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Abstract

This paper studies the social acceptance of nuclear energy and nuclear waste. Using a randomized choice experiment, we find that the prospects of a nearby nuclear waste repository reduce the acceptance of nuclear power. This result indicates the the Not-In-My-Backyard problem is partially driven by free-riding: individuals willing to accept the advantages of nuclear energy but not willing to internalize the associated cost. We also find that economic incentives decrease free riding and potentially help solve the Not-In-My-Backyard problem.

Keywords

environmental policy, nuclear power, nuclear waste, NIMBY, crowding intrinsic motivation

JEL Classification

C91, D71, D72, Q53, Q58, R53

1 Introduction

"Why should you have nuclear waste in your backyard?" This rhetoric question was asked by then-president Trump at a rally in Las Vegas in February 2020. It referred to a major decision by Trump not to fund licensing a potential nuclear waste site in the Yucca Mountain, Nevada, roughly 80 mi (130 km) northwest of the Las Vegas Valley.[1] This decision was targeting the upcoming presidential election in anticipation of a head-to-head state race with Biden. A reversal from an established solution for nuclear waste, Trump's policy promised to be extremely popular with the local population as the rich history of local opposition suggests.[2] However, it also lead to the abolishing of the single US option for designated long-term storage for high-level radioactive waste, a solution that had taken more than four decades to be elaborated.

Negative attitude towards nuclear waste is not a US-specific phenomenon. As an example, local communities near the town Kimba in Australia have united in a joint bid to prevent the implementation of a government plan to build a local repository (Shepherd, 2022). Negative attitudes towards nuclear waste have been documented in all 27 Member States of the European Union (Eurobarometer, 2008). Nuclear waste repositories belong therefore to the economic and political phenomena referred to as "Not-In-My-Backyard" (NIMBY) projects: projects associated with large net costs for immediate neighbors who as a result oppose the siting of these projects (Feinerman et al., 2004).[3]

Strong NIMBY opposition to nuclear waste repositories as also not a novel phenomenon. As an example, more than 30 years ago, when asked in a telephone survey about the minimum distance they would like to live away from each of ten different types of facilities, participants indicated a median distance of 200 miles from a nuclear waste facility (Flynn et al., 1990). This distance was three to eight times the distances from other types of facil-

[1]The case is described in the New York Times article "One Side of a Nuclear Waste Fight: Trump. The Other: His Administration." from February 23rd, 2020.

[2]See Ryan (2012) for an example of how the local population has opposed the Yucca Mountain site proposal.

[3]Other examples for NIMBY facilities are prisons and airports.

ities such as nuclear power plants and pesticide manufacturing plants. The early literature has documented multiple cases of fierce local opposition to planned repositories (Slovic et al., 1991, 2016). However, in the present context of climate emergency, the question of how to deal with nuclear waste and local opposition to repositories has been rolled out anew as an increasing number of governments is considering building new or extending the lifetimes of existing nuclear power plants.[4]

Scholars have developed several approaches for solving the NIMBY problem. A major approach in the economic literature is to create a "political market" for NIMBY facilities (Mitchell and Carson, 1986), a traditional instrument from the economic toolkit. This market mechanism would allocate nuclear waste repositories through a referendum, in which the local population is offered a package of economic incentives (private or communal) in exchange for a yes vote. The economic incentives represent a compensation for the negative externalities that arise from the NIMBY facility, while the referendum represents a "market" transaction. Thus, the political market mechanism is equivalent to allocating property rights to the communities. Under the basic premise that local population responds positively to economic incentives, this mechanism leads to a welfare-maximizing allocation of NIMBY facilities.[5]

However, this mechanism has been challenged. Early studies have found that economic incentives substantially reduce the acceptance of nuclear waste facilities, arguing that compensation payments may be perceived as bribes, see, e.g., Kunreuther and Easterling (1996) for a review of this literature. The influential paper by Frey and Oberholzer-Gee (1997) finds that economic incentives crowd out intrinsic motivation and dramatically corroborates support for nuclear waste repositories. Subsequent studies have replicated this result (Kim et al., 2019). These findings suggest that the main economic mechanism for solving the NIMBY problem of nuclear waste - the political market approach - may in fact be ineffective. Other mechanisms suggested by the literature are also associated with substantial

[4] See for example an article by Kerstin and Neuerer (2022) in the influential German newspaper "Handelsblatt" which discusses the Swiss and German permanent repository policies.

[5] This insight follows from the Coase Theorem (Coase, 1960; Medema, 2020).

drawbacks, meaning that currently there is no viable economic solution for the nuclear waste problem.[6]

However, the empirical studies on the effect of economic incentives on the acceptance of nuclear waste facilities listed above all share a common feature: their findings are based on *sequentially asking all participants the same acceptance question twice* - once without including information on economic incentives and once with. The effect of economic incentives is then inferred from the difference in answering the two sequential questions. The main advantage of this pragmatic approach is that it is a low-cost approach. It requires smaller samples than experimental studies with a treatment and a control group (because each person belongs to both groups). However, this approach is associated with two potential biases. First, asking the same question a second time adding a remuneration offer may be interpreted by participants as a clue about undisclosed problems. Thus, a reversal of answers would thus capture the framing effect and bias the interpretation of the estimates.[7] A very similar problem will occur if participants interpret the second question as a signal of social desirability. This is particularly likely when the interviews are conducted in person as in Frey and Oberholzer-Gee (1997), see, e.g., Presser and Stinson (1998) for a study on effect of the mode of data collection on the truthfulness of the answers.

The objective of this paper is to empirically re-evaluate the NIMBY problem of nuclear waste and the political market solution with an approach that does not induce the framing effects that exist in the related literature. To that end, we design and implement a choice experiment that allows us to measure (i) the social acceptance of new nuclear power plants, (ii) the social acceptance of new nuclear waste repositories, (iii) the effect of building a near-

[6]One mechanism to deal with NIMBY projects is the so-called "political approach" by Feinerman et al. (2004). In their approach, the government decides where to place the NIMBY facility. Feinerman et al. (2004) shows that the socially optimal solution will differ from the one decided by the government, unless there is perfectly elastic housing demand. A different mechanism is proposed by Fredriksson (2000), who suggest that the community producing the socially desirable good should also host the NIMBY facility associated with it. Due to geological requirements on the nuclear waste facility, this solution cannot be applied to nuclear waste. Finally, a solution based on variation in local environmental taxes is considered in Markusen et al. (1992). This solution bears similarities to the political market solution.

[7]Evidence for framing effects in surveys is pervasive, see, e.g., Ahlert et al. (2016), Stalans (2012), and Dillman et al. (1995).

by nuclear repository on the acceptance of new nuclear power plants and (iv) how economic incentives impact (i)-(iii).

To motivate our design, note first that an implicit definition of a NIMBY problem is a project or a facility that is a mixture of a socially desirable good and a private bad (Feinerman et al., 2004). We use (i) as an estimate of the extent to which a nuclear power plant is perceived as a public good, while (ii) provides an estimate of the degree of local opposition, and therefore, a measure of the private bad. Taken together, (i) and (ii) characterize the extent of the NIMBY problem in the context of nuclear power. To see the added value of (iii), note further that the social desirability of a project does not specify who exactly gains from it. Socially desirable undertakings are typically loosely defined as projects which increase overall welfare (Frey and Oberholzer-Gee, 1997). More specifically, it is not clear whether the gains of the new technology (e.g., nuclear power) are perceived as such by those who would have to bear the local cost from the byproduct (nuclear waste). In this paper, we argue that such a distinction provides important insights about the anatomy of the NIMBY project and its potential remedies. In particular, willingness to adopt a new technology (nuclear power plants) but only as long as someone else bears the potential cost (nuclear waste) is a form of free-riding. We refer to this free-riding phenomenon as "Yes, but not in my backyard" (YNIMBY). The estimate of (iii) captures precisely this YNIMBY phenomenon. It measures the decrease in the acceptance rate of new nuclear power plants that would result if individuals are forced to bear the associated costs. Finally, studying the effect of economic incentives on (i)-(iii) (that is, our fourth type of estimates (iv)) is informative about the potential effectiveness of the political market solution to both the NIMBY and the NIMBY problems.

Our study provides several important findings. First, the acceptance of new nuclear power plants is 67%, which is substantially higher than when respondents also have to accept new close-by repositories (54%). This confirms that nuclear power is a NIMBY phenomenon in the sense that it is generally associated with social gains, but that the actual implementation could possibly fail because of local opposition. Second, we find a large and significant estimate of (iii). Specifically, the acceptance of new nuclear power decreases by more than 10% when respondents are told that new power plants would make it necessary to build a near-by nuclear waste repository. This decrease in support is indicative of the presence of a large group of free-riders (YNIMBY). The effect is entirely driven by female participants: their acceptance rate falls by 26% as a result of the information of near-by repositories, compared to a close to zero effect for male participants. Finally, we find that economic incentives substantially increase both social acceptance of nuclear power and nuclear waste, and they also decrease the share of free-riders to almost zero.

Our paper contributes to the related literature in several ways. First, it contributes both methodologically and conceptually to the above discussed literature on the effect of economic incentives on the NIMBY problem. On the methodological side, a main advantage of our experiment is that it provides exogenous experimental variation of the information on economic incentives (iv). This experimental variation ensures a comparison of two distinct groups (a treatment and a control one), so that no framing effects of the types discussed above arise. In addition, a unique feature of our experiment is that it was implemented in a staggered way. Due to the large increase of energy prices in 2022, the staggered implementation allows us to use a second source of experimental variation of economic incentives. Both types of variation of the treatment lead to the same result: economic incentives increase the acceptance of the NIMBY project. Thus, our results challenge the findings by the existing studies and call for re-evaluation of the conclusions. On the conceptual side, our design allows to learn about a novel aspect of the anatomy of the NIMBY problem, namely the free-riding YNIMBY phenomenon. To the best of our knowledge, this is the first paper to estimate the extent of free-riding in the context of a NIMBY good.

Our paper is also related through the estimates (i) and (ii) to the studies that study the public perception of nuclear power and nuclear waste, respectively. Typically, these studies are based on non-experimental cross-sectional surveys, see, e.g., Kim et al. (2014), Lee (2020), Mah et al. (2014), and Wang and Kim (2018) for nuclear power and Litmanen et al. (2010) for nuclear waste.[8] Thus, their findings have largely a descriptive nature. In addition, these studies either focus on (i) or on (ii), so that they are not suited to provide evidence on the free-riding YNIMBY mechanism. Another limitation of these studies is related to the volatility of the acceptance rates over time. In particular, our study documents a large change of acceptance rates within a very short term period of time (less than a year). We also show that this change in opinions is strongly correlated with changes in the economic incentives. Thus, this instability of public opinion, or put differently, the strong dependence of the acceptance rate on the underlying economic conditions put into question the added value of cross-sectional surveys on acceptance of nuclear power for long-term public policy.

Finally, our paper is related to the literature on gender differences in risk aversion. A large body of research has documented that women show higher risk aversion than men, see, e.g., Borghans et al. (2009), Byrnes et al. (1999), Cárdenas et al. (2012), Charness and Gneezy (2012), and Friedl et al. (2020). Our results partially challenge this conclusion. While women appear to be more risk averse than men regarding nuclear waste (as measured by (ii)), they are less risk averse with respect to new nuclear power plants (as measured by (i)). We also show that part of the difference in the answers is in fact caused by free-riding rather than pure risk aversion.

The paper is structured as follows. In Section 2, we describe our experiment and present descriptive statistics. In Section 3, we define the treatment effects of interest and explain their interpretation. In section 4, we present the empirical results. Section 5 discusses limitations and concludes. Details about the experimental setup and additional results are provided in an appendix.

[8] The largest and most notable such surveys used are the the so-called Special Eurobarometer surveys financed by the European Commission, see, e.g., Eurobarometer 72.2 for nuclear energy and special Eurobarometer 297 for nuclear waste.

2 Experimental setup and descriptive statistics

2.1 Experimental setup

Experimental conditions. Our experiment is designed as a stated choice experiment. The experiment was conducted at five universities: Franklin University of Switzerland (Lugano, CH), University of Basel (CH), University of St. Gallen (CH), Sofia University St. Kliment Ohridski (BG) and Halmstad University(SE).[9] All participants were students at the aforementioned universities. The experiment was performed either in class or online. The experiment was conducted at varying times, and for some universities, it was conducted repeatedly. However, no student in our sample took part more than once. Figure 5 in the online appendix A summarizes the timing, location, and the implementation forms. Details on the fields of study of all (both online and in-class) participants is provided in appendix A.

In the in-class form, the experiment was performed at the beginning of the class. Students were invited to participate in a survey on nuclear power, without initially being informed that it is part of an experimental study. Then, we distributed the paper-based questionnaire. Students were asked not to communicate with each other while filling the questionnaire. This restriction was implemented to avoid that the students learn there are different versions of the questionnaire (and ultimately, to avoid that the students learn they participate in an experiment). The questionnaires were collected immediately after the students filled them.

The online form consisted of two different forms, depending on the institutional setting. At the University of St. Gallen, the experiment was conducted using the survey tool Unipark.[10] Participants were recruited on a first-come-first-served principle via the Behavioral Lab of the University of St. Gallen, an institutional unit responsible for implementing behavioral lab experiments. They were recruited from a large existing pool of potential

[9] With the exception of Franklin University of Switzerland, the choice of the institutions corresponds to the employment locations of the authors. Franklin University of Switzerland was chosen as a pilot location.

[10] https://www.unipark.com/

participants. Participants received a one-time participation remuneration of 5 CHF. Given that the survey takes on average between 2 and 4 minutes (according to own estimates), this remuneration represents a rather generous per-hour compensation.

The online experiment at the Sofia University, on the contrary, was performed via cohort-specific email lists. Emails were sent through the university e-learning platform (Moodle) to undergraduate students enrolled in specific courses. The Quiz tool of the platform was utilized to enter the four variants of questions, and to randomly assign only one of the questions to each student. Each time answers were collected, the survey time was restricted to a relatively narrow time window to limit the potential of communication. There was no remuneration for participation.

Experimental content. Each participant was randomly assigned to one of four different treatment arms. The random assignment in the online forms was implemented via standard random number generators. In the in-class form, de facto randomization was achieved through (a) an ex ante blind order selection of the questionnaire sheets (implemented manually) and the order of seating of students.

Each version of the survey has two parts: a background motivational text part, and a questions part. In each of the four versions, the background part begins with the following motivation text:

Background: Recent events such as the war in Ukraine have exposed the energy vulnerability of ***Switzerland*** *as well as the urgent necessity to develop a mid-term energy strategy. In recent debates, the* ***Swiss*** *government has indicated its willingness to revise its "No more Nuclear Power" strategy and investigate whether new nuclear power plants should be built. Nuclear power has been recently endorsed as a "green energy" by the European Commission, and it has been highlighted that its usage has the potential to reduce global CO2 emissions.*

The text highlighted in **bold** was chosen according to the respective location. It was not highlighted in the actual questionnaires.

In version 1, the background text part consists only of the text presented above. The questions part consists of the two questions (all four version of the questionnaire can be found in appendix A.):

1. "If there is a new referendum on building new nuclear power plants would you vote..." The answer options, listed vertically below the questions, are "Yes to new nuclear power plants" and "No to new nuclear power plants". The correct answer must be indicated by a tick mark in an empty box at the beginning of each option.

2. "You are..." The answer options are "Male", "Female", and "Prefer not to say".

In version 2, the two questions are identical and the following additional text is added to the background text:

According to unconfirmed sources, a large nuclear repository for low- and middle-radioactive nuclear waste are supposed to be built less than 12 km distance from Zurich.

The location of the hypothetical repository was chosen according to our ad hoc assessment of where students are most likely to live and work. This choice is thus supposed to trigger the perception that the repository is "In My Backyard". In some cases, it was clear which location is a likely candidate for a future living and working location: for the University of St. Gallen and Sofia University, these were Zurich and Sofia, respectively. In the other three cases, it was less obvious, so we simply chose the city of the corresponding university itself. Missspecifying the future living location is discussed in section 5 below.

In version 3, the background text from version 1 was repeated, and the following sentences were added to it:

According to unconfirmed sources, a large nuclear repository for low- and middle-radioactive nuclear waste are supposed to be built less than 12 km distance from Zurich. The additional risk of cancer associated with contamination of ground water is estimated to be less than 1%.

The question part of version 3 consists again of two questions:

1. "1. If there is a local referendum, would you vote for allowing to build a repository

near Zurich?" The answer options are "Yes, I would vote for building a repository." and "No, I would vote against a repository.".

2. "You are..." The answer options are the same as above: "Male", "Female", and "Prefer not to say".

Finally, in version 4, the question part remains identical to the question part of version 3. The background part adds the following additional sentence to the background text of version 3:

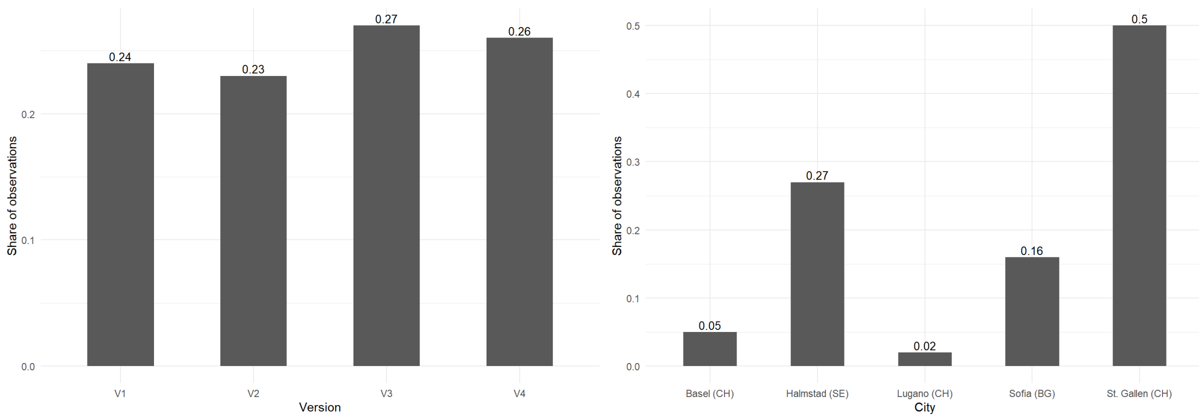
If a repository is built, all citizens living within a radius of 20 km will receive a one-time compensation of ***10000 CHF****.*

Again, the bold highlighted text (which was not highlighted in the original survey) varied according to the location, see appendix A for details. The amount was adjusted according to the local living standard.

2.2 Descriptive statistics

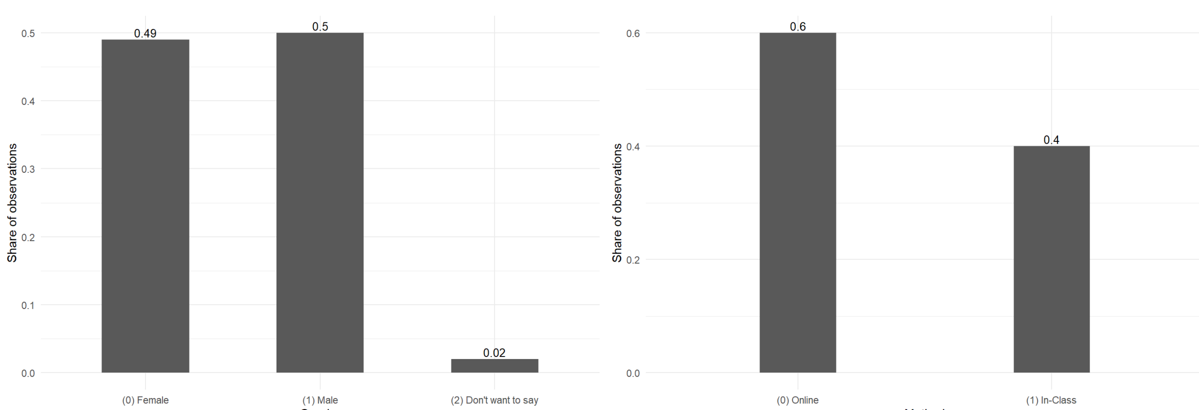
In this section, we present descriptive statistics of background characteristics. Our final sample consists of 728 questionnaires. Fig 1a displays the sample size (measured on the vertical axis) for each of the four versions of the questionnaire. The figure reveals that sampling resulted in a relative balanced (regarding the treatment arms) sample. Figure 1b shows the sample size for each of the five locations. The pilot location (Franklin University in Lugano) has the lowest sample size, while University of St. Gallen has the largest one.

Next, figure 2a displays the distribution of gender in the sample. 0.02% of all participants preferred not to state their gender, while men and women have roughly similar shares, 49.9% and 48.6%, respectively. Finally, figure 2b displays the shares of online and in-class questionnaires. 435 (60%) individuals took part in the online form (from these, 320 from the University of St. Gallen, and 115 from Sofia) and 293 (40%) in the in-class form.



(a) Distribution of observations across versions. (b) Distribution of observations across locations.

Figure 1: Sample size per version and location.



(a) Distribution of observations across gender. (b) Distribution of observations across methods (online vs. in-class).

Figure 2: Sample size per gender and method.

3 Empirical framework

Notation. We embed our empirical analysis in the Rubin causal evaluation framework (Imbens and Rubin, 2015). Let the binary treatment variable D_{1i} represent the informational treatment of the second version for individual i, $i = 1, \ldots, n_1$. In particular, $D_{1i} = 1$ means that individual i is exposed to the information that new repositories should be built close to the respective living or work location of individual i if new power plants are to be built. $D_{1i} = 0$ means that no such information is provided to individual i. We analogously define the binary treatment variable D_{2i}. In particular, define $D_{2i} = 1$ to indicate that individual i has been told that a remuneration will be provided for the local population if a new near-by repository is to be built (and $D_{2i} = 0$ otherwise). Thus, $D_2 = 1$ corresponds to the additional information provided in version 4 of the questionnaire.

Next, let the binary random variable $Y_{1i}(d_1)$ denote the potential decision of individual i for $(Y_{1i}(d_1) = 1)$ or against $(Y_{1i}(d_1) = 0$ a new nuclear power plant in the hypothetical case that she is assigned to treatment $D_{1i} = d_1$, where $d_1 \in \{0, 1\}$. Analogously, define the binary random variable $Y_{2i}(d_2)$ to denote the potential decision of individual i for $(Y_{2i}(d_1) = 1)$ or against $(Y_{2i}(d_1) = 0$ a new near-by repository in the hypothetical case that she is assigned to treatment $D_{2i} = d_2$. The actually realized (measured) outcomes of an individual are denoted by Y_{1i} and Y_{2i}.

Finally, let the random variable X_i denotes the answer of individual i to the gender question, with $X_i = 0, 1, 2$ meaning “female”, “male”, and “prefer not to say”, respectively.

Estimands of interest. With this notation, we can define the estimands of interest.

We define the following quantities:

$$\Delta_{NPP} := \mathbb{E}[Y_{1i}(0)],$$

$$\Delta_{NW} := \mathbb{E}[Y_{2i}(0)],$$

$$\Delta_{FR} := \mathbb{E}[Y_{1i}(1) - Y_{1i}(0)],$$

$$\Delta_{€} := \mathbb{E}[Y_{2i}(1) - Y_{2i}(0)].$$

The estimand Δ_{NPP} corresponds to the hypothetical share among respondents that would vote for a new nuclear power plant when no information on nearby nuclear waste facilities is provided (an "unconditional Yes" to new nuclear power plants). This estimand aims to measure the social acceptance of nuclear power.

The estimand Δ_{NW} corresponds to the share of estimands that would say "Yes" to nearby nuclear waste repositories if no remuneration is offered. It is an unconditional measure of potential local opposition. The difference between Δ_{NPP} and Δ_{NW} can be thought as the propensity that an otherwise socially accepted technology fails to be adopted because of local opposition (which corresponds to the definition of NIMBY that we adopted).

The estimand Δ_{FR} represents the average treatment effect on the acceptance of new nuclear power plants of being exposed to the information that a new repository would be built in the own backyard. Put differently, Δ_{FR} represents the share of individuals that would vote for new power plants *unless* the repository is built close to their homes. As a result, Δ_{FR} is a measure of free riding: these individuals are willing to enjoy the benefits of the new technology but not willing to internalize the potential costs.

Finally, the estimand $\Delta_{€}$ represents the average treatment effect of economic incentives on the acceptance of a NIMBY project.

Identification and estimation. Our experimental setup provides a straightforward way to identify and estimate the four quantities. These can be recovered from the sample means. In particular, it is straightforward to show the following relationships:

$$\hat{\Delta}_{NPP} := \frac{1}{n_1} \sum_{i \in Version_1} Y_{1i} \xrightarrow{p} \Delta_{NPP} \tag{1}$$

$$\hat{\Delta}_{NW} := \frac{1}{n_3} \sum_{i \in Version_3} Y_{2i} \xrightarrow{p} \Delta_{NW} \tag{2}$$

$$\hat{\Delta}_{FR} := \frac{1}{n_2} \sum_{i \in Version_2} Y_{1i} - \frac{1}{n_1} \sum_{i \in Version_1} Y_{1i} \xrightarrow{p} \Delta_{FR}, \tag{3}$$

$$\hat{\Delta}_{€} := \frac{1}{n_4} \sum_{i \in Version_4} Y_{2i} - \frac{1}{n_3} \sum_{i \in Version_3} Y_{2i} \xrightarrow{p} \Delta_{€}, \tag{4}$$

where n_k denotes the number of individuals in the sample assigned to Version $k = 1, 2, 3, 4$ of the questionnaire, and $\xrightarrow{p}$ denotes weak convergence. Expressed in words, equation (1) ((2)) states that a consistent estimator for Δ_{NPP} (Δ_{NW}) can be constructed as the share of "Yes"-votes in the observed sample of individuals assigned to version 1 (3). Equation (3) states that a consistent estimator of the effect Δ_{FR} ($\Delta_{€}$) can be constructed as the difference of "Yes"-shares in Versions 2 and 1 (4 and 3).

4 Empirical results

4.1 Evidence on the NIMBY problem

We start with presenting general evidence on the NIMBY problem. First, the estimate of the acceptance of new nuclear power $\hat{\Delta}_{NPP}$ is equal to 66.9%, while the estimate of the acceptance of nearby nuclear waste repositories is 54.8%. Thus, the nuclear power acceptance is 22% higher than the acceptance of local nuclear waste. A t-test for equality of means yields a t-statistics equal to 2.38, which corresponds to a p-value of 0.017. These estimates suggest that nuclear waste represents an important hurdle for the general acceptance of nuclear power, even though a majority of participants in our sample accept nuclear waste repositories.

It is informative to compare these results with estimates from existing studies. Both estimates are larger than estimates based on previous surveys, see, e.g., Sonnberger et al. (2021) for a recent survey and literature review in the context of acceptance of nuclear power and Rasmussen et al. (2020) in the context of nuclear waste. One possible reason is that traditionally, surveys in both fields have maintained a sampling procedure that generates a sample representative in terms of demographic and socio-economic characteristics for the respective populations. In contrast, our study uses only students as experimental participants. Previous studies have shown that higher education is positively correlated with the acceptance rates (Wang and Kim, 2018). Hence, each of our estimates can be interpreted as an upper bound of the acceptance in the corresponding total population.[11]

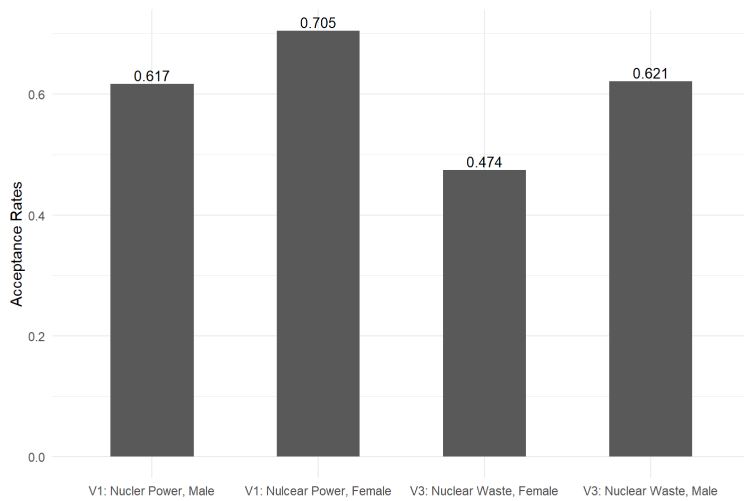


Figure 3: Gender differences in the acceptance of new nuclear power plants and local nuclear waste repositories.

Next, we turn to gender differences in the acceptance rates. Figure 3 shows for each of the questions (new nuclear power plants (Version 1) and new nuclear waste repositories (Version 3)) the gender-specific acceptance rates. Based on this graph, several conclusions can be made. First, new power plants have a higher acceptance rate among women (70%) than among men (61.7%). This finding contrasts previous studies, which tend to find higher

[11] A further possible reason is the timing of the survey and in particular, the relationship between acceptance rates and energy prices. We investigate this relationship below.

acceptance of nuclear power among men (Wang and Kim, 2018). It also contradicts the findings of the literature on risk aversion that women are more risk averse than men. However, this interpretation is not the only possible one. In particular, our questionnaire framed nuclear power as a possible solution to the climate crisis. Thus, the observed difference in acceptance rates might capture differences in pro-environmental attitudes as well.[12]

Second, we find a reverse pattern for nuclear waste. While 62.1% of the men would accept a repository in their backyard, only 47.4% of the women would do. This difference is consistent with the findings of a recent survey by Rasmussen et al. (2020). There are two takeaways from the nuclear waste acceptance estimates. First, men show similar acceptance rates for nuclear power plants and nuclear waste repositories, while these rates strongly diverge for women. This suggests that the NIMBY problem is pronounced for - and largely driven by - the female part of the population. Second, the reversal of the patterns implies that differences in risk aversion alone cannot explain the differences in acceptance rates. Below, we show that the YNIMBY phenomenon is one likely explanation.

4.2 Evidence on the YNIMBY phenomenon

We turn now to Δ_{FR}, i.e. the effect of a nearby nuclear waste repository on the acceptance of nuclear power plants. The sample estimate $\hat{\Delta}_{FR}$ is equal to -0.065. Compared to the baseline acceptance level $\hat{\Delta}_{NPP}$ (66.9%), the estimated effect is roughly equal to a 10% reduction. The p-value is equal to 0.21 and a 95% confidence interval is equal to $[-0.036, 0.17]$. Thus, although associated with some uncertainty, the estimate suggests that there 10% of the participants who are in favor of nuclear power are free-riders: they would not accept to internalize the associated costs.

Next, we estimate the gender-specific average treatment effects. For women, $\hat{\Delta}_{FR}$ is equal to -0.23. Compared to the baseline acceptance level of women (70%), this effect

[12]There is a limited evidence on gender differences in pro-environmental attitudes and behaviors. While Li et al. (2022) finds that survey answers of females tend to reveal higher environmentalist attitude than male answers, Vicente-Molina et al. (2018) find men tend to have higher elasticity of behavioral change when exposed to environmental programs.

corresponds to a 32.8% decrease and is thus over three times larger than the effect on the whole population. The p-value is very small and equal to 0.001. In contrast, the estimated effect for men is equal to 0.003 and the corresponding p-value is equal to 0.96, implying that, statistically, the effect is almost impossible to distinguish from 0.

Together, these estimates suggest the striking result that the free-riding YNIMBY component of the NIMBY problem is largely driven by women. This finding is consistent with the reversal of differences in unconditional acceptance rates $\hat{\Delta}_{NPP}, \hat{\Delta}_{NW}$ found in subsection 4.1 above.

4.3 Evidence on the effect of economic incentives

Finally, we turn to studying the effect of economic incentives on the acceptance rates. We present both experimental evidence from comparing treatment with control results, as well as evidence from the staggered implementation of the experiment.

Cross-sectional evidence. First, we study the conjecture by Frey and Oberholzer-Gee (1997) that economic incentives lead to a crowding out of intrinsic motivation and that this crowding out effect dominates the "rationality"-based effect of the pure economic incentive. This conjecture is represented by the test hypothesis

$$H_0 : \Delta_{FR} \leq 0. \tag{5}$$

The test statistic $\hat{\Delta}_{€}$ is constructed as described in equation (4), namely by comparing sample acceptance rates in the subgroups of participants assigned to Version 3 and Version 4 of the survey. The estimate for $\hat{\Delta}_{€}$ is equal to 0.053. To put this into perspective, this effect is equivalent to an increase in the acceptance of nearby nuclear waste repositories by roughly 10% compared to the baseline level (54.8%). The p-value corresponding to the test hypothesis H_0 is equal to 0.14, so that the uncertainty associated with the estimate is of a modest magnitude. These results suggest that *economic incentives likely increase the acceptance of nuclear waste repositories*. Our experimental finding contradicts the repeated-question survey results by Frey and Oberholzer-Gee (1997) that use the same individuals as a treatment and control group.

Evidence from the staggered implementation of the experiment. We utilize the staggered implementation of the experiment to provide further evidence on the effect of economic incentives on the social acceptance of nuclear waste. In particular, in 2022, there was a substantial fluctuation in energy prices driven largely by the military invasion of Russia in Ukraine. This fluctuation in prices can be interpreted as a change in the cost of the substitute for nuclear energy, and hence, as a change in the opportunity costs of not accepting waste. One natural approach is therefore to study the relationship between some proxy of this opportunity cost and the acceptance rate change. We use electricity spot prices as a proxy of the opportunity cost of not accepting nuclear energy and waste. Since electricity spot prices vary substantially both within one day as well as during the week, we compute the average price for the seven days prior the day on which a given individual participated in the experiment.[13]

We first present graphical evidence for Halmstad.[14] Figure 4 shows a plot of spot prices (horizontal axis) vs. acceptance rate of nuclear waste (vertical axis). The graph reveals a strictly increasing monotonic relationship: the higher the electricity spot price, the higher the acceptance rate. At the price level above 230 €/MWh, the acceptance rate is higher than 95%. Importantly, the sport prices were not monotonically increasing over time.[15] Thus, the depicted correlation is not a spurious consequence of a general time trend.

Next, using a simple Probit regression, we regress the individual acceptance dummy

[13] Prices were retrieved from the entsoe Transparency Platform, https://transparency.entsoe.eu

[14] Including all countries in the graph would capture the country-specific fixed effects, which would lead to a spurious relationship. The graphical evidence focuses on Halmstad because there the experiment was implemented at four different points in time.

[15] In particular, the seven days price averages are 176 €/MWh (for 09.05.2022), 85 €/MWh (13.05.2022), 244 €/MWh (09.09.2022), and 66 €/MWh (28.09.2022).

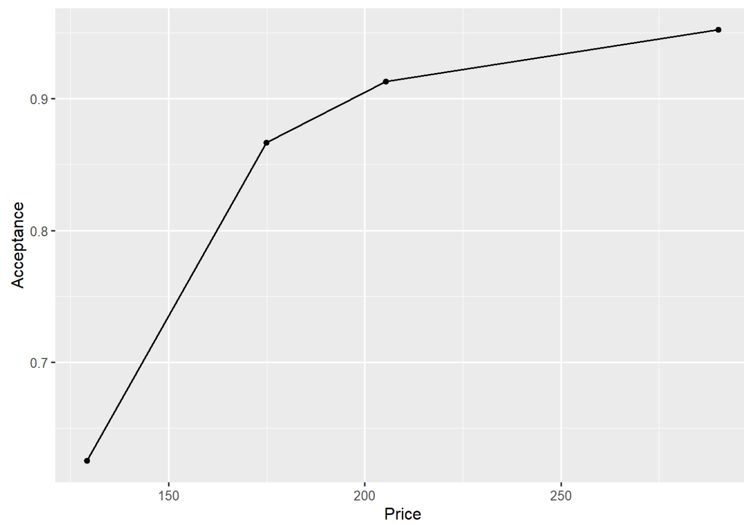


Figure 4: Electricity spot prices (in Euro) vs. acceptance rate of nuclear waste repositories in Sweden.

variable on prices and country fixed effects. The estimate of the price coefficient is 0.22 and the p-value is 0.11, indicating a positive relationship between prices and acceptance rate. One advantage of these estimates is that because of the short period of time, they are unlikely to capture spurious correlations between prices and long-term changes of cultural and or institutional norms. Thus, all three sets of results - the one using experimental cross-sectional, the graphical representation for Halmstad, and the probit regression that utilizes the staggered implementation of the experiment - all point in the same direction: economic incentive increase the support for nuclear waste repositories, thus mitigating the NIMBY problem. Nevertheless, the regression estimates must be interpreted with caution due to potential omitted variable and/or functional form missspecification biases.

5 Limitations and Concluding remarks

In this paper, we presented evidence on the NIMBY problem in the context of nuclear power and on economic incentives as potential solution. One obvious limitation of the study is that the sample we used is not fully representative for the corresponding country populations.

However, as we argued in the paper, our results most likely represent lower bounds for the true effects because higher education is typically association with higher acceptance of nuclear energy and nuclear waste. This argument is further enhanced by the fact that the sample is drawn from countries, in which populations are traditionally more friendly towards nuclear energy (Wang and Kim, 2018). In addition, the NIMBY in the true population should be higher because of the choice of the location in our experiment. In particular, in our experiment, the location choice was based on our assessment about the future work and living location of the students, so that for some, this location might differ than the actual/intended one. Nevertheless, our estimates should be interpreted as caution. Thus, a promising path forward for future research is replicating the study using more diverse and larger study samples.

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A Details on the expeirmental setup

Figure 5 describes the timeline, the form (online vs. in-class), and location of the experiment.

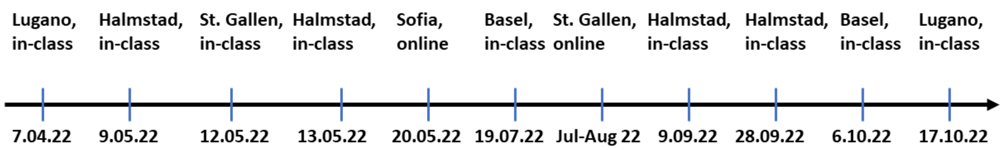

Figure 5: Timeline and form of the experiment.

The experiment was performed with students from the following fields ("NaN" when the subject is unknown): business administration and economics (Sofia University), business administration (Halmstad), environmental sciences (Lugano and Basel) and NaN (University of St. Gallen).

The amounts stated as an economic incentive in version 4 in each location were as follows: 10000 CHF in Lugano, Basel, and St. Gallen, 100000 SEK in Halmstad, and 150 BGN in Sofia.

The following four figures (figure 6a - 7b) provide screenshots from the survey versions in St. Gallen.

VERSION 1

Background: Recent events such as the war in Ukraine have exposed the energy vulnerability of Switzerland as well as the urgent necessity to develop a mid-term energy strategy. In recent debates, the Swiss government has indicated its willingness to revise its "No more Nuclear Power" long term strategy and investigate whether new nuclear power plants should be built. Nuclear power has been recently endorsed as a "green energy" by the European Commission, and it has been highlighted that its usage has the potential to reduce global CO_2 emissions.

QUESTIONS:

1. If there is a new referendum on building new nuclear power plants would you vote

☐ **Yes to new nuclear power plants**

☐ **No to new nuclear power plant**

2. You are

☐ **Male** ☐ **Female** ☐ **Prefer not to say**

(a) Version 1.

VERSION 2

Background: Recent events such as the war in Ukraine have exposed the energy vulnerability of Switzerland as well as the urgent necessity to develop a mid-term energy strategy. In recent debates, the Swiss government has indicated its willingness to revise its "No more Nuclear Power" long term strategy and investigate whether new nuclear power plants should be built. Nuclear power has been recently endorsed as a "green energy" by the European Commission, and it has been highlighted that its usage has the potential to reduce global CO_2 emissions. However, new power plants mean large amounts of new radioactive nuclear waste. According to unconfirmed sources, a large nuclear repository for low- and middle-radioactive nuclear waste are supposed to be built less than 12 km distance from Zürich.

QUESTIONS:

1. If there is a new referendum on building new nuclear power plants would you vote

☐ **Yes to new nuclear power plants**

☐ **No to new nuclear power plant**

2. You are

☐ **Male** ☐ **Female** ☐ **Prefer not to say**

(b) Version 2.

Figure 6: Survey Versions 1 and 2 in St. Gallen.

VERSION 3

Background: Recent events such as the war in Ukraine have exposed the energy vulnerability of Switzerland as well as the urgent necessity to develop a mid-term energy strategy. In recent debates, the Swiss government has indicated its willingness to revise its "No more Nuclear Power" long term strategy and investigate whether new nuclear power plants should be built. Nuclear power has been recently endorsed as a "green energy" by the European Commission, and it has been highlighted that its usage has the potential to reduce global CO_2 emissions. However, new power plants mean large amounts of new radioactive nuclear waste. According to unconfirmed sources, a large nuclear repository for low- and middle-radioactive nuclear waste is supposed to be built less than 12 km distance from Zürich. The additional risk of cancer associated with contamination of ground water is estimated to be less than 1%.

QUESTIONS:

1. If there is a local referendum, would you vote for allowing to build a repository near Zürich?

☐ **Yes, I would vote for building a repository.**

☐ **No, I would vote against a repository.**

2. You are

☐ **Male** ☐ **Female** ☐ **Prefer not to say**

(a) Version 3.

VERSION 4

Background: Recent events such as the war in Ukraine have exposed the energy vulnerability of Switzerland as well as the urgent necessity to develop a mid-term energy strategy. In recent debates, the Swiss government has indicated its willingness to revise its "No more Nuclear Power" long term strategy and investigate whether new nuclear power plants should be built. Nuclear power has been recently endorsed as a "green energy" by the European Commission, and it has been highlighted that its usage has the potential to reduce global CO_2 emissions. However, new power plants mean large amounts of new radioactive nuclear waste. According to unconfirmed sources, one large temporary repository for low- and middle-radioactive nuclear waste is supposed to be built less than 12 km distance from Zürich. The additional risk of cancer associated with contamination of ground water is estimated to be less than 1%. If a repository is built, all citizens living in a radius of 20 km will receive a one-time compensation of 10000 CHF.

QUESTIONS:

1. If there is a local referendum, would you vote for allowing to build a repository near Zürich?

☐ **Yes, I would vote for building a repository.**

☐ **No, I would vote against a repository.**

2. You are

☐ **Male** ☐ **Female** ☐ **Prefer not to say**

(b) Version 4.

Figure 7: Survey Versions 3 and 4 in St. Gallen.