Social costs of fourth generation nuclear energy in Italy after Fukushima: a choice experiment approach

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Abstract

The planned re-introduction of nuclear energy in Italy was abandoned in the aftermath of the Fukushima nuclear accident. Twenty years earlier, soon after the Chernobyl accident, Italians had also voted against nuclear energy. However, a new nuclear energy technology, i.e. fourth generation, is under research and development. This paper investigates its social acceptance by means of a robust methodology, employing 1) choice experiments, 2) structural equation modeling and 3) information treatments within an online nation-wide survey. Results show a great deal of preference heterogeneity: the majority of sampled respondents oppose new nuclear plants in Italy, with some not willing to accept any monetary compensation at all. However, another segment of respondents, more confident that fourth generation nuclear energy goals will be achieved, show a modest support towards the implementation of new nuclear projects. Additional variables were found to affect opposition. Remarkably, choice experiments and structural equation modeling's results are aligned.

Keywords: Fourth generation nuclear energy, choice experiments, Fukushima, Italy.

1. Introduction

In 2011 the European Commission released the 2050 roadmap which aims to reduce CO_2 emissions by a staggering 80% when compared with 1990 (European Commission COM 2011). Italy has recently adopted the National Energy Strategy, which aims to go beyond the 20% reduction goal by 2020 set by EU 2020 strategy. However, it seems there are currently no policies planned or in place so as to reach the European Commission roadmap's goals (ENEA 2013). Currently in Italy, fossil fuels dominate both the energy mix and the amount of energy imported (ENEA 2013). This poses at least two problems. First, the heavy reliance on fossil fuels makes it impossible to achieve the Green House Gas (GHG) emission reductions needed to tackle climate change. Second, there are risks associated with having a high share of imports such as reliance on politically unstable countries and the burden posed to the trade balance (IEA 2009). Hence, it is desirable to decrease fossil fuel consumption and switch to energy sources with zero (or next to zero) GHG emissions, as well as to reduce energy imports and/or make them more diversified. In 2012, Italy's total GHG emissions amounted to about 379 million tons, representing 10.03% of EU's emissions (Eurostat 2014). This share has increased slightly from 1990 levels, when it accounted for 9.2%, although Italian emissions in 2012 decreased by 11.3% compared to twelve years earlier. However, another 10% reduction by 2020 is needed to comply with the EU 2020 strategy and both short and long term structural reforms are necessary to aim at the challenging 2050's 80% reduction. Achievement of these targets can be accomplished by increasing the share of renewables and, according to some views, by including nuclear power in the energy generation mix.

Nuclear energy is not part of the current Italian energy mix. In 1987, one year after the Chernobyl accident, the Italian population voted against nuclear energy. But almost twenty years later, the re-introduction of nuclear appeared to be very likely (Iaccarino 2010). This was not just an isolated case: in 2009 there were 52 countries considering the implementation of nuclear energy (Jewell 2011). However, in 2011 there was another serious nuclear accident, this time in Fukushima, Japan. Mimicking the events of '87, via a referendum, the Italian population once again declared a widespread opposition towards the building of new nuclear plants in Italy[1]. Unsurprisingly, the Fukushima accident has generally worsened nuclear energy's acceptability worldwide (Kim et al. 2013), especially in Japan (Poortinga et al. 2013), as well as affecting subjective well-being negatively (Welsh and Biermann 2014; Rehdanz et al. 2015). Similarly, public opinion had been negatively affected by the Chernobyl's (Eiser et al. 1989; Renn 1990; Verplaken 1989) and the Three Mile Island's nuclear accidents (Melber 1982). There are a few exceptions: after the accident in Japan, nuclear energy's acceptability seems not to have changed in the USA and indeed it appears to have improved in the UK (Srinvasan and Gopi Rethinaraj 2013). This negative effect on public opinion arguably tends to decrease over time (Siegrist and Visschers 2013). However, in 2012, public acceptance of nuclear energy in Italy was still below the EU-27 average (European Commission 2013): only 11% of Italians surveyed would prioritize nuclear energy as energy option thinking about the next 30 years, whereas the EU-27 average was 18%. On the opposite end Czech Republic (44%), followed by Sweden (33%). All in all, preferences towards nuclear energy in Europe seem to be quite negative, especially if compared to renewable energy acceptance: 8 in 10 citizens of EU-27 would prioritize renewable energy sources over nuclear, energy efficiency and carbon capture storage (European Commission 2013).

Nevertheless, a new technology to generate electricity from nuclear power is under research and development (R&D). In 2000, the Generation IV Energy Forum (GIF) – '*a cooperative international endeavour organized to carry out the R&D needed to establish the feasibility and performance capabilities of the next generation nuclear energy systems'* – was established (www.gen-4.org). It consists of twelve countries and the EURATOM, through which Italy is present indirectly[2]. Its work is now focused on developing six IV generation

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[1] However, the Italian government openly declared its interest in contributing towards R&D of new generation reactors (Pistelli 2013).

[2] For example, the Italian company Ansaldo Nucleare and ENEA form part of a consortium to develop a fourth generation prototype (Agostini and Alemberti 2014).

nuclear energy projects, selected in 2002: Gas-Cooled Fast Reactor, Lead-Cooled Fast Reactor, Molten Salt Rector, Sodium-Cooled Fast Reactor, Supercritical-Water Reactor and Very-High Temperature Reactor. All these reactors have in common the following goals: i) to minimize the probability of catastrophic accidents; ii) to minimize the amount of nuclear waste produced; iii) to reduce the number of years needed to dispose and store the nuclear waste; iv) to increase the cost competitiveness compared to other energy sources; v) to increase the protection against terrorist attacks; and vi) to increase passive security. These so-called fourth generation (FG) nuclear energy systems can be thought of as revolutionary if compared to current nuclear technology (Grape et al. 2014).

The first nuclear plants belonging to the fourth generation are forecasted to be available by 2030 (Locatelli et al. 2013), just in time to be able to contribute to the 2050 roadmap targets. However, the FG technology is still underdeveloped (Murty and Charit 2008). For instance, there are currently no materials which can bear the pressure and temperatures planned for the 'Very high temperature reactors' project, (Abram and Ion 2008; Locatelli et al. 2013). The technology costs are the other issue of concern as they are currently undetermined (Kessides 2012; Kosenius and Ollikainen 2013). Hence, besides social acceptability, FG implementation also needs to rise to both technological and economic challenges.

This paper focuses on social acceptability and preferences for FG nuclear energy technology: to the best of our knowledge, this is the first study on the matter. We employ choice experiments, a survey based stated preference method (Bateman et al. 2002), to estimate the willingness to accept (WTA) compensation of Italian residents and its determinants for the installation of new FG nuclear power plants in Italy. In addition, this study implements a structural equation modeling framework in order to further characterize the determinants of acceptance, drawing on the environmental psychology literature. Finally, an information treatment is carried out in order to test the sensitivity of results towards different level of information on nuclear energy. These are the three pillars of the framework we implement in order to model individual preferences for nuclear energy. The rest of the paper is structured as follows: the next section provides a literature review on nuclear energy's acceptance studies; Section 3 describes the data collection methods (i.e. choice experiments) as well as the data analysis methods used; Results are presented and discussed in Section 4; Section 5 present heterogeneity and sensitivity tests' results whereas Section 6 concludes.

2. Literature review

2.1 Stated preference methods

Survey-based stated preference methods have been widely used to estimate public preferences towards a range of energy sources. A body of empirical work has investigated preferences for green electricity without reference to the energy sources that make up the green power mix. Fimereli's (2011) review of the topic concludes that the public tends to be supportive of green power and that willingness to pay is generally positive. In terms of specific relevant attributes, the literature suggests that the public attaches a high value to reductions in GHG emissions and that proximity of energy plants to the place of residence affects public support (Fimereli 2011). Also of relevance, the public acceptability literature suggests the need for direct economic benefits to the host communities (Van der Horst 2007). However, support for clean energy sources in general can often mask substantial differences between specific clean energy technologies (Borchers et al. 2007; Walker, 1995).

More relevant to this paper is the body of work that has investigated preferences for specific energy technologies, particularly nuclear energy. As noted above, evidence on acceptability seems to show that public support or opposition for nuclear power is heterogeneous and varies worldwide (Ansolabehere 2007; European Commission 2013; Ipsos MORI 2011; Macintosh and Hamilton 2007; OECD 2010). There is also mounting evidence on preferences for nuclear energy with a number of valuation studies, mostly contingent valuation, conducted in Taiwan (Liao et al. 2010), China (Sun and Zhu 2014), South Korea (Choi et al. 1998; Huh et al. in press; Jun et al. 2010), Hong Kong (Woo et al. 2014), USA (Murakami et al. 2015; Riddel and Shaw 2003), Japan (Itaoka et al. 2006; Murakami et al.2015), Germany (Kaenzig et al. (2013), UK (Fimereli, 2011), and Italy (Cicia et al. (2012). Unsurprisingly, attitudes towards and preferences for nuclear power appear to be driven more by perceived risk and safety than by perceived environmental benefits (Ansolabehere et al. 2003; Choi et al. 1998; De Boer and Catsburg 1988; Itaoka et al. 2006; Kato 2006; Riddel and Shaw 2003; Rosa and Dunlap 1994). Of particular interest for our research is the study by Cicia et al. (2012), conducted prior to the Fukushima accident. The authors investigated the acceptability of different energy sources in Italy, including nuclear. The results suggest that Italian preferences can be clustered in four groups, none of which are in favour of nuclear energy. Indeed, Italians seem to consistently prefer renewable energy sources (Bigerna and Polinori 2014; Bollino 2009; Strazzera et al. 2012a).

Despite the abundance of previous work on preferences for energy sources, fewer studies used the choice experiment approach to investigate preferences for particular attributes of nuclear energy technology. These existing studies include Huh et al. (in press), Itaoka et al. (2006), Kaenzig et al. (2013), Murakami et al.2015, and Cicia et al. (2012), to our knowledge the only choice experiment study on this topic conducted in Italy. Remarkably, the current study adds to this body of evidence by estimating preferences for fourth generation nuclear power plants in Italy.

2.2 Environmental psychology and nuclear energy

In addition to the economic valuation literature, accumulating literature in the Environmental Psychology field has highlighted the complex interplay of factors influencing social acceptance of nuclear energy, including its perceived benefits and risks; values; place identity-attachment; concern; trust; and socio-economic variables. These factors are usually measured by means of psychometric scales or Likert-like questions. The role of values appears to be of paramount importance as far as nuclear energy is concerned (De Groot et al. 2013). These are defined as determinants of '*beliefs and intentions related to ESB* [Environmentally Significant Behavior]' (De Groot and Steg 2008, p.331) and have been detected extensively in a number of empirical studies (Schwartz 1992; Schwartz, 1994; Schwartz and Huismans, 1995; Schwartz and Sagiv, 1995; Schwartz and Bardi, 2001). More generally, values serve as guiding principles in one's life (Schwartz 1992) and they form part of the Value Belief Norm (VBN) theory (Stern et al. 1999; Stern 2000). According to De Groot et al. (2013), perceived risks and benefits mediate the relationship between egoistic, altruistic and biospheric values and nuclear energy's acceptance. Individuals with greater egoistic value orientation tend to consider risks and benefits of nuclear mostly for themselves; those who predominately have an altruistic value orientation instead tend to consider risks and benefits for other people; finally, biospheric led individual should are expected to focus on the effects for the biosphere.

FG nuclear is a technology under research and development. With this in mind, respondents have been asked to state to what extent they are confident the goals of the IV gen forum are going to be reached: this provides a measure of confidence, distinguished from the concept of trust. In the context of nuclear energy, Siegrist et al. (2000) defined trust as '*the willingness to rely on those who have the responsibility for making decisions and taking actions related to the management of technology* […]' (Siegrist et al. 2000, p.354), suggesting to be indeed relevant in shaping acceptance of nuclear energy. In this study we hypothesize that confidence, together with perceived risks and benefits, affects fourth generation nuclear energy acceptance. At the same time, we gathered data so as to measure place identity-attachment, which has also been suggested to mediate risk perception, although with effects that differ depending on whether respondents have been living close to nuclear plants (Kovacs and Gordelier 2009; Venables et al. 2012). Finally, authors have suggested the importance of concern and emotional involvement: this has been found to be an important predictor of the willingness to take action against the implementation of contested projects (Atkinson et al. 2004; Han 2014).

3. Methodology

3.1 Choice Experiments

Choice experiments (CE) are a stated preference technique that have become a popular alternative to contingent valuation (Bateman et al. 2002; Hanley et al. 2001; Louviere et al. 2000). In a choice experiment, respondents are presented with a series of scenarios, each composed of different attributes, varying at different levels. Respondents are then asked to choose their most preferred scenario. If a money attribute is included, the implicit price of each of the other attributes (i.e. marginal WTP or WTA) can be calculated as well as the total welfare change provided by various scenario options. Although widely used in the environmental valuation field, specific applications of CE to the valuation of nuclear energy are rare (for an example see Itaoka et al. 2006).

There are potentially two distinct advantages in using this methodology for the valuation of preferences for nuclear energy. First, CE are particularly well suited to value changes that are multidimensional (with scenarios being presented as bundles of attributes) and where trade-offs between the various dimensions are of particular interest. Second, WTP or WTA is inferred implicitly from the stated choices, avoiding the need for respondents to directly place a monetary value on scenario changes. This latter characteristic has led to suggestions that CE formats may be less prone to protest responses than say contingent valuation as attention is not solely focused on the monetary attribute but on all the scenario attributes (Hanley et al. 2001). This is particularly relevant when dealing with nuclear energy-related scenarios that may be particularly prone to protest votes, given the notoriously strong views held towards nuclear energy by many people. On the negative side, complex CE can pose a significant cognitive burden to respondents leading to non-utility maximising strategies and choice errors (Bateman et al. 2002; Hanley et al. 2001).

Besides the choice experiment questionnaire, we collected extensive information on socio-economic characteristics, views on public expenditure areas, skepticism towards climate change, views on different energy sources, psychometric scales to measure perceived risks and benefits, questions on Chernobyl and Fukushima, concern about Fukushima, questions and information on Fourth Generation nuclear power, on where the nuclear plants are in Europe as well as some information of the nuclear accidents of Chernobyl and Fukushima (information treatment).

3.1.2 Experimental design

The choice experiment scenario asked respondents to imagine they had a chance to choose between a series of options regarding the construction of IV generation nuclear power plants in Italy. The selection of attributes and levels was informed by a literature review and interviews with experts, while pilot studies (via 15 face-to-face pre-test questionnaires and three on-line questionnaire pilots with 60 respondents) were also used to fine tune the survey instrument as well as some of the attribute definitions and levels. The attributes chosen were: atmospheric emission reductions, nuclear waste reduction, distance from the nuclear power plant, public investments and electricity bill reductions. Table 1 depicts the attributes and their levels.

Table 1. Attributes and levels of the choice experiments

Attributes	Levels
Distance from the nuclear plant	20, 50, 100, or 200 Km from the city of residence
Nuclear waste reduction	30%, 20%, 10% or no reduction
Atmospheric emission reduction	20%, 10% or no reduction
Electricity bill reduction	30%, 20%, 10% or no reduction
Public investments 1: Construction of hospitals	Yes or No
Public investments 2: Land Recovery measures	Yes or No

Nuclear energy is generally identified as an energy source with close to zero atmospheric emissions and therefore instrumental in tackling climate change (Apergis et al. 2010; Hayashi and Hughesm 2013; Srinivasan and Gopi Rethinaraj 2013; Samseth 2013; Van der Zwaan 2013; Wang et al. 2013). However, evaluations of actual emissions differ depending on the assumptions made about fuel cycle (i.e. whether the fuel is, at least partly, re-used), emissions during the construction phase, and waste management and decommissioning. In light of these considerations, we selected the attribute *Atmospheric Emission reduction* associated with implementation of nuclear energy in Italy, starting from the first year of operation, compared to current levels of emissions.

Truelove (2012) found that the production of waste from nuclear plants was the most important component of perceived risks by the public. This is particularly relevant for the case of Italy, where a national waste disposal site is yet to be established. Moreover, as noted above, nuclear waste reduction represents a common goal of the IV generation technology. Hence, we selected the attribute *Nuclear Waste Reduction* with respect to current nuclear technology. The levels were set according to current information and discussions with experts. It was not specified whether the waste reduction would be derived from recycling the fuel, from greater efficiency or from a combination of the two[3]. During normal operation, a nuclear plant poses potential threats to the environment (Beheshti 2011) and human health (Fairlie 2013). In case of nuclear accident, those living nearby would suffer the most (Munro 2013; Steinhauser et al. 2014). We therefore selected *Distance from the nuclear plant* as a further attribute. On this note, previous research has shown that proximity to nuclear plants in operation tends to reduce the extent to which risks are perceived (Pidgeon et al. 2008; Venables et al. 2012). But in Italy there are no nuclear plants in operation. Hence, a project including a nuclear plant further away

[3] The pre-test suggested respondents were not responsive to these additional pieces of information.

should be preferred, ceteris paribus. The smallest level of 20km from the town of residence of the respondent was chosen following Italian laws regulating the compensations measures in case of construction of nuclear plants (Iaccarino 2010).

It also seemed important to include an attribute representing the *Public investments* made possible due to energy savings arising from the construction of FG nuclear plants (Gregory et al. 1991; Mansfield et al. 2002; Yamane et al. 2011). The importance of including such attributes in a study aimed at assessing social acceptance of energy sources was previously shown by Strazzera et al. (2012b). The choice of what type of public investments to include was informed by the online pilots, where new hospitals, as well as investments in land recovery measures appeared to be highly valued[4].

As the study aims to unveil Italians' willingness to accept compensation for FG nuclear power plants, a monetary attribute was included in the choice cards. The payment vehicle employed was an *Electricity bill reduction*. It is beyond the scope of this work to establish what effect the re-introduction of nuclear power in Italy would have on the electricity prices and on the bill of households and firms. A multitude of factors can influence these outcomes: the level of competition in the Italian electricity market (Creti et al. 2010), characterized by high transaction costs between producers and communities (Garrone and Groppi 2012), the price of other energy sources in the energy mix, and the possible escalation in construction costs (Kessides 2012; Kosenius and Ollikainen 2013). The Italian government might even decide to subsidize prices, at least for those living in proximity to the nuclear power plants, as planned when the nuclear re-introduction was under way before the Fukushima accident (Iaccarino 2010). We selected plausible electricity bill reductions, along with a '*no decrease'* level.

Respondents were presented with a series of choice tasks, each consisting of a pair of nuclear energy scenarios, containing the five attributes and levels described in Table 1, and were asked to choose their most preferred scenario in each case. In addition, there was also an opt-out option, that is, respondents could decide to choose neither of the two nuclear energy options. Given five attributes and their levels, with two options per choice task, the total number of possible choice scenarios is 576[5]. This is clearly excessive and it was therefore necessary to reduce the number of choice tasks to present to respondents using experimental design. A main effects orthogonal design was used leading to a total of 64 choice pairs. This was still excessive for any single respondent and hence the 64 pairs were organized into 8 blocks of 8 choice tasks. The first 300 respondents

[4] Previously tested levels were 'electricity bill reduction for public companies' and 'new schools'.
[5] 4 distance levels * 4 waste reduction levels * 3 emission reduction levels * 4 bill reduction levels * 3 public investments = 576 scenarios.

were each asked to complete a block of 8 choice tasks. These results were analysed and produced priors for a subsequent Bayesian efficient design (Ferrini and Scarpa 2007; Rose and Bliemer 2009), which was then administered to the remaining 900 respondents. The analysis of the 300 initial responses revealed non-linear effects with respect to the *Public investments* attribute levels. Hence these were then included in the design as dummy-coded. For the final Bayesian efficient design, 5 blocks of 8 choice tasks each were retained[6]. The number of attributes and choice tasks appeared not to be an issue for the respondents at the pre-test/piloting stage. One of the choice tasks is presented in Figure 1.

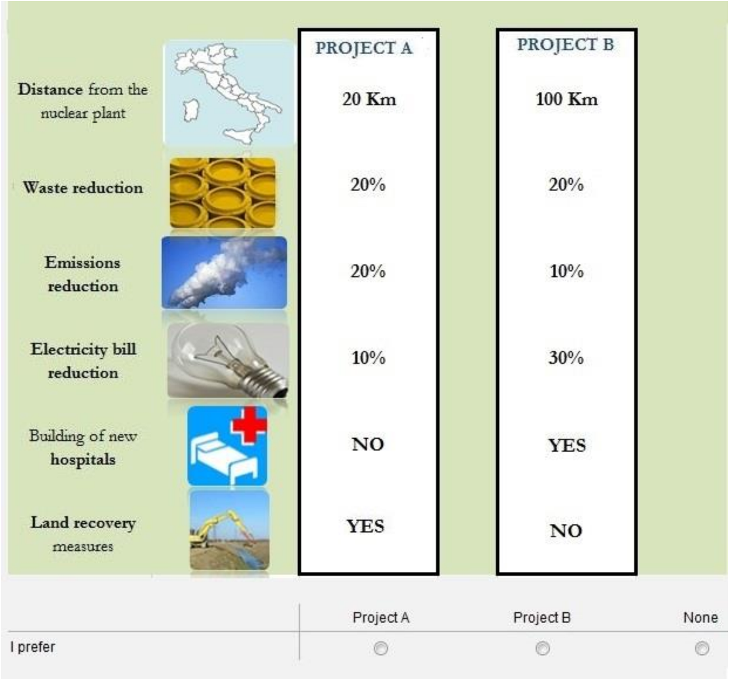

Figure 1: Example of a choice task

3.1.3 Information given to the respondents

Prior to the choice experiments, respondents were given some pieces of information regarding the fourth generation technology. First, they were asked to state the importance of a set of goals of the nuclear industry, without mentioning the label "fourth generation". After having answered these questions, respondents were told those were actually the goals of the fourth generation forum. Subsequently, they were asked whether they had heard before of this technology and the extent to which they were confident each of the goals would have been

[6] The matrix of the experimental design is available from the author upon request. Overlapping levels (equal between alternatives) were allowed, whereas no dominated alternatives were allowed.

reached. This order was chosen so as to make clear to the respondent to first focus on the level of importance, and later on the extent to which they believe the goals will be successfully attained. Remarkably, the information on fourth generation nuclear energy has been administered to all of the respondents.

In the aftermath of Chernobyl and Fukushima, Italians took part in referendums so to state their acceptance of nuclear power. It should be noticed that media coverage in times of nuclear crisis appears to be framed mostly in a negative way (Koerner 2014). On this note, the role of information has been shown to be crucial in shaping nuclear acceptance (Jun et al. 2010; Peters and Slovic 1996; Slovic 1987; Slovic et al. 1991; Slovic et al. 2005). In turn, this seems to be important even considering the broader context of social acceptance of energy sources (Hobman and Ashworth 2013). For instance, Strazzera et al. (2012b) show the significant effect of information on the consumers' willingness to pay for electricity generated by solar vs coal-fired power plants.

Drawing on this literature, in this study half of the respondents have been given additional information on nuclear energy. Specifically, the sample has been split into two information treatments. Half of the respondents have been presented with information on Chernobyl and Fukushima's accidents[7] (Fig. B1 in Appendix), and where nuclear plants are in Europe (Fig. B2 in Appendix). In Figure B2 there is a distinction between reactors in operation (green), not in operation (red), under construction (yellow) and planned (blue)[8].

3.2. Statistical and econometric models

The choice experiment data was analyzed employing a multinomial logit model (MNL), a random parameters with error components (RPL_EC) and a latent class model. An overview of these models is presented in Appendix.

3.2.1 Analysis of psychometric variables[9]

The structural equation model we estimate is characterized by seven latent variables: the values Egoistic, Altruistic and Biospheric; perceived Benefits, Risks, Confidence and, finally, Acceptability. Before running the model, seven independent factor analysis were carried out in order to confirm the validity of each construct. Each analysis consists in estimating a set of k regressions of the form:

$$v_i = \lambda_i \xi + \delta_i \tag{1}$$

[7] The following studies have been consulted so as to describe the two accidents: IAEA (2006), Steinhauser et al. (2014), UNSCEAR (2013).
[8] Source: World Nuclear Association
[9] This section draws on Bartholomew et al. (2008).

Where v_i represents the items, λ_i the factor loadings, ξ stands for the latent construct and finally δ_i are the specific factors. For example, as far as the Egoistic latent factor is concerned, we have a set of 4 regressions, as 4 are the statements used to measure this construct. The model implies the following variances:

$$\mathrm{Var}(v_{ik}) = (\textstyle\sum_k \lambda_{ik}{}^2) + \theta_{ii} \quad (2)$$

The loadings can be interpreted as the covariance between each v_i and the latent factor ξ. The unique variance of each item is represented by θ_{ii}. The complement of uniqueness represents the communality, whose mean is the proportion of total variance explained by the factor.

Once the constructs are validated, it is fair to estimate relationships between the constructs by means of structural equation model. This is characterized by the following measurement equations:

$$x_{i=}\tau_i^{(x)} + \lambda_{i1}^{(x)}\mathrm{Egoistic} + \delta_i,\ i = 1, \dots 4 \quad (3)$$

$$x_{i=}\tau_i^{(x)} + \lambda_{i2}^{(x)}\mathrm{Altruistic} + \delta_i, i = 1, \dots 4 \quad (4)$$

$$x_{i=}\tau_i^{(x)} + \lambda_{i3}^{(x)}\mathrm{Biospheric} + \delta_i, i = 1, \dots 3 \quad (5)$$

$$x_{i=}\tau_i^{(x)} + \lambda_{i4}^{(x)}\mathrm{Confidence} + \delta_i, i = 1, \dots 5 \quad (6)$$

$$y_{i=}\tau_i^{(y)} + \lambda_{i1}^{(y)}\mathrm{Benefits} + \epsilon_i, i = 1, \dots 6 \quad (7)$$

$$y_{i=}\tau_i^{(y)} + \lambda_{i2}^{(y)}\mathrm{Risks} + \epsilon_i, i = 1, \dots 7 \quad (8)$$

$$y_{i=}\tau_i^{(y)} + \lambda_{i3}^{(y)}\mathrm{Acceptance} + \epsilon_i, i = 1, \dots 4 \quad (9)$$

As regards the structural equations, these are as follows:

$$\mathrm{Acceptance} = \beta_{11}\mathrm{Benefits} + \beta_{12}\mathrm{Risks} + \beta_{13}\mathrm{Confidence} + \zeta_1 \quad (10)$$

$$\mathrm{Benefits} = \gamma_{11}\mathrm{Egoistic} + \gamma_{12}\mathrm{Altruistic} + \gamma_{13}\mathrm{Biospheric} + \zeta_2 \quad (11)$$

$$\mathrm{Risks} = \gamma_{21}\mathrm{Egoistic} + \gamma_{22}\mathrm{Altruistic} + \gamma_{23}\mathrm{Biospheric} + \zeta_3 \quad (12)$$

The values Egoistic, Altruistic, Biospheric and Confidence are assumed to be exogenous latent variables. Instead Risks, Benefits and Acceptance are assumed to be endogenous constructs. The x_i in equations (3)-(6)

are the indicators of the exogenous constructs, whereas y_i in equations (7)-(9) represent the indicators of the endogenous latent variables. Moreover, $\tau_i^{(x)}$ and $\tau_i^{(y)}$ symbolize constants whereas $\lambda_{i1}^{(x)}, \lambda_{i1}^{(y)}$ represent the loadings. Considering the structural equations, γ_{ii} stand for the coefficient attached to the exogenous constructs whereas β_{ii} are the coefficients attached to endogenous constructs. Finally ζ_i, δ_i and ϵ_i indicate error terms.

4. Results

The questionnaire was programmed in Qualtrics and administered online to a sample of 1,200 respondents, using an on-line panel offered by a commercial marketing company (Toluna). Quotas on age, gender and area of residence were set so as to be in line with the target population: Italians residents aged 18 and more (DemoIstat 2013). The survey was conducted in March and June 2014.

4.1 Descriptive statistics

4.1.1 Sample characteristics

Descriptive statistics for key socio-economic variables are presented in Table 2. The sample is more educated if compared to the target population. This sample bias has been documented in online surveys (Kellner 2014).

Table 2. Socio-demographic characteristics

Variable	*Statistics*	North	Centre	South
Age	Mean	45.9	42.3	41.6
	S.D.	13.4	14.4	13.7
Household size	Mean	2.9	3.1	3.3
	S.D.	1.1	1.2	1.2
Gender	% Male	45.8	40.6	49.4
Education[a]	% Before high school	15.8	8.6	10.8
	% High school	55.3	54.6	52.8
	% Degree	14	21	18
Observations		529	261	408

[a]The remaining share belongs to *other*

4.1.2 Preferences towards energy sources

Fig. 2 offers a first glance at the preferences towards nuclear energy, compared to the other energy sources. Nuclear is, by far, the least preferred energy source: 45% of the respondents would not want Italy to invest anything on it. In addition, as shown in Figure 3, around half of the respondents believe nuclear will never be re-introduced in Italy, whereas 17% believe it could be re-introduced in 5 to 10 years.

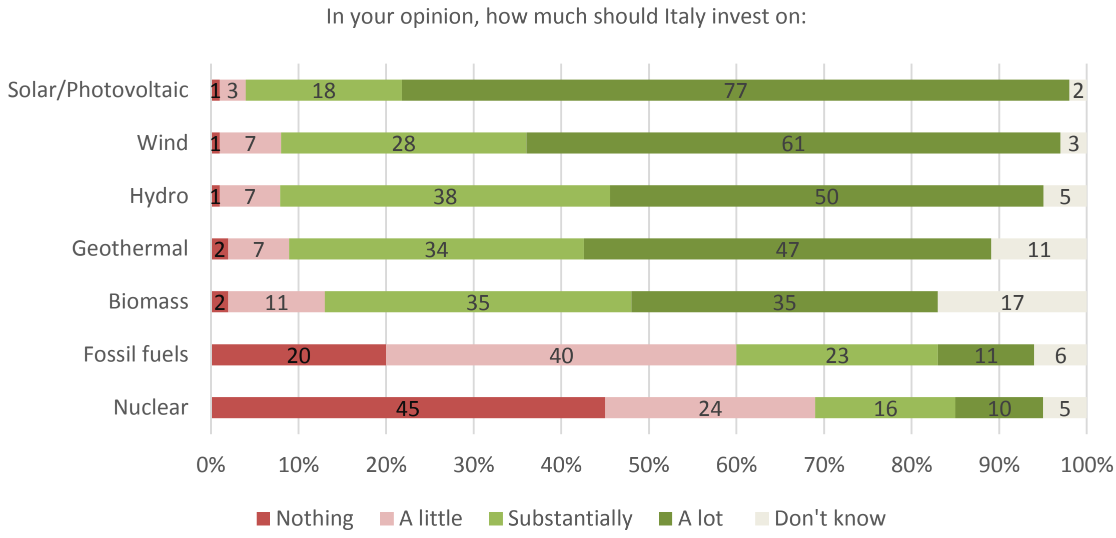

Figure 2: Energy sources-preferences

The percentage of those against investments in nuclear energy is even greater than the comparable statistic for fossil fuels, where it drops to the 20%. On the other hand, Italian respondents seem to strongly prefer investments on renewable energy sources, especially solar/photovoltaic and wind energy.

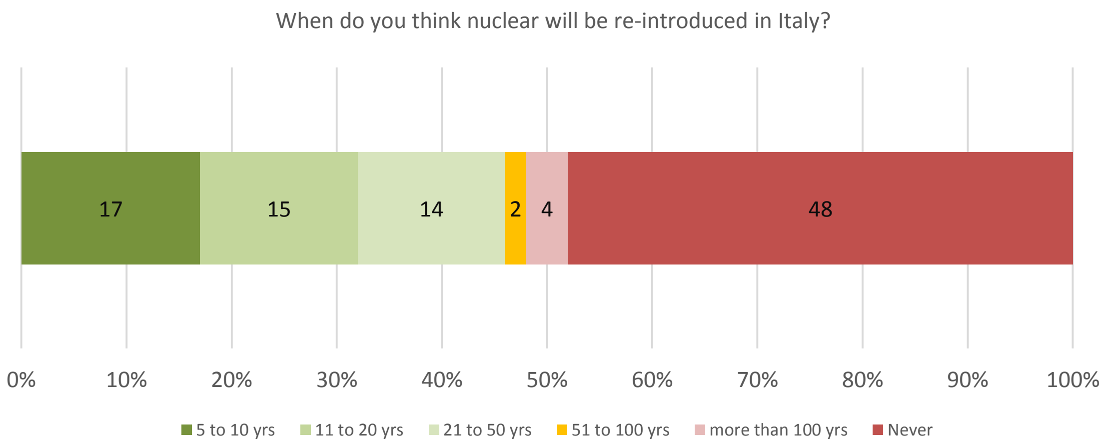

Figure 3: Nuclear energy re-introduction in Italy

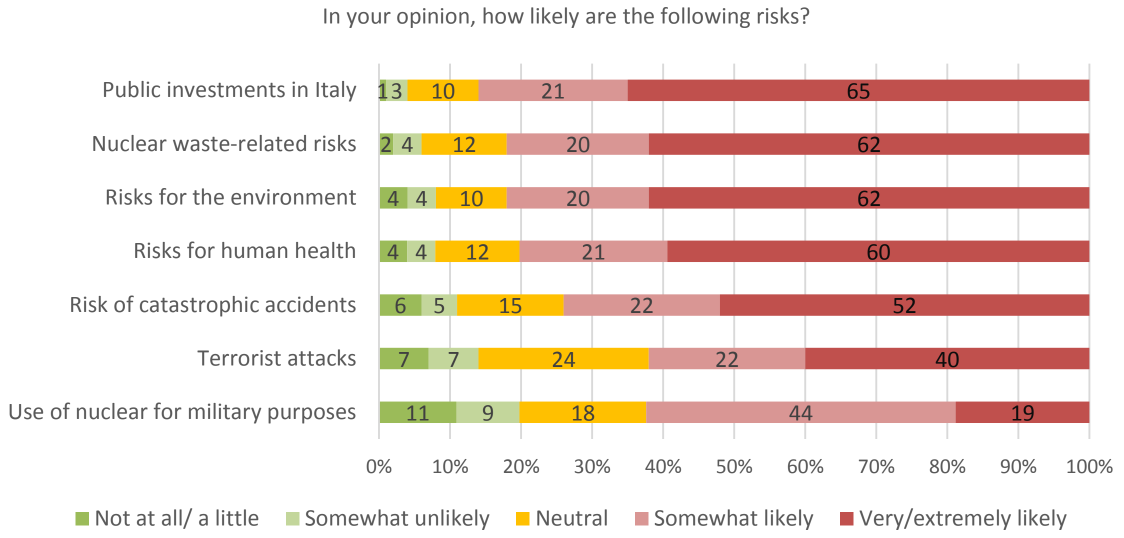

Figure 4: Perceived risks

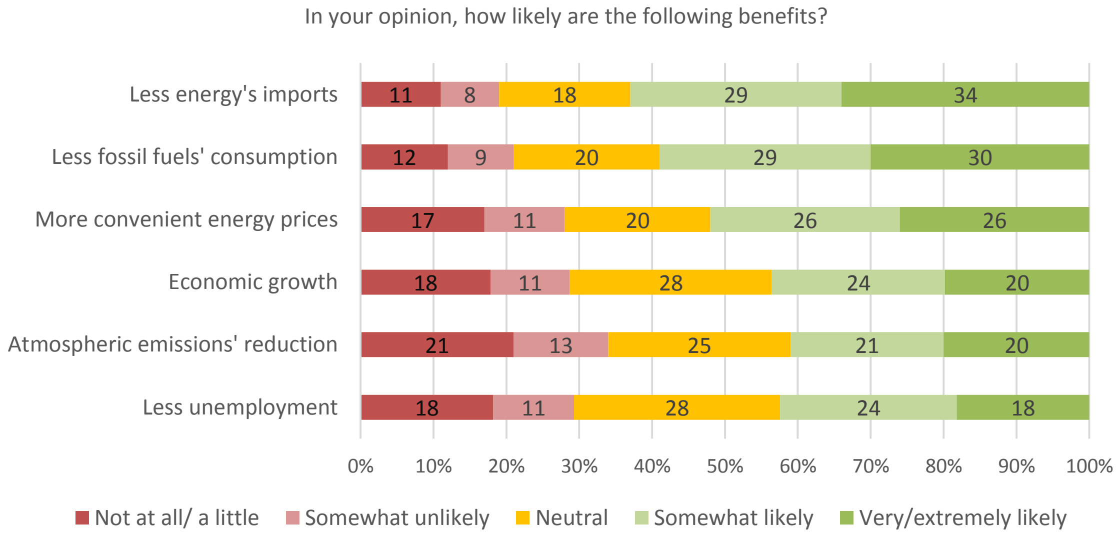

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Figure 5: Perceived benefits

As regards perceived risks of nuclear energy (Figure 4), 65% indicated public investments in Italy as a risky task to carry out. Following closely, 62% indicated nuclear waste related risks and risks for the environment. On the opposite end we find the perceived risk of using nuclear for military purposes, indicated by the 19% as very/extremely likely. As regards perceived benefits, 34% believe it is extremely/very likely energy imports will decrease. However, only 20% think atmospheric emission will be reduced. Similarly, few foresee positive impacts, either in terms of economic growth (20%) and unemployment (18%), as shown in Figure 5.

4.1.3 Fourth generation nuclear energy

Next, we investigate the level of confidence towards fourth generation nuclear energy technology. First, respondents were asked to indicate the level of importance of a set of goals of the nuclear energy industry, without reference to any nuclear energy technology (Figure 6). In turn, respondents were told those were actually the goals of the fourth generation forum and were asked to indicate how confident they were about their achievement.

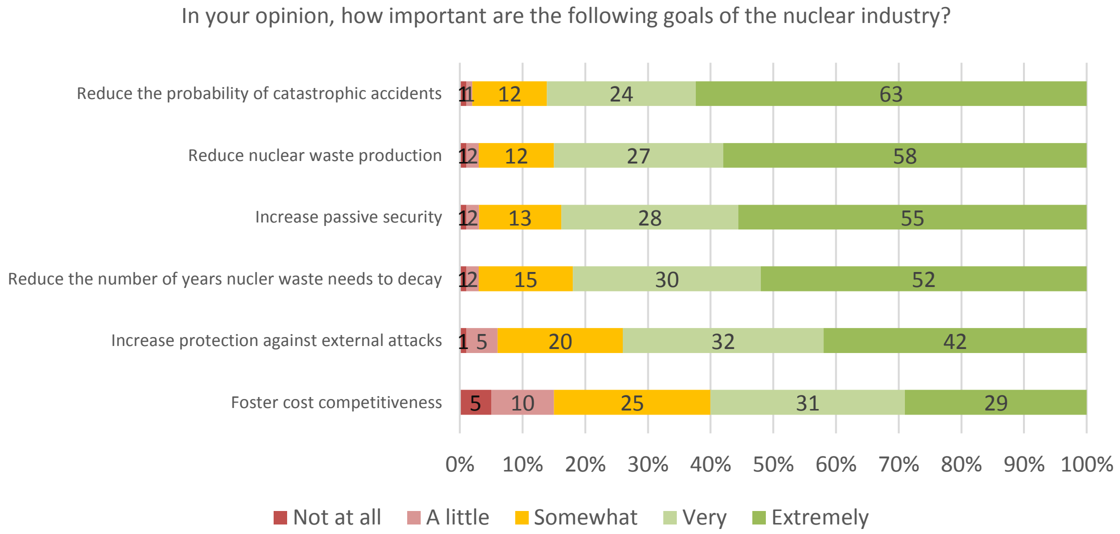

Figure 6: Importance of goals of the nuclear industry

All in all, the most important goal is the reduction of the probability of catastrophic accidents (63%), followed by nuclear waste reduction (58%). However, only between 7%- 8% are extremely confident these goals will be reached (Figure 7). In addition, 37% of the sampled respondents declared to have heard before about fourth generation technology.

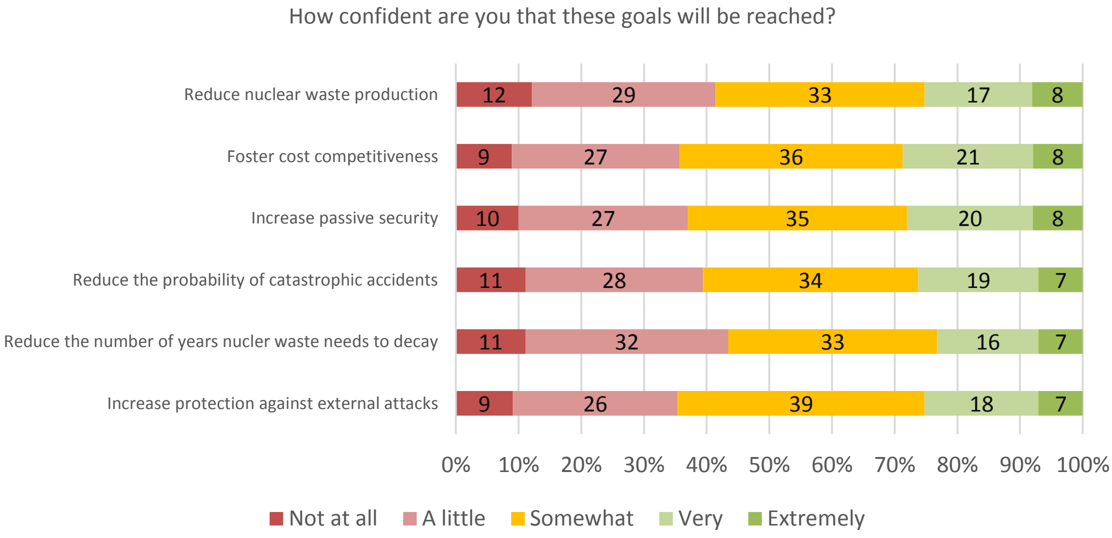

Figure 7: Confidence towards the realization of FG nuclear energy goals

5. Models' estimates

5.1 Structural equation model

Seven independent factor analyses were run so as to confirm the existence of the constructs which will be later employed in the structural equation model. Table A5 in Appendix shows the corresponding results. All in all, based on the proportion of variance explained, results provide support for the selection of one latent construct in each analysis. All the factor loadings are positive, in line with the correlations between the items. A brief analysis of the magnitude of the factor loadings and uniqueness' values is discussed. Considering the factor egoistic, the item v_1 has the smallest uniqueness: most of the variance in the item *social power* is explained by the construct. Instead, the item *equity* seems to be the best represented when it comes to the factor altruistic. For the third value, biospheric, *prevent pollution* and *respect the Earth* have both a uniqueness of .36: around 64% of their variance is explained by this factor. All the factor loadings' magnitude for confidence are greater than .87, and uniqueness values are smaller than .23.

As far as the factor risk is considered, the *risk for human health* and the *risk for the environment* show the greatest covariance, as well as the smallest uniqueness. The factor benefits presents all factor loadings greater than .82 and fairly small uniqueness values. Finally, the construct acceptance seems to account mostly for the variance of the item *the realization of nuclear plants in Italy is acceptable*. However, uniqueness' values of the four items are all equal or smaller than .14.

The structural equation model is presented in Figure 8. In order to ease the presentation, only the coefficients of the structural equations are shown, whereas the coefficient of the measurement equation are shown in Table A6. The model has a log-likelihood of -53400.537 and a comparative fit statistic (CFI) of .912. All the coefficients of the structural equations are statistically significant. In addition, estimated residuals are fairly low[10]. In line with the hypothesis, the path analysis shows that risks and benefits influence acceptance of nuclear energy. The effect of the benefits on acceptance is positive, with a coefficient equal to .273. Instead, perceived risks affect acceptance in a negative way (-.366). In addition, confidence towards the realization of fourth generation goals has a positive effect (.355). In this study, perceived risks and benefits are linked respectively to the values altruistic and egoistic. In line with De Groot et al. (2013) there is no significant effect of the value Biospheric on acceptance of nuclear energy; nevertheless, there is a significant covariance with the value altruistic. In addition, a significant positive covariance is found between confidence and the value egoistic. The measurement equations present all the coefficients statistically significant, consistent with the factor analysis shown in Table A5.

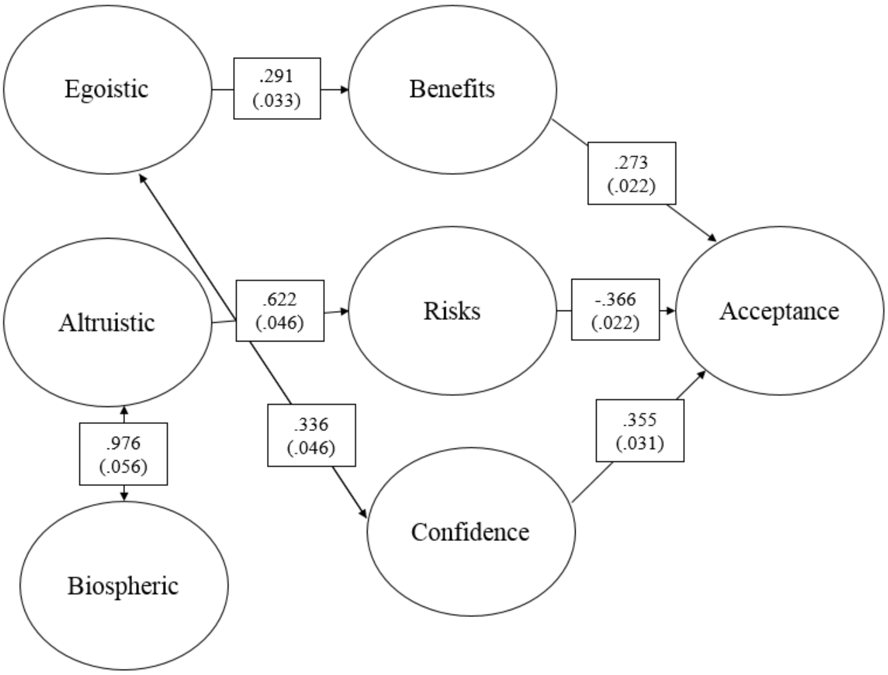

Figure 8: Structural equation model: Path diagram

[10] Standardized root mean squared residual equal to .06.

5.2 Choice experiments results

5.2.1 MNL and RPL_EC models

The choice models have been estimated by means of the software LIMDEP NLOGIT. As a first step, respondents' choices were inspected so as to check for the presence of anomalies; the retained observations amount to 9107. The number of opt outs by respondent is presented in Figure 9. 22% of the respondents always chose none of the options and the same share selected always either project A or B. Some variation is observed when considering values between 1 and 7: the share of respondents opting out decreases monotonically until 6, before slightly increasing at 7 opting outs. All in all, it does not appear to be present a strong tendency towards opting out.

In the following analysis, the deterministic component of the utility function is specified as follows[11]:

$$V_{ij} = \beta_1 ASC + \beta_2 Distance_{200} + \beta_3 Distance_{100} + \beta_4 Distance_{50} + \beta_5 Waste_{30} + \beta_6 Waste_{20} + \beta_7 Waste_{10} + \beta_8 Emission + \beta_9 Hospitals + \beta_{10} Land + \beta_{11} Bill$$

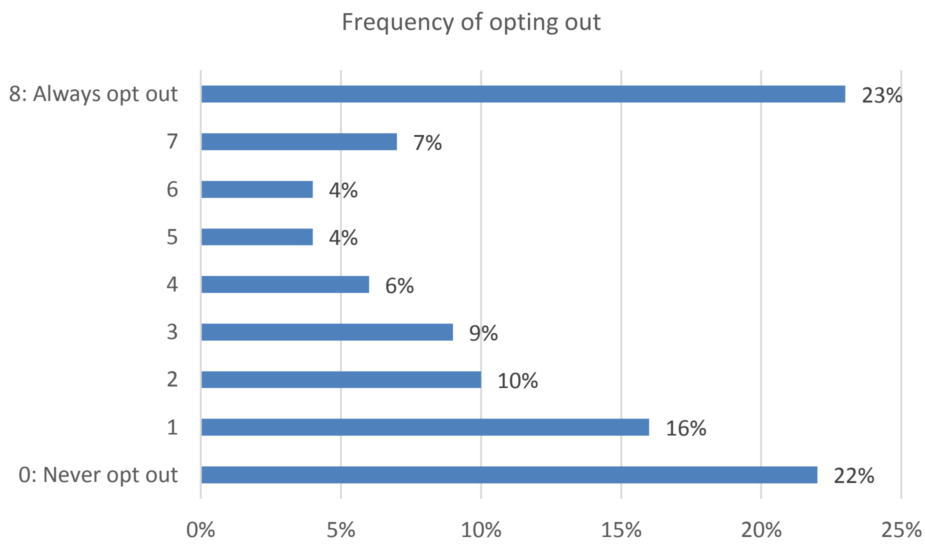

Figure 9: Frequency of opting out

[11] The code of the variables is presented in Appendix, Table C1. Non-linearities were not found in correspondence of different emissions' reduction levels.

As a preliminary step, the analysis of the choice experiment data started with the estimation of a MNL and a Nested Logit model. Although presenting a slightly greater pseudo R^2, the Nested Logit (LL -9188.534 with 13 parameters) did not represent a significant improvement over the MNL (LL -9188.826 with 11 parameters). This is in line with the observed moderate frequencies of opting out. Subsequently, a RPL model with error components was estimated, leading to a substantial improvement in terms of goodness of fit (LL -6882.151 with 21 parameters).

All the random parameters were set to be randomly distributed but the monetary attribute, assumed to be fixed (following Revelt and Train 1998). Table C2 in Appendix shows the estimated coefficients and monetary valuations. The latter represent the willingness to accept a compensation for a worse level of a given attribute (for example, a closer nuclear power plant) or, alternatively, the willingness to forgo so as to assure an improvement of the same.

Turning to the analysis of the coefficients, mean coefficients of the RPL_EC and MNL's models portrait an analogous picture. Unsurprisingly, respondents prefer nuclear plants away from their area of residence. Moreover, this effect is non-linear: the magnitude of the coefficients increases with distance. The attribute representing the fourth generation nuclear, i.e. waste reduction, is highly and positively valued. Similarly, sampled individuals attach a positive value to the reduction of atmospheric emissions. With regards to the public benefits, namely the realization of hospitals and land recovery measures, these are positively valued too. Finally, the private benefit bill reduction is significantly and positively valued.

5.2.2 Latent class model

The latent class approach represents an alternative way to model preference heterogeneity (Boxall and Adamowicz 2002). In addition, we aimed to employ a model that allows to assess the importance of the factors employed in the structural equation model. Specifically, the results of the structural equation model highlighted the role of perceived benefits, risks and confidence in shaping acceptance of nuclear energy. Hence, the score factors of each of these variables have been included in the segment membership probability. In other words, we expect class allocation to be influenced by the three constructs affecting acceptance.

As regards the utility function, this has been specified as follows:

$$V_{ij|s} = \beta_{1|s}ASC + \beta_{2|s}Distance_{200} + \beta_{3|s}Distance_{100} + \beta_{4|s}Distance_{50} + \beta_{5|s}Waste_{30} + \beta_{6|s}Waste_{20} + \beta_{7|s}Waste_{10} + \beta_{8|s}Emission + \beta_{9|s}Hospitals + \beta_{10|s}Land + \beta_{11|s}Bill$$

A three latent class specification, chosen on the basis of the goodness of fit and parameters' significance, is presented in Table 3. The pseudo R squared now equals .358. Inspecting the coefficients, it is indeed confirmed the presence of a great deal of heterogeneity in the data. The goodness of fit has improved considerably compared to the analogous statistic for the MNL and the RPL_EC. According to the model selection criteria AIC, AIC3, CAIC and BIC, this model is deemed to be preferred. In addition, the Ben-Akiva and Swait (1986)'s test for strictly non-nested models confirms the selection of the latent class model over the RPL_EC. These are strong indications in favor of the selection of this model (Strazzera et al. 2013).

The three segments are characterized as follows. The first class is characterized by the greatest value attached to the status quo, as well as for the distance from the nuclear plant. Respondents more likely to belong to this class positively value the health and environmental benefits: waste and atmospheric emissions reduction. Furthermore, land recovery measures are positively valued. Instead, the construction of hospitals and bill reduction are not significantly valued. Respondents more likely to belong to this class are significantly associated with less perceived benefits arising from nuclear than the rest of the sample.

In contrast, the second segment presents a negative value for the ASC: these respondents are more likely to have chosen one of the projects rather than opting out[12]. Unsurprisingly, although distance is positively valued, the magnitude of its coefficients is the lowest across the three segments. Public and private benefits are all positively and significantly valued in this class. Remarkably, this segment is characterized by a significant and positive effect of the variable confidence in affecting class allocation; at the same time, perceived risks are negatively associated to this class. Finally, the third class attaches a positive value to all attributes. However, its distinctive feature is the great value attached to the health and environmental benefits, as well as the public benefit attributes. The difference between class 3 and 2 becomes more apparent after inspecting the monetary valuations. The status quo is valued almost 750€ per family per year in class 3. This becomes negative in class 2: these individuals, confident the IV generation technology will be effective, seem to be willing to forsake 220 € per family per year so as to assure the construction of the nuclear plants. On the other hand, in class 1 is envisaged the presence of individuals which are not willing to accept any monetary compensation at all, although they value public and health/environmental benefits[13]. All in all, one segment of respondents, amounting to 33% of the sample, seem to be strongly against the realization of fourth generation nuclear power plants in Italy whereas another segment, representing the 42% of the sample, seem to be open towards this

[12] This is in line with the large magnitude of the standard deviation of the ASC in the RPL_EC model.

[13] The computations of these MV are affected by the non-significance of the denominator, namely the coefficient attached to the electricity bill's reduction. When the numerator is significant, the monetary valuation tends to infinity; when this is non-significant too, the monetary valuation is not defined.

possibility. These respondents are more prone to believe the FG goals will be met. Finally, a third segment emerges, characterized by preferences positioned in between the other two classes: they would accept monetary compensations, besides public benefits.

Table 3. Latent class model. Dependent variable: Choice

Variable	CLASS 1	CLASS 2	CLASS 3	CLASS 1	CLASS 2	CLASS 3
	Coeff. (S.e.)			Monetary Valuations (€)		
ASC	5.82*** (.627)	-.622*** (.075)	2.07*** (.110)	→+∞	-220.08	750.82
Distance: 20 Km	1.41** (.576)	.682*** (.047)	1.19*** (.081)	→+∞	242.43	432.65
Distance: 50 Km	1.47** (.561)	.618*** (.049)	.864*** (.089)	→+∞	219.74	312.35
Distance: 100 Km	1.41** (.589)	.391*** (.052)	.579*** (.090)	→+∞	138.99	209.5
Waste Reduction: 30%	.752* (.469)	.748*** (.052)	1.05*** (.085)	→+∞	265.89	381.47
Waste Reduction: 20%	.817* (.457)	.696*** (.050)	.767*** (.086)	→+∞	247.39	277.24
Waste Reduction: 10%	.595 (.466)	.270*** (.050)	.625*** (.088)	n.a.	95.95	226.04
Emission Reduction	.399** (.201)	.312*** (.021)	.425*** (.035)	→+∞	110.88	153.78
Hospitals	.240 (.306)	.353*** (.036)	.661*** (.058)	n.a.	125.62	239.21
Land Recovery	1.005*** (.306)	.453*** (.036)	.912*** (.056)	→+∞	161	329.94
Bill Reduction	.0007 (.001)	.002*** (.0002)	.002*** (.0004)			
Class membership function						
Constant	.274*** (.097)	.560*** (.101)	0[a]	/	/	/
Confidence	.001** (.0007)	.380*** (.085)	0[a]	/	/	/
Risks	.136 (.106)	-.178* (.100)	0[a]	/	/	/
Benefits	-.365*** (.103)	-.110 (.112)	0[a]	/	/	/
Average class probability	0.330	0.426	0.244	0.330	0.426	0.244
Log-Likelihood	-6417.239					
Pseudo R^2	0.358					
Observations	9107					

Level of significance: *10%, **5%, ***1%. Robust standard errors estimated. [a]:constrained values.

Posterior class probabilities have been computed[14] so as to assign each respondent to a class, depending on the greatest class membership probability. Individuals assigned to class 2 rarely opted out as shown in Figure 10. As noticed above, these respondents are more prone to believe the fourth generation goals will be met. Instead, those belonging to class 1, not accepting monetary compensations at all, are those who more frequently opted out. Remarkably, 86% of the individuals included in this class chose none of the projects in either 8/8 or 7/8 choice tasks, therefore signalizing a strong opposition towards nuclear. Finally, class three has a number of opt outs mainly between 2 and 6 (96%).

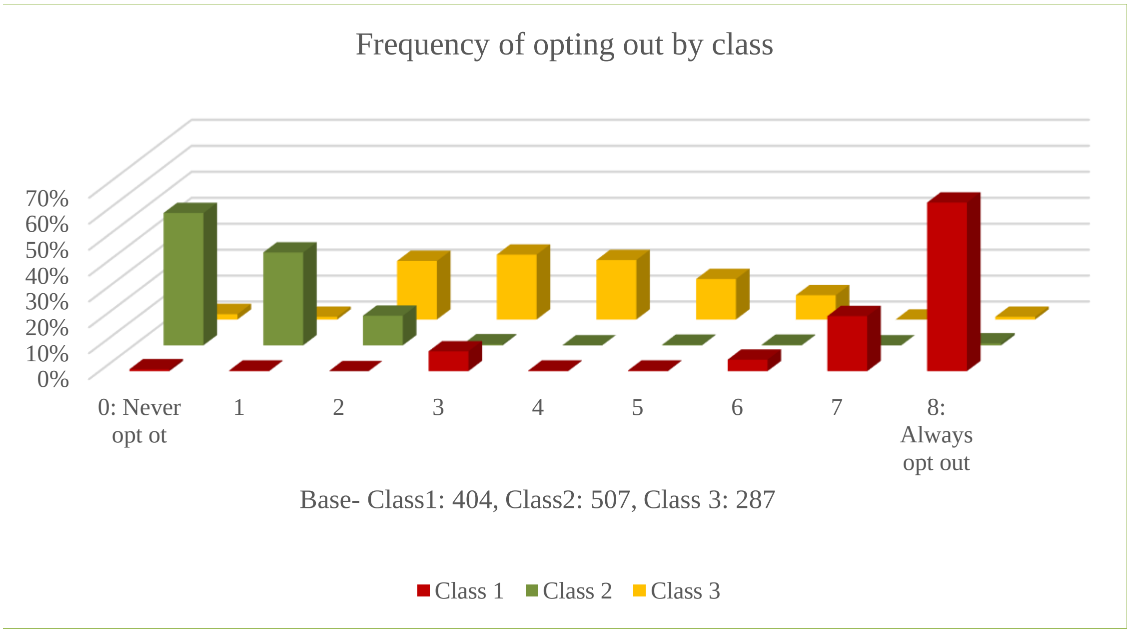

Figure 10: Frequency of opting out by class

5.3 Multivariate analysis and information treatment

As a means of exploring the validity of the results obtained, an additional econometric model has been estimated to explore the effect of observed heterogeneity on the choices that respondents made. The findings from this analysis, which are reported in detail in Appendix D, are supportive of the consistency of the results with the expectation. Remarkably, the number of opt outs appears to be linked with the degree of opposition towards nuclear energy projects, as confirmed by a significant and negative correlation (–0.16) between the number of opt outs and the score factors of the latent variable acceptance. In light of this, an ordered logit model has been

[14] See equation E.9 in Appendix E.

estimated, where the dependent variable, discrete, is the number of opt outs. In summary, we have found that right wing voters and those in favour of Italy investing in nuclear energy are less likely to opt out. Instead, those who stated nuclear energy in Italy will not be introduced before at least one hundred years and those associated with a higher level of perceived risks were more likely to opt out. Considering effects significant within the 15% level, it emerges that preference towards wind energy, having at least a university degree and judging as serious or very serious the Fukushima accident seem to be associated with greater opposition.

The information treatment appears to have affected the degree of opposition towards nuclear. Indeed, those who received information on Fukushima, Chernobyl and on the location of nuclear plants in Europe, were more likely to opt out. As regards the effect on the choice experiments' results, this seems to be limited to the ASC and the land recovery attribute, as shown in Table C3 in Appendix. Remarkably, the additional information provided positively affects the coefficient of the ASC, suggesting a lessened degree of acceptance. By inspecting the effect of this treatment on the constructs benefits, risks and confidence, it is found that perceived risks are significantly higher among the group of treated respondents, whereas perceived benefits and confidence are not statistically different (Table 4).

Table 4. Mean and S.D. of latent constructs by information treatment

	Information treatment: YES			Information treatment: NO			
	Mean	S.D.	Base	Mean	S.D.	Base	T-test[a]
Benefits	-0.038	0.955	514	0.02	0.979	681	1.047
Risks	0.052	0.939	514	-0.031	0.994	681	-1.4829[b]
Confidence	0.004	1.001	505	-0.009	0.955	676	-0.2417

[a]Difference between Mean (no information treatment) and Mean (information treatment)
[b]Significant at 6.92%
The values employed in this analysis are the individual factors scores.

6. Conclusions

In the aftermath of the Fukushima accident Italy stopped all plans of re-introducing operating nuclear power plants in the country, mimicking the decision of phasing out nuclear following the events of Chernobyl. Italy's energy policy needs to be improved by reducing reliance on fossil fuels, diversifying energy sources and increasing the share of energy sources with zero or next to zero GHG emissions. In the views of the proponents of the fourth generation nuclear energy, the latter issue may be tackled by including nuclear energy in the Italian power generation mix. No study was conducted on social acceptance of fourth generation nuclear energy: this paper opens this stream of research and offers a methodological combination of choice experiments, psychometric scales modeled within a structural equation framework and an information sensitivity tests. Remarkably, discrete choice modeling and structural equation modeling results were aligned, providing evidence of the robustness of the findings.

Firstly, a structural equation model was also employed, following De Groot et al. (2013). Acceptance of IV generation nuclear energy is greater among those who envisage the presence of benefits, are less concerned about the risks and, above all, are confident the FG goals will be achieved. In addition, egoistic values were seen to affect perceived benefits, whereas altruistic values affected perceived risks.

These results were taken into account when analyzing the choice experiment data. A latent class estimator was applied, with class membership function of perceived benefits, risks and confidence. Findings depict a situation characterized by three distinct segments of preferences. The first segment of respondents would be strenuously against nuclear energy implementation in Italy, not willing to accept any monetary compensation at all: this is the segment of the *strong opposers (class 1)*, negatively associated with the benefits. A second segment shows respondents with less pronounced opposition, willing to accept monetary compensations in order to put up with new nuclear facilities: this is the segment of the *opposers (class 3)*, negatively associated with perceived risks. Nevertheless, a third class of respondents in which a modest support for FG nuclear technology is found, provided its planned goals are achieved. These respondents are more confident that the goals of the fourth generation technology will be accomplished: this can be defined as the segments of the *moderate supporters (class 2)*.

From the analysis of the determinants of opting out choices, negatively correlated with acceptance of nuclear energy, it emerges that right-wing voters are more likely to favor nuclear energy, in line with previous research (Franchino 2013; Zwick 2005). In addition, opposition seems to be greater amongst those who would prefer investments in wind energy, are highly educated and perceive the Fukushima accident as serious or very serious. Adding to this, the role of information seems to be key in shaping acceptance: results are sensitive to information provided regarding the events of Fukushima and Chernobyl, together with a map showing nuclear plants' location in Europe. This information treatment resulted in greater opposition, channeled through a greater level of perceived risks.

Further research is needed in order to investigate social acceptability of fourth generation nuclear energy in other nations. For instance, it would be interesting to extend the study to countries where nuclear energy is in operation and/or with nuclear plants under construction. In addition, research is needed so as to further investigate the role and determinants of confidence towards the realization of the IV generation nuclear energy goals.

Acknowledgements

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Appendix A: Psychometrics scales and structural equation modeling results

Table A1. Egoistic, Altruistic and Biospheric items

How important are these values for you as guiding principles in your life?

		Opposite to my values	Not at all Important	Very Unimportant	Neither Important nor unimportant	Very Important	Extremely Important
Egoistic	v_1	Social Power: control people					
	v_2	Wealth: money and material goods					
	v_3	Influence: Impact other people's life					
	v_4	Authority: command others					
Altruistic	v_1	Equity: equal opportunities for all					
	v_2	Peace: no war no conflicts					
	v_3	Work for the others					
	v_4	Justice: fight injustices					
Biospheric	v_1	Prevent Pollution					
	v_2	Respect the Earth					
	v_3	Protect the Environment					

Table A2. Confidence items

How confident are you that fourth generation technology goals will be achieved?

		Very confident	confident	Somewhat confident	Undecided	Somewhat confident	confident	Very confident
Confidence	v_1	Reduce the probability of catastrophic accidents						
	v_2	Minimize nuclear waste						
	v_3	Reduce the long term stewardship burden of nuclear waste						
	v_4	Increase the cost-competitiveness compared to other energy sources						
	v_5	Increase protection against terroristic attacks						
	v_6	Increase passive security						

Table A3. Place attachment items

Think about the region you currently reside in. To what extent do you agree or disagree with the following statements?

		Extremely disagree	Disagree	Neither agree nor disagree	Agree	Extremely agree
Place attachment	v_1	I want to live here				
	v_2	I feel I belong here				
	v_3	I feel connected to the people living here				
	v_4	Here I feel at home				

Table A4. Perceived risks and benefits items

How likely are these risks/benefits stemming from the realization of nuclear plants in Italy?

		Very Unlikely	Unlikely	Somewhat Unlikely	Undecided	Somewhat likely	Likely	Very Likely
Risks	v_1	Risk of catastrophic accident						
	v_2	Nuclear waste's risk						
	v_3	Risk of public investments in Italy						
	v_4	Risk for human health						
	v_5	Risk for the environment						
	v_6	Risk of terrorist attacks						
	v_7	Risk of nuclear proliferation						
Benefits	v_1	Economic growth						
	v_2	Rise in employment						
	v_3	Atmospheric emissions' reduction						
	v_4	Energy imports' reduction						
	v_5	Reduction of fossil fuels' consumption						
	v_6	Energy 's prices more affordable						

Table A5. Factor loadings and uniqueness

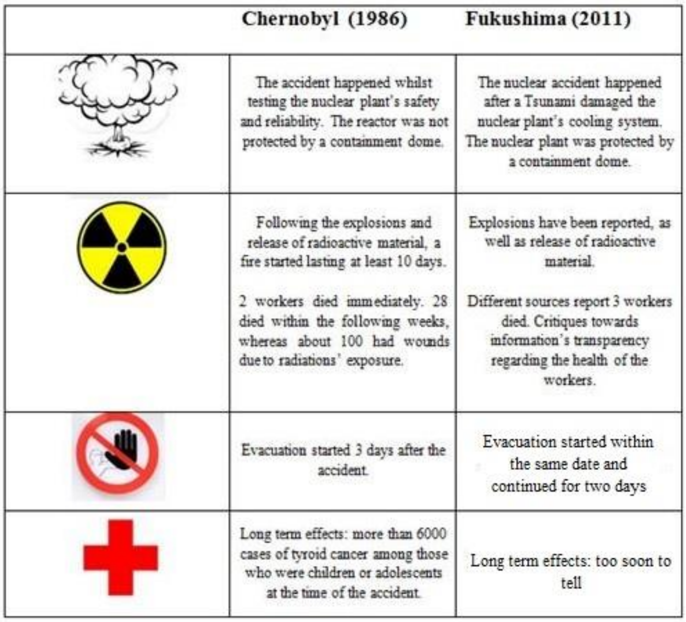
Item	ξ: Egoistic		ξ: Altruistic		ξ: Biospheric		ξ: Confidence	
	F.L.	UN.	F.L.	UN.	F.L.	UN.	F.L.	UN.
v_1	0.81	0.32	0.71	0.48	0.78	0.37	0.89	0.19
v_2	0.54	0.70	0.74	0.44	0.79	0.37	0.89	0.20
v_3	0.59	0.64	0.51	0.73	0.63	0.59	0.89	0.19
v_4	0.80	0.35	0.68	0.53	/	/	0.81	0.34
v_5	/	/	/	/	/	/	0.83	0.29
v_6	/	/	/	/	/	/	0.9	0.19
	ξ: Risks		ξ: Benefits		ξ: Acceptability		ξ: Place Attachment	
	F.L.	UN.	F.L.	UN.	F.L.	UN.	F.L.	UN.
v_1	0.88	0.21	0.88	0.21	0.94	0.11	0.82	0.32
v_2	0.83	0.29	0.83	0.30	0.89	0.19	0.91	0.16
v_3	0.53	0.72	0.77	0.39	0.61	0.62	0.83	0.31
v_4	0.90	0.17	0.83	0.30	0.92	0.15	0.90	0.17
v_5	0.90	0.17	0.83	0.29	/	/	/	/
v_6	0.70	0.49	0.87	0.23	/	/	/	/
v_7	0.68	0.52	/	/	/	/	/	/

Table A6. Measurement equations' coefficients

	Egoistic		Altruistic		Biospheric		Confidence	
	Coeff.	Std. Err	Coeff.	Std. Err	Coeff.	Std. Err	Coeff.	Std. Err
$\lambda_{ii}^{(x)}$	1	c	1	c	1	c	1	c
$\tau_{i}^{(x)}$	3.07	0.04	5.84	0.039	5.84	0.038	2.81	0.032
$\lambda_{ii}^{(x)}$	0.55	0.031	1.07	0.047	1	0.032	1.01	0.021
$\tau_{i}^{(x)}$	4.03	0.043	5.91	0.040	5.92	0.037	2.78	0.032
$\lambda_{ii}^{(x)}$	0.65	0.033	0.81	0.050	0.84	0.033	0.98	0.020
$\tau_{i}^{(x)}$	4.04	0.047	4.95	0.04	5.99	0.036	2.74	0.031
$\lambda_{ii}^{(x)}$	0.90	0.031	1.13	0.045	/	/	0.872	0.023
$\tau_{i}^{(x)}$	2.91	0.045	5.90	0.037	/	/	2.91	0.031
$\lambda_{ii}^{(x)}$	/	/	/	/	/	/	0.833	0.021
$\tau_{i}^{(x)}$	/	/	/	/	/	/	2.87	0.030
$\lambda_{ii}^{(x)}$	/	/	/	/	/	/	1.00	0.020
$\tau_{i}^{(x)}$	/	/	/	/	/	/	2.87	0.032
	Risks		Benefits		Acceptance			
	Coeff.	Std. Err	Coeff.	Std. Err	Coeff.	Std. Err		
$\lambda_{ii}^{(y)}$	1	c	1	c	1	c		
$\tau_{i}^{(y)}$	5.4	0.04	4.1	0.47	2.31	0.033		
$\lambda_{ii}^{(y)}$	0.85	0.02	0.94	0.02	0.92	0.015		
$\tau_{i}^{(y)}$	5.72	0.03	4.08	0.04	2.13	0.033		
$\lambda_{ii}^{(y)}$	0.51	0.02	0.93	0.027	0.51	0.022		
$\tau_{i}^{(y)}$	5.87	0.04	3.99	0.05	2.40	0.031		
$\lambda_{ii}^{(y)}$	0.99	0.019	0.91	0.024	0.89	0.014		
$\tau_{i}^{(y)}$	5.65	0.041	4.76	0.047	2.46	0.03		
$\lambda_{ii}^{(y)}$	0.98	0.019	0.90	0.024	/	/		
$\tau_{i}^{(y)}$	5.7	0.040	4.60	0.047	/	/		
$\lambda_{ii}^{(y)}$	0.74	0.029	1.05	0.023	/	/		
$\tau_{i}^{(y)}$	4.98	0.045	4.32	0.05	/	/		
$\lambda_{ii}^{(y)}$	0.81	0.033	1.05	0.023	/	/		
$\tau_{i}^{(y)}$	4.93	0.051	4.32	0.05	/	/		

c: constrained

Appendix B: Information treatment



	Chernobyl (1986)	Fukushima (2011)
	The accident happened whilst testing the nuclear plant's safety and reliability. The reactor was not protected by a containment dome.	The nuclear accident happened after a Tsunami damaged the nuclear plant's cooling system. The nuclear plant was protected by a containment dome.
	Following the explosions and release of radioactive material, a fire started lasting at least 10 days. 2 workers died immediately. 28 died within the following weeks, whereas about 100 had wounds due to radiations' exposure.	Explosions have been reported, as well as release of radioactive material. Different sources report 3 workers died. Critiques towards information's transparency regarding the health of the workers.
	Evacuation started 3 days after the accident.	Evacuation started within the same date and continued for two days
	Long term effects: more than 6000 cases of tyroid cancer among those who were children or adolescents at the time of the accident.	Long term effects: too soon to tell

Figure B1: Information treatment part A

Figure B2: Information treatment part B

Appendix C: Choice experiments analysis

Table C1. Variables used in the choice experiment econometric models

Choice Experiments-Utility function	Mean	S.D.	Min	Max
ASC	0.33	0.47	0.00	1.00
Distance 20 Km	0.17	0.37	0.00	1.00
Distance 50 Km	0.17	0.37	0.00	1.00
Distance 100 Km	0.50	0.49	0.00	1.00
Waste 30 %	0.16	0.37	0.00	1.00
Waste 20 %	0.17	0.37	0.00	1.00
Waste 10 %	0.17	0.37	0.00	1.00
Emission Reduction	0.62	0.79	0.00	2.00
Hospital	0.26	0.44	0.00	1.00
Land Recovery	0.27	0.44	0.00	1.00
Bill Reduction	68.35	78.61	0.00	203.73
Choice Experiments-Segment membership				
Confidence	-0.002	0.974	-1.829	2.147
Risk	0.002	0.971	-3.537	1.172
Benefits	-0.003	0.969	-2.271	1.809

Table C2. MNL and RPL_EC models. Dependent variable: Choice

	MNL	RPL_EC	RPL_EC	MNL	RPL_EC
				Monetary Valuations (€)	
Variable	Coeff. (S.e.)	Coeff. (S.e.)	S.D.		
ASC	1.60*** (.068)	1.96*** (.141)	3.67*** (.138)	753.4	668.5
Distance: 200 Km	.72*** (.050)	.980*** (.065)	.514*** (.098)	337.8	334.1
Distance: 100 Km	.579*** (.052)	.743*** (.065)	.317** (.154)	273.7	253.1
Distance: 50 Km	.431*** (.053)	.507*** (.063)	.060 (.141)	201.25	172.7
Waste Reduction: 30%	.726*** (.051)	.865*** (.061)	.322** (.162)	340.6	294.8
Waste Reduction: 20%	.606*** (.050)	.723*** (.060)	.187 (.182)	284.9	246.5
Waste Reduction: 10%	.367*** (.052)	.413*** (.063)	.253 (.167)	170.85	140.7
Emission Reduction	.274*** (.021)	.366*** (.026)	.049 (.097)	129.04	124.8
Hospitals	.326*** (.035)	.493*** (.049)	.487*** (.092)	153.2	168.1
Land Recovery	.516*** (.034)	.652*** (.049)	.575*** (.093)	242.3	222.3
Bill Reduction (€)	.0021*** (.000)	.002***[b] (.000)	/	/	/
Log-Likelihood	-9188.826	-6882.151			
R squared	0.08	0.31			
Observations	9107	9107			

Level of significance: *10%, **5%, ***1%. Robust standard errors estimated.

Table C3. RPL_EC model-Information Treatment. Dependent variable: Choice

Variable	β	β*Info_T	S.D.
	Coeff. (S.e.)		
ASC	1.49*** (.102)	.724*** (.160)	2.08*** (.046)
Distance: 200 Km	.899*** (.072)	.093 (.108)	.288*** (.083)
Distance: 100 Km	.719*** (.078)	.024 (.121)	.307** (.146)
Distance: 50 Km	.544*** (.083)	-0.38 (.127)	.155 (.150)
Waste Reduction: 30%	.828*** (.079)	.068 (.126)	.191 (.157)
Waste Reduction: 20%	.683*** (.078)	.050 (.120)	.072 (.164)
Waste Reduction: 10%	.402*** (.077)	-0.001 (.125)	.171 (.122)
Emission Reduction	.327*** (.033)	.024 (.054)	.193*** (.046)
Hospitals	.393*** (.057)	.124 (.084)	.351*** (.080)
Land Recovery	.495*** (.056)	.323 (.087)	.360*** (.082)
Bill Reduction (€)	.002*** (.000)	.0001 (.0006)	.004*** (.000)
Log-Likelihood		-7700.191	
R squared		0.228	
Observations		9107	

Level of significance: *10%, **5%, ***1%. Robust standard errors estimated.

Appendix D: Multivariate analysis

Table D1.Ordered Logit model. Dependent variable: Number of opt outs

Variable	Source	Coefficient	St. Error
Age	Q1	0.005	0.005
Male	Q2	-0.176	0.120
EU_Risk	Q3	-0.030	0.049
Income	Q4	-0.029	0.043
Household size	Q5	-0.012	0.052
Right wing	Q6	-0.338**	0.166
Chernobyl Seriousness	Q7	0.049	0.121
Fukushima Seriousness	Q8	0.143	0.097
Never nuclear	Q9	0.386***	0.11
Investment_Fossil	Q10	-0.068	0.126
Investment_Wind	Q11	0.324	0.204
Investment_solar	Q12	-0.391	0.288
Investment_Nuclear	Q13	-0.244*	0.147
Investment_Hydro	Q14	0.019	0.189
Investment_Geothermal	Q15	-0.160	0.162
Investment_Biomass	Q16	-0.191	0.136
Importance_School	Q17	0.085	0.085
Importance_Immigration	Q18	-0.069	0.072
Importance_Climate change	Q19	0.080	0.074
Importance_Unemployement	Q20	-0.089	0.099
Importance_Economic growth	Q21	0.022	0.084
Importance_Healthcare	Q22	-0.005	0.103
Importance_Crime	Q23	0.005	0.083
Importance_Public debt	Q24	-0.043	0.074
North	Q25	-0.176	0.131
Centre	Q26	-0.093	0.151
Unemployed	Q27	0.045	0.17
Under 16 years old in the household	Q28	0.039	0.029
Student	Q29	0.019	0.229
Degree	Q30	0.226	0.155
Benefits	Score factors (1)	0.022	0.069
Risks	Score factors (2)	0.160**	0.066
Confidence	Score factors (3)	-0.086	0.070
Place attachment	Score factors (4)	-0.030	0.058

Table D1. Continued

Info_Treatment	0.290***	0.113
Log-Likelihood	-2063.1038	
R squared	0.0250	
Observations	1148	

Level of significance: *10%, **5%, ***1%.

Table D2.Ordered Logit model: variables employed in Table D1

Source	Question	Scale/unit
Q1	How old are you?	years
Q2	Gender	0 Female - 1 Male
Q3	In your opinion, how likely is the occurrence of a nuclear accident in Europe?	1 Not at all likely -7 Extremely likely
Q4	What is the income level of your household?	1 less than 10,000 euro- 7 More than 60,000 euro per year
Q5	How many people live in your household?	Number of persons
Q6	For which political party would you vote right now?	1: any right wing party- 0: otherwise
Q7	In your opinion, how serious is the Chernobyl accident?	1: Not at all-5: Extremely
Q8	In your opinion, how serious is the Fukushima accident?	1: Not at all-5: Extremely
Q9	When do you think nuclear power will be re-introduced in Italy	1:Never-0:within 100 years or more
Q10	In your opinion, how much should Italy invest on…	1 Fossil fuels - 0: other
Q11	In your opinion, how much should Italy invest on…	1 Wind - 0: other
Q12	In your opinion, how much should Italy invest on…	1 Solar - 0: other
Q13	In your opinion, how much should Italy invest on…	1 Nuclear - 0: other
Q14	In your opinion, how much should Italy invest on…	1 Hydro - 0: other
Q15	In your opinion, how much should Italy invest on…	1 Geothermal- 0: other
Q16	In your opinion, how much should Italy invest on…	1 Biomass- 0: other
Q17	In your opinion, how important are the following:	School, 1 Not at all important- 5 Extremely important
Q18	In your opinion, how important are the following:	Immigration, 1 Not at all important- 5 Extremely important
Q19	In your opinion, how important are the following:	Climate Change, 1 Not at all important- 5 Extremely important
Q20	In your opinion, how important are the following:	Unemployment, 1 Not at all important- 5 Extremely important
Q21	In your opinion, how important are the following:	Economic growth, 1 Not at all important- 5 Extremely important
Q22	In your opinion, how important are the following:	Healthcare, 1 Not at all important- 5 Extremely important
Q23	In your opinion, how important are the following:	Crime, 1 Not at all important- 5 Extremely important
Q24	In your opinion, how important are the following:	Public debt, 1 Not at all important- 5 Extremely important
Q25	In which region do you currently reside?	1 any region in the North-0 otherwise
Q26	In which region do you currently reside?	1 any region in the Centre-0 otherwise
Q27	What is your occupational status	1 unemployed-0 otherwise
Q28	How many people under the age of 16 live in the household?	Number of persons
Q29	What is your occupational status?	1 student-0 otherwise
Q30	What is your highest level of education?	1 at least one university degree-0 otherwise

Appendix E: Econometric models for choice experiments data

This choice experiment method is based on Lancaster's theory of value (Lancaster 1966) and on the Random Utility theory (McFadden 1974). According to this theoretical framework, respondents choose the option which provides the greatest level of utility. Acknowledging the impossibility of fully characterizing the utility function, this is decomposed into a deterministic and a stochastic part. Formally, utility of individual i for alternative j is given by:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \quad \text{(E.1)}$$

where V_{ij} and ε_{ij} are the deterministic and stochastic components respectively. Specifically, V_{ij} is given by:

$$V_{ij} = \sum_k \beta_{ikj} X'_{ikj} \quad \text{(E.2)}$$

where X is the matrix of the k attributes, whereas β represents the vector of coefficients to be estimated, scale parameter normalized to one. In order to define the stochastic component, the basic assumption is that the error terms are independently and identically distributed. Furthermore, assuming a Gumbel distribution, the Multinomial Logit model (MNL) is obtained, whose choice probabilities are given by:

$$P_{ijt} = \frac{\exp(\beta_k X'_{kjt})}{\sum_j \exp(\beta_k X'_{kjt})} \quad \text{(E.3)}$$

Once the coefficients are estimated, the monetary valuations (MV) can be computed. These are given by the ratio of the coefficients (corresponding to the marginal utility) of the non-monetary over the monetary attribute, as shown in (E.4):

$$MV = \left| \frac{\beta_{non-monetary}}{\beta monetary} \right| \quad \text{(E.4)}$$

However, the MNL assumes independence of irrelevant alternatives, whereas there might be correlation between groups of similar alternatives. As in contingent valuation studies, protest behavior can influence results in choice experiments (Adamowicz et al. 1998; Meyerhoff and Liebe 2008): in our case, respondents might choose the opt out option without seriously considering the scenario attributes just because the scenarios refer to nuclear energy options. Indeed, protest votes are just one of the possible reasons that might lead respondents to choose the status-quo or opt out options. Other studies have suggested loss aversion (Kahneman et al. 1991), task complexity (Boxall et al. 2009; Day et al. 2012; Moon 2004), lack of credibility of the survey (Kataria et al. 2012) or alternatives perceived to be too similar by the respondent (Haaijer et al. 2001). An alternative modeling strategy is represented by a Nested Logit (NL) (Ben-Akiva and Lerman 1985; Hensher et al. 2005), which allows the relaxation of the IIA assumption, although homogeneity in preferences is still in place. A strategy to introduce preference heterogeneity is represented by the Random Parameters Logit (RPL) model (Hensher and Greene 2003; Revelt and Train 1998). According to this model, the utility function is characterized by the presence of an idiosyncratic random deviation of respondent i η_{ik} from the mean value β_k for each of the K attributes:

$$U_{ijt} = \beta_k X'_{kjt} + \eta_{ik} X'_{kjt} + \varepsilon_{ijt} \quad \text{(E.5)}$$

The random distribution must be specified by the analyst, with normal and log-normal distributions often chosen. In this context, the choice probability is given by:

$$P_{ijt} = \int \frac{\exp\left(\beta_{ik} X'_{kjt}\right)}{\sum_j \exp\left(\beta_{ik} X'_{kjt}\right)} \mathrm{f}(\beta_\mathrm{i}|\theta)\mathrm{d}\beta_\mathrm{i} \quad \text{(E.6)}$$

where $\mathrm{f}(\beta_\mathrm{i}|\theta)$ represents the density function of the coefficients and θ the vector of parameters characterizing the deviations from the mean of the coefficients. As the integral in (E.6) does not have a close form solution, estimation requires simulated maximum likelihood (McFadden and Train 2000). Finally, in order to include correlation effects between the alternatives, additional error components are specified (Herriges and Phaneuf 2002) in order to tackle presence of status-quo/opting out effects.

Preference heterogeneity can be also modeled in a latent class framework (Boxall and Adamowicz 2002), according to which utility's parameters are the same within and different between classes:

$$U_{ij|s} = V_{ij|s} + \varepsilon_{ij|s} \quad \text{(E.7)}$$

Given *s* segments, the unconditional choice probability is given by:

$$Pr_{ij} = \sum_s \mathrm{h_s Pr_{j|s}} \quad \text{(E.8)}$$

where $\mathrm{Pr_{j|s}}$ is the choice probability conditioned on the class membership probability $\mathrm{h_s}$, given as follows:

$$\mathrm{Pr_{j|s}} = \frac{\exp(\beta_{k|s} X'_{kjt})}{\sum_j \exp(\beta_{k|s} X'_{kjt})} \quad \text{(E.9)}$$

$$\mathrm{h_s} = \frac{\exp(\gamma_\mathrm{s} \mathrm{Z_s})}{\sum_s \exp(\gamma_\mathrm{s} \mathrm{Z_s})} \quad \text{(E.10)}$$

where $\mathrm{Z_s}$ represents the matrix of socio-economic variates and/or attitudes that condition the segment membership probability. After model estimation, posterior class probabilities can be computed including in (E.8) the estimated coefficients of the utility and segment membership probability function.

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