UNIVERSITY OF GOTHENBURG
SCHOOL OF BUSINESS, ECONOMICS AND LAW

Master Degree Project in Economics

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An natural experiment introducing geographical proximity as a determinant of public response to a nuclear crisis

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Master Degree Project No. 2014:68
Graduate School

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2 June 2014

Abstract

The Fukushima accident from March 2011 in Japan appears to have had global implications for nuclear policy response and public reaction. This paper examines the impact of the disaster on nuclear attitudes in Sweden, a country which repeatedly revised its nuclear policy over the last decades. In a time of nuclear renaissance, it is important to understand the development of nuclear support which might have implications for the future nuclear policy of the country. The paper utilizes individual survey data capturing attitudes before and after the accident. It further applies a natural experiment methodology to control for geographical proximity to a nuclear plant as a determinant of nuclear support and public response in the aftermath of a nuclear crisis. Empirical findings suggest a negative and highly significant effect of Fukushima, but contrary to general beliefs the disaster had very limited effect on people living in the vicinity of nuclear plants in Sweden. Additionally, the study evaluates mechanisms through which the accident may have affected public opinion, e.g. subjective risk, economic, environmental and social priorities, knowledge and socio-demographic characteristics.

Key Words: Nuclear energy, Fukushima, Public opinion
JEL Classification: Q48, Q54

Supervisor: Andreea Mitrut

* I take this opportunity to express my deep gratitude and regards to my thesis supervisor Andreea Mitrut who helped me conceptualize the project and guided me throughout the course of this thesis. I would also like to thank the Swedish National Data Service and the University of Gothenburg for making the data available.

1. Introduction

The biggest nuclear accidents of the 20th century, Three Mile Island in 1979 and Chernobyl in 1986, caused a major decrease in public acceptance of nuclear power in the following years and encouraged several countries to abolish their nuclear programs (Moniz 2011, Midden and Verplanken 1990). The last decade, however, has been a time of a *nuclear renaissance* with nuclear power being viewed as the way out of fuel poverty and the world's rising carbon footprint (Hultman 2011, Visschers, Keller and Siegrist 2011, Hartley 2006). Governments have started to reverse their phase-out plans and even make plans for nuclear expansion, potentially adding about 60,000 megawatts of generating capacity, a sixth of the world's current nuclear capacity (Moniz 2011).

The Fukushima accident from March 2011 in Japan once again triggered discussions about nuclear power's controversy – while associated with undeniable benefits, it also brings great risks (Rogner 2010). The accident triggered various policy responses around the world (Thomas 2012, Templeton and Fleschmann 2011). Germany decided to abolish nuclear power with broad public support, and other countries such as Belgium, Italy, Japan and Switzerland put an end to their plans to re-introduce the power source (Echavarri 2013, Moniz 2011). France, UK and USA opted to maintain nuclear power, while China, India, Russia and South Korea, together accounting for 80 percent of the current nuclear capacity under construction, sustained their construction plans (Echavarri 2013, Thomas 2012, Moniz 2011).

Because Sweden repeatedly revised its nuclear policy, it is a good context in which to evaluate the possible effects of Fukushima on nuclear attitudes. In the aftermath of Chernobyl, the country was supposed to be the first one in the world to opt out of nuclear power, but it instead revoked the official phase-out policy in 2009, two years before the Fukushima accident (Roßegger and Ramin 2013). It has been a priority for the country to increase its non-carbon energy capacity, which encouraged investment in nuclear power as a low-carbon energy alternative (Ek 2005). Historically, Sweden also experienced significant international political pressure, particularly from Denmark, that led to the closure of the Barsebäck reactors located in close proximity to the Danish capital (Modern Power Systems 2010). It should also be noted that the Fukushima accident has not yet led to any policy changes in the country (Roßegger and Ramin 2013).

Opposition in Sweden was extremely high immediately after Chernobyl with 75 percent of the nation and all political forces supporting a phase-out (Holmberg 2005). Since then studies have shown a trend towards more favorable nuclear attitudes and, in 2003, supporters of nuclear power outnumbered opponents for the first time in the Swedish history (Holmberg 2005).

The study aims to make a contribution to existing literature by conducting an in-depth assessment of the impact of Fukushima on nuclear public support in Sweden. A better understanding of the underlying determinants of nuclear attitudes in Sweden might further enable a more accurate prediction of long-term development of public nuclear support.

This paper utilizes several nationally representative surveys covering a time span from 2007 to 2011 (SOM Institute 2007, 2008, 2009, 2010, 2011). In addition to information about individual nuclear preferences, the sample provides insights on standard demographic characteristics and risk, attitudinal and knowledge mechanisms. Applying the framework of a natural experiment, the study first employs a before-after empirical strategy, followed by a difference-in-difference strategy, which allows for a cross-sectional differentiation based on respondents' exposure to existing nuclear plants in Sweden. Ultimately, people residing in close proximity of a nuclear plant are the ones that would be more affected in the case of a nuclear accident in Sweden, which makes the post-Fukushima reaction of those people particularly interesting to study. Overall, this paper offers significant evidence for a negative public reaction shortly after the accident in 2011 among individuals residing relatively far from a nuclear plant. The effect of the accident on people living in the vicinity of existing nuclear plants is, however, more difficult to interpret with a generally insignificant change of phase-out and nuclear investment attitudes and even a slight increase in nuclear policy attitudes after the accident.

Section 2 discusses previous empirical findings. Section 3 depicts the Swedish context and describes the data. The econometric strategies and specifications are explained in Section 4. Section 5 presents the paper's main results and evaluates the robustness and sensitivity of the findings. Section 6 discusses main results and Section 7 concludes.

2. Literature

The following section provides support for the study's design and discusses prior studies with insights on the effect of nuclear accidents, geographical distance and other determining mechanisms on nuclear attitudes.

2.1 Nuclear Accidents

The frequency and magnitude of anti-nuclear protests around the world increased sharply after the biggest nuclear meltdown in the US history, the Three Mile Island accident in 1979 (Franchino 2014). Similarly, the catastrophe in Chernobyl triggered massive waves of public concern on a global scale (Depledge 1986). Both accidents caused major decrease in public acceptance of the power source immediately after they occurred, followed by some recovery effects and stabilization of the public support on levels slightly lower than before the accidents (Midden and Verplanken 1990).

Sweden was severely hit by fallouts from Chernobyl, which triggered a negative reaction towards nuclear power (Drottz-Sjöberg and Sjöberg 1990). No major nuclear disaster occurred in the following years though, and nuclear support gradually recovered with the perceived risk of nuclear accident diminishing from 6.8[1] in 1986 to 5.4 in 2004 (Holmberg 2005).

Similar effects have been reported following the Fukushima nuclear crisis, particularly, a drop in nuclear public support and the level of trust in the industry (Prati and Zani 2013, Visschers and Siegrist 2013, Kim, Kim and Kim 2013). Decreased benefit perceptions in relation to the accident are found to be another driver for decreased acceptance (Siegrist, Sütterlin and Keller 2014). It has also been argued that the accident will have major short- and medium-term implications for public support and political agendas on a global level (He, et al. 2014).

2.2 Geographical Proximity

Prior literature often applies the term *NIMBY* or *Not in My Backyard*, the basic concept being that people might hold a positive attitude towards high risk facilities in general, but be more negative towards the construction and maintenance of such facilities in close geographical proximity to their homes (Tanaka 2004). The political decision to close Barsebäcks reactors in Sweden in 1999 and 2005 was also influenced by concerns about the potential economic and social hazards in the vicinity of the third largest Swedish city, Malmö,

[1] Perceived risk of nuclear accident is measured on a scale from 1 (very low risk) to 10 (very high risk)

and the Danish capital, Copenhagen (Hedberg and Holmberg 2008).

More importantly, the distance to a nuclear plant is an objective measure of health risk and safety (Franchino 2014). Although objective risk is generally positively correlated with subjective risk perceptions, the opposite relationship has been suggested by several studies advocating that proximity instead strengthens nuclear support (Franchino 2014). A potential explanation is that there are economic benefits from the local nuclear power plant (Hecht 2009, Freudenburg and Davidson 2007) and people are more familiar with the facility (Parkhill 2010).

2.3 Other Determinants

Prior literature has identified four main factors determining nuclear preferences – risk perceptions, attitudinal and value indicators, demographics, and level of knowledge (Stoutenborough, Sturgess and Vedlitz 2013, Whitfield, et al. 2009).

2.3.1 Risk Perception and Trust

Opposition to nuclear power generally stems from risk of nuclear accidents and disposal of nuclear waste and low trust in the nuclear industry (Whitfield, et al. 2009, Tanaka 2004). Subjective risk can be determined by personal vulnerability, disaster and post-disaster events, stigma and fear of health effects (Bromet and Havenaar 2007). Since nuclear waste must be stored indefinitely, individual discount rates for future costs could be essential for risk perceptions (Jenkins-Smith 2011). Heterogeneous public preferences and the level of knowledge further trigger differences in the probability assessment of nuclear terrorism risk (Li, et al. 2012).

Trust is essential for the assessment of positive and negative information about nuclear power with distrustful individuals judging both types of information more negatively than trustful ones (Cvetkovich, et al. 2002). The trust factor further reflects perceived control over the safety regulations - perceived lack of control is less important if individuals have trust in the nuclear power authorities (Costa-Font, Rudisill and Mossialos 2008, Sandquist 2004).

2.3.2 Attitudinal and Value Indicators

Economic, environmental and social priorities have been found important for the formation of nuclear attitudes.

Nuclear power has often been promoted as ensuring a secure, affordable and environmentally acceptable energy supply (Bickerstaff, et al. 2008, Plight, Eiser and Spears 1984). Due to its low carbon footprint, it has been extensively explored as a potential response to global warming (Li, et al. 2012, Corner, et al. 2011, Ramana 2011). The power source has been previously characterized as a *clean* energy resource by 55 percent of respondents in Sweden (Ek 2005). Nevertheless, individuals place higher importance on economic benefits as they reach households directly while climate benefits are more difficult to realize (Visschers, Keller and Siegrist 2011).

Some studies report that nuclear power engenders negative externalities by reducing social welfare and possibly the welfare of future generations (Ramana 2011, Costa-Font, Rudisill and Mossialos 2008). The importance of political standpoint for nuclear attitudes has also been well-documented (Costa-Font, Rudisill and Mossialos 2008, Pifer 1996).

2.3.3 Knowledge

The relationship between knowledge and nuclear preferences has proved to be rather inconsistent (Yim and Vaganov 2003, Pifer 1996). Some suggest that implicit preferences and affective judgments about nuclear power are independent from knowledge and cognitive judgments (Ramana 2011, Siegrist, Keller and Cousin 2006). Other studies argue that supporters and opponents are more knowledgeable about nuclear power in comparison to individuals who are undecided (Stoutenborough, Sturgess and Vedlitz 2013, Pifer 1996).

Access to media is essential for energy policy attitudes (Kubota 2012, Costa-Font, Rudisill and Mossialos 2008). Extreme imagery of past nuclear disasters has previously spiked public awareness, heightened perceptions of risk and encouraged individuals to pursue phase-out (Slovic 2012, Slovic, Layman, et al. 1991, Drottz-Sjöberg and Sjöberg 1990). According to the so-called *asymmetry principle*, negative information engenders a stronger reaction from the public in comparison to positive information (Cvetkovich, et al. 2002), which might have reinforced the post-Fukushima reaction.

2.3.4 Demographic Characteristics

Gender is often outlined as an indicator of nuclear policy preferences with women opposing nuclear power more often than men (Sjöberg 2009, Pifer 1996). These findings have been explained by men’s higher perceived need of additional energy as a prerequisite for economic growth and women’s greater safety concerns (Kubota 2012).

Men, town residents and people with high education and family income have been found to be more likely to support nuclear power, while age has been less of a significant determinant of nuclear attitudes (Yu, et al. 2012).

3. Data and Descriptive Statistics

3.1 The Swedish Context

Public opinion and national policy in relation to nuclear power have been evolving in parallel fashion in Sweden (Holmberg and Hedberg 2011). After a non-binding referendum in 1980, a decision to phase out nuclear power by 2010 was supported with a majority of 66 percent of the voters, which made Sweden the first country in the world to take such a decision (Holmberg 2005, Holmberg and Hedberg 2011, Roßegger and Ramin 2013). Stimulated by rising electricity prices and the lack of any serious nuclear accidents, proponents of nuclear power grew in numbers and, eventually, outnumbered nuclear opponents in 2003 (Holmberg 2005). The phase-out plan was revoked by a government coalition in 2009, a decision supported by the Swedish Parliament in 2010, as a part of a strategy to secure energy supply and face global warming (Roßegger and Ramin 2013). Furthermore, Sweden has one of the highest levels of individual energy consumption in the world and nuclear energy comprise to about 40 percent of the domestic energy production (World Nuclear Association 2014a).

Both units of the Barsebäck nuclear power plant located only 20 km from Copenhagen, the capital of anti-nuclear Denmark, were closed in 1999 and 2005 respectively, triggering a strong negative reaction by Swedish industry and trade union leaders (World Nuclear Association 2014b). Interestingly, the first significant shift in public opinion happened in the years 1999-2005, when the proportion of people supporting the phase-out plans decreased from 57 percent in 1998 to 33 percent after the closure of the second Barsebäck unit in 2005 (Holmberg and Hedberg 2011). A new trend of increased opposition has been established since 2009, after several years of no significant fluctuations in public acceptance (Holmberg and Hedberg 2012).

3.2 Data

This article utilizes several cross-sectional datasets comprising a nationally representative sample in Sweden with around 3000 respondents annually (SOM Institute 2007, 2008, 2009, 2010, 2011). The number of observations varies across the outcomes of interest since attitudinal questions have only been asked to a portion of the respondents[2]. Examination of socio-demographic characteristics of the sub-sample with information on *nuclear policy attitudes* suggests that it is representative of

[2] The annual sample size ranges from 3,007 (in 2011) to 4,824 (in 2009) for *Nuclear Policy Attitudes*, from 1,463 (in 2011) to 3,209 (in 2010) for *Phase-out Attitudes* and from 1,309 (in 2011) to 1,439 observations (in 2010) for *Investment Attitudes* and the number of observations is further restricted by the controls included in the regressions.

the population; on the other hand, the sub-samples with information on *phase-out attitudes* and *investment attitudes* might be less representative and subject to some bias as they on average include fewer people with low education and more who are employed, married, males or with high education[3]. Finally, questions about risk perceptions with respect to nuclear accidents, unsafe disposal of wastes and nuclear weapons are missing from the 2010 survey.

The main outcomes of interest are ordinal indicators of nuclear policy attitudes, attitudes towards nuclear phase-out and future investment in this industry. First, *nuclear policy attitudes* are measured on an ordinal 5-point scale taking values from *phase out immediately* to *maintain nuclear power and build new reactors*, including a no-firm opinion alternative. As this dependent variable reflects policy content, it is considered to be more stable in time than in the case of a simpler *in favor* and *against* attitude-examination and more relevant for policy implications (Holmberg and Hedberg 2011).

Second, attitudes towards the phase-out policy, *phase-out attitudes*, are measured on an ordinal scale estimating how respondents regard the decision to phase out nuclear power in the long run. The variable is measured on a 5-point Likert scale ranging from the phase-out policy being a *very bad suggestion* to it being a *very good suggestion.* The decision to abolish phase-out plans in the long run has been regarded as a radical policy change (Roßegger and Ramin 2013) and any changes in the public acceptance of this decision as a result of the Fukushima accident have important policy implications.

Third, public opinion with respect to future investment in nuclear power, *investment attitudes*, measures the desired future level of nuclear investment in comparison to its current level. Attitudes towards nuclear investments are measured on a four-value scale ranging from *no investment in nuclear power* to *higher investment than today*. The effect of the accident on nuclear investment is considered less straightforward to predict. While some people might believe that higher investment would improve safety, others might have been more motivated to support lower levels of investment and a long-term phase-out.

[3] Appendix 1 provides a comparison based on demographic characteristics between the total sample and the three sub-samples with values for the three outcomes of interest.

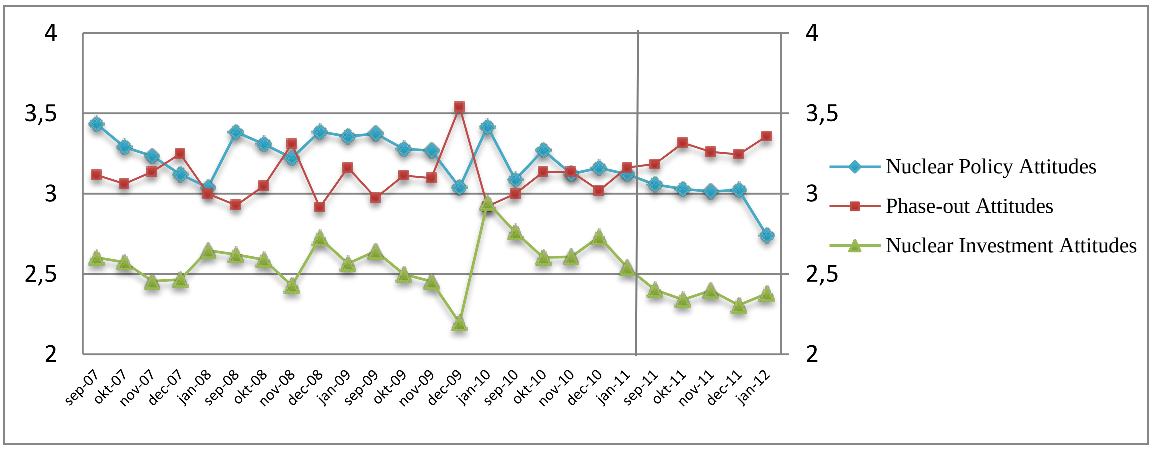

Figure 1: Nuclear policy preferences in Sweden, 2007-2011. Source: SOM Institute 2007-2011
Note: The vertical line depicts the time of the Fukushima accident in March 2011. *Nuclear policy attitudes* and *Phase-out attitudes* are measured on a 5-point scale (from 1 to 5), while *Investment attitudes* is measured on a 4-point scale (from 1 to 4).

The development of nuclear policy preferences in Sweden before and after the accident in Fukushima is shown on Figure 1. The Fukushima disaster was followed by a slight drop in nuclear policy and investment support and a gradual increase in phase-out attitudes. There also appear to be cycles in the movement of nuclear preferences, which are controlled for in the econometric analysis by the addition of monthly dummies. Furthermore, the study controls for the main determining mechanisms, namely, demographic, attitudinal and value indicators, knowledge and risk perceptions.

The study further includes indicators of proximity to a nuclear plant and municipality fixed effects. People living close to nuclear plants would be most affected in the case of a nuclear accident in Sweden, suggesting that they might be influenced differently by the news about Fukushima. The study controls for the effect of living in an immediate evacuation zone around a nuclear plant and the recommended evacuation zones with a radius of 80 kilometers (US NRC 2013). While there are three nuclear plants currently active in Sweden, Ringhals, Oskarshamn and Forsmark, the study also includes Barsebäck which has not yet been officially dismantled[4] (World Nuclear Association 2014a).

3.3 Descriptive Statistics

As shown on Table 1, the difference between the nuclear attitude levels before and after the meltdown in 2011 is significant for all of the dependent variables and it describes a negative trend in the preferences for nuclear power in Sweden.

[4] The plant in Barsebäck is treated as an active plant in the analysis since its destruction will not begin until around 2020 and nuclear waste is still stored in close proximity to the plant. Excluding the plant from the group of active plants does not change the results significantly and such calculations can be provided upon request.

Table 1: Descriptive statistics (including comparison of the means before and after the event)

	2007-2010 (B)		2011 (A)		Difference (A – B)	Mean	Std. Dev.
	Mean	N	Mean	N			
Nuclear Power Attitudes:							
Nuclear Policy Attitudes	3.295	14,401	3.031	3,007	-0.264***	3.249	1.269
Phase-out Attitudes	3.089	7,795	3.254	1,463	0.164***	3.115	1.315
Investment Attitudes	2.581	5,649	2.373	1,309	-0.208***	2.542	0.983
Demographic Characteristics:							
Female	0.529	16,532	0.534	4,720	0.005	0.530	0.499
Age	50.052	16,532	50.789	4,720	0.736**	50.216	18.045
Low household income	0.333	13,858	0.308	4,208	-0.024***	0.326	0.469
Medium household income	0.435	13,858	0.391	4,208	-0.044***	0.425	0.494
High household income	0.232	13,858	0.300	4,208	0.068***	0.248	0.432
Employed	0.561	16,189	0.561	4,606	0.001	0.561	0.496
Married	0.500	16,124	0.501	4,594	0.001	0.500	0.500
Children	0.723	16,228	0.720	4,613	-0.003	0.723	0.448
Low education	0.221	16,162	0.196	4,468	-0.025***	0.216	0.411
Medium education	0.536	16,162	0.535	4,468	-0.000	0.535	0.499
High education	0.243	16,162	0.269	4,468	0.025***	0.249	0.432

Note: Definitions and descriptive statistics of all variables can be found in Appendix 2. Tests for whether difference is statistically different from zero. Significance level: * p<0.1; ** p<0.05; *** p<0.01

The comparison of the means suggests that respondents in 2011 had more favorable attitude towards nuclear phase-out and demonstrated lower support of investments in the nuclear industry, which is consistent with the expected effect of the Fukushima disaster. The proportion of respondents in support of immediate or long-term phase-out policy increased from 32.93 percent before 2011 to 41.53 percent after the Fukushima accident, while the proportion of nuclear power proponents decreased rapidly. Similarly, the number of respondents advocating lower level of nuclear investment or no investment at all grew from 45 percent before the event to 53.86 percent in 2011.

If the groups of respondents before and after the meltdown are truly comparable, the estimate of the post-effect should be unbiased (Remler and Van Ryzin 2010). As shown in Table 1, the groups are similar in terms of gender, employment and relationship status and, in addition, the study controls for potential differences in observables.

4. Econometric Specifications

The empirical specification first considers a *before-after* strategy, which compares public opinion after Fukushima with its values before the event. The design allows for a comparison of nuclear preferences before and after the event and assesses the potential changes via significance tests (Druckman 2004). The outcome of interest, y_i, represents nuclear policy preferences, phase-out attitudes, or nuclear investment attitudes in the following econometric specification:

$$y_i = \alpha_0 + \alpha_1 y2011_i + \alpha_2 y2010_i + \alpha_3 y2009_i + \alpha_3 y2008_i + \alpha_4 X_i + \alpha_5 \text{Monthly FE}_i + \alpha_6 \text{Municipality FE}_i + \varepsilon_i$$

First, the outcomes of interest are regressed on a set of yearly dummy variables in an attempt to reveal any patterns in development of nuclear public support. The 2011-dummy can also be defined as the post-event dummy, which equals 1 for observations taken after the accident and 0 for observations taken before. Other yearly dummies are included, $y2010_i$, $y2009_i$ and $y2008_i$, together with the post-event dummy, capture the change in public support in comparison to the base year, 2007. The effect of the accident can be evaluated by the difference in coefficients of the post-event dummy and the yearly dummy for 2010, the last measurement of attitudes before Fukushima.

Second, monthly and municipality fixed effects are added to the specification. Furthermore, in a series of distinct stages, the study adds determinants of nuclear attitudes, X_i, starting by demographic characteristics, such as gender, age, employment and relationship status, household income, education and proximity to a nuclear plant. Following a stepwise approach, the study tests the change in results after the addition of attitudinal, trust and knowledge indicators to measure the importance of economic and environmental concerns, media access, confidence in the nuclear industry and political preferences for the outcomes of interest. Finally, the paper addresses the significance of risk indicators accounting for perceived risk of nuclear accidents, risk of unsafe disposal of nuclear waste and risk of nuclear weapons. Finally ε_i denotes the error term.

A simple comparison of the dependent variables' means before and after the accident provides no information about whether Fukushima affected respondents who live close by nuclear plants differently than those who live further away. In order to disentangle the *disaster effect* from the *distance effect*, the study attempts a more complex natural experiment framework – a *difference-in-difference* (DD) approach. It enables a cross-sectional comparison between respondents inhabiting areas in close proximity to a nuclear plant and others living farther away.

Geographical proximity to nuclear plants is further considered to be one of the most effective measures of objective risk (Franchino 2014). That makes respondents who live closer to nuclear power plants, the treatment group, more exposed to risk of radiation in case of a problem with the plant or unsafe disposal of nuclear waste. A large number of empirical studies highlight the importance of geographical proximity for health hazards and safety, degradation of the environment and levels of concern and acceptance (Franchino 2014, Venables 2011, Adrian 2009, Kaatsch, et al. 2008, Silva-Mato, et al. 2003). Also, this group has been introduced to additional economic benefits from production of nuclear energy in comparison to the rest of Sweden in terms of employment opportunities and solid energy supply.

In the DD framework, the post-coefficient is amended to test the difference between nuclear attitudes after Fukushima and the entire period before the accident (2007-2010). This strategy further highlights the cross-sectional difference between the treatment and comparison groups. The DD approach delivers solid evidence of causality and internal validity relying on two before-after comparisons in relation to groups of respondents living close (treatment group) and farther away (comparison group) from nuclear plants in Sweden (Remler and Van Ryzin 2010).

The *difference-in-difference* approach is captured in the following model:

$$y_i = \beta_0 + \beta_1 y2011_i + \beta_2 Proximity_i + \beta_3 (y2011_i * Proximity_i) + \beta_4 X_i + \beta_5 \text{Monthly FE}_i + \beta_6 \text{Municipality FE}_i + \varepsilon_i$$

where y_i is the outcome of interest and the $y2011_i$ coefficient captures the difference in the outcome of interest before and after the accident. $Proximity_i$ is a dummy variable taking values of 1 if a respondent lives in a close geographical proximity to a nuclear plant and 0 otherwise. The coefficient of the interaction term, $y2011_i * Proximity_i$, captures the influence of the accident on the treatment group. In a stepwise process, the study again accounts for additional controls for demographics, attitudinal and risk indicators as well as monthly and municipality fixed effects. Although the treatment and comparison groups are similar in terms of demographic observables, the added controls account for possible differences between them and for omitted variable bias in the results (Remler and Van Ryzin 2010). Finally, errors are clustered at the municipality level under both empirical strategies in order to get improvements in efficiency and tackle serial correlation of unknown form (Fujiwara 2011).

The study expects that the Fukushima accident decreased nuclear public support in Sweden, since the event has been considered to be a wake-up call for the risks of nuclear industry on a global scale (Fam, et al. 2014). The $proximity$ factor, on the other hand, most likely intertwines a positive and a negative effect, which makes the sign of β_2 and β_3 coefficients less easy to predict. While some negative externalities are likely to occur such as visual disamenities, noise pollution and low-level emission of radioactive elements and residues (Davis 2011), nuclear plants are also major employers for the local community (Freudenburg and Davidson 2007). The benefits from having a nuclear plant for the local community might also reduce the negative impact of the accident on the treatment group, which makes the interaction term's sign less straightforward to predict.

5. Results

5.1 Main Results and Heterogeneity

The estimations in Table 2 apply a before-after empirical strategy and report a number of interesting results in relation to determinants of nuclear policy attitudes (Panel A), nuclear phase-out attitudes (Panel B) and attitudes towards investment in the nuclear industry (Panel C). Due to the ordinal nature of the dependent variables, an ordered logit (OLOGIT) is generally the appropriate tool to examine the data (McKelvey and Zavoina 1975).

The results of the OLOGIT analysis in Panel A reveal a significant fall of nuclear attitudes in 2011, which is consistent with the study's expectations. The specification in Column 3 indicates that nuclear policy attitudes are significantly more favorable in 2010 in comparison to their level in 2007, which is then followed by a significant drop in nuclear public support in 2011. One can infer that the difference between the yearly dummy coefficients for 2010 and 2011 is also statistically significant at the 5 percent significance level.

The examination of Panel B and Panel C offers consistent results - an evident increase of the phase-out policy support between 2010 and 2011 at the 5 percent significance level and a decrease in nuclear investment aspirations at the 1 percent during the same period. The pre-event yearly dummies in Panel B and Panel C show no significant fluctuations in the phase-out and nuclear investment attitudes in Sweden in the entire 2007-2010 period.

Table 2 also presents the effect of background variables on public support and hence provides information about the potential indirect impact of the accident on nuclear attitudes via their determinants. The perceived risk of nuclear accidents, unsafe disposal of waste and nuclear weapons has a negative effect on investment and nuclear policy attitudes and positive effect on phase-out attitudes. Respondents with high *confidence in the industry* are also more likely to support the maintenance of nuclear power and less likely to advocate nuclear phase-out. The Fukushima accident significantly increased perceived risk and decreased trust in the industry, which is consistent with the drop in nuclear support in 2011.[5]

[5] Examination of the effect of the disaster on the risk and trust indicators is presented in Appendix 4.

Table 2: Before-after estimates. OLOGIT (1) No controls, (2) Incl. Demographics, (3) Incl. Knowledge and Attitudes(4) Incl. Risk

Panel A: Nuclear Policy Attitudes	(1)	(2)	(3)	(4)
y2011	-0.366***	-0.481***	-0.239**	-0.490***
	(0.039)	(0.041)	(0.097)	(0.109)
y2010	-0.078*	-0.109***	0.207**	-
	(0.041)	(0.042)	(0.097)	-
y2009	0.022	-0.024	0.044	-0.128
	(0.036)	(0.037)	(0.090)	(0.097)
y2008	0.059	0.078*	0.164*	0.151
	(0.039)	(0.043)	(0.094)	(0.107)
Proximity		0.170***	0.988***	0.887***
		(0.013)	(0.057)	(0.072)
Proximity 80 km		0.127***	-1.128***	-0.696***
		(0.014)	(0.072)	(0.094)
Female		-1.030***	-0.942***	-0.569***
		(0.028)	(0.057)	(0.070)
Age		0.018***	0.022***	0.027***
		(0.001)	(0.002)	(0.003)
Medium household income		0.277***	0.102	0.100
		(0.041)	(0.080)	(0.086)
High household income		0.688***	0.270***	0.226**
		(0.047)	(0.094)	(0.109)
Employed		-0.006	-0.022	-0.084
		(0.035)	(0.076)	(0.090)
Married		0.069**	-0.077	-0.126
		(0.034)	(0.069)	(0.092)
Children		-0.143***	-0.225***	-0.165*
		(0.045)	(0.080)	(0.099)
Medium education		0.158***	0.112	0.107
		(0.046)	(0.093)	(0.103)
High education		0.030	0.140	0.100
		(0.049)	(0.097)	(0.120)
Concern economic crisis			0.122*	0.237***
			(0.067)	(0.088)
Environmental interests			-0.264***	-0.163**
			(0.065)	(0.074)
Media access			0.139**	0.165**
			(0.058)	(0.074)
Confidence in the industry			1.280***	0.830***
			(0.060)	(0.086)
Centerpartiet			-0.093***	-0.100***
			(0.018)	(0.023)
Moderaterna			0.122***	0.086***
			(0.015)	(0.018)
Vänsterpartiet			-0.070***	-0.057***
			(0.017)	(0.021)
Folkpartiet			0.058***	0.045**
			(0.015)	(0.020)
Socialdemokraterna			0.091***	0.067***
			(0.013)	(0.017)
Miljöpartiet			-0.210***	-0.187***
			(0.014)	(0.018)
Kristdemokraterna			0.016	0.009
			(0.014)	(0.018)
Sverigesdemokraterna			0.053***	0.076***
			(0.013)	(0.014)
Risk of nuclear accidents				-0.225***
				(0.023)
Risk of unsafe waste disposal				-0.189***
				(0.019)
Risk of nuclear weapons				-0.057***
				(0.016)
Monthly controls	NO	YES	YES	YES
Municipality controls	NO	YES	YES	YES
N	**17,371**	**15,771**	**5,288**	**3,985**
Pseudo R^2	**0.00**	**0.05**	**0.17**	**0.23**

Panel B: Phase-out Attitudes	(1)	(2)	(3)	(4)
y2011	0.222***	0.353***	0.243**	0.506***
	(0.058)	(0.070)	(0.108)	(0.110)
y2010	0.064	0.075	-0.019	-
	(0.050)	(0.066)	(0.091)	-
y2009	-0.007	0.049	-0.022	0.183*
	(0.062)	(0.073)	(0.090)	(0.100)
y2008	-0.068	-0.026	0.022	0.010
	(0.063)	(0.073)	(0.084)	(0.092)
Proximity		-0.309***	-0.703***	-0.832***
		(0.025)	(0.048)	(0.058)
Proximity 80 km		-0.331***	0.333***	0.308***
		(0.032)	(0.066)	(0.074)
Female		0.870***	0.738***	0.397***
		(0.048)	(0.057)	(0.064)
Age		-0.018***	-0.016***	-0.021***
		(0.002)	(0.002)	(0.003)
Medium household income		-0.162***	0.011	0.131
		(0.056)	(0.071)	(0.090)
High household income		-0.597***	-0.173*	-0.040
		(0.069)	(0.090)	(0.100)
Employed		-0.098*	-0.047	-0.036
		(0.058)	(0.074)	(0.080)
Married		-0.004	-0.001	-0.017
		(0.051)	(0.068)	(0.085)
Children		0.204***	0.233***	0.184**
		(0.067)	(0.071)	(0.084)
Medium education		-0.203***	-0.185**	-0.213**
		(0.070)	(0.093)	(0.109)
High education		0.037	-0.192**	-0.122
		(0.077)	(0.094)	(0.123)
Concern economic crisis			-0.077	-0.149**
			(0.059)	(0.071)
Environmental interests			0.470***	0.275***
			(0.068)	(0.081)
Media access			-0.081	0.017
			(0.066)	(0.071)
Confidence in the industry			-1.060***	-0.570***
			(0.054)	(0.071)
Centerpartiet			0.085***	0.097***
			(0.019)	(0.024)
Moderaterna			-0.113***	-0.081***
			(0.015)	(0.018)
Vänsterpartiet			0.064***	0.050**
			(0.015)	(0.020)
Folkpartiet			-0.031*	-0.038*
			(0.018)	(0.023)
Socialdemokraterna			-0.086***	-0.062***
			(0.013)	(0.017)
Miljöpartiet			0.238***	0.212***
			(0.016)	(0.019)
Kristdemokraterna			-0.024*	-0.025
			(0.014)	(0.016)
Sverigesdemokraterna			-0.062***	-0.090***
			(0.011)	(0.013)
Risk of nuclear accidents				0.183***
				(0.020)
Risk of unsafe waste disposal				0.181***
				(0.021)
Risk of nuclear weapons				0.079***
				(0.015)
Monthly controls	NO	YES	YES	YES
Municipality controls	NO	YES	YES	YES
N	**9,236**	**6,922**	**5,291**	**3,960**
Pseudo R^2	**0.00**	**0.05**	**0.15**	**0.21**

Panel C: Investment Attitudes	(1)	(2)	(3)	(4)
y2011	-0.351***	-0.534***	-0.549***	-0.871***
	(0.066)	(0.083)	(0.100)	(0.118)
y2010	0.079	0.012	0.093	-
	(0.060)	(0.069)	(0.101)	-
y2009	-0.025	-0.113	-0.172*	-0.445***
	(0.063)	(0.076)	(0.092)	(0.099)
y2008	0.049	0.044	-0.012	-0.056
	(0.061)	(0.076)	(0.090)	(0.102)
Proximity		0.829***	1.059***	0.897***
		(0.027)	(0.050)	(0.074)
Proximity 80 km		-0.332***	-0.908***	-0.580***
		(0.034)	(0.074)	(0.093)
Female		-1.111***	-1.004***	-0.712***
		(0.055)	(0.064)	(0.082)
Age		0.019***	0.018***	0.026***
		(0.002)	(0.002)	(0.003)
Medium household income		0.239***	0.133	0.035
		(0.065)	(0.085)	(0.090)
High household income		0.748***	0.365***	0.254**
		(0.081)	(0.094)	(0.102)
Employed		0.084	0.057	0.032
		(0.061)	(0.074)	(0.085)
Married		0.046	0.018	0.013
		(0.052)	(0.061)	(0.081)
Children		-0.189**	-0.225***	-0.205**
		(0.081)	(0.075)	(0.096)
Medium education		0.108	0.007	0.136
		(0.067)	(0.098)	(0.119)
High education		0.040	0.176*	0.258*
		(0.070)	(0.100)	(0.144)
Concern economic crisis			0.102	0.224***
			(0.067)	(0.080)
Environmental interests			-0.379***	-0.193**
			(0.073)	(0.090)
Media access			0.172***	0.193**
			(0.062)	(0.080)
Confidence in the industry			1.443***	0.979***
			(0.057)	(0.080)
Centerpartiet			-0.063***	-0.067***
			(0.018)	(0.025)
Moderaterna			0.096***	0.056***
			(0.016)	(0.019)
Vänsterpartiet			-0.069***	-0.051**
			(0.017)	(0.023)
Folkpartiet			0.055***	0.049***
			(0.015)	(0.018)
Socialdemokraterna			0.081***	0.061***
			(0.015)	(0.020)
Miljöpartiet			-0.203***	-0.183***
			(0.015)	(0.020)
Kristdemokraterna			0.025**	0.015
			(0.013)	(0.018)
Sverigesdemokraterna			0.064***	0.088***
			(0.013)	(0.014)
Risk of nuclear accidents				-0.250***
				(0.026)
Risk of unsafe waste disposal				-0.161***
				(0.020)
Risk of nuclear weapons				-0.105***
				(0.018)
Monthly controls	NO	YES	YES	YES
Municipality controls	NO	YES	YES	YES
N	**6,943**	**6,385**	**4,982**	**3,754**
Pseudo R^2	**0.00**	**0.07**	**0.20**	**0.28**

Note: Robust standard errors clustered at the municipality level in parenthesis. The results of the OLOGIT analysis are presented in different columns depending on the controls included in the regressions. While no extra controls besides the yearly dummies are considered in Columns 1, demographic controls as well as municipality and monthly fixed effects are regarded in Columns 2. The effects of additional controls examining knowledge and attitudinal and value indicators are presented in Columns 3 and risk perception controls are finally added in Columns 4. Columns (4) do not include data from 2010. Significance level: * p<0.1; ** p<0.05; *** p<0.01

Females, younger adults and those with children are found to be less likely to support the promotion of nuclear energy. The indicators of education and media access illustrate a positive and significant relationship between knowledge and nuclear policy preferences. The pattern of income indicators and economic priorities is positive and significant with the high-income respondents and those who worry about the economy being more likely to support nuclear maintenance. Finally, the term expected to capture environmental priorities, *environmental interests*, shows a consistent and significant negative correlation with nuclear policy attitudes. Table 2 further indicates that seven of the eight political attitudinal indicators are significant predictors of nuclear power support.

The analysis further reveals that those who live in the vicinity of a nuclear plant are more likely to support nuclear energy and nuclear investment and less likely to support phase-out. The estimates in Panel A and Panel C reveal the significant positive effect of *proximity* at the 1% level, while the coefficients in Panel B are consistently negative and significant at the 1% level across the different econometric specifications. The opposite influence is indicated by the *proximity 80km* coefficients suggesting that inhabitants of the extended evacuation zone with a radius of 80 kilometers of each plant are instead less likely to support the promotion of nuclear energy. Negative and highly significant coefficients for *proximity 80 km* are obtained in Panel A and Panel C, while a strong positive relationship in Panel B suggests that people living in 80-kilometer vicinity of a plant are more likely to favor a nuclear phase-out.

The significance of the *proximity* indicator in determining nuclear support motivated the study to apply a more solid empirical framework and instead examine the effect of Fukushima based on how far respondents live from nuclear plants in Sweden. This DD strategy is superior in terms of its internal validity as it conducts two before-after comparisons – that of the treatment and comparison groups (Remler and Van Ryzin 2010).

The treatment group consists of respondents residing in close proximity to a nuclear plant - those who live in municipalities with a nuclear plant or in neighboring municipalities if the plants are located close to the border. Overall the treatment group represents respondents who live in the emergency zone in case of an accident with the local nuclear plant.[6]

[6] Appendix 3 presents a map of the territory of Sweden where the nuclear plants are located and outlines the municipalities considered to be in closest proximity to the plants. In determination of the treatment group, the study considers the regulations regarding Emergency Planning Zones with a radius of 10 miles (16 kilometres) around each reactor site (US NRC 2014).

Table 3: Descriptive statistics of the treatment and the comparison groups (2007-2011)

	Before (2007-2010)					After (2011)				
	Comparison	N	Treatment	N	Diff.	Comparison	N	Treatment	N	Diff.
Nuclear Power Attitudes:										
Nuclear Policy Attitudes	3.286	14,021	3.603	380	-0.316***	3.024	2,902	3.210	105	-0.185
Phase-out Attitudes	3.095	7,586	2.885	209	0.210**	3.270	1,413	2.8	50	0.470***
Investment Attitudes	2.573	5,507	2.887	142	-0.314***	2.360	1,264	2.756	45	-0.396***
Demographic Characteristics:										
Female	0.529	16,087	0.539	445	-0.011	0.535	4,570	0.493	150	0.042
Age	50.034	16,087	50.730	445	-0.697	50.831	4,570	49.507	150	1.324
Low household income	0.334	13,493	0.301	365	0.032	0.308	4,074	0.328	134	-0.021
Medium household income	0.435	13,493	0.441	365	-0.006	0.391	4,074	0.396	134	-0.004
High household income	0.232	13,493	0.258	365	-0.026	0.301	4,074	0.276	134	0.025
Employed	0.561	15,759	0.570	430	-0.008	0.561	4,462	0.535	144	0.027
Married	0.499	15,689	0.538	435	-0.039	0.502	4,448	0.493	146	0.008
Children	0.721	15,792	0.800	436	-0.079***	0.719	4,468	0.752	145	-0.033
Low education	0.221	15,726	0.239	436	-0.018	0.198	4,326	0.141	142	0.057*
Medium education	0.535	15,726	0.543	436	-0.008	0.532	4,326	0.648	142	-0.116**
High education	0.244	15,726	0.218	436	0.026	0.270	4,326	0.211	142	0.059

Note: Difference (Before) refers to the difference between the comparison and the treatment groups before the accident (2007-2010) and the Difference (After) – to the difference between the treatment and the comparison groups after the accident in 2011. Tests for whether difference is statistically different from zero. Significance level: * $p<0.1$; ** $p<0.05$; *** $p<0.01$

Although the study assumes that Fukushima had global implications, this is not the same as saying that it affected everyone the same way. The concept of objective risk might explain why people living close to nuclear plants might be affected differently by the news about the accident. Furthermore, it is argued that residents of the emergency evacuation zones around the reactors are subject to some economic benefits from having a local nuclear plant and are generally more aware of the plant's location, compared to respondents who live further away.

The DD framework assumes that the treatment and comparison groups are otherwise similar (Remler and Van Ryzin 2010). Table 3 compares the treatment group with the rest of the sample based on nuclear support before and after the accident as well as other critical socio-demographic characteristics. The difference between the groups before the accident is significant with the treatment group demonstrating more favorable attitudes towards nuclear power. Interestingly enough, while nuclear policy attitudes were equalized after the disaster, the difference between the groups in terms of their phase-out and investment attitudes increased in 2011. The groups show no significant differences in terms of distribution of gender, age, household income and employment, marital status and education.

In addition, Table 4 sheds light on the interaction term between the post-event dummy and proximity to a nuclear plant indicator. The crossed term is designed to capture the effect of the accident solely on the treatment group i.e. how much more (or less) the treatment group changed after the event as opposed to the comparison group (Remler and Van Ryzin 2010). The before-after analysis has previously suggested that the pre-event period between 2007 and 2010 has been characterized by rather stable attitudes. This motivated the exclusion of the yearly-dummies in the DD analysis, which means that the post-event dummy now contrasts nuclear attitudes in 2011 with their pre-accident values.

Table 4 presents DD estimates as a result of OLS and OLOGIT analyses. An OLOGIT analysis is considered to be the most appropriate for estimating models with dependent variables both discrete and ordinal (Borooah 2002). Nevertheless, some previous papers have been cautious about inferring strong conclusions about the magnitude and significance of interaction terms in nonlinear models (Buis 2010, Ai and Norton 2003). It is clear, however, that the estimated crossed terms in the OLS and OLOGIT regressions are no significantly different from each other in the majority of the cases, suggesting that the results are very robust.[7]

As expected, the post-event coefficient shows a consistent and highly significant negative effect on nuclear policy preferences and a positive effect on phase-out support. The coefficient estimating the effect of proximity to a nuclear plant is positive and significant in Panel A and Panel C and negative and significant in Panel B of the OLOGIT analysis, which is consistent with the results from the before-after estimation.

Although the interaction terms in Panel B show the expected positive pattern in the regressions with additional controls, they are insignificant at the 10 percent in all specifications. While the accident seems to have significantly altered phase-out attitudes in the country, the effect is mainly captured by a change in the attitude level of the comparison group. Panel A and Panel C, on the other hand, reveal a positive pattern for the interaction term though insignificant in the majority of the cases. The OLOGIT results from Panel A even demonstrate a positive and significant at the 10% level interaction term. Overall, the DD estimation suggests that the accident might have triggered a different influence on the treatment group compared to respondents living farther away from nuclear plants in Sweden.

[7] Appendix 5 presents the marginal effects for Column 1b of the OLOGIT analysis following the recommendations of Buis (2010) for the calculation of the marginal effect of the interaction term via the *predictnl* command in Stata. It should be noted that the significance level of the interaction terms does not change for nuclear policy attitudes and phase-out attitudes, but it turns positive and significant for investment attitudes.

Table 4: Difference-in-difference estimates. (1) No controls, (2) Incl. Demographics, (3) Incl. Knowledge and Attitudes, (4) Incl. Risk

	OLS				OLOGIT			
Panel A: Nuclear Policy Attitudes	(1a)	(2a)	(3a)	(4a)	(1b)	(2b)	(3b)	(4b)
y2011	-0.259***	-0.301***	-0.174***	-0.217***	-0.366***	-0.465***	-0.367***	-0.511***
	(0.025)	(0.026)	(0.043)	(0.042)	(0.035)	(0.039)	(0.077)	(0.089)
Proximity	0.317***	1.159***	0.758***	1.098***	0.468***	0.188***	0.853***	0.716***
	(0.073)	(0.046)	(0.111)	(0.103)	(0.096)	(0.032)	(0.080)	(0.100)
y2011* Proximity	-0.134	-0.162	0.175	0.247	-0.195	-0.191	0.543*	0.616*
	(0.092)	(0.113)	(0.209)	(0.172)	(0.151)	(0.164)	(0.310)	(0.358)
Monthly controls	NO	YES	YES	YES	NO	YES	YES	YES
Municipality controls	NO	YES	YES	YES	NO	YES	YES	YES
N	**17,371**	**15,771**	**5,288**	**3,985**	**17,371**	**15,771**	**5,288**	**3,985**
R^2	**0.01**	**0.14**	**0.39**	**0.50**				
Pseudo R^2					**0.00**	**0.05**	**0.17**	**0.23**
Panel B: Phase-out Attitudes	(1a)	(2a)	(3a)	(4a)	(1b)	(2b)	(3b)	(4b)
y2011	0.173***	0.245***	0.144***	0.212***	0.222***	0.338***	0.245***	0.430***
	(0.035)	(0.040)	(0.048)	(0.051)	(0.046)	(0.057)	(0.084)	(0.096)
Proximity	-0.211**	-1.664***	-0.650***	-0.966***	-0.296**	-0.260***	-0.732***	-0.838***
	(0.094)	(0.082)	(0.109)	(0.116)	(0.130)	(0.071)	(0.084)	(0.089)
y2011* Proximity	-0.258	-0.156	0.096	0.021	-0.347	-0.219	0.109	0.043
	(0.249)	(0.243)	(0.179)	(0.161)	(0.362)	(0.352)	(0.310)	(0.323)
Monthly controls	NO	YES	YES	YES	NO	YES	YES	YES
Municipality controls	NO	YES	YES	YES	NO	YES	YES	YES
N	**9,236**	**6,922**	**5,291**	**3,960**	**9,236**	**6,922**	**5,291**	**3,960**
R^2	**0.00**	**0.14**	**0.37**	**0.48**				
Pseudo R^2					**0.00**	**0.05**	**0.15**	**0.21**
Panel C: Investment Attitudes	(1a)	(2a)	(3a)	(4a)	(1b)	(2b)	(3b)	(4b)
y2011	-0.212***	-0.253***	-0.198***	-0.226***	-0.386***	-0.520***	-0.518***	-0.680***
	(0.031)	(0.033)	(0.032)	(0.033)	(0.057)	(0.067)	(0.078)	(0.095)
Proximity	0.314***	-0.900***	-0.255***	0.152**	0.623***	0.791***	1.021***	0.797***
	(0.049)	(0.065)	(0.094)	(0.073)	(0.081)	(0.061)	(0.082)	(0.154)
y2011* Proximity	0.080	0.097	0.012	0.109	0.114	0.182	0.044	0.301
	(0.170)	(0.149)	(0.118)	(0.201)	(0.365)	(0.335)	(0.327)	(0.590)
Monthly controls	NO	YES	YES	YES	NO	YES	YES	YES
Municipality controls	NO	YES	YES	YES	NO	YES	YES	YES
N	**6,943**	**6,385**	**4,982**	**3,754**	**6,943**	**6,385**	**4,982**	**3,754**
R^2	**0.01**	**0.18**	**0.42**	**0.54**				
Pseudo R^2					**0.00**	**0.07**	**0.20**	**0.28**

Note: Robust standard errors clustered at the municipality level in parenthesis. 2011-dummy plays the role of a post-event dummy contrasting the estimates in 2011 with their value in the entire pre-event period (2007-2010). While no extra controls are considered in Columns 1, demographic controls as well as municipality and monthly fixed effects are regarded in Columns 2. The effects of additional controls examining knowledge and attitudinal and value indicators are presented in Columns 3 and risk perception controls are finally added in Columns 4. Columns (4) do not include data from 2010. Significance level: * p<0.1; ** p<0.05; *** p<0.01

The sensitivity of the results is examined in Table 5. The post-event dummy and proximity indicator demonstrate similar patterns and significance level across the homogeneous groups as previous findings. Fukushima seems to have affected negatively nuclear support of females from the treatment group, although none of the examined crossed terms are significant. On the other hand, males from the treatment group appear to be more likely to support the maintenance of nuclear power after the accident with the interaction term being positive and significant at the 10 percent in the econometric specification in Panel A. Even though the interaction term estimates are insignificant in Panel B and Panel C, they again demonstrate the opposite trend in comparison to the female sub-sample.

Table 5: Sensitivity check of the difference-in-difference estimates. OLOGIT.

	Females		Males		Low and Medium Risk		High Risk	
Panel A: Nuclear Policy Attitudes	(1a)	(2a)	(1b)	(2b)	(1c)	(2c)	(1d)	(2d)
y2011	-0.321***	-0.231**	-0.430***	-0.549***	-0.334***	-0.344***	-0.279***	-0.503***
	(0.045)	(0.114)	(0.054)	(0.114)	(0.056)	(0.088)	(0.098)	(0.194)
Proximity	0.384***	0.554***	0.624***	1.172***	0.501***	0.704***	0.342	1.952***
	(0.127)	(0.124)	(0.149)	(0.175)	(0.149)	(0.104)	(0.342)	(0.306)
y2011* Proximity	-0.229	-0.122	-0.303	0.889*	0.190	0.813**	-0.242	-1.595***
	(0.263)	(0.586)	(0.327)	(0.478)	(0.350)	(0.326)	(0.552)	(0.240)
Background controls	NO	YES	NO	YES	NO	YES	NO	YES
N	**9,129**	**2,682**	**8,242**	**2,606**	**5,454**	**3,902**	**1,940**	**1,234**
Pseudo R^2	**0.00**	**0.15**	**0.00**	**0.17**	**0.00**	**0.17**	**0.00**	**0.19**
Panel B: Phase-out Attitudes	(1a)	(2a)	(1b)	(2b)	(1c)	(2c)	(1d)	(2d)
y2011	0.150**	0.203	0.305***	0.343***	0.369***	0.238**	0.255***	0.324*
	(0.067)	(0.125)	(0.072)	(0.115)	(0.055)	(0.097)	(0.098)	(0.178)
Proximity	-0.418**	0.088	-0.213	-1.215***	-0.576***	-1.013***	-0.244*	-0.681**
	(0.186)	(0.132)	(0.161)	(0.157)	(0.075)	(0.110)	(0.134)	(0.289)
y2011* Proximity	-0.295	0.642	-0.330	-0.211	0.023	0.112	-0.067	0.136
	(0.608)	(0.512)	(0.501)	(0.484)	(0.193)	(0.328)	(0.415)	(0.332)
Background controls	NO	YES	NO	YES	NO	YES	NO	YES
N	**4,841**	**2,679**	**4,395**	**2,612**	**5,378**	**3,877**	**1,911**	**1,224**
Pseudo R^2	**0.00**	**0.15**	**0.00**	**0.15**	**0.00**	**0.15**	**0.00**	**0.21**
Panel C: Investment Attitudes	(1a)	(2a)	(1b)	(2b)	(1c)	(2c)	(1d)	(2d)
y2011	-0.342***	-0.563***	-0.445***	-0.616***	-0.481***	-0.505***	-0.364***	-0.784***
	(0.083)	(0.134)	(0.076)	(0.105)	(0.056)	(0.083)	(0.112)	(0.180)
Proximity	0.475**	0.747***	0.883***	1.548***	0.650***	0.592***	0.346	1.317***
	(0.217)	(0.151)	(0.173)	(0.185)	(0.075)	(0.132)	(0.309)	(0.372)
y2011* Proximity	-0.120	-0.490	0.141	0.470	0.161	0.445	0.809	0.083
	(0.583)	(0.580)	(0.373)	(0.583)	(0.367)	(0.441)	(0.559)	(0.471)
Background controls	NO	YES	NO	YES	NO	YES	NO	YES
N	**3,510**	**2,464**	**3,433**	**2,518**	**5,061**	**3,680**	**1,776**	**1,168**
Pseudo R^2	**0.00**	**0.20**	**0.00**	**0.20**	**0.00**	**0.21**	**0.01**	**0.27**

Note: Robust standard errors clustered at the municipality level in parenthesis. 'Low and Medium Risk' refers to the sub-sample with relatively low perception of risk (*Risk of nuclear accidents, Risk of unsafe waste disposal* or *Risk of nuclear weapons*) (1-7); the 'High Risk' refers to respondents with highest risk perceptions (8-10). The columns with background variables include socio-demographic indicators, knowledge and attitudinal indicators, municipality and month fixed effects. Significance level: * p<0.1; ** p<0.05; *** p<0.01

The distinction between cohorts with high and low risk perception provides information about the relation between subjective risk and effect of the disaster. While the DD estimation found no significant reaction of the treatment group following Fukushima, the sensitivity check suggests that individuals with high risk perceptions living in close proximity to nuclear plants are less likely to support nuclear power after the accident. The interaction term is negative and highly significant in Panel A though statistically insignificant in other specifications.

The sensitivity check suggests that Fukushima reduced nuclear support of respondents from the treatment group who are sensitive to changes in the subjective likelihood of a nuclear crisis, while the opposite effect took place for individuals with low and medium levels of perceived risk. The interaction term in Panel A regarding the low and medium risk sub-sample is positive and significant at the 5 percent level, which signals that those respondents were more likely to support nuclear power after the accident.

5.2 Robustness check

The following section discusses potential threats to the identification strategy and concerns about the internal validity of the results.

A critical assumption of the difference-in-difference strategy is the *parallel trend assumption*, which advocates that in the absence of a disaster, the average change of nuclear attitudes of the treatment group would have been the same as the observed change of the control group (Pettersson-Lidbom and Thoursie 2013). It should be noted that no control group clear of any effect from the disaster could be utilized in the study as it is argued that Fukushima had global implications for nuclear support (Thomas 2012).

That being said, the examination of the nuclear policy preferences of the comparison group across time does suggest that nuclear attitudes were relatively stable for the entire period between 2007 and 2010 and changed significantly in 2011, after the accident. In the absence of other significant events regarding nuclear power during 2011 in Sweden, this suggests that the post-event dummy is most likely estimating the true disaster effect.

Figure 2 indicates a slight parallel trend between the attitudes of the treatment and comparison groups before the disaster. The treatment group is considerably smaller and might be more easily affected by outliers, which could explain the higher volatility of nuclear preferences. Figure 2 visualizes the results from the DD estimation regarding the post-event period, with nuclear policy preferences dropping significantly for the comparison group and remaining relatively stable for the treatment group. Finally, it is likely that a larger sample size would be needed to detect the significance in the change of phase-out attitudes and investment attitudes of the treatment group.

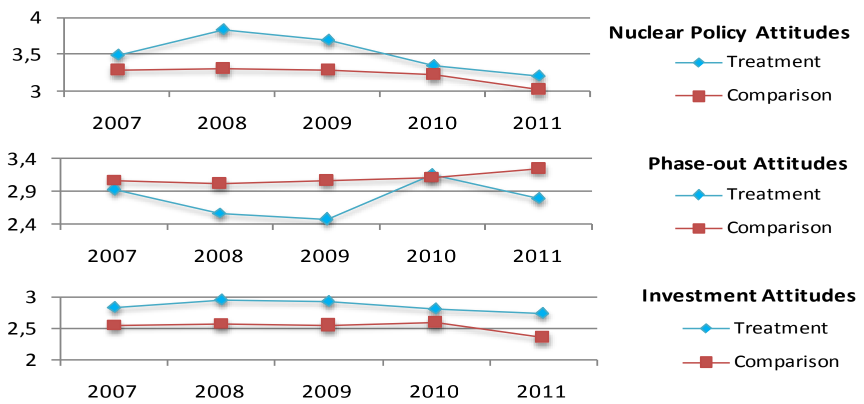

Figure 2: Development of nuclear attitudes across the treatment and the comparison group, 2007-2011. Source: SOM Institute 2007-2011. Note: The figure aims to show the difference in the reactions of the treatment and the comparison groups to the news of the Fukushima accident in March 2011. *Nuclear policy attitudes* and *Phase-out attitudes* are measured on a 5-point scale (from 1 to 5), while *Investment attitudes* are measured on a 4-point scale (from 1 to 4).

Another potential threat to the paper's identification strategy is that the *proximity* control might be endogenous. Suppose that individuals choose to move away from a nuclear power plant if they are exceptionally against the technology. This is in line with the *Tiebout hypothesis* according to which consumers reveal their preferences by moving from one local community to another based on their personal valuations of the community's services until they find a place that maximizes their personal utility (Hindriks and Myles 2006). This would cause reverse causality, since nuclear preferences would be determining exposure to a nuclear plant as opposed to the causal relationship running only in the opposite direction. As a result, the treatment group would be comprised of fewer strong opponents than in the period before the construction of the local plant. This would inflict some bias in the results, which might explain the difference in nuclear policy preferences between the groups.

The study assumes that such potential bias is likely stronger for the most extreme opposition of nuclear power. It seems more likely that one would move to a non-nuclear community only if they are really against the power source and the risks associated with it, and less likely that one would do so if they have no firm opinion on the matter or support nuclear power. Appendix 6 examines the results of a truncated sample of respondents excluding the strongest opposition from both groups. According to the previous assumption, this truncated sample will be less affected by bias. This is used as a falsification test to show whether the positive value of the *proximity* coefficient is only driven by this potential bias, or it is driven by other factors as well. The results for the *proximity* coefficients still replicate the pattern from Table 4 and are highly significant. This suggests that even if some sample bias occurs, it is not the only factor driving the positive and significant proximity effect.

Another more technical assumption of the OLOGIT analysis maintains that the statistical significance of an independent variable does not vary across the ordered categories of the dependent variable (Borooah 2002). This regression assumption would be violated if some independent variables are, for example, significant in determining nuclear attitudes of nuclear opponents, but insignificant in determining attitudes of nuclear supporters. The study applies a Brant test, which provides evidence that this technical assumption of the OLOGIT analysis might be violated for some of the independent variables in the DD estimation.[8]

[8] Appendix 7 presents the results from the Brant test

Therefore, it is prudent to re-examine previous results of the DD estimation via an alternative method and look for potential changes in the results. An alternative to the OLOGIT when the regression assumption has been violated is the generalized OLOGIT (GOLOGIT) model, which allows all independent variables to gain or lose significance across the ordered categories of the dependent variable (Stoutenborough, Sturgess and Vedlitz 2013, Williams 2006). For the independent variables not violating the regression assumption, the GOLOGIT provides one coefficient which can be interpreted in the same manner as in the OLOGIT analysis.

The results of the GOLOGIT regarding independent variables violating the assumption are, however, slightly more difficult to interpret. In those cases, instead of estimating one ordered logistic regression, the analysis conducts a series of binary logistics regressions which essentially capture the same information about the dependent variable (Williams 2006). Level 1 captures the independent variable's coefficient in a binary model where the lowest outcome of the ordinal dependent variable is coded as 0 and the rest of the outcomes are coded as 1. Level 2 treats the lowest two outcomes of the ordinal dependent variable as 0 and the rest as 1. The principle is the same for the other levels with the final level corresponding to the contrast between all the lower categories of the ordinal dependent variable (1,2,3 and 4 for Panel A and Panel B; 1,2 and 3 for Panel C) which are coded as 0 and the outcome at the right end of the ordinal scale coded as 1.

Table 6 presents the GOLOGIT analysis of the DD estimates. The GOLOGIT analysis of the post-event dummy and the proximity factor provides similar conclusion to the OLOGIT analysis. Nevertheless, the OLOGIT analysis fails to detect the significance of the interaction term in any of the econometric specifications, while the GOLOGIT sheds more light on the impact of the disaster on the treatment group.

The interaction term is negative and highly significant at Level 2 of the first regression in Panel A. This can be interpreted to mean that respondents from the treatment group were less likely to support an alternative policy to nuclear phase-out in the aftermath of the Fukushima accident. The coefficient however turns insignificant when background controls are accounted for.

Table 6: GOLOGIT analysis of the difference-in-difference estimates.

	Panel A: Nuclear Policy Attitudes		Panel B: Phase-out Attitudes		Panel C: Investment Attitudes	
	(1a)	(2a)	(1b)	(2b)	(1c)	(2c)
y2011		-0.346(.075)***			-0.386 (.057)***	-0.523 (.075)***
Level 1	-0.220 (.070)***	-	0.409 (.089)***	0.499 (.137)***	-	-
Level 2	-0.355 (.042)***	-	0.341 (.060)***	0.389 (.096)***	-	-
Level 3	-0.367 (.044)***	-	0.143 (.056)**	0.125 (.092)	-	-
Level 4	-0.493 (.063)***	-	0.129 (.064)**	0.168 (.101)		
Proximity	0.465 (.096)***	0.048 (.275)		-0.151 (.172)**	0.623 (.081)***	0.296 (.228)
Level 1	-	-	-0.308 (.171)***	-	-	-
Level 2	-	-	-0.412 (.122)***	-	-	-
Level 3	-	-	-0.218 (.190)	-	-	-
Level 4	-	-	-0.109 (.172)	-		
y2011* Proximity			-0.399 (.360)	0.190 (.311)	0.114 (.365)	-0.081 (.293)
Level 1	-0.438 (.432)	-0.923 (.801)	-	-	-	-
Level 2	-0.443 (.097)***	0.048 (.411)	-	-	-	-
Level 3	-0. 237 (.175)	-0.064 (.243)	-	-	-	-
Level 4	0.336 (.159) **	0.967 (.382)**	-	-		
Background controls	NO	YES	NO	YES	NO	YES
N	**17,371**	**5,288**	**9,236**	**5,291**	**6,943**	**4,982**
Pseudo R^2	**0.01**	**0.18**	**0.00**	**0.15**	**0.01**	**0.19**

Note: Robust standard errors clustered at the municipality level in parenthesis. The columns with background variables include socio-demographic indicators, knowledge and attitudinal indicators, county and month fixed effects. County fixed effects work as a substitute for municipality fixed effects due to the restricted number of variables that could be included in the model.
Significance level: * p<0.1; ** p<0.05; *** p<0.01

At Level 4, the interaction term is positive and significant at the 5 percent significance level in the binary logistic regression contrasting support of nuclear expansion (coded as 1) with the rest of the nuclear policies (coded as 0). The significant coefficient can be interpreted to mean that respondents from the treatment group were more likely to support nuclear expansion after the disaster, which has been previously suggested by the partially significant crossed term in the OLOGIT analysis of nuclear policy attitudes. The GOLOGIT analysis confirms OLOGIT findings regarding the interaction terms in Panel B and Panel C.

Overall, the GOLOGIT analysis confirms previous conclusions about the effect of the Fukushima accident on the comparison and the treatment groups, suggesting that the results are robust even if analyzed by an alternative model.

6. Discussion

The empirical results suggest something slightly counterintuitive - that the comparison group was more negatively affected by the Fukushima event than the treatment group. Past evidence from the effect of Fukushima has similarly argued that the further away respondents live from a nuclear plant, the larger is the decrease in their nuclear support (Kim, Kim and Kim 2013).

The GOLOGIT analysis provides evidence that it is the difference in the reaction of nuclear supporters from the two groups that drives this result. While nuclear supporters from the comparison group were less likely to maintain their support of the power source in 2011, supporters from the treatment group did not change their policy preferences significantly. It could be that nuclear supporters from the comparison group did not account properly for the risk factor when they evaluated nuclear policies prior to Fukushima and reconsidered their policy preferences in 2011. That being said, the treatment group was shown to be more likely to select a higher level for perceived risk of nuclear accident[9], which might also be a sign of them objectively accounting for the risks related to having a local nuclear plant and an explanation to their lack of significant reaction to the Fukushima accident. Previous studies have further outlined trust in the industry as a potential driver for differences in public reaction in the aftermath of a nuclear crisis (Kubota 2012).

Alternatively, nuclear supporters from the treatment and the comparison group might differ in terms of their benefit perceptions. Being entitled to more economic benefits from having a local nuclear plant (Hecht 2009, Freudenburg and Davidson 2007), nuclear supporters from the treatment group might have more stable attitudes towards nuclear power compared to respondents from the comparison group. This idea has been supported by other studies which particularly measured perceived benefits related to nuclear power (Visschers and Siegrist 2013).

An even more surprising result is that the treatment group is found to be more likely to support nuclear maintenance and the construction of new plants in the post-event period. The study, however, refrains from drawing strong conclusions about this result. While it is possible that the treatment group expects maintenance of nuclear power to improve safety for the local community, the development of nuclear policy preferences suggests that attitudes might have been simply bouncing back to their stable level after a drop in 2010.

In line with previous studies (Prati and Zani 2013, Visschers and Siegrist 2013), respondents from the post-event period were found to be more likely to express high values of subjective risk and less likely to have high confidence in the nuclear industry, which is thought to have indirectly affected their nuclear policy preferences negatively. Moreover, level of subjective risk was found to be a significant determinant of the post-event reaction of the treatment group. The accident triggered a significant negative reaction of respondents living in close proximity to nuclear plants who perceive the risk of nuclear accidents, unsafe disposal of waste

[9] Complete table available in Appendix 4

and nuclear weapons to be relatively large. As the treatment group is exposed to higher levels of objective risk (Franchino 2014), it is only logical that individuals who are more susceptible to this risk will be most affected by the accident. On the other hand, respondents from the treatment group, who assign lower probability to the risks of nuclear power, were found to be more likely to encourage its maintenance in the aftermath of Fukushima. As these respondents characterize risks related to having a local nuclear plant to be relatively low, it is also possible that they consider the Fukushima accident to have little or no relevance to their community.

The current study contributes to a better understanding of the role of gender not only as a determinant of nuclear policy preferences, but also as a factor shaping individual reactions to a nuclear crisis. While the study confirms previous findings about females being less supportive of nuclear power (Stoutenborough, Sturgess and Vedlitz 2013, Kubota 2012), the sensitivity analysis further provides evidence that males from the comparison group experienced a more significant drop in nuclear policy preferences than females. This is likely caused by males having more favorable pre-accident nuclear preferences, which allowed them to lower their nuclear support without having to select a more extreme policy alternative such as an immediate phase-out.

Moreover, men from the treatment group were more likely to support policies promoting nuclear power after Fukushima while no change in attitudes was detected for women. A potential explanation to this result could be that males from the treatment group have higher perceived benefits of nuclear power in comparison to females from the same group. With male workers prevailing in various economic, political and technical fields, men perceive a higher need for secure energy supply which affects positively their benefit perceptions (Kubota 2012).

In order to get a better understanding of the dynamics of spatial context, the study further examines attitudinal trends of respondents who live in the extended evacuation zone within a radius of 80 kilometers around each nuclear plant. The empirical results suggest that they are significantly less likely to support policies promoting nuclear power than both the treatment group and the population living farther away from nuclear plants. The *proximity effect* indicates that such respondents would be exposed to higher levels of radiation and higher health and environmental damage than the general population in the case of a nuclear accident in Sweden, which explains the pattern of the *proximity 80 km* coefficient (Kim, Kim and Kim 2013). Furthermore, the *distance effect* is the reason for such respondents to be less familiar with the technology and benefit less from the nuclear plant explaining the difference between this group of respondents and the treatment group.

The study advocates a more holistic approach to nuclear policy and public support where those are discussed not only in isolation, but considering the economic, environmental and social context as well. This would allow for better communication of the different risks and benefits arising from the use of nuclear power and enable the public to form a more objective view of their preferences.

The relationship between environmental values and nuclear support is found to be particularly interesting. Environmentalists are generally found to be ambivalent to the nuclear technology with it being carbon efficient, but at the same time subject to potential environmental hazards (Visschers, Keller and Siegrist 2011, Hultman 2011). Examination of the cross-sectional surveys has indicated that the negative relationship between environmental interests and nuclear policy preferences is mostly driven by the post-event period, suggesting that in the aftermath of Fukushima environmentalists were less likely to support nuclear power. A potential interpretation of this result is that environmental risks related to nuclear power have finally outweighed the environmental benefits from the resource for the sub-sample of environmentalists. In line with prior literature (Visschers, Keller and Siegrist 2011), this paper argues that in a time of a nuclear crisis the detrimental consequences for society and the environment become more evident than the long-term effect of carbon efficiency.

While not surprising, it is interesting to note that higher concern about the economic state has a positive effect on nuclear policy preferences. Political views have also been found to determine nuclear policy preferences, which is in line with previous literature’s findings that positions taken by political parties and the occurrence of nuclear accidents have been the most important factors for the development of mass attitudes to nuclear power in Sweden (Holmberg and Hedberg 2012). Other factors that were shown to contribute to policy preferences were level of knowledge about nuclear power in terms of education and media access, political views and a number of demographic characteristics among which age, income and family status.

While the study identifies a general decrease in nuclear support in Sweden, it provides no insights about whether the attitude change is permanent or transitory. Further research is necessary to conclude about the long-term effects of the accident in Sweden and thus the significance of the impact in terms of policy implications. Studies following previous nuclear crises have outlined a partial return of nuclear attitudes to their levels before the accident within several months or years (Prati and Zani 2013).

Nevertheless, empirical highlights consistently suggest nuclear policy perceptions in Sweden are sensitive to safety violations and nuclear accidents. Since nuclear investment requires substantial capital and faces long-term safety-related challenges, nuclear maintenance and expansion policies should account for potential shifts in public attitudes and their determinants. At the same time, information about the implications of a potential nuclear phase-out should be available to consumers. Uncertainty about electricity prices, energy supply and employment might be reasons for consumers to shy away from promoting a phase-out policy.

7. Conclusion

The purpose of this paper is to explore the influence of the Fukushima accident in Japan during March 2011 on nuclear policy preferences in Sweden. The study stresses the importance of distance to a nuclear plant as a factor influencing the public reaction to a nuclear disaster.

The empirical analysis utilizes consequent cross-sectional datasets allowing for the examination of individual nuclear policy preferences and their determining mechanisms (SOM Institute 2007, 2008, 2009, 2010, 2011). This study tests the influence of the disaster on public support for nuclear power applying a natural experiment methodology.

As expected, the study finds a negative and highly significant effect from the disaster on nuclear policy attitudes and investment in the industry attitudes and a positive and significant effect on phase-out support. Furthermore, empirical results suggest that the negative effect of the disaster increases with distance from a nuclear plant, having a very limited impact on people residing in closest proximity to nuclear plants in Sweden. Such respondents are instead found to have much more favorable attitudes towards nuclear power which stay relatively stable in the aftermath of Fukushima.

However, the paper outlines several threats to the empirical strategy. Arguably the biggest one is the lack of a control group that is clear of any influence from the Fukushima accident. That being said, attitudes have been found to be relatively fixed prior to the accident which supports the idea that the estimated effect is the true effect of the disaster.

This study directly extends previous research on the impact of the Fukushima accident in Sweden by explicitly attempting to assess the importance of distance to a nuclear plant for the post-event reaction of the public. The paper also focuses particularly on the impact on different homogeneous cohorts identifying factors such as risk perception, environmental priorities and gender as important for the formation of nuclear attitudes in the aftermath of Fukushima. The main explanation offered by this research is the varying levels of perceived benefits and subjective risk among respondents, which has also been outlined by previous studies (Stoutenborough, Sturgess and Vedlitz 2013, Kubota 2012, Visschers, Keller and Siegrist 2011).

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Appendix

Appendix 1: Comparison between the whole sample and three sub-samples with information about the three outcomes of interest (Nuclear policy attitudes, Phase-out attitudes and Investment attitudes)

	Sub-Sample (S)			**Whole Sample (W)**			**Difference (W-S)**
	Mean	Std. Dev.	N	Mean	Std. Dev.	N	
Nuclear Policy Attitudes							
Female	0.53	0.50	17,408	0.53	0.50	21,252	0.005
Age	50.09	17.97	17,408	50.22	18.04	21,252	0.124
Low household income	0.32	0.47	16,305	0.33	0.47	18,066	0.002
Medium household income	0.43	0.50	16,305	0.42	0.49	18,066	-0.005
High household income	0.25	0.43	16,305	0.25	0.43	18,066	0.002
Employed	0.57	0.50	17,140	0.56	0.50	20,795	-0.007**
Married	0.50	0.50	17,045	0.50	0.50	20,718	-0.001
Children	0.72	0.45	17,151	0.72	0.45	20,841	-0.001
Low education	0.21	0.41	17,068	0.22	0.41	20,630	0.002
Medium education	0.54	0.50	17,068	0.54	0.50	20,630	-0.003
High education	0.25	0.43	17,068	0.25	0.43	20,630	0.001
Phase-out Attitudes							
Female	0.52	0.50	9,258	0.53	0.50	21,252	0.006*
Age	50.08	17.70	9,258	50.22	18.04	21,252	0.136
Low household income	0.32	0.47	7,189	0.33	0.47	18,066	0.003
Medium household income	0.43	0.50	7,189	0.42	0.49	18,066	-0.006*
High household income	0.24	0.43	7,189	0.25	0.43	18,066	0.004
Employed	0.57	0.49	9,103	0.56	0.50	20,795	-0.010**
Married	0.51	0.50	9,057	0.50	0.50	20,718	-0.008**
Children	0.73	0.45	9,103	0.72	0.45	20,841	-0.005
Low education	0.20	0.40	9,054	0.22	0.41	20,630	0.011***
Medium education	0.54	0.50	9,054	0.54	0.50	20,630	-0.003
High education	0.26	0.44	9,054	0.25	0.43	20,630	-0.009***
Investment Attitudes							
Female	0.51	0.50	6,958	0.53	0.50	21,252	0.025***
Age	50.16	17.39	6,958	50.22	18.04	21,252	0.054
Low household income	0.31	0.46	6,628	0.33	0.47	18,066	0.020***
Medium household income	0.44	0.50	6,628	0.42	0.49	18,066	-0.013***
High household income	0.25	0.44	6,628	0.25	0.43	18,066	-0.007**
Employed	0.59	0.49	6,870	0.56	0.50	20,795	-0.025***
Married	0.51	0.50	6,821	0.50	0.50	20,718	-0.015***
Children	0.73	0.44	6,853	0.72	0.45	20,841	0.005**
Low education	0.19	0.39	6,862	0.22	0.41	20,630	0.024***
Medium education	0.54	0.50	6,862	0.54	0.50	20,630	-0.004
High education	0.27	0.44	6,862	0.25	0.43	20,630	-0.021***

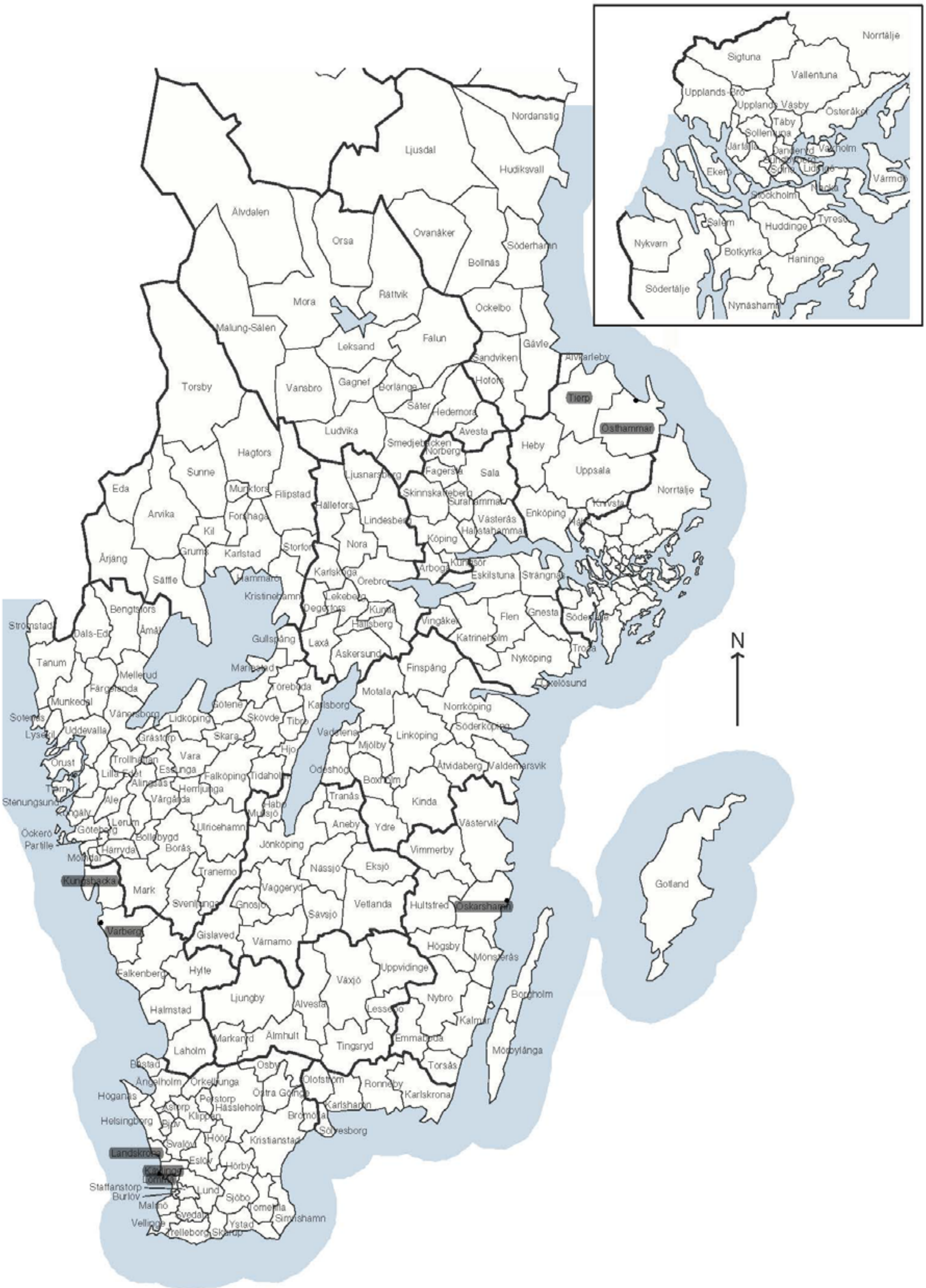
Note: The difference column shows the difference between the mean from the whole sample and the sub-samples with information on outcomes of interest. Significance level: * p<0.1; ** p<0.05; *** p<0.01

Appendix 2: Descriptive Statistics

Variable	Definition	Obs	Mean	Std. Dev.	Min	Max
Dependent Variables						
Nuclear Policy Attitudes	Policy attitudes towards nuclear power. Values: 1.Phase out as soon as possible, 2.Phase out when current reactors used up, 3. No firm opinion, 4.Use nuclear power but don't build new reactors, 5.Use nuclear power and build more reactors	17,408	3.25	1.27	1	5
Phase-out Attitudes	Attitudes towards nuclear phase-out. *Should Sweden phase out nuclear power in the long run?* Ranging from 1. Very bad suggestion to 5. Very good suggestion	9,258	3.12	1.32	1	5
Investment Attitudes	Attitudes towards investment in nuclear power. *How much should Sweden invest in nuclear power?* Values: 1. No investment in nuclear power, 2. Invest less than today, 3.Invest approximately the same amount, 4. Invest more than today	6,958	2.54	0.98	1	4
Independent Variables						
Proximity	Dummy variable for proximity to a nuclear plant in Sweden taking value of 1 for individuals who live very close to a nuclear plant and 0 otherwise. Appendix 3 outlines the municipalities that are considered in close proximity to nuclear plants in Sweden.	21,252	0.03	0.16	0	1
Proximity 80 km	Dummy variable for proximity to a nuclear plant in Sweden taking value of 1 for individuals living in the recommended evacuation zone (in the radius of 80 km) in the case of a nuclear accident, and 0 otherwise	21,252	0.38	0.48	0	1
Risk of nuclear accidents	Opinion on the risk of nuclear accidents: *What is the risk of a major nuclear accident in Sweden?* Ranging from 1. Very small risk to 10. Very large risk	5,829	4.02	2.53	1	10
Risk of unsafe waste disposal	Opinion on the risk of nuclear waste: *What is the risk of Sweden not being able to manage and dispose of nuclear waste?* Ranging from 1. Very small risk to 10. Very large risk	5,796	4.68	2.77	1	10
Risk of nuclear weapons	Opinion on the risk of nuclear weapons: *What is the risk of nuclear power providing countries with nuclear weapons?* Ranging from 1. Very small risk to 10. Very large risk	5,778	5.28	2.85	1	10
Confidence in the industry	Dummy variable for high confidence in the nuclear industry taking values of 1 for high and very high confidence in the nuclear industry and 0 otherwise	7,447	0.42	0.49	0	1
Concern economic crisis	Dummy variable for economic priorities (concern about the economic crisis) taking values of 1 for individuals expressing worries about the economic crisis and values of 0 otherwise	12,436	0.71	0.46	0	1
Environmental interests	Dummy variable for environmental interest taking values of 1 for individuals that are interested in environmental questions and 0 otherwise	7,770	0.76	0.43	0	1
Media access	Dummy variable for regular search for information on the internet (media access) taking values of 1 if individuals search for information every day or almost every day and 0 otherwise	17,622	0.59	0.49	0	1
Female	Dummy variable for gender taking values of 1 for females and 0 for males	21,252	0.53	0.50	0	1
Age	Age	21,252	50.22	18.04	16	90

Low household income	Dummy variable for relatively low household income taking a value of 1 for household members with household income below 300,000 SEK per year before tax and 0 otherwise	18,066	0.33	0.47	0	1
Medium household income	Dummy variable for relatively medium household income taking a value of 1 for household members with household income between 300,000 SEK and 600,000 SEK per year before tax and 0 otherwise	18,066	0.42	0.49	0	1
High household income	Dummy variable for relatively high household income taking a value of 1 for household members with household income above 600,000 SEK per year before tax and 0 otherwise	18,066	0.25	0.43	0	1
Employed	Dummy variable for employment taking values of 1 for employed individuals and 0 otherwise	20,795	0.56	0.50	0	1
Married	Dummy variable for marital status taking values of 1 for married individuals and 0 otherwise	20,718	0.50	0.50	0	1
Children	Dummy variable for having children taking values of 1 for individuals with children and 0 otherwise	20,841	0.72	0.45	0	1
Low education	Dummy variable for low education taking a value of 1 for individuals with low education and 0 otherwise	20,630	0.22	0.41	0	1
Medium education	Dummy variable for medium education taking a value of 1 for individuals with medium education and 0 otherwise	20,630	0.54	0.50	0	1
High education	Dummy variable for medium education taking a value of 1 for individuals with high education and 0 otherwise	20,630	0.25	0.43	0	1
Centerpartiet	Attitudes towards the Swedish Center Party (Centerpartiet). Ranging from Dislike Strongly (-5) to Like Strongly (5)	7,463	-0.16	2.46	-5	5
Moderaterna	Attitudes towards the Moderate Party (Vänsterpartiet). Ranging from Dislike Strongly (-5) to Like Strongly (5)	7,501	0.23	3.26	-5	5
Vänsterpartiet	Attitudes towards the Swedish Left Party (Sweden). Ranging from Dislike Strongly (-5) to Like Strongly (5)	7,415	-1.10	2.85	-5	5
Folkpartiet	Attitudes towards the Swedish Liberal People's Party (Folkpartiet). Ranging from Dislike Strongly (-5) to Like Strongly (5)	7,380	0.02	2.53	-5	5
Socialdemokraterna	Attitudes towards the Swedish Social Democratic Party (Socialdemokraterna). Ranging from Dislike Strongly (-5) to Like Strongly (5)	7,513	0.50	2.85	-5	5
Miljöpartiet	Attitudes towards the Swedish Green Party (Miljöpartiet). Ranging from Dislike Strongly (-5) to Like Strongly (5)	7,435	0.30	2.69	-5	5
Kristdemokraterna	Attitudes towards the Swedish Christian Democrats (Kristdemokraterna). Ranging from Dislike Strongly (-5) to Like Strongly (5)	7,423	-0.72	2.64	-5	5
Sverigesdemokraterna	Attitudes towards the Swedish Democrats (Sverigesdemokraterna). Ranging from Dislike Strongly (-5) to Like Strongly (5)	7,493	-3.02	2.84	-5	5

Appendix 3: Map of nuclear power plants in Sweden. Source: Statistics Sweden and own calculations



Note: Black dots on the map represent the approximate location of the nuclear municipalities. Respondents who live in the municipalities closest to the nuclear plants together comprise the treatment group from the difference-in-difference framework. Those municipalities are marked in grey and they are selected based on their relative distance to the nuclear plants. In determination of treatment group, the study considers the regulations regarding Emergency Planning Zones with a radius of 10 miles (16 kilometres) around each reactor site (US NRC 2014). A complete map of Sweden with scale can be found under the following link: http://www.scb.se/grupp/klassrummet/_dokument/kommuner_text.pdf

Appendix 4: Before-after estimates for some independent variables.

	OLOGIT			LOGIT
	Risk of nuclear accidents	Risk of unsafe disposal of waste	Risk of nuclear weapons	Confidence in the industry
y2011	0.621***	0.342***	1.192***	-0.237**
	(0.134)	(0.130)	(0.133)	(0.092)
Trend	-0.124***	-0.151***	-0.372***	0.008
	(0.041)	(0.041)	(0.038)	(0.024)
Proximity	0.106***	-0.009	-0.168***	-0.042**
	(0.035)	(0.028)	(0.029)	(0.021)
Proximity 80 km	-0.223***	-0.214***	0.041	0.351***
	(0.037)	(0.045)	(0.033)	(0.032)
Female	0.939***	1.027***	0.503***	-0.560***
	(0.052)	(0.048)	(0.049)	(0.054)
Age	-0.000	-0.006***	0.013***	0.005*
	(0.002)	(0.002)	(0.002)	(0.002)
Medium household income	-0.338***	-0.276***	-0.319***	0.285***
	(0.067)	(0.075)	(0.071)	(0.065)
High household income	-0.660***	-0.590***	-0.510***	0.669***
	(0.084)	(0.086)	(0.093)	(0.081)
Employed	-0.010	-0.081	-0.135**	0.079
	(0.068)	(0.061)	(0.060)	(0.062)
Married	0.036	-0.053	0.060	0.078
	(0.058)	(0.055)	(0.076)	(0.059)
Children	0.133*	0.157*	0.031	-0.101
	(0.069)	(0.081)	(0.072)	(0.083)
Medium education	-0.265***	-0.268***	-0.181**	0.062
	(0.074)	(0.071)	(0.078)	(0.079)
High education	-0.282***	-0.178**	-0.220**	-0.090
	(0.084)	(0.083)	(0.092)	(0.081)
Monthly controls	YES	YES	YES	YES
Municipality controls	YES	YES	YES	YES
N	**5,322**	**5,303**	**5,286**	**6,755**
Pseudo R^2	**0.04**	**0.04**	**0.04**	**0.06**

Note: Robust standard errors clustered at the municipality level in parenthesis. The risk regressions do not include data from 2010. The variable *Trend* incorporates a time trend and takes values from 1 for 2007 to 5 for 2011. Significance level: * p<0.1; ** p<0.05; *** p<0.01

Appendix 5: Difference-in-difference estimates. Marginal Effects.

	Nuclear Policy Attitudes	Phase-out Attitudes	Investment Attitudes
y2011	-0.055***	0.034***	-0.059***
	(0.005)	(0.007)	(0.008)
Proximity	0.071***	-0.046**	0.093***
	(0.015)	(0.020)	(0.012)
y2011* Proximity	0.013	-0.054	0.046**
	(0.020)	(0.073)	(0.022)
Background controls	NO	NO	NO
N	**17,371**	**9,236**	**6,943**

Note: Marginal effects are calculated for the highest values of the dependent variables: outcome of 5 in Panel A and Panel B and outcome of 4 in Panel C. Robust standard errors clustered at the municipality level in parenthesis. The Pseudo R^2 values are collected from the OLOGIT analysis prior to the estimation of the marginal effects. Other yearly dummies are not included resulting in y2011-dummy showing the post-event change in the dependent variables in comparison to the entire pre-event period (2007-2010). The interaction terms' coefficients and standard errors have been calculated using the delta method with the *predictnl* command in Stata 13.
Significance level: * p<0.1; ** p<0.05; *** p<0.01

Appendix 6: Difference-in-difference estimates of the truncated sample (Nuclear Policy Attitudes > 1)
(1) No controls, (2) Incl. Demographics, (3) Incl. Knowledge and Attitudes, (4) Incl. Risk

	OLS				OLOGIT			
Panel A: Nuclear Policy Attitudes	(1a)	(2a)	(3a)	(4a)	(1b)	(2b)	(3b)	(4b)
y2011	-0.236***	-0.272***	-0.141***	-0.187***	-0.385***	-0.481***	-0.335***	-0.458***
	(0.026)	(0.028)	(0.041)	(0.042)	(0.043)	(0.048)	(0.083)	(0.096)
Proximity	0.272***	0.227***	0.186*	0.825***	0.456***	0.402***	0.973***	1.065***
	(0.036)	(0.027)	(0.110)	(0.127)	(0.062)	(0.032)	(0.096)	(0.141)
y2011* Proximity	-0.074	-0.043	0.335	0.277	-0.112	-0.083	0.795**	0.782
	(0.129)	(0.101)	(0.206)	(0.239)	(0.241)	(0.184)	(0.401)	(0.519)
Monthly controls	NO	YES	YES	YES	NO	YES	YES	YES
Municipality controls	NO	YES	YES	YES	NO	YES	YES	YES
N	**15,797**	**14,363**	**4,780**	**3,577**	**15,797**	**14,363**	**4,780**	**3,577**
R^2	**0.01**	**0.13**	**0.34**	**0.43**				
Pseudo R^2					**0.00**	**0.05**	**0.16**	**0.22**
Panel B: Phase-out Attitudes	(1a)	(2a)	(3a)	(4a)	(1b)	(2b)	(3b)	(4b)
y2011	0.110***	0.218***	0.137***	0.215***	0.148***	0.315***	0.221**	0.406***
	(0.036)	(0.043)	(0.052)	(0.055)	(0.049)	(0.063)	(0.091)	(0.102)
Proximity	-0.177*	-1.426***	0.731***	0.293**	-0.267*	-0.292***	-0.794***	-0.947***
	(0.098)	(0.089)	(0.114)	(0.114)	(0.140)	(0.082)	(0.082)	(0.092)
y2011* Proximity	-0.250	-0.168	-0.015	-0.012	-0.346	-0.193	0.074	0.046
	(0.255)	(0.268)	(0.181)	(0.163)	(0.383)	(0.406)	(0.297)	(0.314)
Monthly controls	NO	YES	YES	YES	NO	YES	YES	YES
Municipality controls	NO	YES	YES	YES	NO	YES	YES	YES
N	**8,542**	**6,294**	**4,786**	**3,555**	**8,542**	**6,294**	**4,786**	**3,555**
R^2	**0.00**	**0.13**	**0.33**	**0.42**				
Pseudo R^2					**0.00**	**0.05**	**0.13**	**0.18**
PanelC: Investment Attitudes	(1a)	(2a)	(3a)	(4a)	(1b)	(2b)	(3b)	(4b)
y2011	-0.185***	-0.229***	-0.186***	-0.214***	-0.366***	-0.515***	-0.506***	-0.646***
	(0.032)	(0.033)	(0.034)	(0.037)	(0.063)	(0.072)	(0.086)	(0.106)
Proximity	0.277***	0.644***	0.052	0.088	0.613***	0.764***	0.991***	0.724***
	(0.048)	(0.078)	(0.062)	(0.095)	(0.080)	(0.087)	(0.126)	(0.197)
y2011* Proximity	0.049	0.075	0.068	0.145	0.076	0.127	0.129	0.328
	(0.230)	(0.222)	(0.214)	(0.245)	(0.511)	(0.532)	(0.584)	(0.792)
Monthly controls	NO	YES	YES	YES	NO	YES	YES	YES
Municipality controls	NO	YES	YES	YES	NO	YES	YES	YES
N	**6,276**	**5,778**	**4,485**	**3,356**	**6,276**	**5,778**	**4,485**	**3,356**
R^2	**0.01**	**0.17**	**0.38**	**0.48**				
Pseudo R^2					**0.00**	**0.07**	**0.19**	**0.25**

Note: Robust standard errors clustered at the municipality level in parenthesis. R^2 estimates the fit of the OLS regressions (on the left) and the Pseudo R^2 estimates the fit of the OLOGIT regressions (on the right). 2011-dummy plays the role of a post-event dummy contrasting the estimates in 2011 with their value in the entire pre-event period (2007-2010). While no extra controls are considered in Columns 1, demographic controls as well as municipality and monthly fixed effects are regarded in Columns 2. The effects of additional controls examining knowledge and attitudinal and value indicators are presented in Columns 3 and risk perception controls are finally added in Columns 4. Columns (4) do not include data from 2010. Significance level: * *p*<0.1; ** *p*<0.05; *** *p*<0.01

Appendix 7: Brant test

	Nuclear Policy Attitudes		Phase-out Attitudes		Investment Attitudes	
	Chi2	Prob.	Chi2	Prob.	Chi2	Prob.
y2011	10.81**	0.013	14.91***	0.002	1.81	0.405
Proximity	0.34	0.953	2.27	0.518	4.13	0.127
y2011* Proximity	8.23**	0.041	2.38	0.497	5.27*	0.072

Note: A significant test statistic provides evidence that the regression assumption the OLOGIT analysis is based on has been violated. The Brant test relates to the OLOGIT estimates presented in Table 4, Column 1b. Significance level: * *p*<0.1; ** *p*<0.05; *** *p*<0.01