coal or gas-based power plants in order to separate the change in nuclear-risk perception from that in industrial-risk perception and control for possible changes in energy policy that are concomitant to the accident. We exploit the Nationwide dataset to include more transaction con-

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[16] We use the proximity to nuclear waste sites—which are not active power plants—to construct an alternative treatment, T_i^w, where $T_i^w = 1$ for all LSOAs whose centroid is within a potential evacuation zone of a nuclear waste site with intermediate- or high-level wastes, and $T_i^w = 0$ for all LSOAs within 20–100 kilometres and not in any potential evacuation zones.

[17] Employing an alternative post-treatment period that starts at March 11 2011 rather than at the end of that month gives similar results. Moreover, discarding observations for the months of March and April 2011 does not alter our findings.

trols. Finally, we explore the heterogeneity of the Fukushima impact on house prices alongside plant characteristics, such as their technology, their date of inception, and their installed capacities.

The previous baseline specification provides an average estimate of β_1 across treated units. To estimate how (fixed) consumptive and productive amenities mitigate housing market reactions to the accident, we re-estimate Equation (1) with interactions between a measure of amenities at the LSOA level, A_i, and time-varying right-hand side variables including the treatment. The coefficient before the triple interaction, $A_i \times T_i \times \mathbb{1}_{t>\tau}$, captures treatment heterogeneity along amenities A_i. A positive estimate indicates that the abundance of local amenities has an anchoring effect on households. The role of productive amenities (i.e., mobility of the local industrial structure), consumptive amenities (e.g., nature, schools, public services) as well as local topography characteristics and average moving costs in an LSOA, is studied.

2.3 Descriptive statistics

Table 2 provides summary statistics for the average LSOA, the average treated, and control LSOAs in 2010. There are few differences between LSOAs in the potential evacuation zone of a nuclear power plant or a nuclear waste site and peripheral LSOAs. While the number of transactions per month is constant across the different subsamples, the average price is markedly lower in neighbourhoods closer to nuclear power stations or waste sites, which may reflect a lack of employment opportunities (see the *employment* deprivation score). This wedge indicates higher deprivation which—as we document in the following sections—results from the opening of nuclear plants in the 1970s and the later dynamics of residential sorting. This price gradient as a function of distance to the nuclear facilities is more apparent in Figure 3 and shows a sharp (spatial) decrease starting 20 kilometres from the plant.

Pre-Fukushima differences in average price levels between areas close to nuclear sites and those more distant are expected. However, these differences in levels are not directly threatening our difference-in-differences identification strategy. A threat to the identification strategy would arise if housing markets in neighbourhoods close to a nuclear plant follow different trends than those further away (Angrist and Pischke, 2008). In order to test for these pre-existing differential trends, we run the baseline specification over the pre-accident period, between January 2007 and February 2011, and define the news shock as if the Fukushima accident had occurred in March 2010. Instead of discussing the results of this regression (see Appendix Table A1), we provide a visual interpretation in Figure 4, where we display the estimates of the price gap between treated and control areas between 2006 and each year over the period 2007–2013. More precisely, we estimate Equation (1), replace $T_i \times \mathbb{1}_{t>\tau}$, by the interactions of T_i and year dummies, and use the Nationwide data to control for a large set of property characteristics. As is apparent from Figure 4 and Appendix Table A1, there is no difference in trends before the accident. Market adjustments to the catastrophe occur abruptly in the non-calendar year April 2011–April 2012, and remain stable afterwards.

3 Average effect of the Fukushima incident

This section is organised as follows. First, we analyse how the news shock affects property prices and the number of transactions in our benchmark specification. We also explore the persistence of the effect and changes in the price distribution. Second, we provide a series of robustness checks to support our benchmark estimates. In particular, we show the robustness of our estimates to (i) alternative treatment definitions and an alternative control group based on the proximity to other industrial parks, (ii) differential trends depending on local socio-economic characteristics, and (iii) the addition of a large set of transaction controls. We then document how the variation of the Fukushima impact on housing prices relates to plant characteristics.

3.1 Baseline results

We first quantify the average hedonic price response to the news shock on nuclear risk. In Table 3, we report the estimates of specification (1) over the period January 2007–December 2014 for the average price (in logarithms, see line 1), the number of transactions (in logarithms, see line 2), and the volume of transactions (in logarithms, see line 3). We estimate three variations of specification (1). In column 1, we report estimates without LSOA fixed effects, and without controlling for transaction controls. In column 2, we add LSOA fixed effects and also add transaction controls in column 3.

We find a consistent price decrease of about 3.5% in the neighbourhood of active nuclear plants after the Fukushima accident. The number of transactions decreases by about 1%, and this quantity drop coupled with the price decrease implies a drop in the volume of transactions of about 4.5%. The estimates are robust across specifications: controlling for constant unobserved heterogeneity and transaction controls does not modify our conclusions. The relatively modest decrease in the number of transactions (1%) compared to the price drop (3.5%) points to a low price-elasticity of housing supply: the shift in demand translates mostly into a decrease in price. This result stands in stark contrast with studies having documented a rest-vacancy effect, i.e., households refusing to lower their prices and waiting for a future rebound (Bléhaut, 2014). In Appendix C, we discuss in detail how this finding could indicate a permanent effect of news shocks on risk perception. The intuition is as follows. The more permanently the news shock is expected to affect housing demand, the less households would postpone their decision to sell: housing supply would then be relatively inelastic.

The reported estimates are quantitatively large, and because treated zones represent about 5% of the housing stock in England and Wales, there are aggregate implications. Using the effect of the catastrophe on transactions in treated zones as a starting point, the annual loss in transaction volume is about 160 million pounds (sterling) and the drop in the value of the property stock near nuclear facilities is around 7.6 billion pounds—which corresponds to an overall 0.2% decrease in the value of the aggregate housing stock. However, these computations ignore spillovers to control areas and other equilibrium effects on the relative dynamics of housing markets.

We have provided evidence of a shift in housing demand around nuclear facilities. We now examine whether this shift is short lived or persistent, and we go beyond the average effect and study the distributional effects of the news shock. First, we separate the treated period into two periods, April 2011–November 2012 and December 2012–December 2014, and run specification (1) with two different dummies. The results are reported in Appendix Table A2. We find no evidence that the effect was short lived. If anything, the price drop is larger after December 2012, possibly reflecting an additional announcement effect. The break between the two periods corresponds to the contract renewal of some nuclear plants. Second, we plot the difference-in-differences estimates of the quantile regressions based on specification (1) with LSOA fixed effects and transaction controls in Figure 5.[18] We find substantial heterogeneity in the price response across quantiles. The news shock compresses the price distribution: the shift in demand is particularly pronounced for high-value properties. More precisely, the 10%-quantile effect is close to 0 while the 25% and median effects are around -3.5-4%, the 75% effect is around -5.5% and the 90% effect is above -7%. This differential variation within the same LSOA may reflect differences across locally differentiated housing markets. First, richer residents (or buyers of high-value properties) may have a high willingness-to-pay for environmental quality and the news shock thus affects their valuation of a neighbourhood disproportionately. Second, these (potential) residents may differ in their access to

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[18] Estimates of the quantile regressions are reported in Appendix Table A3.

information, i.e., in the precision of their pre-disaster priors or in their capacity to process the Fukushima signal. Third, these (potential) residents may also differ in their mobility or degree of search frictions. Our findings would be consistent with richer households valuing environmental amenities more, better processing the news shock, or being more mobile or less subject to search frictions. We come back to these interpretations in Section 4.

Overall, the Fukushima accident is associated to a large and persistent price drop in at-risk areas in England and Wales. This finding contrasts with previous studies in the US, Sweden and China (Fink and Stratmann, 2015; Zhu et al., 2016; Ando et al., 2017; Tanaka and Zabel, 2018). We next undertake sensitivity analysis and investigate whether our findings derive from a possible employment effect (Boes et al., 2015; Bauer et al., 2017).

3.2 Sensitivity analysis

We now provide a series of robustness checks by varying the treatment and the set of control variables, and by investigating heterogeneity across nuclear facilities.

Nuclear waste sites We first estimate Equation (1) for the alternative treatment T_i^w, i.e., being close to a nuclear waste site that is not an operational power plant. From Appendix Table A4, there is a shift in housing demand that remains lower than the baseline estimate. The price decrease of about 2% for transactions, combined with a quantity drop of 1%, generates an overall 3% drop in transaction volumes. Using similar approaches to those described in the previous section, we verify that the demand shift around waste sites is permanent and that the price distribution within neighbourhoods shifts towards the lower tail (results available upon request).

***Non-nuclear* power plants as alternative control group** Changes in unobservables in at-risk areas could threaten the identification strategy. Areas near large industrial parks are likely to share specific (unobservable) features that may induce large time-varying omitted variation (e.g., employment effects due to changes in energy policy). To rule out such time-varying unobservable characteristics, common to areas near large industrial parks, explaining the price drop observed in at-risk areas after March 2011, we proceed as follows. We extract data on all non-nuclear power plants with at least 50 megawatts of power capacities in 2010 from the Digest of United Kingdom Energy Statistics (DUKES) of the Department of Business, Energy and Industrial Strategy. These plants use either biomass, gas, coal, oil or waste as fuels.

We define the alternative control group as all LSOAs with a centroid of less than 20 kilometres from one of these power plants but not in the evacuation zone of any nuclear plants. We then run specification (1) and report the results in Appendix Table A5. In this specification, we isolate a *nuclear*-specific gradient and not a gradient related to power plants or large industries. In our preferred specification with controls for property characteristics and LSOA fixed effects, the estimates are similar to those of the baseline specification: the price decrease is about 3.6% in at-risk areas and the transaction drop amounts to 1.5%. These findings provide evidence that the estimated hedonic price response is specific to the vicinity of nuclear operators.

Other variations in the treatment definition Our baseline treatment is defined according to the Fukushima evacuation process. We test the robustness of our results to alternative treatment definitions in Appendix Table A6. We first define the treated zone (resp. control zones) as being between 0–15 km (resp. 15–100 km), 0–25 km (resp. 25–100 km) and 0–50 km (resp. 50–100 km) from a nuclear plant (columns 1, 2 and 3 respectively). Second, we consider a continuous treatment, i.e., the distance in kilometres to the closest nuclear plant (column 4). None of these specifications discard the conclusions drawn from the benchmark estimates. In Appendix Table A7, we report estimates of our main regression with a buffer zone between the treated areas (less than 20 kilometres from a nuclear plant) and the control areas (either 30–100 km, 40–100 km, 50–100 km, or 60–100 km). The results suggest that households do respond to nuclear risk within the baseline control zone (20–100 km): inside this zone, areas further away from a nuclear plant are perceived as slightly safer.

Differential trends along LSOA characteristics The baseline results may be biased due to time-varying omitted variation, for instance differential trends in housing prices depending on ecological awareness. We test the sensitivity of our baseline analysis to the addition of differential trends along LSOA characteristics. In column 1 of Appendix Table A8, we include the Green Party's share of the votes at the 2010 UK general election interacted with a post-treatment dummy. We then add the income, employment, health, education, and crime deprivation ranks interacted with a post-treatment dummy (column 2). Then, we add census controls (type of accommodation, high/medium/low education levels, occupational structure) interacted with a post-treatment dummy (column 3). None of those robustness checks modify our conclusions.[19]

The Nationwide data and additional transaction controls We also estimate specification (1) using the Nationwide data and add the number of bedrooms, size in square meters, the construction date, and the type of dwelling (e.g., flat, Victorian house) to our original controls. We report in Appendix Table A9 the difference-in-differences coefficients estimated separately for proximity to nuclear plants (Panel A) and waste sites (Panel B). The results are similar to the findings based on Land Registry data. There is a 3% price drop in neighbourhoods close to active nuclear plants, and a price drop of 1.5% close to waste sites. The estimates remain precise despite the lower number of recorded transactions.

Heterogeneity of the Fukushima impact across power plants In order to study how the effect differs across nuclear sites, we estimate the following baseline specification:

$$p_{izt} = \alpha + \beta T_i \times \mathbb{1}_{t>\tau} \times NP_i + \ldots + \gamma \mathbf{X}_i \times \mathbb{1}_{t>\tau} \times NP_i + \ldots + \delta_{zt} + \nu_i + \varepsilon_{izt}, \quad (2)$$

where i indexes an LSOA, z denotes the closest nuclear plant and t is a month × year. For the sake of exposure, we omit all the 2×2 interactions between T_i ($\mathbf{X}_i$), $\mathbb{1}_{t>\tau}$ and the nuclear site features NP_i. We use the following site characteristics: the opening date (between 1971 and 1995 across plants, column 1 of Appendix Table A10); the year of expected closure (between 2014 and 2035, column 2); the number of reported accidents (between 0 and 14); and the packaged volume of high-level and intermediate-level nuclear wastes (between 10 and 300 thousand m^3, column 4). We find that the response in neighbourhoods of older nuclear plants is higher: the price drop is approximately 2 percentage points higher for the oldest plant relative to the newest (see column 1). Since the age of a nuclear plant and its closure date are negatively correlated, this result also implies that the price drop is larger around plants whose lifetime is shorter. Age is not the only feature that matters. Agents also react more near the largest waste sites: the price drop ranges from zero for sites with almost no nuclear waste to 8% (see column 4) for the largest waste site. This result is not surprising: small waste sites are not visible, and their presence is often ignored by the general public. By contrast, the number of accidents does not seem to matter (column 3). We also construct the ratio of NPP employees to the number of labour market participants in a radius of 20 kilometres and interacted this

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[19] Controlling for (i) the level of council taxes, (ii) average (local) labour market tightness, and (iii) school quality does not alter our results (results available on request).

ratio with our treatment (column 5). While the coefficient before the interaction is significantly different from zero, it is positive, indicating that neighbourhoods with large employment ratios experience a smaller hedonic price response. This effect is nonetheless small: a standard deviation in the employment ratio is associated with less than a percentage point increase in prices.

3.3 Employment, risk perception and policy uncertainty

In this section, we proceed in two steps. We first provide empirical support for the risk-perception channel versus a possible employment effect. We then discuss contextual elements and describe a narrative approach in order to better understand the degree of policy (un)certainty in the wake of the Fukushima incident.

In the first step, we evaluate the extent to which our findings derive from expectations of a future phasing out and the resulting employment effects near existing facilities. In this regard, we first investigate whether the hedonic price response depends on the relative size of the nuclear plant in the local economy. We proxy this relative size by the share of the working population in the vicinity of a nuclear plant that works at the plant, and we explore whether there is treatment heterogeneity along this dimension. As shown in column 5 of Appendix Table A10, the hedonic price response is slightly *lower* around more “influential” nuclear power plants, which casts doubt on the influence of the employment channel. Second, we use our previous analysis on the persistence of the response to cast further doubt on the role of the employment channel. Indeed, the renewal of some nuclear facilities was announced at the end of 2012/beginning of 2013, and we did not see any price rebounds afterwards (see Appendix Table A2). If anything, the price gap increases over time. Third, we find a price response around nuclear *waste sites* despite their modest shares in local employment.

In the second step, we provide a narrative approach to better understand policy discussions (and thus the expectations of economic agents) and adjustments following the Fukushima incident. We first analyse the structure of local authorities’ expenditures and the amount of central government grants received by local authorities. We collect data on public transfers for the period 2008–2014 from the Department for Communities and Local Government and we find no evidence of a change in these two outcomes in both treated and control areas after the accident (see Appendix D). We collect data on Members of Parliament’s votes regarding nuclear power issues over the period 2001–2015 from `www.publicwhip.org.uk` (see Appendix D for more details). No policy change that would be concomitant to the accident is apparent, and discussions about the subject were rare. Interestingly, MPs for at-risk constituencies did not change their votes on nuclear issues.[20]

4 Anchoring amenities and the hedonic price response

In the previous section, we quantify the average hedonic price response in at-risk areas. Some elements, however, hint at treatment heterogeneity; for instance, the larger response of the top quantiles. In this section, we further investigate treatment heterogeneity and focus on variations in amenities across neighbourhoods. To be precise, we first discuss the theoretical intuition governing residential dynamics and the specific interaction between permanent (or anchoring) amenities and impermanent amenities (e.g., a news shock on environmental quality). We then relate spatial treatment heterogeneity to measures of anchoring production and consumptive amenities. We also document the role of anchoring amenities in the long run. To do so, we use information on plants opened in the 1970s and describe residential sorting and deprivation dynamics in the subsequent decades.

4.1 Theoretical intuition

We describe the theoretical intuition behind the empirical investigation of anchoring amenities and rely on Lee and Lin (2018). Lee and Lin (2018) develop a stylised model of residential sorting in which permanent amenities (natural amenities in their empirical application) and amenity shocks govern household sorting and then test their model predictions on US neighbourhoods over the period 1880–2010.

The main ingredients of the model are as follows. Individuals have preferences over consumption and neighbourhood amenities, and there is complementarity between consumption and amenities such that richer individuals sort themselves into high-amenity neighbourhoods. There is no mobility cost and the smallest difference in amenity leads to sorting. Neighbourhood amenities comprise a permanent amenity, a temporary shock, and an endogenous amenity, increasing in average neighbourhood income—which can, for instance, be interpreted as peer effects or production spillovers.

In such a model, a higher dispersion in permanent amenities across neighbourhoods generates a more persistent spatial distribution of individuals over time and

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[20] We did find, however, an increase in citizens' votes for the Green Party of about 2.6 percentage points in treated areas compared to control areas between the 2010 and 2015 general elections. This effect is poorly estimated due to limited data availability at such a high level of disaggregation (see Appendix D). This discrepancy between the votes of local constituents and the activity of their representatives could be explained by the small shares of votes for the Green Party, even after the accident.

limits the impact of temporary shocks. The intuition is the following. A large persistent amenity *anchors the rank* of neighbourhood N across all neighbourhoods. As even a small difference in amenity leads to some sorting along income, rich residents tend to sort into neighbourhood N, which increases its desirability to other residents, and leads to additional sorting motivated by the endogenous amenity. As long as the neighbourhood rank is unchanged, its composition will hardly be affected by temporary shocks. Dispersion in permanent amenities thus influences the persistence of sorting and house prices through the permanence of neighbourhood ranking.

The application to our framework is straightforward. We divide amenities into relatively permanent amenities (whether exogenous, e.g., natural, or slow-moving endogenous amenities, e.g., immobile production or persistent consumptive amenities) and transitory endogenous amenities (mobile production), and the news shock is interpreted as an exogenous shock to the cost of living in the proximity to a nuclear plant.[21] The model prediction in this context is that persistent amenities anchor neighbourhoods to high incomes and high house prices over time, and persistent disamenities anchor neighbourhoods to low incomes and low house prices.

In our simple test, we analyse the magnitude of the hedonic price response as a function of permanent amenities. As LSOAs near nuclear plants are more deprived than others before the accident, the additional disamenity shock should lead to an increase in the housing price gap between at-risk and safer areas, increased dispersion in amenities between at-risk and safer areas, and the flight of richer residents. The distribution of housing prices *within* LSOAs should become more compressed, a prediction which is consistent with our quantile analysis (see Figure 5).

4.2 Anchoring factors

We investigate treatment heterogeneity along differences in (permanent) amenities across neighbourhoods.

Productive amenities Productive amenities, e.g., stable labour demand related to match-specific or industry-specific human capital, should exert an anchoring force on households living in their vicinity and limit the amplitude of the hedonic price response following the news shock.

To measure the extent to which areas retain persons due to local job charac-

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[21] In Lee and Lin (2018), the nature of this shock is not particularly important—because individuals are perfectly mobile in each period—and the shock may be quite persistent, as in our application with the news shock.

teristics, we rely on the industrial structure of the local labour force. Booth et al. (1999) document variation in job mobility across industries. Light manufacturing, distribution, and finance are sectors with high job mobility. Following this line of thought, for all LSOAs, we measure the shares of employees working in industries with a high level of job mobility in 1971 (*Mobility (ind., 1971)*), and in 2011 (*Mobility (ind., 2011)*). Similarly, for each LSOA, we compute the share of workers having an *occupation* with high job turnover (*Mobility (occ., 2011)*) in 2011.[22]

We first provide visual evidence on the mitigating role of local productive amenities, and plot the average transaction price as a function of the distance to the closest nuclear plant for high-mobility (left panel of Figure 7) and low-mobility LSOAs (right panel) before (blue) and after (red) the Fukushima accident. High-mobility LSOAs are defined as having a share of workers in high-mobility industries above the median among all LSOAs in 2011. Figure 7 shows that the price gradient becomes steeper after the accident in high-mobility LSOAs (left panel) and such variation is less marked in low-mobility LSOAs (right panel).

We provide more precise estimates in Table 4, where we identify the role of productive amenities by augmenting specification (1) with an interaction of the treatment variable and measures of local amenities. All estimated equations include LSOA fixed effects and property controls, and we only report the coefficient before the triple interaction. Standardised effects are reported between brackets to allow for an easy comparison with the average treatment effect. First, we use the share of the labour force working in high-mobility industries in 2011: an additional percentage point in this share increases the price drop by 0.45 percentage points (a standardised effect of $-.024$, in column 1). An LSOA in the top 90% in terms of mobility experiences a price decrease of around -0.072 versus one of -0.014 for an LSOA in the top 10%. This estimate remains constant when adding interactions between the treatment and (a) the *occupational* structure of the labour force, (b) the share of high-mobility industries in 1971 (column 3), and (c) interactions of the treatment with other LSOA characteristics such as the deprivation percentile, the unemployment rate, and an LSOA rurality dummy (column 4). When we allow treatment effects to vary with the share of workers in high-turnover occupations, we find that an additional percentage point in the high-mobility occupational share only marginally amplifies the price response. An obvious explanation is that industries are better predictors of job mobility than occupations (Booth et al., 1999). We then allow treatment effects to vary with the LSOA industrial composition as measured

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[22] In Booth et al. (1999), various characteristics, such as gender, age, and the date of entry into the job market, impact job mobility. However, LSOA populations are quite homogeneous along these dimensions in stark contrast to the large dispersion in industrial structure across LSOAs.

in 1971 and find negligible differences along this dimension (column 3). We also estimate how LSOA characteristics—in terms of deprivation score, unemployment, and rurality—contribute to treatment heterogeneity across LSOAs (column 4). Deprivation and unemployment do explain a small part, but industry-based measures of job mobility remain the influential predictor.

Overall, our findings suggest that the presence of industries with low job turnover before the news shock is the crucial production characteristic that exerts an anchoring effect on households' (re)location decisions afterwards.

Consumptive amenities In this part, we examine how treatment effects vary with local consumptive amenities. We replicate the previous analysis with measures of consumptive amenities instead of measures of local production. As column 1 of Table 5 shows, the number of public services and schools per inhabitant has limited predictive power. Along the same lines, the presence of nature-related amenities, such as national parks, botanical gardens, and zoos mitigates the effect of the news shock (column 2) but the magnitude of this opposing force is small. In addition, the level of pollution, as measured by SO_2 concentration, does not correlate with treatment heterogeneity.

In Appendix Table A11, we show that geographical differences (elevation, latitude, downwind position relative to a close nuclear plant) do not explain treatment heterogeneity. While being crucial to Lee and Lin (2018)'s empirical application, natural amenities account for a much lower degree of persistence in house prices across neighbourhoods than does industry structure.

Mobility and search costs We then explore how commuting and mobility costs affect persistence in the spatial distribution of residents and thus house prices. The argument is quite similar in nature to the one used for job mobility: the lower are moving costs, the larger is the number of residents who can instantaneously adjust their housing demand. Job mobility is one dimension governing the rigidity of housing demand (Gardner et al., 2001; Böheim and Taylor, 2002). In Table 6, we explore the predictive power of four additional proxies of moving costs on treatment heterogeneity. In column 1, we consider a *No commute* variable, which is defined as the share of co-workers (people working in the same LSOA) who live within the at-risk area. A high share indicates that it is relatively difficult for a treated household to relocate outside the at-risk area, or equivalently, commuting costs are so high that few households commute. The large and positive estimate implies a higher hedonic price response where a lower share of co-workers lives within the at-risk area and where the mobility costs of residents in a treated area should arguably be lower.

In column 2, we look at the average number of children per household, as families with children are likely to have higher relocation costs. Our findings are consistent with this intuition. In columns 3 and 4, we look at the share of social housing and the share of non-white British. On the one hand, these proxies should capture local disamenities and, according to Lee and Lin (2018), the hedonic price response should be stronger. On the other hand, these residents may be less mobile. The negative and substantial effects show that the former channel dominates the latter.

In conclusion, we find non-negligible interactions between anchoring amenities and a news shock on environmental risk, which is consistent with Lee and Lin (2018). However, when exploring which type of anchoring amenity is most quantitatively relevant, we find that the rigidity of local production as the main (and novel) factor. This finding does not contradict Lee and Lin (2018), and one would argue (rightfully) that the local production structure is an endogenous factor and adjusts both ex-ante and ex-post. Our argument is that some industries may be slow-moving, and this contributes to relocation rigidities. Relocation rigidities then intervene in the persistence of housing demand across space.

Anchoring amenities may help alleviate endogenous neighbourhood sorting and the deterioration of neighbourhoods that may be triggered by a local shock. In the next section, we test the validity of this hypothesis in the longer run.

4.3 Long-term dynamics following the opening of plants

Based on the previous findings and the theoretical intuition, we can conjecture that similar dynamics were observed following the opening of nuclear facilities in the 1970s.[23] However, and in contrast with the previous section, we can quantify the long-term impact of this amenity shock. We test the following hypotheses: in the long run, (i) opening a plant increases deprivation in at-risk areas, and (ii) this effect should be stronger in those at-risk neighbourhoods without anchoring amenities.

To provide evidence of long-term demographic and socio-economic changes in the vicinity of nuclear plants, we analyse how the distance to nuclear plants impacts population size and deprivation over the period 1971–2011. We estimate a difference-in-differences regression in which the spatial treatment (LSOA centroid less than 20 kilometres from a nuclear plant) is interacted with Census year dummies (1971, 1981, 1991, 2001, 2011). The dependent variable is either the standardised population size

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[23] The installation of nuclear facilities induces positive employment effects, which suggests caution in comparing the market responses to the Fukushima news shock and to the opening of these plants.

or standardised deprivation.[24] The reference year 1971 corresponds to the early stage in the deployment of nuclear plants in the UK and all active plants (but one) in 2010 were already operational in 1991 (see Table 1).

We test the first hypothesis: opening a plant increases deprivation in at-risk areas. As shown by the first column of Table 7, proximity to a nuclear plant did not induce a large population change between 1971 and 1981 but had a detrimental impact on the population dynamics from 1981 onward. The population drop over four decades in spatially treated neighbourhoods amounts to a quarter of the standard deviation of population in 1971 (about 10% of the average LSOA population). As shown in the second column of Table 7, the share of low-skilled workers in the vicinity of a plant relative to the periphery markedly increased between 1971 and 2011, with most of the effect occurring between 1971 and 2001.[25] In 2001, the treatment effect represents around one-third of the standard deviation of the distribution of low-skilled workers across LSOAs in 1971. Part of the increase in the share of low-skilled workers could be driven by a labour demand surge for low-skilled workers fostered by power plants or suppliers. Two elements contradict this interpretation. First, it is unclear why the industrial fabric around nuclear plants would bias labour demand towards lower-skilled jobs. Second, the population decrease near nuclear plants hints at outmigration flows—biased towards higher-skilled individuals—as the main factor.

We then test the second hypothesis: the dynamics of deprivation should be stronger in those at-risk neighbourhoods without anchoring amenities. As the industrial structure was key in understanding the impact of the news shock in 2011, we verify that it is also key in understanding dynamics following the opening of plants.[26] To do so, we separate LSOAs based on their industrial composition in 1971 and define high-mobility LSOAs as those with an above-median share of workers in mobile industries in 1971. We still rely on Booth et al. (1999)'s classification of industries with higher job turnover, but the industrial structure is sufficiently different from the one in 2011 for the two indexes to be quite orthogonal. In Figure 8, we plot standardised population in 1971 (blue) and 2001 (red) as a function of the distance to the closest nuclear plant for high-mobility (left panel) and low-mobility LSOAs (right panel). In Figure 7, we plot the LSOA share of low-skilled workers in 1971 (blue) and 2001 (red) for high-mobility (left panel) and low-mobility

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[24] Population size and the share of low-skilled workers are computed over areas that are equivalent to the 2011 Census LSOAs and geographic units are thus nested across the different census waves.

[25] This feature explains why we observe parallel trends just before the Fukushima incident.

[26] Due to data limitations, we cannot verify that moving costs, as proxied by the share of coworkers working in a safe LSOA, play a role in explaining household sorting after the deployment of nuclear plants.

LSOAs (right panel). While the two types of LSOAs are quite similar and there is no relationship between population and the share of low-skilled workers in 1971, the situation dramatically changed over the following three decades. We observe a large hump in the share of low-skilled workers around nuclear plants, and this hump is particularly marked within high-mobility LSOAs. A similar difference is visible for population size. The population is calculated within 2011 administrative units such that it should be quite constant across LSOAs by construction. In 1971, however, the population is still computed within 2011 LSOAs and may thus diverge across LSOAs. Our findings indicate larger outmigration (difference between population sizes in 1971 and 2011) in high-mobility neighbourhoods compared to low-mobility neighbourhoods. The deprivation observed near nuclear plants today is explained by neighbourhood sorting *à la* Tiebout (1956), rather than by a process of environmental injustice—and political decisions to construct in already-deprived areas (Banzhaf and Walsh, 2008; Depro et al., 2015).

These findings support the hypothesis that the persistence of the spatial distribution of income over time depends on the presence of anchoring amenities. Our two main experimental variations (opening plants in the long run and news shocks in the short run) provide consistent estimates and show that the endogenous response to environmental (dis)amenities may be mitigated by the existing distribution of amenities within a neighbourhood. In the endogenous dynamics of residential sorting and firm location choices, various spillovers may play a role. The increased deprivation in at-risk areas—due to the departure of richer households—should reduce the provision of local endogenous amenities (Kuminoff et al., 2013) and affect household welfare through local peer effects (Durlauf, 1996, 2004) or homophily (Schelling, 1971). Residential sorting will impact local labour demand as in Lin (2017): local labour market tightness and the set of available skills are important components of firm productivity (Haskel and Martin, 1993). Firms reliant on highly skilled and mobile labour force should be the first to exit the neighbourhood. Through these different spillovers, a modest amenity shock may lead to persistent spatial disparities in the income distribution.[27]

5 Conclusion

We study empirically the impact of a news shock on environmental risk (i.e., the Fukushima incident in 2011 and its perception in England and Wales) and uncover

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[27] Heblich et al. (2016) document that within-city income inequalities in England and Wales nowadays are largely explained by–now gone–differences in exposure to air pollutants during the nineteenth century.

the following stylized facts: (i) the average hedonic price response is large, with house prices decreasing by 3.5% in the (potential) evacuation zones of nuclear facilities; (ii) there is a compression of the price distribution indicating a flight of richer residents; (iii) the hedonic price response depends on the presence of anchoring amenities, in particular the (local) structure of production and commuting costs.

To understand the long-term impact of these mechanisms, we study the dynamics of residential sorting after the deployment of nuclear facilities from 1971 to 2011. A higher environmental risk—induced by the proximity to nuclear power plants—leads to a flight of richer residents, a process which can be mitigated by the local distribution of amenities. Indeed, with local disamenities or highly mobile labour demand, an additional disamenity leads to additional sorting along income. The departure of rich residents induces lower endogenous amenities which further reduces the desirability of the neighbourhood. Along this equilibrium adjustment, tipping forces may induce large reversals of fortune and non-negligible spatial inequalities. Natural amenities (Lee and Lin, 2018) or the structure of production may anchor the neighbourhood ranking and mitigate these direct and indirect dynamics.

These findings shed light on important policy issues. First, they highlight the mitigation role of specific immobile productive amenities after an amenity shock. This finding relates to the literature on place-based policies. We showed that persistence in the local production structure may alleviate tipping dynamics in residential sorting following local shocks to amenities. Such a result illustrates the (beneficial) ex-ante role of place-based policies in mitigating shocks, whereas most of the literature discusses the role of place-based policies in compensating (ex-post) for existing economic shocks (Glaeser and Gottlieb, 2008; Kline and Moretti, 2014; Neumark and Simpson, 2015). Nevertheless, this anchoring role is not necessarily positive: a non-mobile or overly specialised industrial structure may induce large reversals of fortune following aggregate fluctuations, e.g., structural change (Glaeser et al., 2015; Franck and Galor, 2017). Second, the research indicates that support for nuclear power among local communities is unstable. Priors of local communities on industrial risk are affected by news shocks about remote accidents, and the role of such uncertainty on neighbourhood sorting and selection may be significant. The short-term cost of informing residents about environmental risk needs to be evaluated against the cost of fluctuations induced by uncertainty in the long-run.

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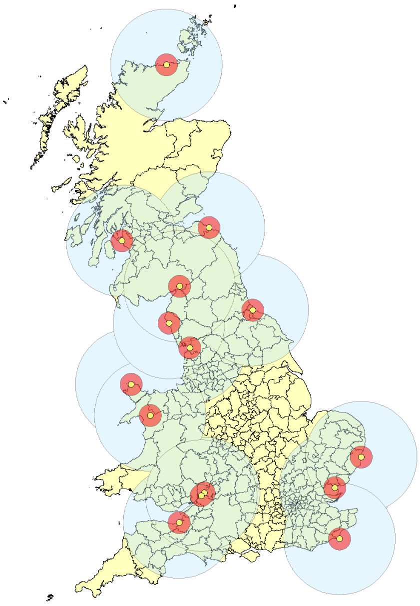
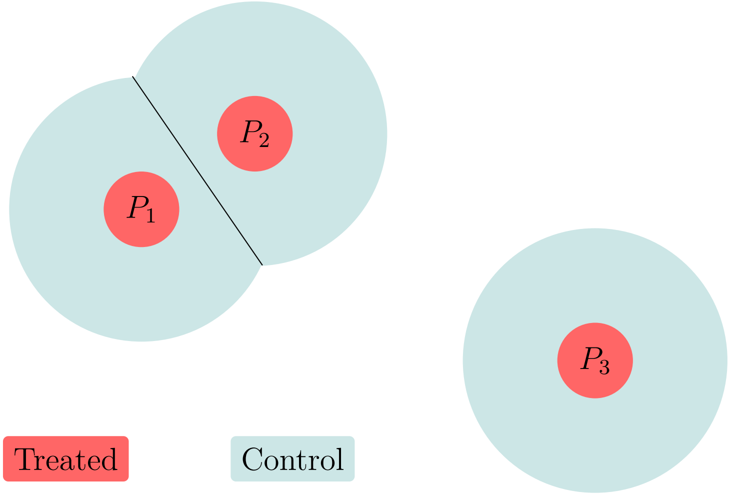
Figures and tables

Figure 1. Map of nuclear power plants in Great Britain (2012).



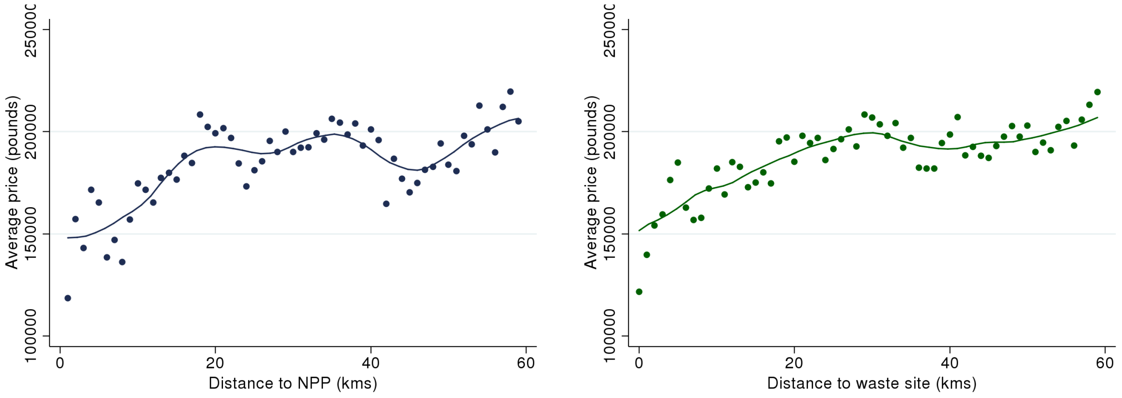
Notes: This figure shows the distribution of nuclear plants (yellow dots), and our definitions of treated (red) and control (teal) areas in Great Britain (2012).

Figure 2. Treated and control groups around nuclear plants P_1, P_2, and P_3.



Notes: Treated areas (red) are defined as all LSOAs with a centroid within 20 kilometres of a nuclear power plant. Control areas (teal) are defined as being between 20 and 100 kilometres from a nuclear power plant and not in any other evacuation zone. All LSOAs are also associated with the closest nuclear plant, which we define as the zone of influence of a particular plant P_z. For instance, LSOAs located in both the evacuation zones of P_1 and P_2 but closer to the P_2 plant (north of the black line) are associated with the plant P_2.

Figure 3. Average transaction prices as a function of distance to nuclear plants and waste sites.

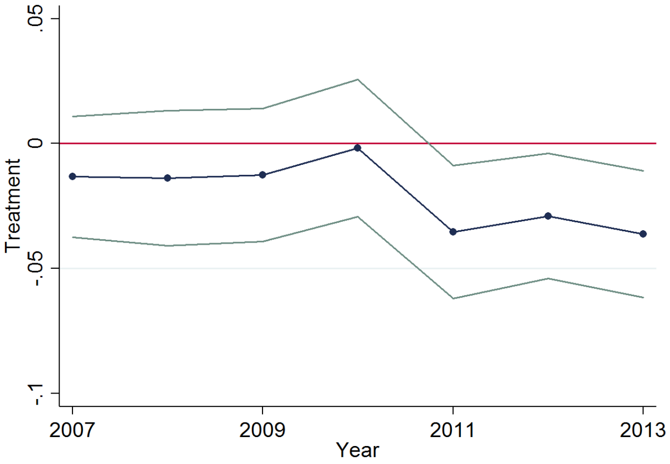


(a) Nuclear Plant.

(b) Waste site.

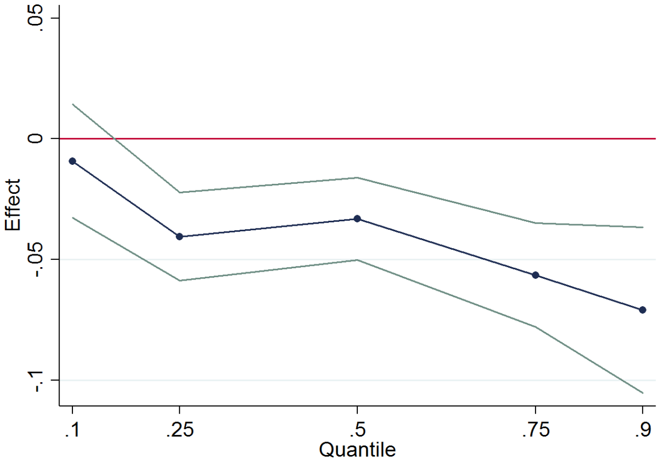
Notes: This figure displays the average transaction prices as a function of distance to nuclear plants (left panel) and waste sites (right panel) over the period January 2007–December 2014.

Figure 4. Treatment effects per year (event-study approach).



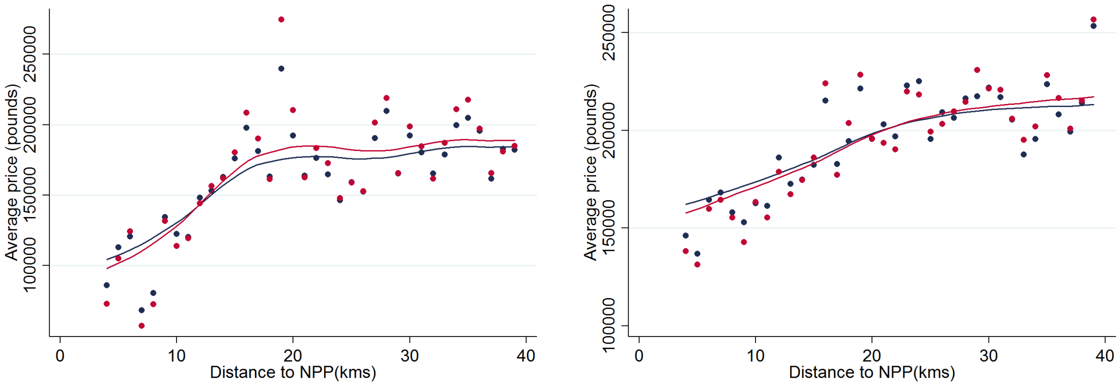
Notes: This figure displays the yearly treatment effects of living within the 20-kilometre radius of a nuclear plant for transaction prices over the period January 2007–December 2014 (Nationwide transaction dataset). 2006 is the reference year.

Figure 5. Effect of the Fukushima accident on the housing market—quantile regressions.



Notes: This figure reports the difference-in-differences coefficient, i.e., the coefficient before the treatment (LSOA centroid less than 20 kilometres from a nuclear plant) interacted with a dummy for post-Fukushima, for different quantiles. The associated table is Appendix Table A3.

Figure 6. Average transaction prices as a function of distance to nuclear plants for neighbourhoods with high- and low-mobility industries before (blue) and after (red) the Fukushima accident.

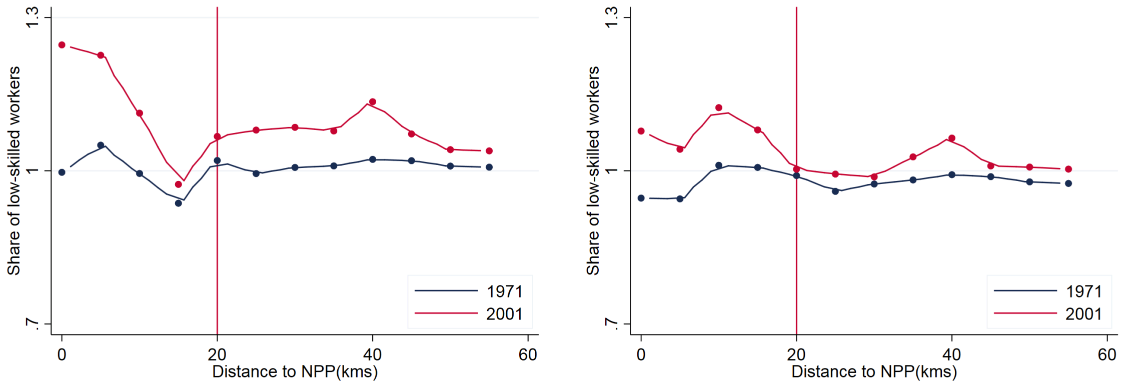


(a) High-mobility LSOAs.

(b) Low-mobility LSOAs.

Notes: The two panels display the average prices as a function of distance to nuclear plants in high-mobility neighbourhoods (left panel) and low-mobility neighbourhoods (right panel) over the period January 2007–March 2011 (blue) and April 2011–December 2014 (red). Areas (LSOAs) with high-mobility industries are defined as having a share of workers in (light) manufacturing, distribution and finance above the median among all LSOAs in 2011 (Booth et al., 1999).

Figure 7. Shares of low-skilled workers as a function of distance to nuclear plants in 1971 and 2001—areas with high- and low-mobility industries.

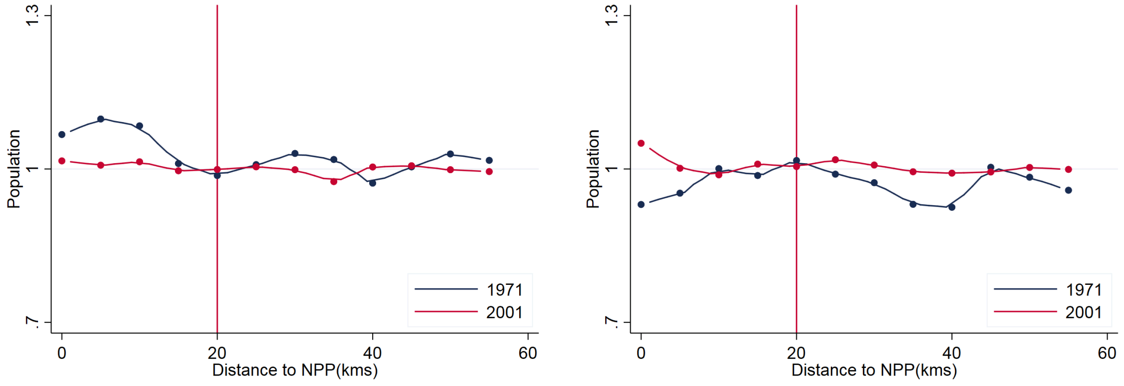


(a) High-mobility LSOAs.

(b) Low-mobility LSOAs.

Notes: These figures display the shares of low-skilled workers as a function of distance to nuclear plants in 1971 (teal) and 2001 (red) for areas with high- and low-mobility industries. Areas with high-mobility industries are defined as having a share of workers in (light) manufacturing, distribution and finance that is above the median among all LSOAs in 1971 (Booth et al., 1999). The share of high-skilled workers is the share of workers in the following one-digit occupational categories: Managers; Professionals; Associate Professionals. The share of low-skilled workers consists of all remaining categories.

Figure 8. Population size as a function of distance to nuclear plants in 1971 and 2001—areas with high- and low-mobility industries.



(a) High-mobility LSOAs.

(b) Low-mobility LSOAs.

Notes: These figures display the size of the population in 1971 and 2001 as a function of distance to nuclear plants for areas with high- and low-mobility industries. Population size is computed for areas equivalent to LSOAs of the 2011 UK Census. The LSOA population size in 2001 is not correlated with the distance to the nuclear plant as the 2011 LSOAs are built to have similar population size (between 400 and 1200 households) and populations in 2001 and 2011 are spread in a similar way across space. Areas (LSOAs) with high-mobility industries are defined as having a share of workers in (light) manufacturing, distribution and finance that is above the median among all LSOAs in 1971 (Booth et al., 1999).

Table 1. Commercial nuclear plants in the United Kingdom as of February 2011.

Name	Capacity (MW_e)	Reactors	Opening	(Expected) Closure	Type	Location	Latitude	Longitude
				Active plants				
Wylfa†	980	2*	1971	2014	Magnox	Wales	53.417	-4.483
Heysham A†	1155	2	1989	2019	AGR	England (NW)	54.028	-2.916
Heysham B	1220	2	1989	2023	AGR	England (NW)	54.028	-2.916
Hinkley Point B†	1220	2	1976	2023**	AGR	England (SW)	51.209	-3.127
Hunterston B	1190	2	1976	2023**	AGR	Scotland	55.722	-4.890
Dungeness B	1110	2	1985	2018	AGR	England (SE)	50.914	0.964
Hartlepool†	1190	2	1989	2024***	AGR	England (NE)	54.635	-1.181
Torness	1250	2	1988	2023	AGR	Scotland	55.968	-2.409
Sizewell B†	1188	1	1995	2035	PWR	England (E)	52.215	1.620
Oldbury†	434	2	1967	2012	Magnox	England (SW)	51.649	-2.571
				Closed plants				
Berkeley	276	2	1962	1989	Magnox	England (SW)	51.692	-2.494
Hunterston A	300	2	1964	1990	Magnox	Scotland	55.722	-4.890
Trawsfynydd	390	2	1965	1991	Magnox	Wales	52.925	-3.948
Dounreay Fast reactor	234	5	1976	1994	Magnox	Scotland	58.578	-3.752
Hinkley Point A	470	2	1965	2000	Magnox	England (SW)	51.209	-3.134
Bradwell†	246	2	1962	2002	Magnox	England (E)	51.741	0.897
Calder Hall (Sellafield)†	200	4	1956	2003	Magnox	England (NW)	54.421	-3.497
Chapelcross	200	4	1959	2004	Magnox	Scotland	55.016	-3.226
Sizewell A	420	2	1966	2006	Magnox	England (E)	52.215	1.620
Dungeness A	450	2	1965	2006	Magnox	England (SE)	50.914	0.964

Source: Department of Energy & Climate Change (DECC), and the PRIS database of the International Atomic Energy Agency (IAEA). The table includes all commercial nuclear plants. A number of research and development reactors also produce some power for the grid, such as the two Winfrith reactors (England, SW), and the prototype Windscale reactor on Sellafield site (England, NW). *Capacity* is the Reference Unit Power (Net Capacity). The *Opening* is the date at which the commercial operation started for the first reactor on a given site. * Reactor 2 at Wylfa site closed on April 25, 2012. Wylfa-1 was permanently shut down on December 30, 2015. *(Expected) Closure* represents the (expected) date of the closure of the last operational reactor on a given site. *Type* is the reactor technology. ** On December 4, 2012, Hinkley Point B and Hunterston B has been given a 7-year life extension, from 2016 to 2023. *** On November 5, 2013, Hartlepool has been given a 5-year life extension and its closure date was postponed from 2019 to 2024. † indicates sites that could host new reactors: on June 23, 2011, the government confirmed a list of eight sites suitable for new power stations by 2025, all of which are adjacent to existing nuclear sites.

Table 2. Descriptive statistics in 2010.

Sample	All	$T_i = 1$	$T_i = 0$	$T_i^w = 1$	$T_i^w = 0$
Observations	308,326	12,064	207,493	32,440	133,247
			Housing market		
Volume of transactions†	514542.0	400105.8	541658.6	390673.9	533633.8
Average price†	226297.8	179361.5	238280.8	177173.9	233955.0
Number of transactions	2.169	2.157	2.167	2.146	2.173
fraction of new buildings	0.040	0.045	0.038	0.039	0.040
fraction of flats	0.158	0.089	0.187	0.096	0.167
			Deprivation scores		
Income rank	.533	.525	.520	.535	.534
Employment rank	.533	.470	.530	.492	.540
Barriers to housing rank	.503	.609	.472	.595	.493
			Distance to nuclear facilities		
Distance to plants	80.59	13.71	65.56	59.28	82.18
Distance to waste sites	52.82	13.62	53.70	12.30	56.35

Notes: A unit of observation is a month × LSOA. The deprivation scores are the percentile in the distribution over all the LSOAs in England. A rank of 1 (resp. 0) means that the LSOA has the highest (resp. lowest) deprivation score in England. †: All monetary variables are expressed in Sterling pounds. T_i (resp. T_i^w) is equal to 1 for all LSOAs whose centroid is within the potential evacuation zone of a nuclear power plant (resp. nuclear waste site), and to 0 for LSOAs in a band of 20-100 km.

Table 3. Effect of the news shock on the housing market.

Nuclear plants	(1)	(2)	(3)
Price	-.0379***	-.0241***	-.0325***
	(.0033)	(.0021)	(.0018)
Number of transactions	.0016	-.0098***	-.0136***
	(.0040)	(.0037)	(.0039)
Volume of transactions	-.0363***	-.0340***	-.0462***
	(.0054)	(.0044)	(.0044)
Observations	1,754,282	1,754,282	1,577,723
Controls (housing characteristics)	No	No	Yes
LSOA fixed effects	No	Yes	Yes

Notes: Each cell displays the result of a separate regression (specification 1). The unit of observation is a LSOA × month. We only report the difference-in-differences coefficient, i.e., the coefficient before the treatment (LSOA centroid less than 20 km from a nuclear plant) interacted with a post-Fukushima dummy. Robust standard errors are reported in parentheses. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$. All specifications include month × zone dummies which clean for all time variations in the 100 km-neighbourhood of any nuclear plant.

Table 4. The role of neighbourhood characteristics (industry composition in 2011).

	(1)	(2)	(3)	(4)
Treat. × Mobility (ind., 2011)	-.4591***	-.3927***	-.4730***	-.3304***
	(.0369)	(.0374)	(.0371)	(.0380)
	[-.0241]	[-.0206]	[-.0248]	[-.0173]
Treat. × Mobility (occ., 2011)		-.0970***		
		(.0312)		
		[-.0058]		
Treat. × Mobility (ind., 1971)			.0237**	
			(.0112)	
			[.0038]	
Treat. × Deprived				-.0158***
				(.0043)
				[-.0079]
Treat. × Rural				-.0003
				(.0034)
				[-.0002]
Treat. × Unemployment				-.1358**
				(.0530)
				[-.0057]
Observations	1,575,918	1,575,918	1,575,918	1,575,918
Controls (housing)	Yes	Yes	Yes	Yes
LSOA fixed effects	Yes	Yes	Yes	Yes

Notes: Each column displays the result of a separate regression (specification 2). The unit of observation is a LSOA × month. We only report the difference-in-differences coefficient, i.e., the coefficient before the treatment (LSOA centroid less than 20 km from a nuclear plant) interacted with a post-Fukushima dummy. Robust standard errors are reported in parentheses. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$. All specifications include month × zone dummies which clean for all time variations in the 100 km-neighbourhood of any nuclear plant. *Deprivation* is a dummy for neighbourhoods with a deprivation score above the median. *Mobility (industry, 2011)* is the share of workers in (light) manufacturing, distribution and finance. *Mobility (industry, 1971)* is the share of workers in (light) manufacturing, distribution and finance in 1971. *Mobility (occupation, 2011)* is the share of managers, professionals, clerks and self-employed. These industries/occupations have been selected following Booth et al. (1999) (see Section 4).

Table 5. The role of neighbourhood characteristics (consumptive amenities).

	(1)	(2)	(3)
Treatment × Public services	-3.392***		
	(.9850)		
	[-.0058]		
Treatment × Schools	-1.460		
	(3.008)		
	[-.0008]		
Treatment × Nature & Historical		7.589***	
		(2.651)	
		[.0052]	
Treatment × Pollution			-.0019
			(.0021)
			[-.0025]
Observations	1,573,719	1,573,719	840,215
Controls (housing)	Yes	Yes	Yes
LSOA fixed effects	Yes	Yes	Yes

Notes: Each column displays the result of a separate regression (specification 2). The unit of observation is a LSOA × month. We only report the difference-in-differences coefficient, i.e., the coefficient before the treatment (LSOA centroid less than 20 km from a nuclear plant) interacted with a post-Fukushima dummy. Robust standard errors are reported in parentheses. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$. All specifications include month × zone dummies which clean for all time variations in the 100 km-neighbourhood of any nuclear plant. *Public services* is the number of public services per residents in the LSOA (excluding schools, but including job centres, hospitals, health centres, government buildings, courts etc.); *Schools* is the number of schools and universities per resident in the LSOA. *Nature & Historical* is the number of national parks, botanical gardens or historical Heritage sites per resident in the LSOA. *Pollution* is the SO_2 concentration as measured by the Department for Environment, Food & Rural Affairs (DEFRA) in 2011, and averaged at the LSOA level.

Table 6. The role of neighbourhood characteristics (moving costs).

	(1)	(2)	(3)	(4)
Treatment × No commute	.1583***			
	(.0129)			
	[.0184]			
Treatment × Children		.1565***		
		(.0371)		
		[.0077]		
Treatment × Social housing			-.0533***	
			(.0165)	
			[-.0061]	
Treatment × Non-White				-.0643***
				(.0207)
				[-.0129]
Observations	1,575,918	1,575,918	1,575,918	1,575,918
Controls (housing)	Yes	Yes	Yes	Yes
LSOA fixed effects	Yes	Yes	Yes	Yes

Notes: Each column displays the result of a separate regression (specification 2). The unit of observation is a LSOA × month. We only report the difference-in-differences coefficient, i.e., the coefficient before the treatment (LSOA centroid less than 20 km from a nuclear plant) interacted with a post-Fukushima dummy. Robust standard errors are reported in parentheses. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$. All specifications include month × zone dummies which clean for all time variations in the 100 km-neighbourhood of any nuclear plant. *No commute* is the share of individuals working in the same LSOA ("co-workers") who are living in the treated zone (controlling for distance to the nuclear plant). *Children* is the average number of children per household (Census 2011). *Social housing* is the share of council housing, while *Non-Whites British* is the share of "non-Whites British" based on self-declarations in the Census 2011.

Table 7. Nuclear plants and long-term evolution of neighbourhoods (1971–2011).

	Population	Low-skilled workers
Treatment × 1981	-.0462	.0635***
	(.0367)	(.0228)
Treatment × 1991	-.1824***	.1839***
	(.0367)	(.0228)
Treatment × 2001	-.1242***	.3307***
	(.0367)	(.0228)
Treatment × 2011	-.2429***	.2740***
	(.0367)	(.0228)
Observations	120,162	119,245
Controls (zone × wave)	Yes	Yes
LSOA fixed effects	Yes	Yes

Notes: Each column displays the result of a separate regression (specification 1). Each observation is a LSOA × wave (1971, 1981, 1991, 2001, 2011). Population and the share of low-skilled workers are standardised variables (within each Census wave). We only report the difference-in-differences coefficients, i.e., the coefficient before the treatment (LSOA centroid less than 20 km from a nuclear plant) interacted with year dummies. Robust standard errors are reported in parentheses. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$. All specifications include wave × zone dummies which clean for all time variations in the 100 km-neighbourhood of any nuclear plant.

ONLINE APPENDIX—not for publication

A Additional tables and figures

Table A1. Pre-treatment differential trends—placebo check.

Nuclear plants	(1)	(2)
Price	-.0036	.0010
	(.0053)	(.0034)
Observations	740,020	740,020
Controls (housing characteristics)	No	Yes
LSOA fixed effects	No	Yes

Notes: Each cell displays the result of a separate regression (specification 1). The unit of observation is a LSOA × month. We only report the difference-in-differences coefficient, i.e., the coefficient before the treatment (LSOA centroid less than 20 km from a nuclear plant) interacted with a dummy equal to 0 between January 2007 and February 2009, and 1 between March 2009 and February 2011. Robust standard errors are reported in parentheses. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$. All specifications include month × zone dummies which clean for all time variations in the 100 km-neighbourhood of any nuclear plant.

Table A2. Persistence of the hedonic price response.

Price	(1)	(2)
Treatment (04/11–11/12)	-.0191***	-.0231***
	(.0042)	(.0023)
Treatment (12/12–12/14)	-.0306***	-.0435***
	(.0040)	(.0021)
Observations	1,758,151	1,576,378
Controls (housing characteristics)	No	Yes
LSOA fixed effects	No	Yes

Notes: Each cell displays the result of a separate regression (specification 1). The unit of observation is a LSOA × month. We only report the difference-in-differences coefficient, i.e., the coefficients before the treatment (LSOA centroid less than 20 km from a nuclear plant) interacted with period dummies. Robust standard errors are reported in parentheses. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$. All specifications include month × zone dummies which clean for all time variations in the 100 km-neighbourhood of any nuclear plant.

Table A3. Effect of the news shock on the housing market—quantile regressions.

Quantiles	.10	.25	.50	.75	.90
Price	-.0092	-.0405***	-.0332***	-.0565***	-.0710***
	(.0120)	(.0093)	(.0087)	(.0110)	(.0175)
Observations	158,319	158,319	158,319	158,319	158,319
Controls (housing)	Yes	Yes	Yes	Yes	Yes

Notes: Each cell displays the result of a separate regression (specification 1). The unit of observation is a LSOA × month. We only report the difference-in-differences coefficient, i.e., the coefficient before the treatment (LSOA centroid less than 20 km from a nuclear plant) interacted with a post-Fukushima dummy. Robust standard errors are reported in parentheses. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$. All specifications include month × zone dummies which clean for all time variations in the 100 km-neighbourhood of any nuclear plant. For computational purposes, we only keep a random subsample of the whole sample (10%).

Table A4. Effect of the news shock on the housing market—nuclear waste sites.

	(1)	(2)	(3)
Price	-.0180***	-.0146***	-.0193***
	(.0027)	(.0017)	(.0016)
Number of transactions	-.0012	-.0106***	-.0137***
	(.0033)	(.0030)	(.0034)
Volume of transactions	-.0192***	.0252***	.0331***
	(.0044)	(.0036)	(.0039)
Observations	1,600,981	1,600,981	1,429,256
Controls (housing characteristics)	No	No	Yes
LSOA fixed effects	No	Yes	Yes

Notes: Each cell displays the result of a separate regression (specification 1). The unit of observation is a LSOA × month. We only report the difference-in-differences coefficient, i.e., the coefficient before the treatment (LSOA centroid less than 20 km from a waste site) interacted with a post-Fukushima dummy. Robust standard errors are reported in parentheses. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$. All specifications include month × zone dummies which clean for all time variations in the 100 km-neighbourhood of any waste site.

Table A5. Effect of the news shock on the housing market—large non-nuclear power plants as an alternative control group.

	(1)	(2)	(3)
Price	-.0294***	-.0281***	-.0360***
	(.0034)	(.0021)	(.0018)
Number of transactions	-.0071*	-.0060	-.0145***
	(.0042)	(.0039)	(.0041)
Volume of transactions	-.0366***	-.0342***	-.0506***
	(.0057)	(.0045)	(.0046)
Observations	1,067,441	1,067,441	954,933
Controls (housing characteristics)	No	No	Yes
LSOA fixed effects	No	Yes	Yes

Notes: Each cell displays the result of a separate regression (specification 1). The unit of observation is a LSOA × month. The sample is composed of LSOAs in the proximity of nuclear plants or large power plants (see Section 3). We only report the difference-in-differences coefficient, i.e., the coefficient before the treatment (LSOA centroid less than 20km from a nuclear plant) interacted with a post-Fukushima dummy. Robust standard errors are reported in parentheses. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$.

Table A6. Effect of the news shock on the housing market—robustness checks with other treatment definitions.

Price	(1)	(2)	(3)	(4)
Treatment (0-10 km)	-.0140***			
	(.0035)			
Treatment (0-15 km)		-.0266***		
		(.0023)		
Treatment (0-25 km)			-.0336***	
			(.0014)	
Distance (km)				.00016***
				(.00001)
Observations	1,576,368	1,576,368	1,576,368	1,576,368
Controls (housing characteristics)	Yes	Yes	Yes	Yes
LSOA fixed effects	Yes	Yes	Yes	Yes

Notes: Each cell displays the result of a separate regression (specification 1). The unit of observation is a LSOA × month. We only report the difference-in-differences coefficient, i.e., the coefficient before the different spatial treatments interacted with a post-Fukushima dummy. Robust standard errors are reported in parentheses. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$. All specifications include month × zone dummies which clean for all time variations in the 100 km-neighbourhood of any nuclear plant.

Table A7. Effect of the news shock on the housing market—robustness checks with "doughnut" definitions for the treatment.

Price	(1)	(2)	(3)	(4)
Treatment (0-20 vs 30-100 km)	-.0365***			
	(.0018)			
Treatment (0-20 vs 40-100 km)		-.0383***		
		(.0019)		
Treatment (0-20 vs 50-100 km)			-.0452***	
			(.0020)	
Distance (0-20 vs 60-100 km)				-.0529***
				(.0020)
Observations	1,459,037	1,348,799	1,209,363	1,048,753
Controls (housing characteristics)	Yes	Yes	Yes	Yes
LSOA fixed effects	Yes	Yes	Yes	Yes

Notes: Each cell displays the result of a separate regression (specification 1). The unit of observation is a LSOA × month. We only report the difference-in-differences coefficient, i.e., the coefficient before the different spatial treatments interacted with a post-Fukushima dummy. Robust standard errors are reported in parentheses. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$. All specifications include month × zone dummies which clean for all time variations in the 100 km-neighbourhood of any nuclear plant.

Table A8. Effect of the news shock on the housing market—robustness checks with additional controls.

PANEL A: Nuclear plants			
	(1)	(2)	(3)
Price	-.0449***	-.0318***	-.0293***
	(.0024)	(.0024)	(.0024)
Observations	727,032	727,032	727,032
Trends (green votes)	Yes	Yes	Yes
Trends (deprivation indices)	No	Yes	Yes
Trends (census)	No	No	Yes
Trends (housing characteristics)	Yes	Yes	Yes
LSOA fixed effects	Yes	Yes	Yes
PANEL B: Nuclear waste sites			
	(1)	(2)	(3)
Price	-.0421***	-.0318***	-.0290***
	(.0023)	(.0023)	(.0023)
Observations	607,793	607,793	607,793
Trends (green votes)	Yes	Yes	Yes
Trends (deprivation indices)	No	Yes	Yes
Trends (census)	No	No	Yes
Trends (housing characteristics)	Yes	Yes	Yes
LSOA fixed effects	Yes	Yes	Yes

Notes: Each cell displays the result of a separate regression (specification 1). The unit of observation is a LSOA × month. We only report the difference-in-differences coefficient, i.e., the coefficient before the treatment (LSOA centroid less than 20 km from a nuclear plant) interacted with a post-Fukushima dummy. Robust standard errors are reported in parentheses. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$. All specifications include month × zone dummies which clean for all time variations in the 100 km-neighbourhood of any nuclear plant. See Section 3 for a description of control variables.

Table A9. Effect of the news shock on the housing market—Nationwide data.

PANEL A: Nuclear plants	(1)	(2)
Price	-.0319***	-.0250***
	(.0055)	(.0033)
Observations	402,113	402,113
Controls (housing characteristics)	No	Yes
LSOA fixed effects	Yes	Yes
PANEL B: Nuclear waste sites	**(1)**	**(2)**
Price	-.0157***	-.0134***
	(.0043)	(.0026)
Observations	380,886	380,886
Controls (housing characteristics)	No	Yes
LSOA fixed effects	Yes	Yes

Notes: Each cell displays the result of a separate regression (specification 1). The unit of observation is a LSOA × month. We only report the difference-in-differences coefficient, i.e., the coefficient before the treatment (LSOA centroid less than 20 km from a nuclear plant) interacted with a post-Fukushima dummy. Robust standard errors are reported in parentheses. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$. All specifications include month × zone dummies which clean for all time variations in the 100 km-neighbourhood of any nuclear plant.

Table A10. Effect of the news shock on the housing market—the role of plant characteristics.

	(1)	(2)	(3)	(4)	(5)
Treat. × Connection	.00103***				
	(.00014)				
Treat. × Exp. closure		.00187***			
		(.00017)			
Treat. × Accidents			.00031		
			(.00143)		
Treat. × Package				-.00028***	
				(.00006)	
Treat. × Job ratio					.00380***
					(.00059)
Observations	1,577,723	1,577,723	1,577,723	1,577,723	1,577,723
Controls (housing)	Yes	Yes	Yes	Yes	Yes
LSOA fixed effects	Yes	Yes	Yes	Yes	Yes

Notes: Each column displays the result of a separate regression (specification 2). The unit of observation is a LSOA × month. We only report the difference-in-differences coefficient, i.e., the coefficient before the treatment (LSOA centroid less than 20 km from a nuclear plant) interacted with a post-Fukushima dummy. Robust standard errors are reported in parentheses. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$. All specifications include month × zone dummies which clean for all time variations in the 100 km-neighbourhood of any nuclear plant. *Connection* is the year of connection to the grid. *Exp. closure* is the expected date of closure of a plant. *Accidents* is the number of accident that occurred in a plant before 2011. *Package* is the package volume of waste in 1000 m^3. *Job ratio* is the share of the working population in the vicinity of a nuclear plant that works for the plant.

Table A11. Effect of the news shock on the housing market—the role of geography.

	(1)	(2)	(3)
Treatment × Elevation	.00022***		
	(.00005)		
Treatment × Latitude		.00203	
		(.00116)	
Treatment × Orientation			.00032
			(.00056)
Observations	1,575,941	1,576,378	1,576,378
Controls (housing)	Yes	Yes	Yes
LSOA fixed effects	Yes	Yes	Yes

Notes: Each column displays the result of a separate regression (specification 2). The unit of observation is a LSOA × month. We only report the difference-in-differences coefficient, i.e., the coefficient before the treatment (LSOA centroid less than 20 km from a nuclear plant) interacted with a post-Fukushima dummy. Robust standard errors are reported in parentheses. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.10$. All specifications include month × zone dummies which clean for all time variations in the 100 km-neighbourhood of any nuclear plant. *Orientation* is the absolute angle difference with the predominant wind direction (a value of 0 usually corresponds to being oriented North-East with respect to the nuclear plant).

B Data and context

B.1 Nuclear reactors in the UK

Table B1. Commercial nuclear reactors in the world at the end of 2010.

	Operational reactors	Capacities (GW)	Fleet age (years)	Share of power	Reactors' construction
OECD	*343*	*326*	*27*	*21%*	*12*
United States	104	106	31	19%	1
France	58	66	25	75%	1
Japan	54	49	25	27%	2
Germany	17	21	28	23%	0
Korea	21	19	17	31%	5
Canada	18	13	26	15%	0
United Kingdom	19	11	29	16%	0
Other	52	40	28	24%	3
Non-OECD	*98*	*68*	*21*	*4%*	*55*
Russia	32	24	28	15%	11
Ukraine	15	14	22	48%	2
China	13	11	8	2%	28
India	19	5	17	3%	6
Other	19	14	24	9%	8
World	441	393*	26	13%	67

Notes: Reproduced from IEA (2011). *Operational reactors* is the number of operations reactions as of the end 2010. *Capacities* are installed gross capacities in gigawatt (GW). * 393 GW of gross capacity is equivalent to 374 GW of net capacity. *Fleet age* is the average fleet age in years. *Share of power* is the share of total domestic electricity produced with nuclear plants. *Reactors' construction* is the number of reactors in construction at the end of 2010.

All the active power plants in the UK were, in 2010, three times smaller than the Fukushima-Daiichi plant in terms of installed capacities.

UK reactors are based on different technologies to the Boiling Water Reactor (BWR) technology used at the Fukushima-Daiichi plant. A dozen *Generation I* nuclear power reactors were constructed during the 1960s and early 1970s with the UK-specific *Magnesium non-oxidising technology* (Magnox). These reactors were designed to operate either as a power plant or as a producer of plutonium for weapons. This Magnox technology is associated with low thermal efficiency, and thus high production costs, and has not been competitive enough to be exported outside the UK. All closed plants were based on the Magnox technology. By contrast, only two—Oldbury and Wylfa— of the more recent operational plants were using this technology as of March 2011.

A second generation of reactors (Advanced Gas-cooled Reactors, AGR) were constructed between 1975 and 1988 to replace the Magnox power plants. This UK-specific technology was used at seven operational plants as of March 2011. Being considered safe, these power plants were given life extensions even after the

Fukushima incident. In February 2012, *Electricité de France* (EDF) revealed its expectations to extend the life of all of its *AGR* nuclear reactors (with expected closure ranging from 2019 to 2028). In December 2012, the life duration of two nuclear plants (Hunterston B and Hinkley Point B) was approved sending a strong signal to EDF for the rest of its *AGR* fleet.

The last nuclear power plant built in the UK—Sizewell B, connected to the grid in 1995 and expected to close down in 2035—operates under the *PWR* technology (Pressurised Water Reactor, *Generation II*). New projects, such as the Evolutionary Power Reactor (EPR) at Hinckley Point C (*Generation III*), are based on variations of this PWR technology.

It is unclear whether UK reactors are "safer" than their Japanese counterparts. Indeed, the merits of each reactor design in terms of safety depend on the types of accidents that are considered. Some argue that UK nuclear reactors are less prone to core meltdown after a failure of the coolant system—the industrial cause of the Fukushima accident—than Japanese ones. Dr Mike W. Weightman, Chief Inspector of Nuclear Installations in the UK, declared that "*the temperature increases [in Magnox reactors and AGRs] would be slow allowing ample time for operator intervention*" after a failure of the cooling system, because of their "*low power density and high thermal inertia*" of these reactors (Weightman, 2011). Important differences in reactor design relate to their cooling system. Intervention on BWRs—such as those at the Fukushima-Daiichi plant—can be difficult to make if pressure increases in the reactor: any steam released from the reactor due to necessary venting would contain radioactive products, as the power generation and the reactor cooling use the same water system. In PWRs (e.g., Sizewell B), the steam for power generation is a separate system to the reactor cooling water. However, PWR design does not ensure full safety regarding core-meltdown risk. Indeed, the Three Miles Island reactors (in the US) that experienced a partial core meltdown in 1979 were PWRs.[28] Unlike PWR and BWR, Magnox and AGRs are cooled by carbon dioxide and graphite moderated.

Safety measures and nuclear regulations are also important to determine the level of nuclear risk in each country. Both Japan and the UK have supposedly independent authorities in charge of running safety tests and determining appropriate regulations (see Bredimas and Nuttall, 2008, for an overview of nuclear regulations in these countries).[29]

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[28] PWRs represent about 60% of the world's commercial reactors. The Chernobyl plant in Ukraine has four RBMKs—graphite-moderated nuclear power reactors—that used light water as a coolant.

[29] Safety measures depend on the perceived risk, which is a function of past accidents. Benoît

Local hazards matter to assess exposure to nuclear risk. Natural hazards are more frequent in Japan than in the UK. Indeed, the World Risk Index of the United Nations University ranks Japan as the 17^{th} riskiest country in the world concerning natural hazards, whereas the UK is ranked 131^{st} out of 171. This synthetic ranking accounts for country exposure and vulnerability to natural disasters such as earthquakes, cyclones, floods, droughts, and sea-level rise. However, terrorism risk as measured by past terrorist attacks is more prevalent in the UK. Using the Global Terrorism database of the University of Maryland, we counted 386 incidents, including 26 with casualties, in the UK (mostly due to the conflict in Ireland) between January 2000 and March 2011. Over the same period, 23 incidents were reported in Japan, all without casualties. Both natural and man-made hazards matter in the overall nuclear risk assessment, as revealed by the communication of plant manufacturers. On the website of Areva—one of the industry leaders—the public can learn about the safety improvements of Areva's EPR reactor in these terms: "*Unrivalled level of safety: Resistance to plane crashes and seismic vibrations; quadruple safety device redundancy; core meltdown risk further reduced and minimisation of the consequences from such an accident thanks to a special compartment isolating the molten core.*"

B.2 Waste sites in the UK

Appendix Table B2 contains detailed information about nuclear waste sites in the UK. Nuclear wastes are divided into three categories.

High Level Wastes (HLW) are wastes with high levels of radioactivity. HLW are mostly spent nuclear fuel and highly radioactive reprocessing liquors. One challenge in storing them is that their temperature could rise significantly because of radioactivity. They are currently stored in steel containers to cool down for 50 years. Only the Sellafield site, in the North-West of England, is used to store HLW after being conditioned and packaged in the Waste Vitrification Plant on-site.[30] In the late 1970s, three granite sites close to the Scottish borders were examined for HLW but they all encountered strong public opposition and were abandoned.

Intermediate Level Wastes (ILW) are used-fuel-rod casings, used-ion-exchange resins and parts of decommissioned reactors that are highly radioactive but do not require any cooling process. The storage of ILW outside of nuclear power stations is frequent. Nowadays, a dozen of those sites store more than 1,000 m^3 of waste

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and Dubra (2013) provide an analytical framework to study how insufficient prevention measures can stem from rational agents' decisions when they face highly uncertain risk.

[30] The packaged volume of nuclear waste of any type in Sellafield is higher than the combined volume for all the other sites in the UK.

Table B2. Nuclear waste sites in the United Kingdom in 2010.

Location	Site owner	HLW (m^3)	ILW (m^3)	LLW (m^3)	Latitude	Longitude	Type
Amersham	GE	0	341	4090	50.224	-7.658	Radiochemical production
AWE Aldermaston	MoD	0	4730	41900	51.362	-1.139	Defence establishments
BAESM Barrow-in-Furness	MoD	0	0	37.5	54.110	-3.226	Defence establishments
Berkeley	NDA	0	6910	30300	51.692	-2.494	Nuclear power station
Bradwell	NDA	0	5770	51400	51.741	0.897	Nuclear power station
Calder Hall	NDA	0	9410	51000	54.421	-3.497	Nuclear power station
Capenhurst (1 & 2)	NDA	0	0	5580	54.522	-8.145	Nuclear fuel production and reprocessing
Capenhurst (1 & 2)	Urenco	0	3	2810	54.522	-8.145	Nuclear fuel production and reprocessing
Cardiff	GE	0	466	11400	51.523	-3.250	Radiochemical production
Chapelcross	NDA	0	6230	167000	55.016	-3.226	Nuclear power station
HMNB Clyde	MoD	0	0	770	50.299	-6.988	Defence establishments
Culham	UKAEA	0	817	8100	51.658	-1.228	Research establishments
RRMPOL Derby	MoD	0	0	1960	52.910	-1.434	Defence establishments
HMNB Devonport	MoD	0	328	17600	50.383	-4.183	Defence establishments
DSDC North Donnington	MoD	0	0	125	49.767	-7.557	Defence establishments
Dounreay	NDA	0	11300	113000	58.578	-3.752	Research establishments
Dungeness (A & B)	NDA (A)	0	6940	34900	50.914	0.964	Nuclear power station
Dungeness (A & B)	EDF (B)	0	7080	19600	50.914	0.964	Nuclear power station
Eskmeals	MoD	0	0	101	54.316	-3.400	Research establishments
Hartlepool	EDF	0	7680	14700	54.635	-1.181	Nuclear power station
Harwell (1 & 2)	NDA	0	6870	99600	51.600	-1.283	Research establishments
Harwell (1 & 2)	GE	0	0.1	40.4	51.600	-1.283	Research establishments
Heysham (1 & 2)	EDF (1)	0	7620	15200	54.028	-2.916	Nuclear power station
Heysham (1 & 2)	EDF (2)	0	7670	19100	54.028	-2.916	Nuclear power station
Hinkley Point (A & B)	NDA (A)	0	7270	57400	51.209	-3.134	Nuclear power station
Hinkley Point (A & B)	EDF (B)	0	7340	15500	51.209	-3.134	Nuclear power station
Hunterston (A & B)	NDA (A)	0	8350	57600	55.722	-4.890	Nuclear power station
Hunterston (A & B)	EDF (B)	0	8030	15300	55.722	-4.890	Nuclear power station
LLWR near Drigg	NDA	0	250	22100	54.379	-3.456	Industrial and landfill sites
N RTE Vulcan	MoD	0	156	35.7	58.578	-3.752	Defence establishments
Oldbury	NDA	0	6120	32900	51.649	-2.571	Nuclear power station
HMNB Portsmouth	MoD	0	0.2	17.9	50.804	-1.102	Defence establishments
Rosyth & Devonport	MoD	0	3670	2840	56.020	-3.453	Defence establishments
Rosyth Royal Dockyard	MoD	0	116	183	56.020	-3.453	Defence establishments
Sellafield (Sellafield Ltd)	NDA	1330	302000	3160000	54.420	-3.497	Nuclear fuel production and reprocessing
Sellafield (NNL)	NDA	0	0	856	54.420	-3.497	Nuclear fuel production and reprocessing
Sizewell (A & B)	NDA (A)	0	6140	38700	52.215	1.620	Nuclear power station
Sizewell (A & B)	EDF (B)	0	3260	13400	52.215	1.620	Nuclear power station
Springfields	NDA	0	0	240000	53.775	-2.808	Nuclear fuel production and reprocessing
Torness	EDF	0	7260	20300	55.968	-2.409	Nuclear power station
Trawsfynydd	NDA	0	13400	60700	52.925	-3.948	Nuclear power station
Windscale	NDA	0	13800	12100	54.420	-3.497	Nuclear fuel production and reprocessing
Winfrith	NDA	0	1590	9560	50.682	-2.261	Research establishments
Wylfa	NDA	0	8430	59500	53.417	-4.483	Nuclear power station

Source: The 2010 UK Radioactive Waste Inventory, Department of Energy & Climate Change (DECC). *Packaged volumes* once all wastes at April 1, 2010 and future arisings have been packaged. As indicated by the DECC, *"Packaging is the loading of waste into a container for long-term management. The packaged waste volume is the displacement volume of the container. It represents a 'final' waste volume. Typically the packaged waste volume is between 20% and 50% greater than the conditioned waste volume, depending on the type of container."* LLW packaged volumes do not contain those waste streams suitable for landfill disposal. We exclude from the analysis sites that contain momentarily waste for transports or sites that could not be located with precision such as some defence estates.

produced from uranium enrichment, nuclear fuel manufacture, nuclear power production, spent fuel reprocessing, research and development, medical and industrial sources, and defence activities.

Low Level Wastes (LLW) are low in radioactivity, and their storage does not require advanced facilities. Sites containing exclusively LLW are unlikely to be noticed by the public.

B.3 International response to the Fukushima accident

The Fukushima accident had various impacts on national nuclear programs, as documented by Davis (2012); World Energy Council (2012). We can distinguish three groups of countries based on their responses to the incident.

A first group of countries made significant downward adjustments to their nuclear plans. This includes Japan, where Prime Minister Naoto Kan called for an immediate phasing out of all nuclear plants in order to pursue a safety investigation.[31] Since then, Japan has resumed nuclear power generation.

In Germany, Chancellor Angela Merkel decided to shut down eight of the 17 domestic nuclear power plants directly after the Fukushima accident and to phase down by 2022 all the remaining ones. Switzerland took a similar path when the government banned the construction of new reactors and decided to gradually phase out nuclear power generation by 2034 in May 2011. In 2003, Belgium decided to phase out its nuclear plants over the period 2015–2025 and reaffirmed this schedule after the Fukushima accident. In Italy, after the 1987 referendum that put an initial stop to the nuclear power program, a second referendum in June 2011 shut down again the future of nuclear energy in the country: Silvio Berlusconi's government's proposal to build nuclear plants was massively rejected.

A second set of countries sent mixed signals in the aftermath of the Fukushima accident but then defended their nuclear programs. In France, François Hollande, as a candidate to the 2012 presidential elections, pledged to scale down the nuclear program, and close the Fessenheim site, France's oldest active nuclear plant. However, the nuclear power program remained mostly untouched under his presidential

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[31] The Japanese government's emergency response to the accident involved setting up a *Restrictive Area* with compulsory evacuation in a 20-kilometre radius from the damaged plant on March, 12. On March 15, people living within 20–30 kilometres of the plant were advised to stay indoors (*Evacuation Prepared Area*). On April 22, the government asked people in areas where cumulative radiation doses might reach 20 mSv (millisievert) within a year of the occurrence of the accident to evacuate (*Deliberate Evacuation Area*). On June 16, various small-sized areas with air radiation doses exceeding 20 mSv per year (*Specific Spots Recommended for Evacuation*) were proposed for evacuation. On September 30, the *Evacuation Prepared Area* was lifted, but the *Restrictive Area* in the 20-kilometre radius around the plant was maintained.

mandate (2012–2016). In China, the government first announced a suspension of the approval of new nuclear reactors, and a stress test on all existing plants. However, China's pre-Fukushima ambitious nuclear development was eventually confirmed by the Chinese National Energy Administration in December 2011. In the US, the decrease in natural gas prices has accelerated the phasing out of nuclear power despite stable political support over Barack Obama's presidential mandates (2009–2013, 2013–2017).

A small group of countries unequivocally announced the continuation of their nuclear programs in the aftermath of the accident. South Korea decided to continue the expansion of its nuclear industry and Russia reaffirmed its plan to double installed capacities. The UK belongs to this group. As documented in the next subsection, the nuclear program was not threatened in the UK, so expectations about phasing out nuclear plants early were short lived.

B.4 The Nationwide data

Nationwide is the second largest mortgage provider in the UK, covering about 13–15% of the market in terms of volume. As a consequence, the sample of transactions is substantially smaller than Land Registry. The percentage of Land Registry transactions in the Nationwide data was 10.19, 10.46, 10.62, 9.63, 10.42, 16.19, and 16.55 between 2007 and 2013. The huge increase in 2012 relates to Nationwide's strategy to cut fees. While the share of transactions varies with time, it is important to verify that such changes are not correlated with the treatment: the ratio of transactions included in the Nationwide dataset increased between 2007–2011 and 2012–2013 in similar proportions in treated (less than 20 kilometres from a nuclear plant) and non-treated zones (between 20 and 100 kilometres from a plant in the baseline specification). The Nationwide dataset mostly covers small transactions, and these lower price quantiles are slightly over-represented. As before, however, the bias is similar in treated and non-treated zones.

The Nationwide dataset includes a wide range of controls for property characteristics (e.g., the construction date, the number of bedrooms, bathrooms, garages, size in square meters, and heating facilities), and these controls alleviate the main issue with Land Registry, i.e., the limited set of individual-transaction controls. Accordingly, we mostly use the Nationwide data to clean for within-LSOA compositional effects.

B.5 Additional data on neighbourhood characteristics

We describe below the various data sources of LSOA characteristics.

Census From the Census 2011, we reconstruct in each LSOA the average quality of accommodation, the average age of inhabitants, the number of schooling years, and the LSOA composition in terms of ethnicity and religion. We measure the industrial and occupational composition of the labour force, the population, the characteristics of the stock of properties (tenure and amenities), and the share of social housing. These data were retrieved from `http://casweb.ukdataservice.ac.uk` and `http://infuse.ukdataservice.ac.uk`.

Deprivation The English Indices of Deprivation (2010) were constructed by the Social Disadvantage Research Centre at the Department of Social Policy and Social Work at the University of Oxford. The index is a weighted average of several subindices for each output area (Income Deprivation, 22.5%, Employment Deprivation, 22.5%, Health Deprivation and Disability, 13.5%, Education, Skills and Training Deprivation, 13.5%, Barriers to Housing and Services, 9.3%, Crime, 9.3%, Living Environment Deprivation, 9.3%).

The Income Deprivation measure sums the number of adults and children in families with Income Support, income-based Jobseeker's Allowance, Pension Credit (Guarantee), or Child Tax Credit. Asylum seekers in England in receipt of subsistence support, accommodation support, or both are also included.

The Employment Deprivation score sums the number of claimants of (a) Jobseeker's Allowance, (b) Incapacity Benefit or Severe Disablement Allowance, (c) Employment and Support Allowance, and (d) Participants in New Deal.

The Health Deprivation and Disability measure combines a measure of premature death with a morbidity/disability ratio, emergency admission to hospital, and the proportion of adults suffering from mood and anxiety disorders.

The Education value combines the average points score of pupils taking English, maths, and science Key Stage 2/3 and 4 exams (this measure is already part of our controls), the proportion of absences from secondary school, and the proportion of young people aged under 21 not entering higher education.

The Barriers to Housing and Services measure rates the housing conditions for households, i.e., the proportion of all households in an LSOA with insufficient space to meet the household's needs, the number of households requiring housing assistance, the proportion of households under 35 whose income is not sufficient to afford its occupation.

The Crime Deprivation index combines the rates of violence/burglary/theft and criminal damage.

The Living Environment Deprivation measure captures the quality of housing, and two measures relating to air quality and road traffic accidents.

Votes at the UK General Elections The information on the vote shares obtained by the different parties at the UK Parliament General Elections in 2010 and 2015 was downloaded from the Electoral Commission website `http://www.electoralcommission.org.uk/`

Local taxes We collected the Average Council Tax per Dwelling that is available at the Billing authority (BA) on the Department for Communities and Local Government website. We then linked each to an LSOA. In parallel, we measured the number of properties assigned to each council tax band for each domestic property type in each geographic area (LSOA). Council tax bands define eight valuation bands (nine bands in Wales), i.e., A: Up to 40,000, B: 40,001 up to 52,000, C: 52,001 up to 68,000, D: 68,001 up to 88,000, E: 88,001 up to 120,000, F: 120,001 up to 160,000, G: 160,001 up to 320,000, H: 320,001 and above, on the basis of the domestic property value on April 1, 1991 (April 1, 2003 in Wales).

School performance We collected information about the performance of schools provided by the Department of Education for the period 2009–2013 and we constructed (i) a proxy for each school size (number of pupils per school) and (ii) proxies for students' quality, i.e., the Average Point Score for each one of the stages (KS2, KS4, KS5).

C Estimating the price-elasticity of housing supply

The effect of the Fukushima incident on the English housing market results from a combination of (i) a shift in risk perception, (ii) the disamenity associated with additional nuclear risk, and (iii) the housing market response to the shift in housing demand. While we cannot identify separately the contribution of these fundamentals, e.g., the elasticity of housing demand to risk perception, we describe these elements in the following lines.

We consider the following housing demand schedule $D(p) = \bar{D}(p) - v(r)$, where:

- $\bar{D}$ captures the observed housing characteristics and the local amenities. These elements are captured in the empirical specification by LSOA fixed effects, transaction characteristics, access to schools in the output area, deprivation indices, housing stock, percentage of highly educated individuals, students, retired, and region-specific trends.
- $r = E[C = 1|I]$ is the expected probability of a nuclear catastrophe C conditional on information set I, and v is the valuation associated with such catastrophic risk.

This example is illustrative, and we model the demand shift as a parallel shift, i.e., v does not depend on prices. With heterogeneous agents and some correlation between access to information and housing demand, this hypothesis would be violated.

In parallel, we assume that there is a housing supply schedule $S(p, r)$. We keep its formulation general but we impose some restrictive assumptions in the following lines.

Permanent shift in expectations With imperfect information on nuclear risk, the occurrence of a catastrophe should modify the information set that Bayesian agents use to establish their housing demand. Let us assume that the occurrence of a catastrophe is a permanent shock on agents' expectations: they are perfectly Bayesian and never forget about past realisations. Letting I' denote the new information set and assuming that all other amenities remain the same, the demand curve shifts downward by

$$v\left(E[C = 1|I]\right) - v\left(E[C = 1|I']\right) \approx \underbrace{-v'(r)}_{\text{valuation}} \cdot \underbrace{\left[r' - r\right]}_{\text{perception}}.$$

By contrast, housing supply should be independent of revisions in r: agents cannot gain by waiting if they want to sell their house, and so supply remains inelastic.

The price drop entirely reflects the change in risk perception weighted by the household's risk aversion. If we interpret transactions in the housing market as small frictional adjustments to reach the new equilibrium, then the market liquidity and the number of transactions per month should not vary after the catastrophe.

Transitory shift in expectations If, instead, the occurrence of a catastrophe is a transitory shock at least according to some agents' expectations, the housing supply schedule will be increasing, reflecting the idea that some agents may refuse to sell their house below a certain price, accounting for the expected future price.

In contrast with the previous case, the decrease in prices reflects the change in risk perception weighted by the household's risk aversion but also the elasticities of housing demand and supply (partly driven by the expectations in a future price recovery). In such a scenario, if we interpret transactions in the housing market as small frictional adjustments to reach the new equilibrium, there will be fewer transactions after the catastrophe. Some households will refuse to sell their house given the current demand schedule and will wait for better opportunities thereby lowering the number of transactions.

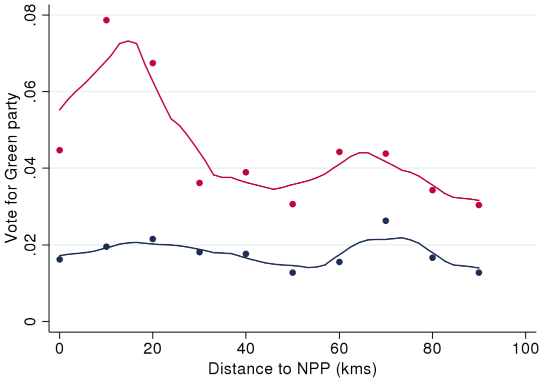
Our results indicate that the shift in expectations was permanent. Indeed, the relatively modest decrease in the number of transactions (1%) compared to the price drop (3.5%) points to a low price-elasticity of housing supply. The modest decrease in the number of transactions also implies that the price decrease essentially reflects the demand shift (and not elasticities of housing demand or supply coming from market imperfections or heterogeneities in risk valuations).

The large price decrease of about 3.5% may indicate that households have a high disamenity from being exposed to nuclear risk, or that they have sharply modified their risk perception.

D The news shock and votes for the Green Party

We collect data on vote shares, and notably vote shares for the Green Party—the only anti-nuclear party in the UK—from the Electoral Commission. As voting data are available at the constituency level, we locate our LSOA within each constituency. We weight vote shares by the LSOA area in each constituency when its borders overlap with several constituencies. In Figure B1, we plot the vote shares for the Green Party, as a function of the distance to the closest nuclear plant.

Figure B1. Vote shares for the Green Party at the UK General Elections in 2010 (blue) and 2015 (red) as a function of distance to nuclear plants.



This figure displays the average vote shares for the Green Party as a function of distance to nuclear plants at the 2010 (blue) and 2015 (red) UK General Elections. Vote shares are at the constituency level. The distance of a constituency to its closest nuclear plant is computed as the average distance between LSOA centroids in this constituency and the nuclear plant.

We compare more formally how the gap in vote shares between treated and control areas changed between the 2010 and 2015 general elections in Table B3. The unit of observation is a LSOA and an election year $\{2010, 2015\}$; we thus cluster standard errors at the constituency × year level. As apparent in the first and third columns of Table B3, the Fukushima incident seems to be associated with a shift in votes from the Labour Party to the Green Party. This shift is both observed in the proximity to nuclear plants and in the proximity to waste sites. While the amplitude of this shift is not negligible, the Green Party remains a confidential force in the United Kingdom with about 3.6% of votes in the General Election of 2015.

Table B3. Effect of the Fukushima accident on electoral results (difference-in-differences between 2010 and 2015).

PANEL A: Nuclear plants			
	(1)	(2)	(3)
Votes	Green	Conservative	Labour
Treatment × ($t = 2015$)	.0265**	.0115	-.0390**
	(.0133)	(.0180)	(.0187)
Observations	13,842	18,252	18,248
LSOA fixed effects	Yes	Yes	Yes

PANEL B: Waste sites			
	(1)	(2)	(3)
Votes	Green	Conservative	Labour
Treatment × ($t = 2015$)	.0243*	.0109	-.0385**
	(.0144)	(.0179)	(.0186)
Observations	13,842	18,252	18,248
LSOA fixed effects	Yes	Yes	Yes

Each cell displays the result of a separate regression. The unit of observation is a LSOA/election year. We only report the difference-in-differences coefficient, i.e., the coefficient before the treatment (LSOA centroid less than 20 km from a nuclear plant) interacted with a dummy for 2015. The dependent variables are votes for the Green/Labour/Conservative parties at the 2010 and 2015 UK General Elections. Standard errors in parentheses are clustered at the constituency × year level. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.1$. All specifications include month/zone dummies which clean for all time variations in the 100 km-neighbourhood of any nuclear plant (Panel A) or waste sites (Panel B).

E Policy after the Fukushima accident

To verify that the Fukushima accident did not trigger political adjustments that could specifically impact treated areas, we first study the evolution of the expenditures of local authorities, then that of the central government's grants. Local authorities fund their budget using four main sources: (i) the council tax, (ii) the uniform business rate for local businesses, (iii) central government grants, and (iv) a variety of fees and charges. We collected data on central government grants and local authorities' expenditures from the Department for Communities and Local Government over the period 2008–2014. We did not find any evidence of a change in the allocation of central government's grants, or in the structure of local authorities' expenditures between treated and control areas after the accident.

Second, we examine the evolution of MPs' votes at the Westminster Parliament before and after the accident. We collect data on MPs' votes over the period 2001–2015 from `www.publicwhip.org.uk`. We select drafts whose titles include either the words "energy", "power", " environment", "nuclear" (but no mention of "trident"—the name of the UK nuclear weapons program—or "nuclear weapon"), "climate", "green", or "renewable". We then classify the drafts into pro-nuclear, anti-nuclear, and neutral. This leaves us with 10 pro- and three anti-nuclear drafts over the period. MPs' political positions on nuclear power are summarised by their votes—Aye/No/Abstain—on these drafts. For instance, an "Aye" vote from an MP to a draft defending a pro-nuclear policy was labelled as pro-nuclear. Then, we estimate whether MPs in treated areas have changed their views regarding nuclear power after the Fukushima accident. We find no evidence of a shift in MPs' votes.