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Learning, Proximity and Voting: Theory and Empirical Evidence from Nuclear Referenda

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Abstract

This paper presents novel evidence on the pattern of voting in referenda and develops a spatial learning model that helps explain such behavior. In particular, we shed light on the determinants of voters' choices over nuclear power using data on two Italian referenda. Exploiting the panel structure of the data, we document that voting against nuclear power increases, whenever the distance from the closest nuclear plant decreases. However, we detect a different voting behavior between municipalities close to existing reactors and those close to proposed ones. A possible explanation is that many citizens hold more precise information on nuclear safety because they have experienced the presence of a reactor in their vicinity for many years. Therefore, we propose a model of voting with endogenous information acquisition interacting both proximity and learning effects, whose results are compatible with the empirical findings. Citizens receive public and private signals and revise their beliefs on the risk of living close to a plant. Such revision process is nested into a spatial voting model establishing conditions for a similar or different voting behavior of the electorate based on the proximity from the reactor.

Keywords: Bayesian Learning, Referendum, Nuclear Power, Proximity

JEL codes: D72, D83.

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1. Introduction

TV and Radio coverage, campaign advertisements, public debates, and even politically oriented social contents are essential in forming opinions. The diffusion of information plays a role in cases such as local or national elections, but it is even more critical in the event of referenda. For instance, voters must decide between two or more alternatives about a particular policy issue that is sometimes unfamiliar or too technical. Citizens may acquire information from a wide variety of sources, e.g., pamphlets, editorials, or direct mailings that could influence their voting decisions.

In some cases, the issues of the referendum are relatively new to the voter and may involve the construction of some facilities in the surrounding area. Communities react to such possibility with extreme apprehension. They can pay more attention and change their perception of the costs and benefits of a project whenever the target of the proposed siting is in their vicinity. The public reaction could be a function of the perceived risk of building a facility close to their community, as in our analysis, nuclear plants. Thus, the perception among communities may differ in the same referendum, whenever a part of the electorate has pre-existing views or more precise information about this risk.

One contribution of our paper is to show how a different pattern of voting outcomes appears by looking at two Italian referenda about nuclear power held in November 1987 and June 2011. We investigate how proximity influences community voting in a setting where citizens are uncertain about the real risk of a facility. The structure of our data is essential since the 2011 referendum gathers information about the municipalities close to the *existing* plants, built before 1987 and never demolished, and to the *proposed* plants, made in case the referendum in 2011 had been passed.

We first rely on a *differences-in-differences* design exploiting the panel structure of data for 1987 and 2011 at a *province* level. We show that voting outcomes against nuclear power increase whenever the distance from the closest nuclear plant decreases and this is driven by the proposed construction of new plants. Second, we develop a local analysis by taking into account the municipalities relatively close to both existing or proposed nuclear plants in 2011 to evaluate potential differences in voting behaviors.

As one can intuitively expect, the closer the community to a reactor, the larger the vote against nuclear energy. That is a *proximity* effect well-known in the political economy literature.[1] Note, however, that this holds only around the proposed nuclear plants. Instead, communities surrounding the existing facilities have different reactions to the presence of nuclear power stations when proximity varies. We observe that communities closer to the existing reactor vote in favor of nuclear energy, while as the distance from the reactor increases, the municipalities vote against the nuclear option.

[1] See *inter alia* Coates and Humphreys (2006) and Groothuis and Miller (1997).

The negative reaction against the presence of the facility smoothly decreases beyond a certain distance from the reactor. Such non-monotonic pattern of voting behavior in the 2011 referendum could be mainly compatible with different explanations, e.g., a cost-benefit analysis across communities or balanced budget incentives for the municipalities close to the nuclear plants.

This paper proposes an alternative view discussing the possibility that potential information sources induce different or similar behaviors in voting outcomes across communities. We offer a theoretical explanation by introducing a *learning* process in a spatial voting model with endogenous information acquisition. Voters have information about the risk of having a facility close to their community. Naturally, voters close to pre-existing nuclear stations have more precise information on the risks of a nuclear accident since they have experienced it for many years. Voters close to proposed plants are instead exposed to a less accurate flow of information and therefore put effort in acquiring more of it.[2]

Our theoretical analysis consists of two steps. First, we consider the composition of the voters' payoffs according to public and private signals that voters receive. Opinions, rumors, commentaries are, in general, good examples of how individuals select the sources of their information based on their judgments.[3] Second, once the revision process is completed, individuals choose to vote in favor or against a proposal. We study such voting behavior when the distance from the reactor varies. We show how similarities or differences in voting outcomes emerge across communities, respectively, close to existing and proposed reactors. Intuitively, our empirical findings can be explained by the tradeoff between *learning* and *proximity* effects. For instance, a similar pattern of voting is possible when the distance from the nuclear reactor is large enough. It is reasonable since the role of private information diminishes at a more considerable distance, and the proximity effect is less prominent. Signals are even less precise due to the increasing distance, which reduces the difference in voting across communities. Alternatively, if the distance of the community from the reactor diminishes, we argue that a different non-monotonic U-shaped pattern in voting behavior may appear. This result is possible when the information captured by the community closer to the existing reactor is more precise than the one received by the community closer to the proposed reactor and the public news. Naturally, the lower the distance, the larger the risk perceived by the community due to the proximity.

[2]Interestingly, people in the provinces close to proposed plants have regularly visited *online* pages paying attention to the word '*nucleare*' ('nuclear' in Italian) to increase their knowledge of the topic. We capture this effect using Google Trend data, see Subsection 3.4 for further details.

[3]For instance, anti-nuclear campaigners led by the greens or political movements have organized different meetings in Italy after the Japanese Fukushima nuclear disaster in March 2011. The massive participation of people confirms the necessity of capturing information from various sources. See for instance http://www.repubblica.it/ambiente/2011/06/05/news/l_italia_si_mobilita_per_i_referendum_gli_appuntamenti_fino_all_8_giugno-17201072/

However, the learning effect may counterbalance the impact of proximity whenever the signals are more relevant. A fuller review of related research is postponed in Section 5.

The remainder of this paper is as follows: Section 2 provides information and data on the Italian nuclear referenda. Section 3 presents the empirical analysis, while the theoretical model is built in Section 4. Section 5 discusses some contributions related to our research and provides some concluding remarks.

2. Institutional background

2.1. Referendum

A referendum represents the first mechanism of direct democracy in which an entire electorate has the opportunity to vote on a particular proposal. It presents a somewhat different set of choices to the voter compared to the typical election asking questions on new areas of policy or previously undisclosed items. It usually offers the electorate a binary option of accepting or rejecting a proposal, although some countries have deliberate multiple-choice referenda, e.g., Sweden and Switzerland, see among others Nurmi (1997, 1998) and Hug (2004). The characteristics of a typical referendum are common around the world. They arise from a variety of legal forms and originate from a conscious political decision taken by a party, a movement or local/national institution.

In Italy, the so-called *popular* referendum, observed in our analysis, is the first type contemplated by the Italian Constitution (art. 75) and can be called at the request of five Regional Councils or $500,000$ voters. In this case, a referendum can abolish an existing law or just part of it, and as in many other countries in the world, it requires a quorum of 50%+1 for its outcome to be valid. Therefore, citizens against the proposal have two options. On one side, they can decide not to go to vote so to reduce the turnout and consequently the possibility to reach the quorum requirement. On the other side, they can vote 'NO' stating their aversion to the issue at stake in the ballot, but indeed contributing to reach the quorum. The first option is of course the one that is less costly for the voter so, while the referendum is stated in terms of YES vs NO to a given topic, the informational content remains on the turnout.[4]

2.2. *Italian nuclear referenda:* 1987 *and* 2011

After the Second World War, Italy started a program for constructing nuclear plants, facilities and reactors. In 1965, Italy ranked third in nuclear capacity after the USA and the UK. In particular,

[4]See Table A.2 in Herrera and Mattozzi (2010) where the usual pattern in referenda with a quorum is a considerable fraction of 'YES' votes among the voters.

four nuclear power plants were constructed between 1958 and 1978 in Latina, Garigliano, Trino and Caorso, and they were actively operating from 1963 to 1987. In November 1987, shortly after the Chernobyl disaster, Italy held its first national referendum to decide whether to shut down its nuclear power plants. More than 65% of the population voted, and 80% of them preferred to switch off all existing nuclear power stations. Note that the demolishing process of these plants is still ongoing nowadays, with some of them containing nuclear fuel. Although Italy experienced little exposure to radiation from the Chernobyl disaster, the accident radically shifted Italian public opinion against nuclear energy. For more than 20 years, Italy had been the only major European Union country without its nuclear power industry. In 2008, the Italian (center-right) government proposed an ambitious plan to reopen the four inactive reactors and to build nine new nuclear reactors in Chioggia, Monfalcone, San Benedetto del Tronto, Mola di Bari, Scanzano Jonico, Palma di Montichiaro, Oristano, Termoli, and Scarlino. This plan was part of Berlusconi's cabinet's program, elected in the same year, to reduce Italy's dependence on imported energy by 25% by 2030. The plan was slowed down for almost three years due to the strong opposition of some Italian regions, center-left parties, and green movements. Finally, another referendum on nuclear power was held on 13 June 2011, right after the Japanese Fukushima accident. This tragic accident caused deep public anxiety throughout the world and damaged the people's confidence towards nuclear power in Italy just a few months before the referendum.[5] This second referendum obtained a 54.8% turnout and the share of *Yes* votes, i.e., in favor of abolishing the construction of nuclear plants, reached 94% of the votes cast. This result definitively rejected the possibility of a nuclear revival in Italy.

3. Empirical analysis

In this section, we present our empirical analysis based on the two Italian referenda discussed above. We first exploit the panel dimension of the *provincial-level* data to test whether being closer to nuclear facilities increases the population's aversion to the construction of nuclear plants. Second, we exploit the fine-grained *municipality-level* data of 2011 referendum, together with the different nature of the nuclear power stations, i.e., existing vs. proposed ones, to assess the behavior among types of voters.

[5] At the time of the referendum, the Japanese catastrophe had even induced the German government into a U-turn on nuclear power. In particular, Germany's choice to abandon nuclear energy in 2020 might have strongly influenced public opinion in Italy.

3.1. Data on Referenda

We use data from the 1987 provincial level referendum and data from the municipality level for the 2011 referendum. We obtained province-level (municipality-level) data about the referendum held in November 1987 (June 2011) from the Department of Internal Affairs. As the primary dependent variable, we constructed the share of *Yes* votes as the number of *Yes* over the eligible voters, where voting *Yes* means to be in favor of the abrogation of the law re-opening/constructing nuclear plants. In other words, a larger *Yes* share indicates a *greater* aversion to nuclear power.

This variable is called Yes_{dt}, where $d = \{p; m\}$ indicates whether the variable is at province or municipality level, respectively. Note that while the referendum is stated in terms of *Yes* vs. *No* votes to a proposal, the informational content remains on the turnout, i.e., the percentage of individuals casting a ballot among the eligible voters. Indeed, we use the measure of the share of *Yes* votes relative to the eligible voters, which is 98% correlated with the turnout at the municipality level in 2011. Instead, the share of *Yes* votes among the votes cast is not at all informative for the considerations above.[6] The decision of *Non-voting* contributes to reducing the quorum, therefore it can be interpreted as a vote against the proposal. Not surprisingly, the share of *Yes* votes among those going to vote is very high (93.8% on average, minimum is 79.4%) with a standard deviation of less than 3%.[7] This result implicitly suggests that citizens going to vote (almost) surely voted *Yes*.

For the referendum held in 1987, we have information about 95 provinces existing in Italy at that time, while for the referendum held in 2011 we have more than 8000 municipality-level observations. In Subsection 3.3, we explain the procedure to incorporate information for each municipality at the province level.

In 1987, four nuclear power stations were already operating, while in 2011, the construction of nine more plants was on the government's agenda. We consider the relevant distance for each municipality as the one connecting with the closest of the full set of nuclear, existing and proposed, plants.[8] Figures 1 (a) and (b) show the variables $Distance_{m1987}$ and $Distance_{m2011}$, respectively. We can also construct the difference between the distance from the closest old plant and the distance from the nearest proposed plant (see Figure 1 (c)) to better understand the identification strategy used in the panel analysis (Subsection 3.3).

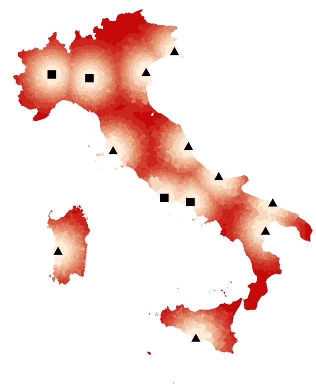
Note that the last variable, named $Difference_{m2011}$, is equal to zero for municipalities whose closest plant is an existing one. Instead, it takes positive values in case the nearest facility is a proposed one. Further, the more significant the difference between the distances from the closest

[6]The correlations between these variables and the distribution of *Yes* votes are shown in Appendix F.
[7]Summary statistics for these variables are shown in Table E.3.
[8]In the next section, we define the *existing* plants in 1987 as *old* ones, while the *proposed* plants in 2011 as *new* ones.

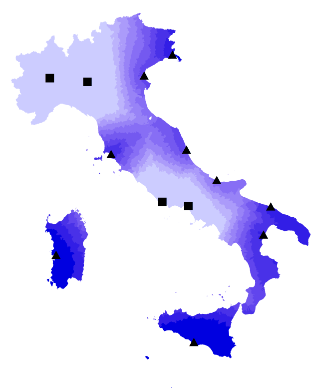
old and new plant, the more it increases. This variable indicates the change in the distance from a nuclear plant occurring in each municipality if the 2011 referendum had been passed. For example, by looking at Figure 1 (c), we observe that the cities in the North-West regions have not experienced any changes in the distance. The reason is that old plants were already present in those regions at the time of the referendum. Instead, municipalities in Sicily and Sardinia, the two largest Italian islands, have experienced the most significant change by hundreds of Kilometers as the nuclear plants in these areas were only the proposed ones.

Figure 1: Distances from nuclear plants

(a) Distance in 1987



(b) Distance in 2011



(c) Difference in distances

Notes. The figures report, using deciles, the distribution of each municipality's distance from the closest nuclear plant (existing or proposed) in 1987 (panel (a)) and 2011 (panel (b)). Panel (c) shows the difference between the distance in 1987 and the one in 2011. Plants existing in 1987 are represented by black squares, while plants proposed in 2011 by black triangles.

3.2. *Controls*

In the province-level, differences-in-differences analysis, we construct a parsimonious set of controls for two reasons: First, any slow-moving control would be absorbed by province fixed effects. Second, conditional on the latter and some time-variant controls (GDP per capita and unemployment level), we are confident that there is little room for omitted variables that could bias our results.[9]

In the municipality-level analysis, a cross-sectional one, we include several controls aimed at reducing the problem of bias introduced by omitted variables. Most of the variables come from the Italian National Institute of Statistics (www.istat.it), while we describe other sources below. Demographics include, among others, the share of over 65 years old inhabitants and the proportion of working-age people with a higher level of education. We can thus take into account different time horizons, which can have an impact on risk preferences over nuclear power and to proxy for income, not available at the municipality level. The share of commuters takes into account the decoupling between the place where people live most of the time and the place where they vote. As for labor market conditions, we have the share of foreigners (as possible substitutes/complements to natives) and the share of unemployment. We exploit information about industrial sectors by looking at the shares of workers in the agricultural, industrial, public administration, educational, tourism, commerce, health, real estate, and, most importantly, the energy sector to control for the structure of occupation, in particular, the direct or indirect linkages between the construction of a nuclear plant and the local labor market conditions. The share of homeownership proxies for a possible aversion to nuclear reactors related to real estate values. We obtained the turnout for the 2008 political election from the Department of Internal Affairs to control for differential propensity in voting. We include the share of the center-right coalition at the 2008 elections, as the center-right government elected in those elections was that responsible for the pro-nuclear power law under scrutiny in the 2011 referendum and therefore we expect this control to be highly correlated with the referendum votes. We also exploit the information provided by Google Trends constructing a Google Index, at province level, searching for the Italian word "nucleare" as the keyword between March and June 2011. The purpose is to capture a concrete measure of local awareness of nuclear power. We have also created the distance from the closest foreigner nuclear plant (Switzerland and France host nuclear power stations, some of them relatively close to the north-western Italian border). We also use the information on municipalities that obtain funds from the central government for hosting a nuclear plant. We, therefore, flag with a dummy those municipalities in the surrounding of the four power plants existing in 1987. Finally, to control for possible sorting of individuals, we look at the distance from those areas particularly

[9] Also, the 95 provinces X 2 periods structure of the data leaves few degrees of freedom to add many controls, as the main specification already includes time and provinces fixed effects.

suitable for the location of power plants, produced by the National Committee for Nuclear Energy in 1979.

3.3. *Differences-in-Differences analysis*

The first question we tackle is whether the distance from the closest nuclear plant has an impact on the local aversion to nuclear power due to risk considerations. We exploit the two waves of (barely identical) referenda occurring in 1987 and 2011 to address this question in a generalized differences-in-differences (*DID*, hereafter) setting with continuous treatment. We thus evaluate the real effect of the distance from the closest nuclear plant on the share of votes against nuclear power, netting out the location-specific and aggregate time-varying behaviors. Mostly geographic factors are at the basis of the decision to build a nuclear plant in a particular place, so location-specific fixed effects would take into account all these unobservables.[10] Figure 2 shows that most of the existing or proposed plants are within or in the surrounding areas identified in 1979 to be suitable for the siting of nuclear plants.

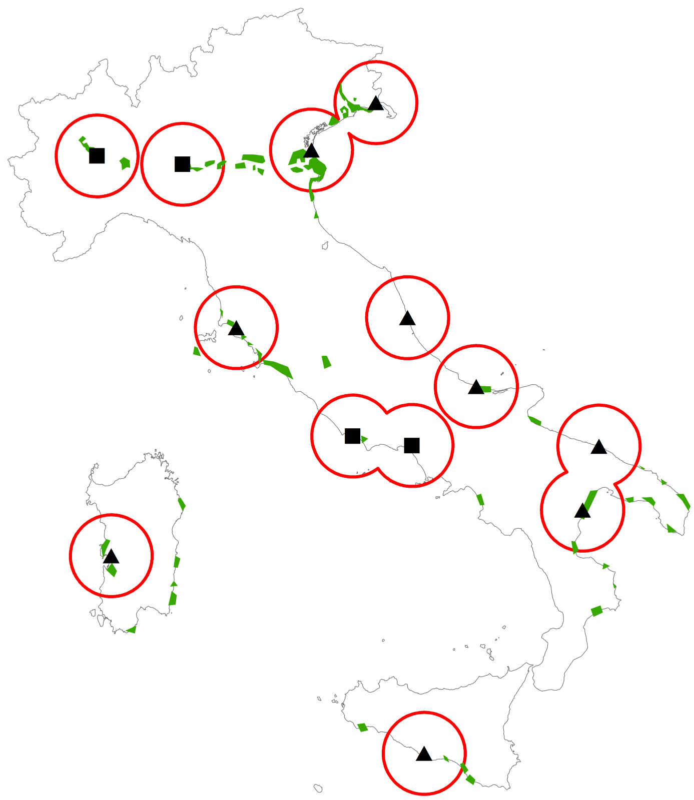
As mentioned in Section 2, all plants existing in 1987 were shut down after the first referendum although this process is ongoing on and some plants still contains nuclear fuels in their reactors. The government planned to re-open the old plants and build other nine plants after the possible favorable response of the second referendum in 2011. This particular pattern suggests that comparing 1987 and 2011, each location either gets close to a new proposed plant or stays at the same distance from the nearest existing plant as depicted in Figure 1 (c). Our regression model becomes:

$$Yes_{pt} = \gamma_p + \lambda_t + \beta Distance_{pt} + \varepsilon_{pt} \tag{1}$$

where γ_p are province fixed effects and λ_t is a time dummy for period 2011. They control for any time-invariant local characteristics (the former) and the aggregate variations over time (the latter). The parameter β is therefore estimated exploiting the change in the distance that occurs at the same location across the two periods. We compute the coordinates of the center of mass of each province p at time t using the distribution of population among its municipalities, pop_{mt} to calculate the distance from plants at the level of provinces ($Distance_{pt}$). We use the 1991 census for the demographic data at the municipal level in 1987, and we exploit the 2011 census for the second referendum. We then compute the latitude and longitude of the center of mass of each province p as,

[10] It seems unlikely that considerations on past voting behavior have strategically driven the decision to build plants first in some places and then in others at the referendum. See the report of the International Atomic Energy Agency, i.e., IAEA (1963), which describes the criteria to select the locations for nuclear sites. This argument, based on the historical narratives and the discussion of the newly formed government from 2008 on, may suggest that the estimates produced with our difference-in-difference estimator being causally robust.

Figure 2: Location of plants, suitable sites and buffers.



Notes. The figure shows the location of plants existing in 1987, represented as black squares, and plants proposed by 2011, described with black triangles. The green areas identify the sites considered as suitable for the siting of nuclear power stations by the National Committee for Nuclear Energy in 1979. Red buffers around plants show the sample used in the municipality-level analysis, i.e., those municipalities within a radius of 60 Km from the closest nuclear plant.

$$lat_{pt} = \frac{\sum_{m \in p} lat_m pop_{mt}}{\sum_{m \in p} pop_{mt}} \tag{2}$$

and

$$lon_{pt} = \frac{\sum_{m \in p} lon_m pop_{mt}}{\sum_{m \in p} pop_{mt}} \tag{3}$$

and we use these coordinates to calculate distances from the closest plant in the two periods as explained in the previous Subsection.

Table 1: Differences-in-Differences results

	(1)	(2)	(3)	(4)	(5)	(6)
Dep.Var.	yes	yes	yes	yes	yes	yes
Dummy plant	2.343	-0.115	4.953			
	(1.898)	(1.410)	(3.578)			
Distance				-0.0345***	-0.0192***	-0.0211***
				(0.00423)	(0.00563)	(0.00709)
Real GDP per capita			-5.53e-05**			-6.53e-05**
			(2.36e-05)			(2.81e-05)
Unemployment			1.636**			1.481**
			(0.707)			(0.674)
Within-province SD of distance			0.144			0.162
			(0.208)			(0.186)
Time Dummy	NO	YES	YES	NO	YES	YES
Province FEs	NO	NO	YES	NO	NO	YES
Observations	190	190	190	190	190	190
R-squared	0.007	0.273	0.841	0.201	0.320	0.857

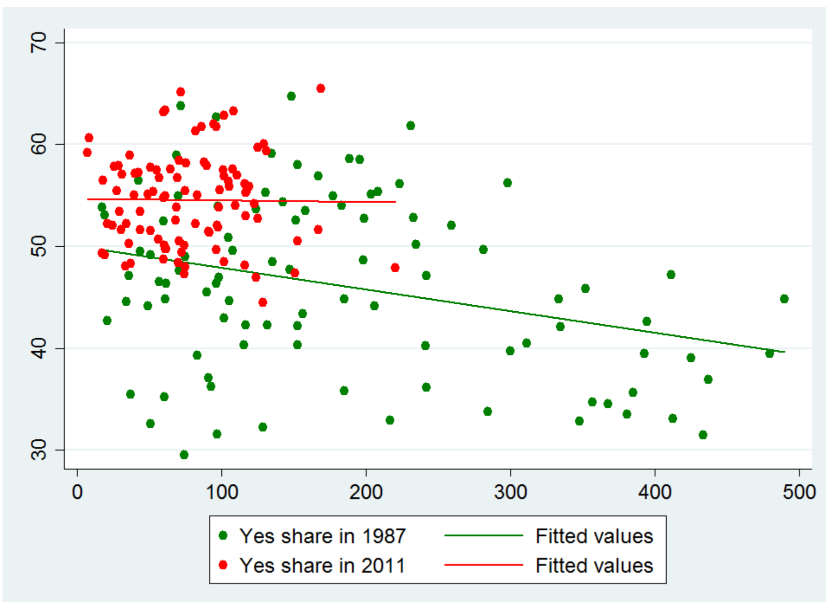
OLS estimates. The unit of observation is the province in two periods. The dependent variable is the number of *Yes* votes divided by the eligible voters. The explanatory variable in columns 1 to 3 is a dummy equal to one if in the province, at each given period, there is an existing or proposed nuclear plant. Instead from columns 4 to 6, it is the distance of the center of mass of the province from the closest existing or proposed nuclear plant in each given period. Columns 1 and 4 are univariate (constant not reported), columns 2 and 5 include a dummy for the second period while columns 3 and 6 includes fixed effects for each of the 95 provinces, the real GDP per capita, the unemployment rate (at macro-area level) and the within-province standard deviation of the distance from each municipality to the closest (existing or proposed) nuclear plant. Standard errors reported in brackets are clustered at the level of provinces. ***, **, * indicate significance at 1-, 5-, and 10-% level, respectively.

OLS estimation of eq. (1), collected in Table 1, calls for two considerations. First, the mere fact of having a nuclear plant in a province is not sufficient for the electorate to vote against nuclear power more than the average (see column 3, which includes time and province fixed effects, where the expected positive coefficient is there but it is not significant at conventional levels). This specification, in fact, might fail in capturing the distance-related risk perception of the electorate. Instead in column 6, we propose the full-fledged *DID* strategy and observe that the distance from the closest plant explains the vote against the nuclear program very precisely. In particular, a reduction of one standard deviation in the distance from a nuclear plant (roughly 100 Km) increases the share of voters against nuclear power by two percentage points, which is 4% at the mean of approximately 50%. Secondly and more importantly for the argument put forward in the introduction about risk perception and information acquisition, the identification here comes only from provinces which are getting closer to nuclear plants recalling Figure 1. Note that provinces already in the vicinity of an existing plant do not contribute to the estimation of parameter β, as their distance does not change over time. This means that the provinces in the former set are those that never experienced the physical presence of a nuclear plant and that at a certain point became aware that the construction of a new nuclear facility close to their community would have been realized in the case of a favorable outcome at the referendum. The provinces in the last set, instead, experienced the physical presence of a plant for decades.

Note that in columns 3 and 6 we also control for time variant variables that could confound our results. First, we have a raw measure of development, the province level real per-capita GDP. Second, we have unemployment level, which is only available for both time periods at the macro-area level (5 zones). Finally, to take into account the dispersion of the voters within each province we calculate the standard deviation of distance from the closest plant from each municipality belonging to the same province.[11]

The clear message of Subsection 3.3 is that the provinces that may perceive the potential risk of having a nuclear facility close to their communities are those more reactive in voting against nuclear power. The simple correlations between the distance from the nearest plant and the *Yes* share for the two periods, reported in Figure 3, help in interpreting the result. Note that in 1987, the provinces far away from the closest plant are not so interested in voting *Yes*, while in 2011 they are those that, more than proportionally, increased their *Yes* votes, making the association between the two variables flatter.

Figure 3: *Yes* votes and the distance from plants, 1987 and 2011



Notes. The figure shows the association between *Yes* votes and the distance from the closest plants (in Kilometers), using green (red) for 1987 (2011) data. Linear fit are added for the both periods.

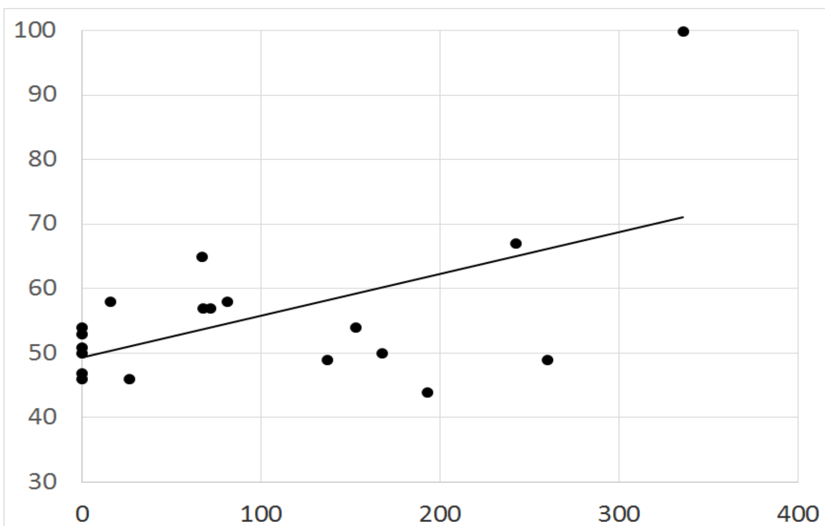
[11] Alternatively, one may prefer to weigh observations for the inverse of such standard deviation to take into account the geographic dispersion of the voters and give less weight to provinces where the distribution of voters is less concentrated around its center of mass. Results in this case are unchanged and are available upon request.

We now turn to the analysis at municipality-level for which data is available for the 2011 referendum to better understand whether there are differential electoral behaviors around existing or proposed plants.

3.4. Local analysis for the 2011 referendum

In this section, we use municipality-level data from the 2011 referendum and study whether different voting behaviors are at play around existing and proposed nuclear plants. It allows for a complete analysis compared to the one in the previous section, exploiting variations coming from areas where nuclear power stations did not exist. We restrict our sample in selecting only the cities in a specific range to unequivocally identify whether their nearest nuclear site is an existing or a proposed one. In particular, we investigate more than 2000 municipalities within a radius of 60 Km from the closest reactor to have disjointed areas. Figure 2 shows the subsample that includes the municipalities within the red buffers around the existing (squares) and proposed (triangles) plants.

Figure 4: Approach of nuclear plants and information acquisition



Notes. The figure reports the correlation between the Google Index of the 20 top provinces for the terms 'nucleare' in the three months before the 2011 referendum and the variable $Difference$, reported in Figure 1, panel (c).

Two considerations are worth making about the two categories of municipalities. It is well-known in the literature on proximity that risk is perceived more if the "risky object" is still not in place.[12]

[12] See Schively (2007) and Rabe et al. (2008). They have discovered that the risk perception of the nearest site is the most important factor related to NIMBY overreaction.

Once the reactor is constructed, risk perception decreases, so we should expect higher *Yes* values around proposed plants. Moreover, information flow and the formation of voters' opinions may undertake different paths based on previous experience of the reactor. Thus, citizens closer to proposed plants are, by definition, less informed about the real nuclear risk. They form expectations on the perceived risk based on other voters' opinions as well as other available sources. We can see this pattern in the data by plotting an index of information acquisition on the topic at stake in the referendum against a variable capturing the extent of the saliency of nuclear power, see Figure 4. Specifically, the former variable is the Google Index for the term 'nucleare' calculated at province capital level in the three months before the 2011 referendum, capturing the intensity of the search for the term on a $0-100$ scale.[13] The latter variable is instead captured by $Difference$, representing how salient the nuclear presence would be in case the referendum had been passed, following the discussion in Subsection 3.1.

As anticipated in Subsection 3.2, we collected several control variables for each municipality to reduce the problem of omitted variable bias, and we estimate in a cross-sectional *OLS* setting the effect of the distance from the closest nuclear plant on the municipality-level share of *Yes* votes, i.e., the measure of the local aversion to nuclear power. Results are proposed in Table 2. In column 1, the main explanatory variables are the *dummy* $d^P = 1 - d^E$, which takes the value one for those municipalities whose closest plant is a proposed one (while taking value zero for the remaining municipalities), and the variable *Distance*, the linear distance from the closest municipalities. The former variable shows a positive and strongly significant effect as expected. The latter delivers a negative and significant one, so overall, the negative relationship between distance and votes against nuclear power holds. However, once we allow for a differential effect of distance on existing and proposed nuclear plants in column 2, the coefficient of the distance from the proposed plants remains negative and becomes larger in absolute terms, while the one relative to existing facilities turns positive and significant. The more flexible quadratic specification in column 3 shows a non-monotonic effect of distance for old plants, implying a minimum in the votes-distance relation at around 33 Km. The dummy d^P takes positive and strongly significant values in both specifications.[14] A non-parametric specification is then developed where, for each municipality, dummies for distance in the ranges $0-10$, $10-20$, $20-30$, $30-40$, $40-50$ and $50-60$ Km (d_1 to d_6) are constructed and interacted with the dummies

[13]The Google Index is computed following the procedure suggested by the Google Trends service, see `https://trends.google.com/trends/`.

[14]In Table E.4, we replicate the results for the quadratic specification and the non-parametric one (presented below) with and without controls. Having controls does not change the results on distances qualitatively. The quadratic specification shows a minimum at 32 Km for the existing plant sample and a monotonic effect of distance in the proposed plant one. The non-parametric results without controls, though less significant, are confirmed.

Table 2: Municipality level cross-sectional local analysis

	(1)	(2)	(3)
Dep.Var.	yes	yes	yes
Constant	50.40***	46.84***	50.55***
	(4.854)	(4.857)	(4.904)
d^P	3.047***	6.048***	4.479***
	(0.302)	(0.593)	(0.964)
Distance	-0.0146**		
	(0.00630)		
$Distance * d^P$		-0.0548***	-0.181***
		(0.00953)	(0.0401)
$Distance^2 * d^P$			0.00182***
			(0.000590)
$Distance * d^E$		0.0189**	-0.196***
		(0.00856)	(0.0410)
$Distance^2 * d^E$			0.00295***
			(0.000546)
Controls	YES	YES	YES
Observations	2,597	2,597	2,597
R-squared	0.546	0.552	0.558

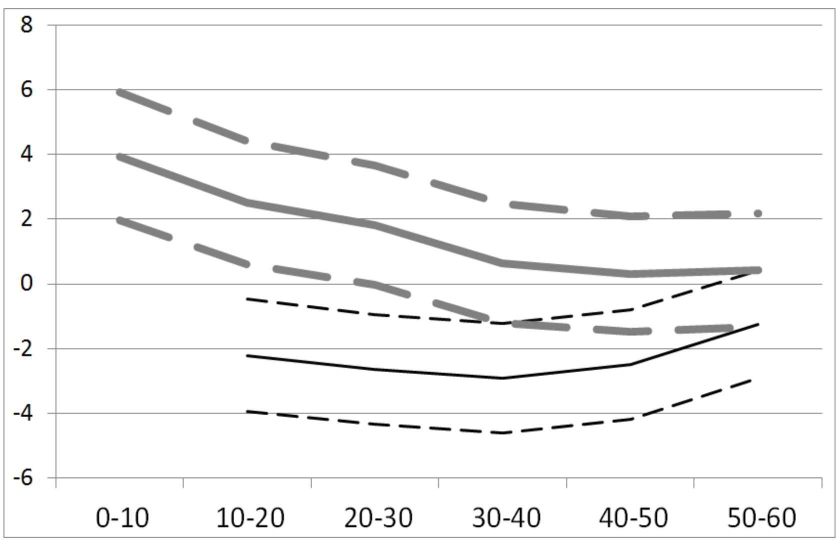
OLS estimates. The unit of observation is the municipality. The dependent variable is the number of ”Yes” votes divided by the size of the electorate. The explanatory variable in column 1 is the distance of the municipality from the closest existing or proposed nuclear plant. Column 2 allows for a differential effect of distance between existing and proposed plants, while column 3 allows distances to enter quadratically. Robust standard errors are reported in parentheses. ***, **, * indicate significance at 1-, 5-, and 10-% level, respectively.

d^P and d^E. In compact form, where the dummy for a distance below 10 Km from an existing plant is taken as a reference point, it is the following:

$$Yes_m = \alpha + \sum_{b=2}^{6} \beta_b^E d_{bm} d_m^E + \sum_{b=1}^{6} \beta_b^P d_{bm} d_m^P + \gamma \mathbf{X}_m + \varepsilon_m \qquad (4)$$

Figure 5 summarizes the results of this regression using this functional form (with all the controls used in the previous specifications). The last findings confirm *i*) a larger concern, i.e., voting against nuclear power, in the areas close to a proposed nuclear plant when distance reduces, *ii*) a non monotonic pattern, i.e., *U*-shaped vote against nuclear energy, with distance in the areas close to an existing plant.[15] In the following section, we set up a theory able to explain such behavior as the outcome of a process of learning about the formation of the public opinion and voting choice.[16]

Figure 5: Differential effect of distance



Notes. The figure reports the coefficients of an OLS estimation of equation 4. The X-axis shows the bins (in Km) of distance from the relevant nuclear plant and the Y-axis indicates the coefficients obtained from the regression. The constant α, corresponding to the baseline category of distance below 10 Km from an existing plant, is 49.86 (the standard error is 4.85). The thin black (thick grey) line connects the coefficients of the distances from the existing (prospected) plant, while dashed lines correspond to 95% confidence intervals.

[15] See Table E.4 which reports further specifications of Table 2 and the results graphically shown in Figure 5.

[16] Figure F.7 reports a strong correlation between our dependent variable and the turnout. All results shown in Table 2 and Figure 5 are confirmed when we use the turnout as dependent variable, see Table E.5.

4. Model Setup

After the analysis proposed in the previous section and in particular the results shown in Figures 4-5 and Table 2, we propose a theoretical framework based on the heterogeneity of information that voters receive. Our results can motivate a similar or different behavior in voting outcomes between communities closer to existing vs. proposed reactors consistent with the empirical analysis.

This section introduces a Bayesian process where voters receive informative signals, for instance, about the potential risk of explosion by the nuclear industry, activists' research, or antinuclear movement community debates. They want to predict the value of the random variable θ, interpreted as the environmental hazard of a facility close to their communities. According to our empirical evidence, θ identifies the perceived risk of a potential nuclear meltdown or a reactor explosion.

There is a unit mass of ex-ante identical citizens indexed by $i \in [0,1]$. We distinguish between the existing nuclear reactors, i.e., *old ones*, and the proposed reactors, i.e., *new ones*. Consider $\gamma \in \{o,n\}$, respectively, indicating *old* and *new* reactor. The private and public signals received by voter i thus depend on the proximity to the closest nuclear plant. We identify with κ^γ the distance of the community from the γ facility.

Formally, voters share a common prior $\theta \sim N(\bar{\theta}, \sigma_\theta^2)$ with precision $\tau_\theta \equiv \sigma_\theta^{-2}$. Each voter i receives a noisy private signal about the common risk, $x_i^\gamma = \theta + \varepsilon_i^\gamma$, with $\varepsilon_i^\gamma \sim N(0, \kappa^\gamma \sigma_{\gamma\varepsilon}^2)$. We consider the possibility that voters relatively far from the (old or new) reactor, have a different perception about the potential risk of a facility compared to the closest ones.[17] This is the reason why the variance depends on the distance from the facility in our setting. The dispersion of information, therefore, increases as the distance of the community from the nuclear plant rises. Error terms in the signals are uncorrelated among voters and with the θ parameter, i.e., $cov(\varepsilon_i^\gamma, \varepsilon_j^\gamma) = 0$ for $\forall i \neq j$ and $cov(\varepsilon_i^\gamma, \theta) = 0$. Secondly, voters receive a public signal $y = \theta + \omega$, with $\omega \sim N(0, \sigma_\omega^2)$.[18] We define $\tau_{\gamma\varepsilon} \equiv (\sigma_{\gamma\varepsilon}^2)^{-1}$ as the precision of the noise in the private signal, and $\tau_\omega \equiv (\sigma_\omega^2)^{-1}$ as the precision of the noise in the public signal. Note that the posterior of public information is $\tau' = Var[\theta|y]^{-1} = \tau_\theta + \tau_\omega$.

Each voter i form their opinion $\upsilon_i^\gamma \in \mathbb{R}$ about the advantage or drawback of nuclear energy and bases their revision process on the information set $I_i^\gamma = \{x_i^\gamma; y\}$. The costly information acquisition is captured by a linear cost of precision $C_i(\tau_{\gamma\varepsilon}) = c\tau_{\gamma\varepsilon}$, where c is a positive cost parameter.[19]

[17] For instance, voters at 3 km from a plant are more interested (and therefore pay more considerable attention) to the presence of the reactor compared to the voters at 60 km.

[18] It is worth to note that the public signal can be even endogenous. For instance, it can be based on other voters' opinions $y = \int_0^1 \upsilon_i^\gamma di + \varpi$, studying the uncertainty of the aggregation process, see e.g., Bayona (2018). An endogenous source of information in the referendum can be explained by the fact that voters make decisions on a particular issue contingent on the noisy contemporaneous forecast about the aggregate action of citizens. Results on this extension are available upon request.

[19] Solutions to the minimization process can be obtained even in case of nonlinear costly information acquisition.

Therefore, each individual i wants to minimize the loss function such that,

$$\min_{\upsilon_i^\gamma} L_i^\gamma(\theta, \upsilon_i) = \mathbb{E}[(\theta - \upsilon_i^\gamma)^2 | I_i^\gamma] + C_i(\tau_{\gamma\varepsilon}) \quad \text{for } \gamma \in \{o, n\} \tag{5}$$

Given $\tau_{\gamma\varepsilon}$, the solution to eq. (5) is $\upsilon_i^\gamma = \mathbb{E}[\theta | I_i^\gamma]$. The prediction error due to the uncertainty about the risk of the facility is therefore $\mathbb{E}[(\theta - \mathbb{E}[\theta | I_i^\gamma])^2] = Var[\theta | I_i^\gamma] = \left(\tau' + \kappa^\gamma \tau_{\gamma\varepsilon}\right)^{-1}$. Thus the minimization process of eq. (5) becomes,

$$\min_{\tau_{\gamma\varepsilon}} L_i^\gamma(\kappa^\gamma, \tau', \tau_{\gamma\varepsilon}) = \left(\tau' + \kappa^\gamma \tau_{\gamma\varepsilon}\right)^{-1} + C_i(\tau_{\gamma\varepsilon}) \tag{6}$$

where $\tau_\gamma^* = \frac{\sqrt{\kappa^\gamma} - \sqrt{c}\tau'}{\sqrt{c}\kappa^\gamma}$ for $\gamma \in \{o, n\}$ is the unique solution to eq. (6).[20] The posterior applying the Bayesian Law is a function of both private and public information of voters,

$$\upsilon_i^{\gamma *} = \mathbb{E}[\theta | x_i^\gamma; y] = \mu^\gamma x_i^\gamma + (1 - \mu^\gamma) y \tag{7}$$

with $\mu^\gamma = \frac{\kappa^\gamma \tau_\gamma^*}{\tau' + \kappa^\gamma \tau_\gamma^*}$ as the weight of the private signal received by voter i at the optimal level of information acquisition precision, τ_γ^*.[21]

4.1. Voting choice

We have described before how private and public sources of information may help agents to form an opinion about the risk of a facility closer to their community. Once the revision process is completed, people translate their opinions into a vote in favor or against a proposal. This logic is captured in this section by introducing a spatial voting model of behavior. In the spirit of Herrera and Mattozzi (2010), each voter faces the decision between two general alternatives, *reform* or *status quo*, respectively $\tilde{\omega} = \{\omega_1, \omega_0\} \in \mathbb{R}$. Our empirical evidence for instance examines the following alternatives, *i*) '*yes*' at the referendum, i.e., for the abrogation of the law about re-opening/constructing nuclear plants, ω_1, or *ii*) '*no*' at the referendum, i.e., in favor of the law that restores nuclear energy, ω_0. Voter i's decision is coded as $\chi_i = 1$ if he votes in favor of ω_1, and $\chi_i = 0$ if he votes in favour of ω_0. Given the large elections, voters' aggregate decision is taken by simple majority rule. First, voters have quadratic payoffs over a unidimensional policy space (*yes/no*), and each voter i chooses

[20] Comparative statics $\frac{\partial \tau_\gamma^*}{\partial \kappa^\gamma} < 0$ correctly suggests that voters at larger distance from the facility have lower incentives to invest in the information acquisition process.

[21] Our framework is extremely flexible. We can imagine that voters revise their opinions according to a public information vector $y^t = \{y_1, y_2, ..., y_t\}$, where each y_t is the public signal received by voters at time t. We can show that the unique linear strategy derived from the Normal distribution simply changes in the weighted average precision of the signals.

the alternative, ω_1 or ω_0, closer to $\upsilon_i^{\gamma*}$, i.e., the voter i's posterior solution of eq. (7). Secondly, even if the learning process helps voters to form opinions on the risk of a facility, they remain imperfectly informed about the real consequences of the alternatives in place. This aspect is modeled by an additional individual and alternative-additive shock to the utility that the voter receives. Thus, the payoff function of a representative voter i is,

$$U_i^\gamma(\tilde{\omega}) = -\frac{1}{\kappa^\gamma}(\upsilon_i^{\gamma*} - \tilde{\omega})^2 + \kappa^\gamma \xi_{i,\tilde{\omega}} \tag{8}$$

where $\xi_{i,\tilde{\omega}}$ has a Normal distribution.[22] Formally, voter i prefers ω_1 to ω_0 if and only if ω_1 is closer to $\upsilon_i^{\gamma*}$ than ω_0.[23] Thus, voter i decides to vote $\chi_i = 1$ if and only if $\Delta U_i^\gamma = U_i^\gamma(\omega_1) - U_i^\gamma(\omega_0)$ > 0, or alternatively, defining $\tilde{\xi}_i \equiv (\xi_{i,1} - \xi_{i,0}) \sim N(0, \sigma_\xi^2)$, if and only if $\tilde{\xi}_i > \psi\left(\varphi - \upsilon_i^{\gamma*}\right)$, where $\psi \equiv \left(\frac{\omega_1 - \omega_0}{\kappa^\gamma}\right)$ and $\varphi = \left(\frac{\omega_1 + \omega_0}{2}\right)$.[24] The difference in the payoffs can then be written as:

$$\Delta U_i^\gamma = \psi\left(\upsilon_i^{\gamma*} - \varphi\right) + \kappa^\gamma\, \tilde{\xi}_i \tag{9}$$

4.2. Differences in voting outcomes between existing and proposed reactors

We now study how the presence of an existing or proposed reactor close to their community may (or not) influence their voting outcomes differently. The distance from the reactors is considered equal in both cases, i.e., $\kappa^n = \kappa^o = \kappa^*$. We formally define the *similarity* in voting behavior between communities close to the existing (new) reactors and the ones close to the proposed (old) reactors.

Definition 1. *A similar voting behavior for a hypothetical voter i, living in communities that surround the existing and proposed reactors, is possible when there is no difference in the voting payoffs, i.e.,* $\Delta\tilde{U}_i = \Delta U_i^n - \Delta U_i^o = 0$.

A similar voting behavior between different communities is due to the role that uncertainty of information plays when the distance κ^* varies. It confirms that Bayesian process becomes completely

[22]With Normal distributions, there is a positive probability that the additional shock in the utility function is negative in equilibrium and the uncertainty can increase or decrease the value of the payoff.

[23]An alternative framework would require to set directly the agent i's payoff function as follows: $U_i^\gamma(.) = \upsilon_i^\gamma - \theta/d_i$ in the event the plant is built or reopened, where θ is the unknown probability of a nuclear accident, d_i is the distance from the plant and υ_i^γ is the utility gained from having a cheap source of power independently of d_i. In this setting, the definition of i) the individual payoffs and ii) the voting choice collapses into the same stage. Voter i gets information about θ, and whether $\mathbb{E}[\theta | I_i^\gamma] > d_i \upsilon_i^\gamma$, where $I_i^\gamma = \{x_i^\gamma; y\}$ is the set of signals, she votes against the proposal. In case the plant is not built or reopened, the voter gets zero payoff and they must vote. The results could be similar to the one proposed in the main text.

[24]The probability of $\chi_i = 1$ in the case of Normal distribution would be equal to $\Phi(\psi[\upsilon_i^{\gamma*} - \varphi])$.

uninformative as the difference in voting outcomes decreases when communities are relatively far from an existing or proposed plant. The following Lemma summarizes the result:

Lemma 1. *Voting outcomes for a hypothetical voter i living in communities that surround existing and proposed reactors are equal as $\kappa^* \to \infty$ for $\gamma \in \{o, n\}$.*

Proof. See Appendix A □

Lemma 1 claims that the information acquisition process may create agreements in voters' outcomes. It underlines a potential common trend between voters living near existing (old) and proposed (new) reactors when the distance from the plant becomes more important. Since the weight assigned to the precisions of the new information is lower when the distance increases, the difference in risk perception systematically decreases for communities located relatively far from an old or a new reactor. Voters consistently update their payoffs by a Bayesian process, but they do not change their optimal choice in response to a signal precision because of the larger impact of the distance. In this case, two effects are in place. First, the learning process is less precise since private information is more uncertain due to the distance, and second, the proximity effect is less prominent. The combination of learning and proximity induces more uninformative signals and a larger perception that nuclear plant is far away. As a result, such combination drives the difference among communities to zero.

Whenever the condition proposed by Definition 1, i.e., $\Delta U_i^n = \Delta U_i^o$ is not satisfied, an alternative pattern of voting outcomes exists. Let us discuss, indeed, the difference in voting outcomes of a hypothetical voter i that lives, respectively, close to an existing reactor and a proposed one, $\gamma \in \{o, n\}$, as $\Delta\tilde{U}_i = \Delta U_i^n - \Delta U_i^o \neq 0$. Moreover, a different voting behavior conditioned on the distance κ^* from the plant is coded $\Delta\tilde{U}_i|_{\kappa^*}$. Proposition 1 below suggests that some conditions in the learning process ensure such behavior,

Proposition 1. *A different voting behavior for a hypothetical voter i living in communities that surround existing and proposed reactors is possible when $\Delta\tilde{U}_i|_{\kappa^*} > \Delta\tilde{U}_i|_{\kappa^*+1}$.*

Proof. See Appendix B □

According to Lemma 1, we observe that differences in voting outcomes are not possible when the distance increases, as both the learning and the proximity effects slide away. Instead, Proposition 1 claims that a different voting behavior may exist when the communities are closer to the nuclear reactors, i.e., when the distance decreases. In particular, it shows that $\Delta\tilde{U}_i|_{\kappa^*} - \Delta\tilde{U}_i|_{\kappa^*+1} > 0$ whether the following sufficient condition is satisfied, i.e., $x_i^o > y/\kappa^*$. This means that if the private information received by a hypothetical voter *i* close to the old reactor is higher than the public information spread across the communities, then the difference in voting outcomes emerges. The larger the distance, the easier it is to satisfy the sufficient condition. The result is reasonable and allows for an interesting interpretation. It requires that the private knowledge voters living in communities closer to existing plants have about the risk of a nuclear accident is larger than the public information across all (existing and proposed) communities. This is possible and consistent with our evidence as communities closer to existing plants have strong pre-existing views about the risk of an explosion as they have experienced the presence of a reactor for many years. However, this is only part of the story because if the distance were too small, the sufficient condition would not be respected.

In other words, the closer is the reactor, the more difficult is for the private information to be higher than the public one. Intuitively this is true in the proximity of the reactor where the information provided by the reactor is common knowledge among communities, and the variance of the private noise tends to zero, i.e., $\varepsilon_i^o \sim N(0, \kappa^o \sigma_{o\varepsilon}^2)$. This result opens the questions on how differences in voting outcomes may emerge when the proximity matters more than the learning process. Corollary 1 summarizes the result.

Corollary 1. *A different voting behavior for a hypothetical voter i that lives in communities in the proximity of the existing and proposed reactors is possible when* $x_i^o > y + \tilde{\tau}^*(x_i^n - y)$, *with* $\tilde{\tau}^* = \tau_o^*/\tau_n^*$.

Proof. See Appendix C □

Formally, the sufficient condition proposed as a solution of Proposition 1, $x_i^o > y/\kappa^*$, is not anymore satisfied as the distance from the reactor is zero, i.e., $\kappa^* = 0$. Corollary 1 shows the condition to obtain a different voting behavior between communities in the proximity of the existing and proposed reactors according to the learning procedure. In particular, the private information owned by voters close to the old reactor should be higher than the public information, as in the previous analysis. However this is not enough as a more strict requirement is necessary due to an additional component, i.e., $\tilde{\tau}^*(x_i^n - y)$, which identifies the *weighted* difference between private information owned by voters close to the new reactor and the public information. Such term can be positive or negative and suggests that when the proximity effect is much stronger as the distance is zero, the learning process may counterbalance the public information by a more precise signal received by communities closer to the new reactor. Therefore, since the information provided by the reactor is common knowledge when the distance is zero, the private information captured by the old reactor should be more precise even more than the difference between the private one perceived by voters closer to the new plant and the public one that all voters receive. In this case, a different voting behavior emerges where voters in the proximity of a proposed reactor prefer to vote '*yes*' at the referendum, i.e., for the abrogation of the law about restoring nuclear energy, while voters in the proximity of an existing reactor prefer to vote '*no*' at the referendum. The reason in the last case is that the voters have strict, precise information about the risk of a nuclear accident in that area.

The condition in Corollay 1 is also helpful to establish a non monotonic pattern of voting behavior between communities closer to existing and proposed reactors when the distance increases.

Proposition 2. *A non-monotonic U-shaped pattern in voting outcomes $\Delta\tilde{U}_i|_{\kappa^*}$ is possible for a hypothetical voter i living in communities where the existing and proposed reactors are located is possible when $x_i^o > y + \tilde{\tau}^*(x_i^n - y)$, with $\tilde{\tau}^* = \tau_o^*/\tau_n^*$. In particular,*

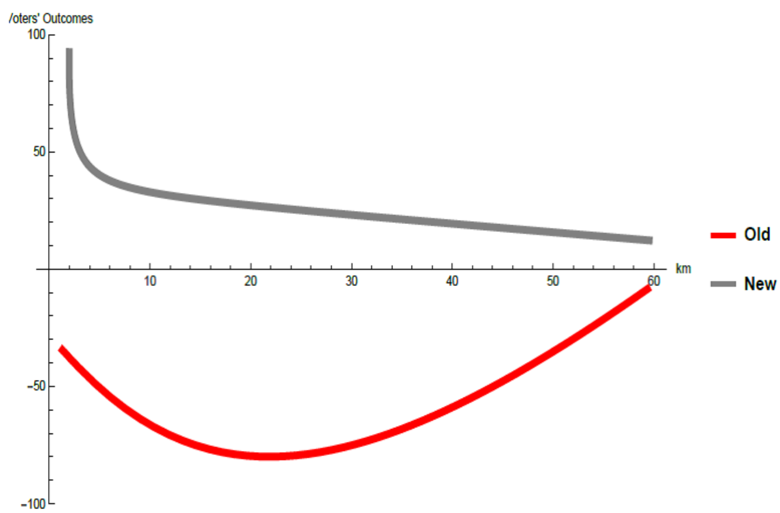
1. *There exists a positive root κ^* identifying the minimum value of $\Delta\tilde{U}_i|_{\kappa^*}$.*
2. *Assuming $\tau_o^* = \tau_n^* = \tau^*$, a minimum value of $\Delta\tilde{U}_i|_{\kappa^*}$ is obtained at $\kappa_{\min} = \frac{\tau' + \tau^*}{2\tau^*}$.*

Proof. See Appendix D □

Points 1 and 2 of Proposition 2 analyze the pattern of voting outcomes studying the condition of a non-monotonic voting behavior. Point 1 shows that a minimum value of $\Delta\tilde{U}_i|_{\kappa}$ exists for a certain value $\kappa^* > 0$. Results are based on the condition, $x_i^o > y + \tilde{\tau}^*(x_i^n - y)$, proposed by Corollary 1. It claims that when voters living in the proximity of an old reactor have larger private signal than voters close to the new reactor plus public information, the pattern of voting is non monotone and there exists a value $\kappa^* > 0$ such that the difference in outcomes $\Delta\tilde{U}_i|_{\kappa^*}$ has a minimum. This suggests that whenever the private information held by voters close to old reactor is extremely precise, the combination of learning and proximity impacts determine a variation in the trend of voting. In particular, Proposition 2 shows that such variation is not constant and a minimum value that justifies the non-monotonic pattern exists. Point 1 is able to identify the existence of a positive root κ^*, while under some simplifications, point 2 studies in a closed form solution the conditions proposed by point 1. It shows that in the simplified case where the precision of the private signals from old and new reactors are equal, i.e., $\tau_o^* = \tau_n^* = \tau^*$, there exists a unique value $\kappa_{\min} = \frac{\tau' + \tau^*}{2\tau^*}$ that minimizes $\Delta\tilde{U}_i|_{\kappa_{\min}}$. Note that the condition, $x_i^o > y + \tilde{\tau}^*(x_i^n - y)$, is still satisfied even if the weights assigned to the private and public information are equal and $\tilde{\tau}^* = 1$. In this case, the role of public information disappears and it is enough that $x_i^o > x_i^n$ to capture the minimum value of $\Delta\tilde{U}_i|_{\kappa}$ at $\kappa_{\min} = \frac{\tau' + \tau^*}{2\tau^*}$.

A simple simulation in Figure 6 confirms the results proposed in Lemma 1, Corollary 1 and Propositions 1 and 2. The values of the parameters are respectively $\tilde{\xi}_i = 0.1$ and $\varphi = 1.5$. The public signal y is 0.4, while the private signals x_i^n and x_i^o are 1.6 and 1.8. The precisions of private signals related to the reactors, i.e., τ_n^* and τ_o^* are 1.2 and 0.45, while $\tau' = 2.2$. First it is observable in Figure 6 how the difference in outcomes between existing and proposed reactors disappears when the effect of distance is much larger as suggested by Lemma 1, while it emerges for communities close to the old plant if and only if the condition $x_i^o > y + \tilde{\tau}^*(x_i^n - y)$ is satisfied as $1.8 > 0.4 + (0.45/1.2)(1.6 - 0.4) = 0.85$.[25] The results proposed in Lemma 1, Corollary 1 and Propositions 1 and 2 in the previous simulation are consistent with our empirical evidence (see Figure 5 in Subsection 3.4) where we observe a similar pattern of voting at a substantial distance associated to a monotonic decreasing trend of voting for communities closer to proposed reactors and a non monotonic pattern for the municipalities closer to existing reactors.

Figure 6: Differences in voting outcomes close to existing and proposed reactors.



Notes. The figure reports the simulation of voting outcomes. The red curve describes the pattern of municipalities that are close to a proposed reactor, while the gray one shows the non monotonic pattern of voting outcomes for municipalities that are close to an existing reactor.

[25]Results related to the pattern of voting outcomes are remarkably robust to changes in the process for different values of parameters.

5. Discussion and Concluding remarks

In this paper, we have observed how voting may substantially vary between communities close to existing nuclear reactor and the ones likely to host a new facility in case of a negative response at the referendum.[26] Such different voting behavior can have different explanations. However, given the detailed empirical setting and the information pattern shown in Section 3, we choose to propose a spatial voting model with a revision process of voters' opinions. Most citizens know remarkably little about the question they are being asked to render a decision, and their attitudes and beliefs may even reflect their physical vicinity to the nuclear facility.

The empirical literature on voting in referenda at the national level is not well-developed. This is the reason why here we focus only on theoretical contributions in the field of the Bayesian revision process. Our paper ties into the burgeoning literature of learning process popularized by Vives (1993) and extended by the branch of literature that studies coordination games *à la* Morris and Shin (2002), Angeletos and Pavan (2004) and Angeletos and Pavan (2007), among others. Notably, recent contributions, see for instance, Colombo et al. (2014), assume that Gaussian-quadratic model and the linear solutions are common hypotheses. Our theoretical explanation is simple in concept; we assume that each voter has a quadratic-payoff function to match the real risk of the facility. We focus on the effect that proximity may have on voting outcomes both at the empirical and theoretical level.

Voters need to acquire information about an issue and then take a binary decision (yes/no) following Herrera and Mattozzi (2010). Public opinion should nevertheless feel more involved whenever the location of the facility is close to their backyard. That motivates the analysis of the distance from the reactor and allows to untangle the impact that *learning* and *proximity* may have on voters' decisions. Another difference to the previous papers is that in our setting, the information acquisition arises endogenously by a linear strategy solution *à la* Burguet and Vives (2000) (see Vives (2008) and Bayona (2018) for an interesting extension with an endogenous signal). The result we obtain involves a symmetric Bayesian equilibrium in the determination of voters' choices as a function of public and private information in addition to the prior value. This can be differentiated just in accordance with the information that voters receive whether the community is closer or not to existing and proposed

[26] According to a political economy view, the dynamics of a general election can be harder to understand than those of a referendum, and the electoral participation is not always guaranteed. In our setting, instead, the involvement in the referendum on nuclear power can be more easily assumed due to the issue at stake, and this is true independently by the voting decision taken. Ethical voting behavior by Coate and Conlin (2004) and Feddersen and Sandroni (2006) according to the utilitarian rule can help explain this mechanism. Ethical behavior suggests that voters benefit in learning since the entire community can benefit from being informed and of course, raises the need for information and induces the participation of the electorate.

reactors. Moreover, this revision process translates into a binary voting outcome *(yes/no)* by looking at a spatial voting model with uncertainty.

We thus investigate the conditions for a similar or different voting behavior across communities in the vicinity of existing and proposed reactors. We imagine a hypothetical voter close to a reactor, and we explain the variation of the voting outcomes conditional on the distance from the plant. For instance, a similar voting behavior between voters living near existing and proposed new reactors is possible when the weight assigned to the precisions of new information diminishes with distance. However, an alternative pattern of voting can be justified under different conditions whenever the effect of proximity matters, i.e., the distance is lower. In this case, if the private information of a community close to an old reactor is larger than the public and private information of the other communities, then the difference in outcomes is non monotonic with a minimum level at intermediate distances. Our analysis confirms the importance of studying learning and proximity effects together and the take-home message is that the impact of current information on voters' strategies can often make a substantial difference in determining referendum outcomes.

Our insights are much more widely applicable. Although we do not apply our results outside the context of the environmental problem, a future avenue in other fields may be fruitful. In particular, we observe that our model could be of extensive use in all those situations where the effect of information precision can depend on virtual or real distance in its broad perspective, and where information acquisition endogenously arises and converges into a final aggregate decision. Among the many examples we can think of, we have the selection of politicians, the process of hiring skilled workers, the decision to launch an IPO, the effects of exchange rate fluctuations in investors' expectations.

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Appendix A. Proof of Lemma 1

Let us start from eq. (9) and for simplicity make a distinction between a hypothetical voter i that lives, respectively, close to an existing reactor and a proposed one, $\gamma \in \{o, n\}$. It follows that,

$$\Delta U_i^n = \psi(\upsilon_i^{n*} - \varphi) + \kappa^n \tilde{\xi}_i \quad \text{and} \quad \Delta U_i^o = \psi(\upsilon_i^{o*} - \varphi) + \kappa^o \tilde{\xi}_i \tag{A.1}$$

Starting by eq. (7), we can refer to $\upsilon_i^{n*}(x_i^n, y) = \mu^n x_i^n + (1-\mu^n)y$ and $\upsilon_i^{o*}(x_i^o, y) = \mu^o x_i^o + (1-\mu^o)y$ as the posterior beliefs of voter i close to an existing reactor (o) and a proposed one (n), with $\mu^n = \frac{\kappa^n \tau_\gamma^*}{\tau' + \kappa^n \tau_\gamma^*}$ and $\mu^o = \frac{\kappa^o \tau_\gamma^*}{\tau' + \kappa^o \tau_\gamma^*}$. We can define $\Delta \tilde{U}_i = \Delta U_i^n - \Delta U_i^o$ such that,

$$\Delta \tilde{U}_i = \psi(\upsilon_i^{n*}(x_i^n, y) - \upsilon_i^{n*}(x_i^n, y)) + (\kappa^n - \kappa^o)\tilde{\xi}_i \tag{A.2}$$

We may explicitly derive eq. (A.2) as a function of the precisions of the signals τ_γ^* and τ'. By symmetry, i.e., $\kappa^n = \kappa^o = \kappa^*$, and taking the limit for $\kappa^* \to \infty$, it follows that,

$$\lim_{\kappa^* \to \infty} \Delta \tilde{U}_i = 0 \tag{A.3}$$

Appendix B. Proof of Proposition 1

Starting from a hypothetical voter i that lives, respectively, close to an existing reactor and a proposed one, $\gamma \in \{o, n\}$, we can define the difference in outcomes conditional on the distance from the plant as $\Delta \tilde{U}_i|_\kappa$ and we observe the effect of varying the distance, κ^γ, for $\kappa^n = \kappa^o = \kappa^*$,

$$\Delta \tilde{U}_i|_{\kappa^*} > \Delta \tilde{U}_i|_{\kappa^*+1} \tag{B.1}$$

such that,

$$[\upsilon_i^{n*}(x_i^n, y) - \upsilon_i^{n*}(x_i^n, y)]_{\kappa^*} > [\upsilon_i^{o*}(x_i^o, y) - \upsilon_i^{o*}(x_i^o, y)]_{\kappa^*+1} \tag{B.2}$$

Rearranging terms of eq. (B.2), it follows that,

$$\frac{(\tau' + \kappa^* \tau_o^*)(y\tau' + \kappa^* x_i^n \tau_n^*) + (\kappa^* x_i^o - y)(\tau' + \kappa^* \tau_n^*)}{\kappa^*(\kappa^* + 1)(\tau' + \kappa^* \tau_n^*)(\tau' + \kappa^* \tau_o^*)} \lesseqgtr 0 \tag{B.3}$$

The sign of eq. (B.3) is of course uncertain although a sufficient condition to have a positive value, $\Delta \tilde{U}_i|_{\kappa^*} - \Delta \tilde{U}_i|_{\kappa^*+1} > 0$ is that $x_i^o > y/\kappa^*$.

Appendix C. Proof of Corollary 1

Taking the limit of the difference of eq. (B.1) for $\kappa^* \to 0$, it follows that

$$\lim_{\kappa^* \to 0} \left[\Delta\tilde{U}_i|_{\kappa^*} - \Delta\tilde{U}_i|_{\kappa^*+1}\right] = \frac{1}{\tau'}\left[(x_i^n \tau_n^* - x_i^o \tau_o^*) + y\,(\tau_o^* - \tau_n^*)\right] \tag{C.1}$$

thus rewriting eq. (C.1), the difference in voting outcomes of a hypothetical voter i in the proximity of an existing and a proposed reactors appears as,

$$\Delta\tilde{U}_{i,\kappa^* \to 0} = \frac{1}{\tau'}\left[(x_i^n \tau_n^* - x_i^o \tau_o^*) - y\,(\tau_n^* - \tau_o^*)\right] \tag{C.2}$$

which suggests that the difference in outcomes at zero distance from the reactor exists when,

$$x_i^o > \tilde{\tau}^*(x_i^n - y) + y \tag{C.3}$$

where $\tilde{\tau}^* = \tau_o^*/\tau_n^*$.

Appendix D. Proof of Proposition 2

The proof is divided in two steps. In the first step, we investigate the existence and the uniqueness of a positive real root, i.e., $\kappa^* > 0$, that satisfies the first- and second- order conditions for a minimum. Then, in the second step, we search for an optimal solution in a closed form as the precisions of the private signals in $\gamma \in \{o, n\}$ are equal, $\tau_n^* = \tau_o^* = \tau^*$.

Differentiating $\Delta\tilde{U}_i$ with respect to κ^*, it follows that,

$$\begin{aligned}\Delta\tilde{U}_i'(\kappa^*) = {} & \frac{x_i^n \tau_n^*\,(\tau' + \tau_n^* + 2\kappa^* \tau_n^*)\,(\tau' + \kappa^* \tau_o^*)^2 - x_i^o \tau_o^*\,(\tau' + \tau_o^* + 2\kappa^* \tau_o^*)\,(\tau' + \kappa^* \tau_n^*)^2}{(\kappa^*+1)^2(\tau' + \kappa^* \tau_n^*)^2(\tau' + \kappa^* \tau_o^*)^2} \\ & - \frac{y\tau'\,(\tau_n^* - \tau_o^*)\,(\tau' + \kappa^* + (2+3\kappa)\tau_n^* \tau_o^*) + (1-2\kappa^*)\tau'\,(\tau_n^* + \tau_o^*)^2}{(\kappa^*+1)^2(\tau' + \kappa^* \tau_n^*)^2(\tau' + \kappa^* \tau_o^*)^2}\end{aligned} \tag{D.1}$$

We can search for a cubic equation in κ^* such that $\Delta\tilde{U}_i'(\kappa^*) \leq 0$. Applying Descartes' rule, we notice that there is only one sign change in $\Delta\tilde{U}_i'(\kappa^*)$ and a positive value root exists such that $\Delta\tilde{U}_i'(\kappa^*) = 0$. Indeed, $\Delta\tilde{U}_i'(0) = \tau'(x_i^n \tau_n^*(\tau' + \tau_n^*) - x_i^o \tau_o^*(\tau' + \tau_o^*) - y(\tau' + \tau_n^* + \tau_o^*) < 0$ if eq. (C.3) is strictly satisfied and $\Delta\tilde{U}_i'(\infty) = \tau_n^{2*} \tau_o^{2*} > 0$, thus the positive real root exists for $\kappa^* > 0$.

Now let us assume that $\tau_n^* = \tau_o^* = \tau$ for the sake of simplicity. Then the solution in closed form for $\Delta\tilde{U}_i'(\kappa^*) \leq 0$ is equal to:

$$\kappa_{\min} = \frac{\tau' + \tau^*}{2\tau^*} \tag{D.2}$$

with $\Delta\tilde{U}_i''(\kappa_{\min}) > 0$. In this case the weight assigned to the public information y is zero as $\hat{\tau}^*$ collapses to zero when $\tau_n^* = \tau_o^* = \tau$ and $\tilde{\tau}^* = 1$. Thus eq. (D.2) shows the κ^*-value that satisfies the local minimum if and only if $x_i^n < x_i^o$ and suggests that the non monotonicity condition proposed in the main text is satisfied.

Appendix E. Tables and extra Results

Table E.3: Descriptive statistics of main variables

Variable	Mean	St.Dev.	Min	Max
Sample: municipality, full sample, 8092 obs.				
Distance from closest plant (Km)	80.5	153.5	0	237.2
Distance from closest existing plant (Km)	153.5	114.1	0	649.0
Distance from closest proposed plant (Km)	162.5	95.7	0	419.3
Sample: municipality restricted to <60 Km, 2693 obs.				
Share of YES votes	53.1	6.7	25.2	78.9
Turnout	56.6	6.5	28.7	80.8
Share of YES votes among voters	93.7	2.9	79.4	100
Distance from closest plant (Km)	39.8	14.0	0	60
Distance from closest existing plant (Km)	118.8	115.3	0.4	467.1
Distance from closest proposed plant (Km)	153.9	114.9	0.0	371.8

Variable	Mean	St.Dev.	St.Dev. Within Prov.	Min	Max
Sample: provinces, panel, 190 obs.					
Distance from closest plant (1987) (Km)	183.2	122.8	15.3	17.1	490.0
Distance from closest plant (2011) (Km)	78.0	39.7	13.5	7.4	220.5

Table E.4: Municipality level cross-sectional local analysis - Old vs New

	(1)	(2)	(3)	(4)
VARIABLES	yes	yes	yes	yes
d^P	6.581***	4.479***		
	(1.316)	(0.964)		
Distance*d^P	-0.125**	-0.181***		
	(0.0612)	(0.0401)		
Distance^2*d^P	0.000486	0.00182***		
	(0.000855)	(0.000590)		
Distance*d^E	-0.148***	-0.196***		
	(0.0523)	(0.0410)		
Distance^2*d^E	0.00228***	0.00295***		
	(0.000723)	(0.000546)		
10-20*old plant			-0.896	-2.204**
			(0.941)	(0.893)
20-30*old plant			-1.017	-2.644***
			(0.913)	(0.869)
30-40*old plant			-1.532*	-2.918***
			(0.896)	(0.861)
40-50*old plant			-1.167	-2.489***
			(0.877)	(0.858)
50-60*old plant			0.0434	-1.243
			(0.858)	(0.847)
0-10*new plant			7.684***	3.940***
			(1.281)	(1.011)
10-20*new plant			5.130***	2.511***
			(1.048)	(0.972)
20-30*new plant			5.053***	1.805*
			(0.951)	(0.938)
30-40*new plant			4.066***	0.646
			(0.927)	(0.939)
40-50*new plant			2.601***	0.295
			(0.904)	(0.908)
50-60*new plant			2.273**	0.428
			(0.890)	(0.890)
Sh. over 65		-17.76***		-17.67***
		(2.759)		(2.762)
Sh. high school		-2.008		-1.814
		(2.783)		(2.787)
Sh. commuters		3.766***		3.706***
		(0.936)		(0.944)
Sh. house owners		7.787***		7.837***
		(1.898)		(1.907)
Sh. foreigners		-10.45***		-10.50***
		(3.163)		(3.156)
Unemp. rate		0.414		0.459
		(3.083)		(3.098)
ln(Population)		0.0335		0.0305
		(0.147)		(0.148)
Sh. agri.		1.530		1.607
		(3.699)		(3.662)
Sh. pub. admin.		21.56***		21.74***
		(5.400)		(5.370)
Sh. construction		-2.532		-2.340
		(4.527)		(4.482)
Sh. manufacturing		7.827**		7.956**
		(3.533)		(3.497)
Sh. tourism		-0.804		-0.569
		(5.658)		(5.620)
Sh. commerce		4.579		4.507
		(5.396)		(5.355)
Sh. health		3.697		3.986
		(5.812)		(5.800)
Sh. real estate		29.21***		30.13***
		(7.934)		(7.948)
Sh. education		24.84***		24.93***
		(5.970)		(5.953)
Sh. energy		0.828		1.002
		(14.64)		(14.59)
Turnout political elect. 2008		0.209***		0.210***
		(0.0245)		(0.0245)
Sh. votes center-right		-0.417***		-0.416***
		(0.0128)		(0.0128)
Google Index		0.00558		0.00552
		(0.00517)		(0.00517)
Distance foreign plant		-0.00736***		-0.00734***
		(0.00109)		(0.00109)
Dummy CIPE transfers		0.0981		-0.0657
		(1.366)		(1.441)
Dist. NCNE areas		-7.252**		-7.093**
		(3.579)		(3.597)
Constant	53.16***	50.55***	52.15***	49.86***
	(0.847)	(4.904)	(0.815)	(4.847)
Observations	2,693	2,597	2,693	2,597
R-squared	0.123	0.558	0.126	0.560

OLS estimates. The unit of observation is the municipality. The sample includes all those municipalities within a redius of 60 Km from the closest existing or proposed nuclear plant. The dependent variable is the number of "Yes" votes divided by the size of the electorate. The explanatory variables in columns 1 and 2 are the distance of the municipality from the closest nuclear plant interacted with the two statuses a municipality can take in terms of being close to an existing or proposed plant, i.e. the dummies d^P and d^E, plus squared terms. This allows for a differential effect of distance between existing and proposed plants. The explanatory variables in columns 3 and 4 are dummies for distance of municipalities from their closest plant in the ranges $0-10$, $10-20$, $20-30$, $30-40$, $40-50$ and $50-60$ Km, interacted with the dummies d^P and d^E. Controls, only present in even columns, are described in the main text. Robust standard errors are reported in parentheses. ***, **, * indicate significance at 1-, 5-, and 10-% level, respectively.

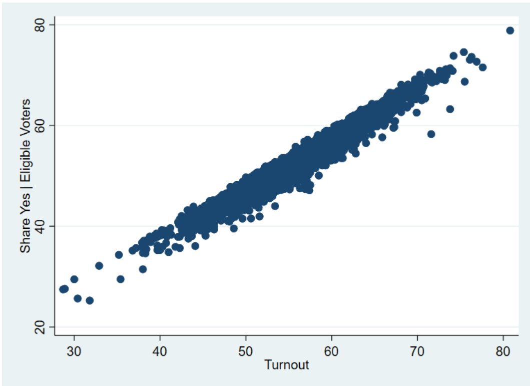
Table E.5: Municipality level cross-sectional local analysis - Old vs New

VARIABLES	(1) turnout	(2) turnout	(3) turnout	(4) turnout
Constant	51.21***	47.86***	51.77***	50.66***
	(4.977)	(4.993)	(5.040)	(4.977)
d^P	3.011***	5.826***	3.778***	
	(0.300)	(0.578)	(0.936)	
Distance	-0.0144**			
	(0.00621)			
Distance*d^P		-0.0522***	-0.157***	
		(0.00938)	(0.0393)	
Distance^2*d^P			0.00152***	
			(0.000581)	
Distance*d^E		0.0170**	-0.209***	
		(0.00847)	(0.0399)	
Distance^2*d^E			0.00311***	
			(0.000534)	
10-20*old plant				-1.829**
				(0.846)
20-30*old plant				-2.446***
				(0.821)
30-40*old plant				-2.741***
				(0.814)
40-50*old plant				-2.381***
				(0.808)
50-60*old plant				-1.050
				(0.800)
0-10*new plant				3.713***
				(0.952)
10-20*new plant				2.592***
				(0.925)
20-30*new plant				1.998**
				(0.884)
30-40*new plant				0.766
				(0.887)
40-50*new plant				0.518
				(0.861)
50-60*new plant				0.563
				(0.843)
Controls	YES	YES	YES	YES
Observations	2,597	2,597	2,597	2,597
R-squared	0.529	0.534	0.540	0.542

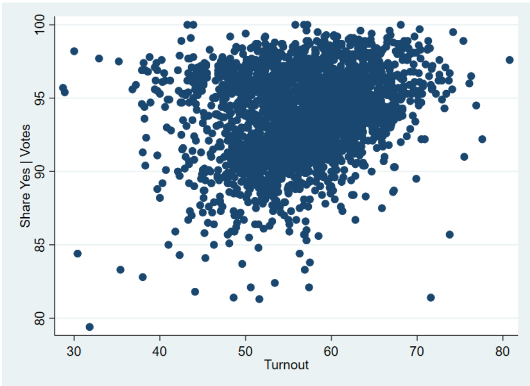
OLS estimates. The unit of observation is the municipality. The sample includes all those municipalities within a radius of 60 Km from the closest existing or proposed nuclear plant. The dependent variable is the turnout. Columns 1 to 3 replicate specifications reported in columns 1 to 3 of Table 2, while column 4 replicates the results shown in Figure 5. Controls are always present and are described in the main text. Robust standard errors are reported in parentheses. ***, **, * indicate significance at 1-, 5-, and 10-% level, respectively.

Appendix F. Graph and Data

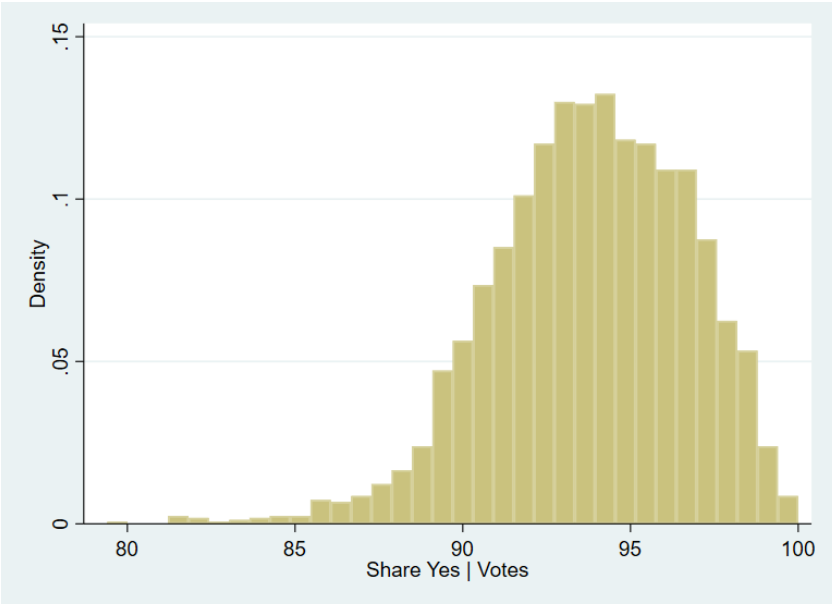
Figure F.7: Turnout, the share of *Yes* votes over eligible voters and the share of *Yes* votes among the votes cast.



(a) Share *Yes* | Eligible voters on Turnout



(b) Share *Yes* | Votes on Turnout



(c) The distribution of the share *Yes* | Votes

Notes. Figures (a) and (b) show the correlations between Turnout and the share of *Yes* votes over eligible voters or the share of *Yes* votes among the votes cast. Figure (c) depicts the distribution of the share of *Yes* votes among the votes cast.