

Individual preferences towards nuclear energy: the transient residency effect

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Abstract

Nuclear energy is an energy source that is usually unfavorable among the public due to its inherent risks. However, it presents a number of benefits, including the possibility to reduce emissions and the contribution to tackle climate change. Among the countries adopting nuclear energy, the United Arab Emirates (UAE) is unusual in that a large share of its residents consists of expatriates who live only part of their lives in the country with no (or highly unlikely) access to citizenship. This distinctive population structure offers the opportunity to investigate the effect of transient residency on acceptance and preferences towards nuclear energy. We conducted this investigation by designing a stated preferences-based survey, targeting an online nationwide sample. The survey collected information on socio-economic characteristics and attitudes, including views on perceived risks and benefits of nuclear energy, views towards different energy sources, and life satisfaction. Results indicate that transient individuals, especially those who are more satisfied with their lives in the UAE, are significantly less likely to oppose the construction of new nuclear plants. These individuals are characterized by a more positive perception of benefits over risks arising from nuclear energy. Policy implications are discussed.

Keywords: Nuclear energy, social acceptability, transient resident, choice experiments, willingness to accept, UAE

JEL Code: C9, D62, D82, Q48, Q51, Q58

1 Introduction

A number of countries in the Middle East-including the UAE-have announced their plans to invest in nuclear energy (El-Katiri 2012). UAE's decision to invest in nuclear energy is motivated by forecasted growth in energy demand. Although the nation has one of the

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world's largest reserves of hydrocarbons (Masdar/IRENA 2015), sustained population and economic growth has significantly expanded energy demand (Mezher et al. 2012; Jayaraman et al. 2015). Therefore, it is necessary to modify the energy mix which means increasing the share of renewable energy sources and considering nuclear energy (AlFarra and Abu-Hijleh 2012; Jayaraman et al. 2015; Betancourt-Torcat and Almansoori 2015).

With the aim of developing a successful nuclear program, the UAE has signed bilateral nuclear-cooperation agreements with the US, Korea and France. In addition, it concluded memoranda of understanding with the UK and Japan, consulted leading nuclear suppliers and made clear its willingness to forsake a full nuclear cycle⁴ (Early 2010; Strategic Comments 2010). This strategy has made the UAE the first Arab state to make tangible progress towards using nuclear power for electricity generation.

Successful implementation of a nuclear energy programme usually requires social acceptance of nuclear energy (Hammond 1996; Ansolabehere et al. 2003; Weisser et al. 2008; Schneider et al. 2016). Arguably, this is of particular relevance in countries where citizens can vote, request referenda, or veto government's choices in terms of energy policy. Yet, even in countries where referenda are currently not in place, opposition to nuclear energy may lessen the likelihood of implementation and/or increase its costs. In the UAE, the government explicitly makes the welfare and happiness of residents objects of its policy. The Emirates Nuclear Energy Corporation (ENEC), the entity responsible for the deployment and operation of the UAE nuclear energy programme, acknowledges the importance of public opinion, as demonstrated by polls commissioned since 2011 (ENEC 2011) and open public forums hosted since 2010 (ENEC 2014, 2017).

⁴ Spent fuel is planned to be stored in dry storage systems after a phase of storage in spent fuel pools (Al Saadi and Yi 2015).

The UAE population exceeds 9 million, with non-nationals accounting for at least 80% of the total (Koch 2016). There is currently neither access to citizenship nor unconditional permanent residency for almost all non-UAE nationals⁵: at some point, expatriates would most likely have to leave the country⁶. While this is true of most expatriates, they are otherwise a highly heterogeneous group. The expatriate population comprises individuals with different backgrounds, nationalities, culture and social status (Hills and Atkins 2013) and includes members facing different challenges and rewards in the workplace (Koch 2016).

This study employs a stated preference technique, choice experiments, implemented through a nation-wide survey to estimate the willingness to accept (WTA) nuclear power plants in the UAE. In a choice experiment, one does not directly ask about monetary valuations attached to different aspects of choice (i.e. about willingness to pay (WTP) or willingness to accept (WTA)). Instead, respondents choose the scenario they prefer and if one of the attributes associated with that choice is monetary, WTP or WTA can be inferred. Therefore, this methodology allows the derivation of the implicit price of each of the other attributes (i.e. marginal WTP or WTA), as well as the total welfare change provided by various scenario options.

In addition to the choice experiment, the survey included questions on socio-economic characteristics, attitudes towards different energy sources, and life satisfaction. Life satisfaction is one of the subjective measures of welfare associated with the term ‘subjective well-being’, which is employed to assess experienced utility (Kahneman and Krueger 2006) and value non-market goods (Van den Berg and Ferrer-I-Carbonell 2007; Dolan and Metcalfe

⁵ The validity of stay on a residence visa varies according to its type and the sponsor. It can be for 1, 2 or 3 years. According to a change in 2019, a residence visa can also be issued for 5 and 10 years subject to certain conditions (The UAE Government portal, <https://government.ae/en/information-and-services/moving-to-the-uae/how-to-become-a-resident-in-the-uae>).

⁶ The presence of a high share of transient residents relative the share of national citizens is a common feature across the GCC countries with the exception of Oman and Saudi Arabia (IOM 2018).

2012; Levinson 2012; MacKerron 2012; MacKerron and Mourato 2013). Transient residents might lack shared hopes and desires for the future of the society (Forstenlechner and Rutledge 2011). Yet, as discussed in Koch (2016), nationalism is exhibited by non-citizens in the UAE, for which the country might represent a ‘home away from home’. To this end, we included questions on life satisfaction into our analysis to assess whether expatriates experienced an overall improvement in their lives after coming to the UAE.

All in all, this research provides insights about factors influencing social acceptance of nuclear energy in a unique country setting where a very large portion of its residents consists of transient residents. Specifically, we aim to test the following hypothesis: a) whether transient residents are more or less likely to oppose the implementation of nuclear energy projects; b) whether the impact of transient residency is significantly greater among residents who feel more satisfied with their life in the UAE; c) whether transient residents, compared to non-transient residents, are more likely to perceive more benefits as opposed to risks of nuclear energy. The rest of the paper is organized as follows: section 2 presents background information on public attitudes towards nuclear energy; section 3 describes the methodology detailing the choice experiment and the survey design; section 4 lays out the data and results; finally, section 5 concludes.

2 Social acceptance of nuclear energy

In the early 1980s the concept of NIMBY (Not in my backyard) was put forward to explain negative views towards nuclear energy and other potential threats with the argument that selfish citizens would oppose the siting of problematic facilities in their neighborhood whilst not opposing them elsewhere (Letcher and Vallero 2019). Since then, decades of research have deepened our understanding around the determinants of acceptance and

opposition of energy sources. Perceived risks and benefits of nuclear energy seem to represent major determinants (Ansolabehere et al. 2003; Ansolabehere and Konisky 2009; Bronfman et al. 2012; Choi et al. 1998; De Boer and Catsburg 1988; Groot and Steg 2008; Greenberg 2009; Groot et al. 2013; Kato 2006; Rosa and Dunlap 1994; Zhu et al. 2016; Wu 2017). Additionally, trust towards regulatory agencies seems key in shaping acceptance (Ansolabehere and Konisky 2009; Greenberg 2009; Siegrist and Cvetkovich 2000; Siegrist et al. 2000; Greenberg and Truelove 2011; Bronfman et al. 2012). Proximity to nuclear plants is also considered as an important factor. In communities with established projects, there is evidence of a more positive view, with perceived risks decreasing as proximity increases (Venables et al. 2012). More generally, people living in countries with nuclear plants in operation tend to state more positive views, with greater shares of respondents indicating advantages outweigh risks of such programmes (Kovacs and Gordelier 2009). When nuclear energy projects are explicitly linked to the possibility of tackling climate change, acceptance seems to be fostered (Visschers et al. 2011). On the other hand, evidence suggests that individuals who are more concerned about the environment, besides climate change, would opt for renewables over nuclear (Ertör -Akyazi et al. 2012). Finally, the information available to the respondents could affect social acceptance. In particular, providing information on benefits and risks seems to reduce opposition towards nuclear energy (Jun et al. 2010; Zhu et al. 2016).

There is scant existing research on social acceptance of nuclear energy in the UAE and, more broadly, in the Gulf Cooperation Council (GCC) countries. Since 2011, global market research companies, commissioned by ENEC, conducted a number of national polls. In 2011, 85% of the UAE residents sampled believed that a peaceful nuclear energy program was

important for the nation according to a research by TNS (ENEC 2011). The latest poll, conducted in 2018 by Nielsen, revealed some of the highest favorability rates for nuclear energy, with 91% of the sampled residents stating that a peaceful energy program is important for the nation (ENEC 2019). Furthermore, according to this poll, support for the construction of peaceful nuclear energy plants in the UAE reached a level of 85%, whereas 75% of the sampled respondents believed that the benefits of nuclear energy outweighed risks. With regards to other GCC countries, data from OECD (2010) and Globescan (2005) showed limited support towards nuclear energy in Saudi Arabia, country where the share of nationals is much greater than the share of expatriates.

3 Methodology

3.1 Choice experiments

Choice experiments (CE), a stated preference technique, are widely used in Environmental Economics (Hanley et al. 2001; Louviere et al. 2000). This method allows one to estimate economic valuations of goods that are not exchanged in markets, based on choices made in a hypothetical setting. We utilize choice experiments to measure preferences towards nuclear plants. Respondents are presented with a series of choice tasks, where nuclear projects with differing attributes are described. Next, they are asked to choose, in each choice task, their most preferred scenario. Each project or scenario is characterized by a set of attributes, and each attribute is characterized by a set of levels. Applications of choice experiment studies to nuclear energy are still scant, and the few exceptions include Contu et al. (2016), Cicia et al. (2012), Itaoka et al. (2006). In this study, the choice experiment scenarios requested respondents to imagine they had a chance to choose between a series of options regarding the construction of current generation nuclear power plants in the UAE.

We presented four choice tasks, each involving a comparison of two hypothetical nuclear power projects and a third option, namely none of the two. The hypothetical projects had four attributes. An example of such choice tasks is displayed in Figure 1.

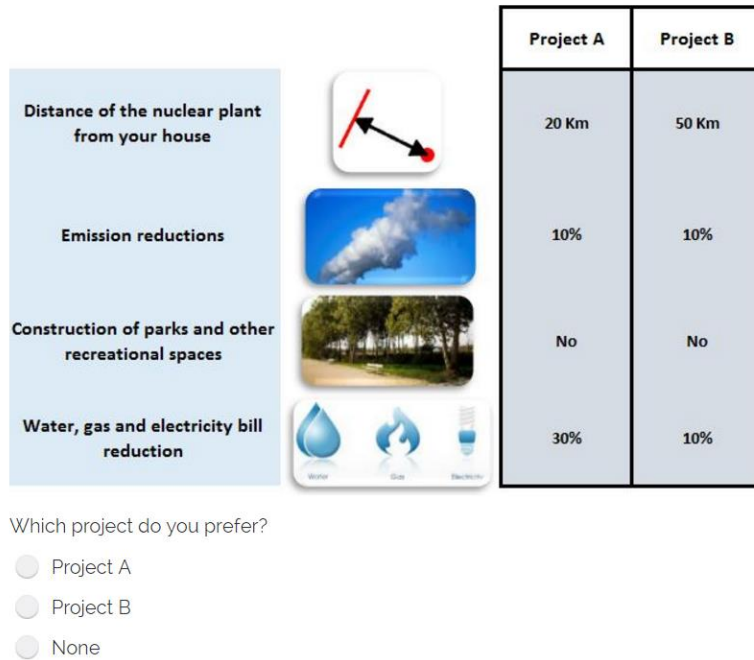


Figure 1: Example of choice task

The four chosen attributes were: ‘atmospheric emission reductions’, ‘distance from the nuclear power plant’, ‘construction of parks or other recreational spaces’ and ‘water, gas and electricity bill reductions’. The selection of attributes and levels was informed by previous studies conducted in Italy and the UK (Contu et al. 2016), as well as by literature review. Table 1 shows the attributes and how many levels each attribute have. The attributes ‘distance from the nuclear plant’ and ‘emission reductions’ proved to be of significant relevance in analogous studies carried out in Italy and UK (Strazzera et al. 2012, Contu et al. 2016). Distance is a key element considering the nuclear plants pose potential threats to the environment (Beheshti 2011) and human health (Fairlie 2013). ‘Construction of parks and

other recreational spaces’ was included as an attribute so as to introduce the potential public benefits typically associated with the construction of nuclear plants (Yamane et al. 2011; Gregory et al. 1991; Mansfield et al. 2002). Finally, ‘water, gas and electricity bill reduction’ was incorporated as the monetary attribute (Strazzera et al. 2012). A combination of water, gas and electricity bill reduction, as opposed to a simple electricity bill reduction, was included due to the relatively low prices of electricity bill in the UAE (Mezher et al. 2012; Griffiths and Mills 2016).

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/house
Atmospheric emission reduction	20%, 10% or no reduction
Construction of parks/recreational spaces	Yes or No
Water, Gas and Electricity bill reduction	30%, 20%, 10% or no reduction

Given four attributes and their levels, with two nuclear project options per choice task, the total number of possible experimental choice task combinations is 9216⁷. This is clearly excessive, so it was therefore necessary to reduce the number of presented choice tasks by means of an experimental design. A Bayesian efficient design⁸ (Sándor and Wedel 2001;

⁷ 4 distance levels * 3 emission reduction levels * 4 bill reduction levels * 2 public investments = 96 scenarios. As each choice card comprises a pair of scenarios, the total number of all possible pairs is 96*96=9216.

⁸ The Bayesian approach requires that the efficiency of a design to be evaluated over many different draws taken from the prior parameter distributions assumed in generating the design. The Bayesian efficiency of a design is, then, calculated by using simulation methods to approximate the expectations for differing designs (Bliemer et al. 2008).

Bliemer et al. 2008; Rose and Bliemer 2009) was prepared. Priors were derived from analogous CE studies conducted in Italy and UK (Strazzera et al. 2012, Contu et al. 2016). The final design consists of 8 blocks of choice experiments with 4 choice tasks in each block, for a total of 32 pairs of projects presented, along with a ‘none’ option (design available upon request). Hence, the number of combinations taken into consideration totaled 256. The design is prepared with the goal to minimize the standard errors of the preference coefficients given the priors inputted, which in a Bayesian approach follow a distribution rather than being fixed. The combinations produced tend to avoid the inclusion of choice situations where the choice is dominated or most likely to be predicted given the value of the priors and the attributes’ levels. The design was generated with the software NGENE.

3.2 Econometric models

When analyzing choice experiment data, we estimate the following utility function⁹ for our econometric analysis¹⁰:

$$V_{ij} = \beta_1 ASC + \beta_2 Distance_{200 Km} + \beta_3 Distance_{100 Km} + \beta_4 Distance_{50 Km} \\ + \beta_5 Emission_{20\%} + \beta_6 Emissions_{10\%} + \beta_7 Parks + \beta_8 Bill$$

ASC refers to the alternative specific constant indicating which of the alternatives is the ‘none’ option. Therefore, the coefficient attached to it, β_1 , describes whether respondents are more or less likely to choose none of the projects. This is an indication of broad acceptance (β_1 negative) or opposition (β_1 positive) towards nuclear energy. Yet, the ‘none’ option could be chosen due to reasons other than acceptance or opposition, such as lack of preferred alternative or difficulty of the tasks.

⁹ Utility of individual i for alternative j is given by: $U_{ij} = V_{ij} + \varepsilon_{ij}$ where V_{ij} and ε_{ij} are the deterministic and stochastic components, respectively, and V_{ij} represents $V_{ij} = \sum_k \beta_{ikj} X'_{ikj}$.

¹⁰ Variable codes are presented in Appendix, Table A1.

The error term of this estimated utility function is assumed to follow a Type I extreme value distribution where errors are distributed identically and independently for all observations. Accordingly, we use a Multinomial Logit model (MNL) to estimate the coefficients. Because the coefficients represent marginal utilities, a ratio of coefficients (when one of the attributes is money) provides a monetary valuation for the other attribute.

Two assumptions associated with the MNL model may be troublesome. First, the MNL model assumes independence of irrelevant alternatives. The assumption is restrictive, but MNL is nevertheless widely used. Second, the MNL model assumes preference homogeneity. Given these difficulties, we check for robustness by employing both a latent class model (Boxall and Adamowicz 2002) and a Random Parameters Logit (RPL) model. According to the latent class model approach, parameters are the same within and different between classes of observation. The RPL model overcomes taste variation issues by assuming preference heterogeneity to follow a continuous distribution and that does not exhibit independence of irrelevant alternatives (Revelt and Train 1998; McFadden and Train 2000).

The latent class (LC) approach represents an alternative way to model preference heterogeneity (Boxall and Adamowicz 2002; Greene and Hensher 2003). As opposed to the RPL model where heterogeneity is modelled in a continuous fashion, the LC model assumes the existence of a given number of segments of preferences, different between and same within. The deterministic component of the utility function, conditional on each segment s , is as follows:

$$V_{ij|s} = \beta_{1|s}ASC + \beta_{2|s}Distance_{200\text{ Km}} + \beta_{3|s}Distance_{100\text{ Km}} + \beta_{4|s}Emission_{20\%} \\ + \beta_{5|s}Emissions_{10\%} + \beta_{6|s}Parks + \beta_{7|s}Bill$$

Finally, in order to inspect and analyze data relative to perceived benefits and risks of nuclear energy, we employ factor analysis. Additional details on the econometric models used in this study are available in Appendix C.

4 Data, descriptive statistics and results

4.1 Data

This study uses survey data collected from 1,961 respondents residing in the UAE. Given that we had four choices in each choice experiment, the total number of observations generated amounts to 7844 for the choice experiment data. The data contain information on socio-economic characteristics and attitudes, including views on different energy sources, perceived risks and benefits of nuclear energy, and life satisfaction. Quotas on age, gender and nationality group were set so as to be in line with the target population: UAE residents aged 18 and more.

We administered the questionnaire online between June and July 2015 using a market research company (YouGov), who recruits members of the panel and receive surveys. Respondents could complete the survey in English or Arabic, based on their preference. The survey flow was designed to incentivize the respondents to think carefully about energy and climate change issues before they participated in the choice experiment exercise focusing on nuclear energy. The survey was prepared in Gryphon, survey programming tool used by YouGov. 10 face-to-face pilots were conducted to test the flow and content. The finalized survey was initially soft-launched with 50 respondents and subsequently fully launched after satisfactory inspection of the initial data collected. All the surveys' views were optimized for both laptop and mobile view (Appendix B shows key screens from the survey, whereas additional information is available upon request).

62 different nationalities took part in the survey, the majority belonging to India (34%), Pakistan (11%), Philippines (10%) and the UAE (10%). In order to define the segment of transient expatriate residents, we rely on stated intention to leave the country. We consider as transient those who intend to leave within the next ten years. Overall, this group constitutes 38% of the total sample and 42% of the expatriates. Other expatriates, who do not plan to leave the UAE in the next ten years, make up 52% of the sampled respondents.

Table 2 presents summary statistics for the complete sample and for the following sub-groups considered throughout the study: UAE nationals, transient and other expatriates. In line with the population structure of the UAE, only 20% of the sampled respondents were born in the UAE. This share grows substantially among UAE nationals (64%). The lowest share of those who were born in the country is among transient expatriates (6%). UAE nationals are also, unsurprisingly, the group of respondents who have been living longest in the country: 6 in 10 have stayed for more than 20 years. In contrast, only 7% of transient residents have stayed in the country for so long. Considering employment, almost 8 out of 10 transient residents work full time. This is the highest share across the groups considered, whereas Emiratis have the lowest share (58%). Emiratis and transient expatriates share the lowest level of unemployment (4.6%). 65% of the respondents are male and average age is 33.8 years. However, a significantly greater share of women (38%) was sampled among the group of other expatriates. Almost half of the sample consists of respondents who are married with children (47%), while 35% are single.

Table 2. Sample structure by socio-demographic variables (% reported)

	All	Transients ^a	Emiratis	Other expats
	N=1961	N=738	N=197	N=1026
Gender				
Male	64.7	67.3	70.1	61.8
Female	35.3	32.7	29.9	38.2
Marital status				
Single-never married	34.5	37.1	32.5	33
Married without kids	15.8	17.6	13.7	14.8
Married with kids	47.4	43	49.2	50.2
Divorced	2	2	4.6	1.6
Widow/widower	0.3	0.3	0	0.4
Employment				
Working full time	70	78.2	58.4	66.4
Working part time	8.7	8.5	19.8	6.6
Full time student	4.8	3.4	8.6	5.2
Retired	0.8	0.7	2.5	0.6
Full-time home-maker or housewife	8.3	4.2	5.1	11.8
Unemployed	6.6	4.6	4.6	8.5
Other	0.8	0.4	1	1
Were you born in the UAE?				
Yes	20.2	6.1	64	21.9
No	79.8	93.9	36	78.1
For how many years have you been living in the UAE				
Less than 1 year	8	10.7	2.5	7
1-2 years	11.4	18	3.6	8.2
3-4 years	12.1	17.8	4.6	9.5
5-6 years	9.8	11.1	5.6	9.6
7-8 years	10.7	11	5.1	11.5
9-10 years	6.7	6.9	3.6	7.1
11-15 years	10.1	10.7	5.6	10.6
16-20 years	8.7	6.5	10.2	9.9
21-30 years	12.7	5	23.9	16.2
More than 30 years	9.8	2.3	35.5	10.3
How long are you planning to stay in the UAE				
Less than 3 months	1.6	4.1	1	0
3 – 6 months	1.2	2.7	1.5	0
6 – 12 months	1.5	3.7	1.5	0
1 – 2 years	7.1	17.2	6.6	0
3 – 4 years	10.5	26	7.1	0
5 – 6 years	9.9	25.1	4.6	0
7 – 10 years	8.4	21.3	3.6	0
More than 10 years	12.5	0	11.2	21.8
I do not plan to move out of the UAE	28.1	0	54.3	43.4
Do not know	19.1	0	8.6	34.8

^aRespondents who stated to intend to leave the UAE within ten years.

With regards to monthly personal income, the highest share is observed for the category AED 5,001-AED 10,000 (22%), followed by AED 2,001-AED 5000 (19%)¹¹. More transient residents have a lower income: 38% up to 5000 AED; whereas Emiratis have the highest income, with 35.5% indicating an income of 25000 AED or more.

Respondents were asked whether the risks of nuclear energy are justified by its benefits, including its contribution to decreasing the impact of climate change. A slightly higher share of transient residents believe so (36.6%), as opposed to UAE nationals (30%) and other expatriates (28%). Solar/photovoltaic energy seems to be the most favored energy source among the respondents. Behind renewable energy, we find nuclear. Although 11% of the respondents would not want the UAE to invest anything on nuclear energy, 26% would like the nation to invest a lot on it. A similar share, 24%, selected 'I do not know'.

We also assessed potential risks and benefits associated with nuclear energy. For each risk and benefit enumerated, respondents were probed to think about nuclear energy in the UAE and nuclear energy in general. The UAE is associated with significantly lower perceived risks, with no significant difference in perceived benefits found. A difference in ratings given to risks and benefits in the UAE emerges comparing different groups of respondents. When compared to UAE nationals, transient residents attach a greater likelihood to both risks and benefits. (Figures 2 and 3)¹².

¹¹The UAE dirham is pegged to the US dollar (fixed at a rate of AED 3.67 to US \$1) since 1997 to date. So AED 5,001-10,000 is equivalent to US \$1360 - \$2720. Also, note that as of November 2019 there is no income tax in the UAE.

¹² This is further explored in Section 4.3 by means of factor analysis.

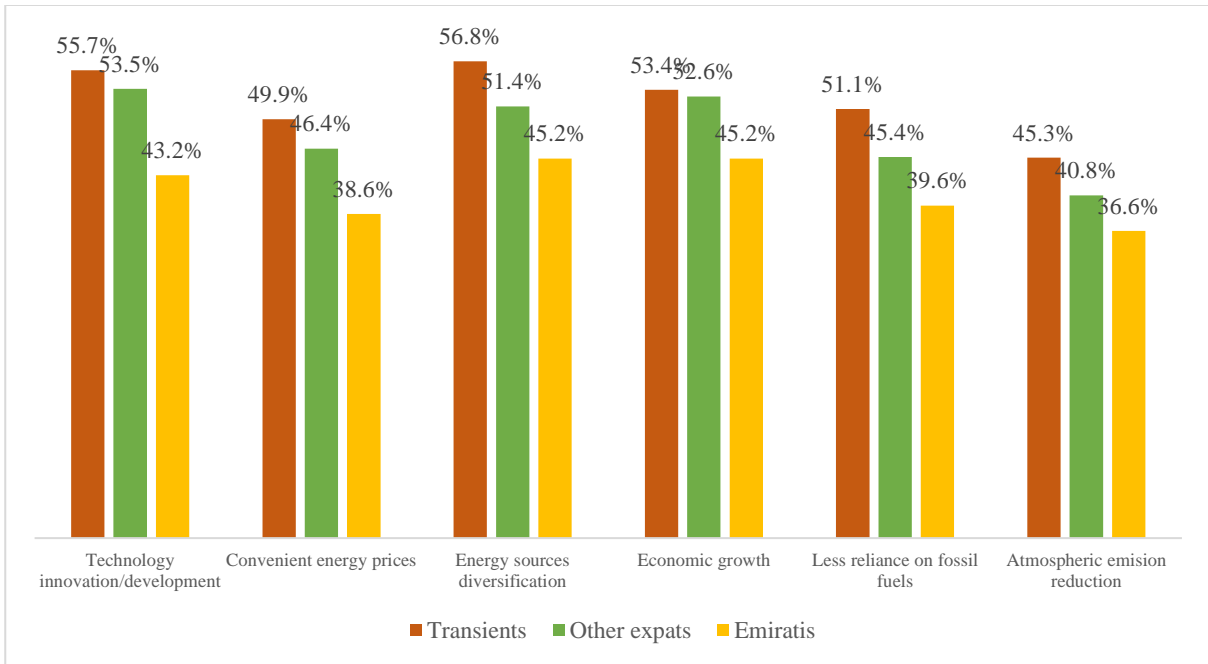


Figure 2: Perceived benefits of nuclear energy in the UAE-sum of likely & very likely

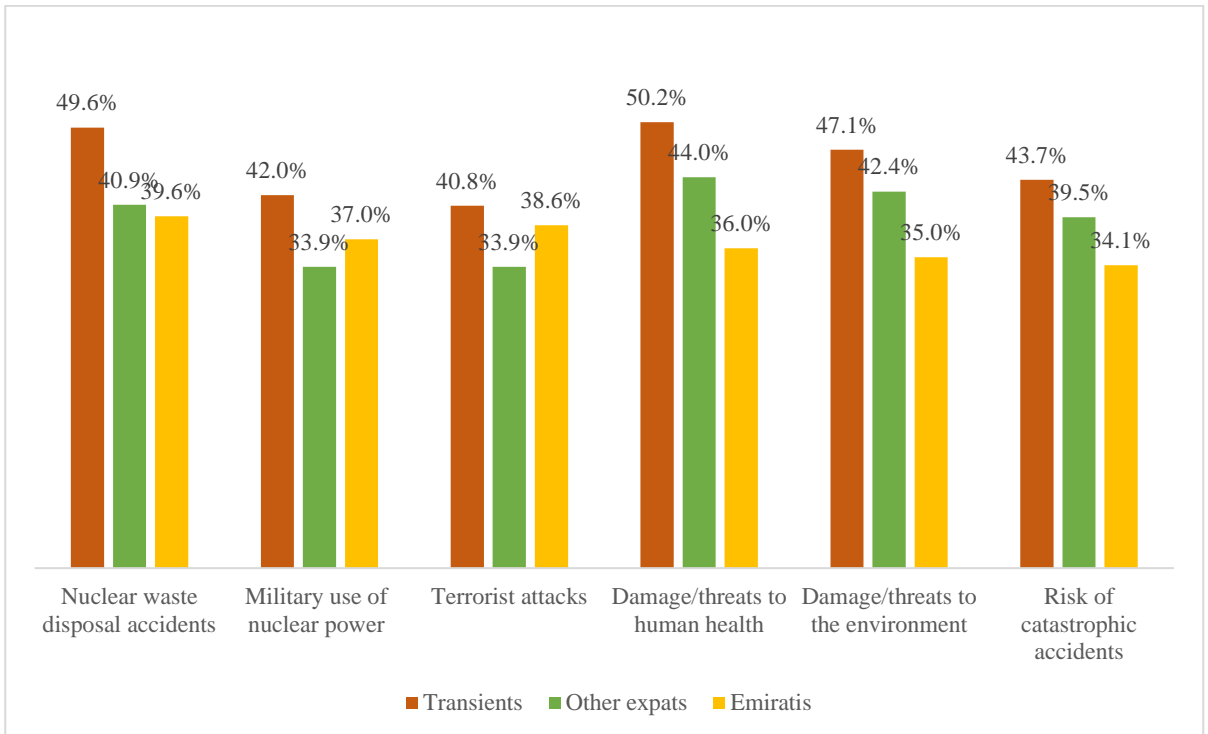


Figure 3: Perceived risks of nuclear energy in the UAE-sum of likely & very likely

Overall life satisfaction in the UAE is greater among Emiratis, with an average score of 7.6 on a 10-point scale. 35% of UAE nationals selected a score of 10 (Very satisfied), compared to just 7.3% of transient residents and 16.4% of other expatriates. Across the whole sample, average life satisfaction is 6.8 (Figure 4). According to the World Happiness Report (2016), the UAE average score on a similar question is 6.6.

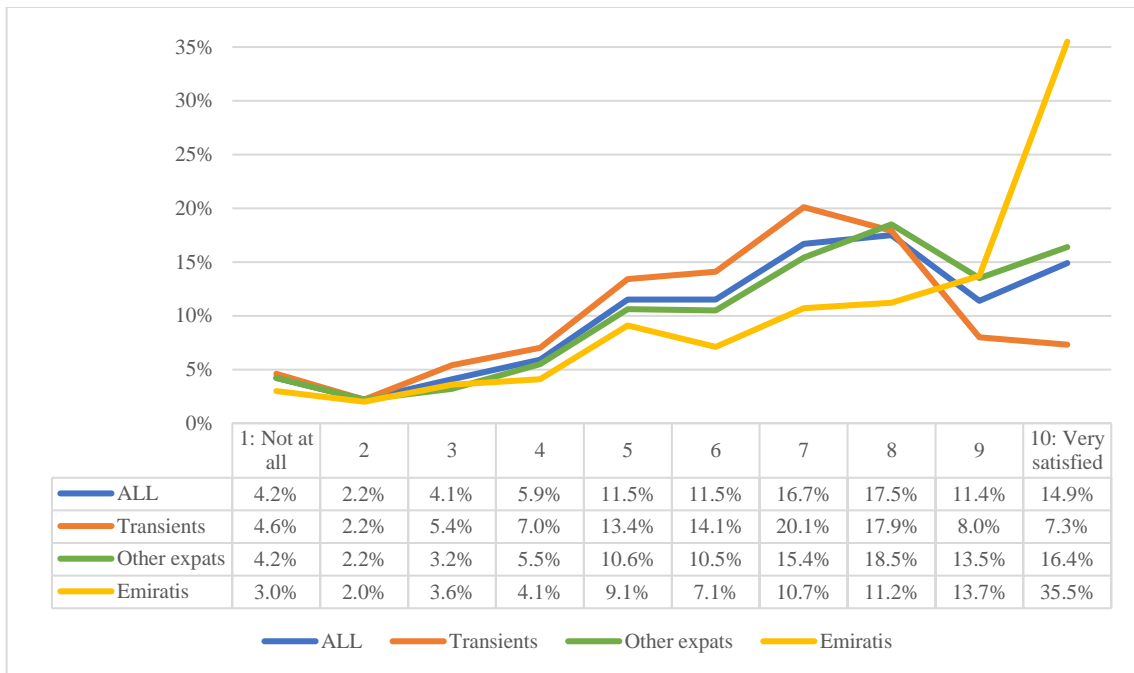


Figure 4: How satisfied are you, overall, with your life in the UAE?

4.2 Choice experiment results

We start our econometric analysis of choice experiment data with MNL and RPL models. For the latter model, all parameters are assumed to be normally distributed excepting the monetary attribute’s coefficient, which is held fixed (Table 3). Although both models have similar implications about preferences, the RPL model seems to be preferable in terms of model fit as it reveals a substantial amount of preference heterogeneity. Both of these models show the presence of a positive attitude towards nuclear options in general, as

indicated by the negative and significant coefficient attached to the alternative specific constant (ASC).

Table 3. MNL and RPL models. Dependent variable: Choice

Variable	MNL	RPL	RPL	MNL	RPL
	Coeff. (S.e.)		S.D.	Monetary Valuations (AED)	
ASC	-.312*** (.065)	-2.46*** (.179)	4.10*** (.186)	-610.1	-4004.7
Distance: 200 Km	.495*** (.048)	.674*** (.055)	.536*** (.165)	966.4	1094.1
Distance: 100 Km	.317*** (.051)	.471*** (.057)	.023 (.113)	619.9	764.8
Distance: 50 Km	.000 (.047)	.073 (.054)	.325* (.184)	→0	→0
Emission Reduction: 20%	.157*** (.042)	.191*** (.045)	.044 (.133)	308.3	310.2
Emission Reduction: 10%	.125*** (.037)	.166*** (.039)	.011 (.115)	245.8	270.3
Parks	.114*** (.026)	.179*** (.032)	.008 (.082)	224.4	291.2
Bill Reduction (AED)	.0005*** (.000)	.0006*** (.000)	/	/	/
Log-Likelihood	-8143.71	-7009.40			
R squared	0.05	0.18			
Observations	7844	7844			

Level of significance: *10%, **5%, ***1%. Robust standard errors in parenthesis. b. fixed coefficient.

As expected respondents prefer nuclear projects located further away from their city of residence. They positively value emission reductions, the building of parks and bill reductions. According to both models all estimated coefficients are significant, with the exception of β_4 (nuclear plant located 50 Km away). While there are non-linear effects attached to distance, no significant difference is present when comparing 20 and 50 Km.

The monetary valuations, shown in the last two columns of Table 3 for the MNL and RPL respectively, represent willingness to accept compensation for a worse level of the attribute considered. Considering RPL estimates, we estimated that respondents would prefer nuclear plants built away from their area of residence, as they would be willing to forgo around 1100 AED (US \$300) a year for a nuclear plant located 200 Km away rather than 20 km away. This reduces to 765 AED (US \$200) for a distance of 100 Km. Overall, distance seems to be a key attribute for the respondents. Emission reductions are positively valued too, around 310 AED (US \$85) for 20% emissions reduction. Similarly, the building of parks is valued around 300 AED (US \$80).

When the monetary attribute's coefficient is fixed, as in the RPL model above, we assume that all individuals have the same preferences for the monetary attribute, which is unrealistic. Thus, in order to allow monetary attribute preferences to be heterogeneous, we can specify this coefficient to be log-normally distributed. With this specification, we make sure that WTP measures have defined moments since the monetary attribute coefficient is constrained to be positive, but the resulting WTP distribution can be highly skewed. One way to overcome this problem is to estimate the mixed logit model in WTP space (Train and Weeks 2005; Meijer and Rouwendal 2006; Hole and Kolstad 2012). Accordingly, we estimate an RPL model in willingness to pay space (Table 4), where the monetary attribute is

assumed to be distributed according to a positive log-normal distribution; remaining coefficients are assumed to be normally distributed. When allowing for heterogeneity in the cost parameter, monetary valuations are substantially lower. Individuals are willing to forgo only 578 AED (US \$157) for a nuclear plant built 200 Km away, 483 AED if 100 Km away. Furthermore, emission reductions are not valued more than 62 AED (for a 10% decrease). Finally, the building of parks is valued 122 AED (US \$33). Although the monetary valuations are more conservative in this case, this model with an additional parameter does not present a superior goodness of fit as opposed to the previous RPL where the cost parameter was set fixed.

Table 4. RPL model (WTP space). Dependent variable: Choice

Variable	Monetary Valuations (AED)	t-statistic	S.D.	t-statistic
ASC	-1318.2	1.09	28.8	0.39
Distance: 200 Km	578.2	1.1	85.5	0.32
Distance: 100 Km	482.9	0.8	64.6	0.16
Distance: 50 Km	77.5	4.2	19.3	0.18
Emission Reduction: 20%	51.3	0.46	67.4	2.3
Emission Reduction: 10%	62	1.36	13.0	0.16
Parks	122.4	76.9	3.37	0.23
Log-Likelihood	-7365.105			
R squared	0.15			
Observations	7844			

Distribution of the monetary attribute assumed to be (positive) log-normally distributed. S.D.: standard deviation. t-value associated to the standard deviation of the monetary coefficient is 2.05.

Given the hypotheses to be tested, we also assess the presence of differences in preferences between different respondent groups, specifically the expatriates who are likely to leave the UAE within 10 years and the ones that are more satisfied with their life in the UAE. Accordingly, we estimated an RPL model using a heterogeneity decomposition where we used two sets of interactions for each utility's coefficient¹³. In the first set of interactions, we used a dummy variable identifying whether the respondent is an expatriate likely to leave the UAE within 10 years (a transient resident). In the second set of interactions, we used a dichotomous variable identifying whether the respondent is an expatriate more satisfied with his/her life in the UAE (regardless of whether he or she classifies as transient or not). For both sets of interactions, we found a significant effect with respect to the ASC: transient respondents and those more satisfied with their lives in the UAE are associated with a lower coefficient, translating into a lower probability of choosing none of the projects. In addition, transient residents are also associated with significantly lower coefficients for the attribute 'distance', thereby confirming a lessened degree of opposition (Table 5).

¹³ All utility function coefficients are assumed to be normally distributed in this model.

Table 5. RPL model with heterogeneity decomposition. Dependent variable: Choice

Variable	B	β^* Transient	β^* Expat_MS	S.D.
	Coeff. (S.e.)			
ASC	-1.90*** (.205)	-1.03*** (.260)	-.666** (.305)	3.99*** (.183)
Distance: 200 Km	.711*** (.069)	-.197** (.100)	.031 (.114)	.497** (.163)
Distance: 100 Km	.469*** (.067)	-.108 (.100)	.008 (.115)	.046 (.108)
Emission Reduction: -30%	.210*** (.064)	-.022 (.091)	-.041 (.106)	.157 (.125)
Emission Reduction: -20%	.256*** (.056)	-.179** (.081)	-.055 (.093)	.005 (.101)
Parks	.171*** (.045)	-.074 (.066)	-.083 (.076)	.006 (.082)
Bill Reduction (AED)	.0005** (.0002)	.0001 (.0002)	.0002 (.0004)	.001*** (.0004)
Log-Likelihood	-6991.641			
R squared	0.188			
Observations	7844			

Level of significance: *10%, **5%, ***1%. Robust standard errors in parenthesis. Model with monetary attribute set as log-normal failed to converge.

Finally, we model a latent class model to confirm further the robustness of our findings. A two class model is considered and presented in Table 6, given that models with more classes did not seem to have a global optimum. The class membership was specified to be a function of

whether expatriates are considering leaving the UAE within the next 10 years and whether respondents belong to the group of expatriates who are more satisfied in the UAE¹⁴.

Table 6. Latent class model. Dependent variable: Choice

Variable	CLASS 1	CLASS 2	CLASS 1	CLASS 2
	Coeff. (s.e.)		Monetary valuation (AED)	
ASC	-1.82*** (.089)	2.31*** (.108)	-2644.4	3606.6
Distance: 200 Km	.643*** (.048)	.196*** (.103)	929.9	306.4
Distance: 100 Km	.462*** (.049)	-.143 (.119)	668.8	→0
Emission Reduction: 20%	.182*** (.045)	.056 (.109)	263.9	→0
Emission Reduction: 10%	.156*** (.039)	-.045 (.105)	225.9	→0
Parks	.159*** (.032)	.256*** (.083)	229.9	400.9
Bill Reduction (AED)	.0006*** (.0001)	.0006*** (.0002)	/	/
Class membership function				
Constant	1.15*** (.079)	0 ^a	/	/
Transient	.438*** (.129)	0 ^a	/	/
Expat_MS	.329*** (.151)	0 ^a	/	/

¹⁴ . These two variables entering the class membership probability were also included as interactions within the RPL model with a heterogeneity decomposition.

Average class probability	0.8	0.2	0.8	0.2
Log-Likelihood		-7021.78		
Pseudo R²		0.184		
Observations		7844		

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

The two segments are characterized as follows. The first class has a negative coefficient attached to the ASC. That is, individuals more likely to be associated with this class are more in favour of nuclear energy in the UAE. In addition, they would prefer nuclear plants be located farther away from their city of residence. Furthermore, they value emission reductions, the construction of parks and other recreational spaces, and reductions in utility bills. Those more likely to belong to class 1 are more likely to leave the UAE within the next 10 years and to be more satisfied with their life in the UAE. The second class has a positive coefficient attached to the ASC, indicating a less favorable stance towards nuclear energy for individuals allocated to this segment. This segment groups individuals who do not value the reduction of atmospheric emissions to a significant extent. However, they do value the building of parks and the provision of private benefits, namely utility bill reductions.

For internal validity purpose, after the choice experiment exercise, respondents were asked to state directly their view towards the building of nuclear plants in the UAE. A 10 points scale was employed where 1 meant ‘absolutely oppose nuclear plants in the UAE’ and 10 ‘absolutely in favor of nuclear plants in the UAE’. This permits us to validate the extent of support and opposition within each segment (Figure 5). As expected, class 2 has a higher share of clear nuclear energy opponents (25% selecting option 1, meaning ‘absolutely oppose nuclear plants in the UAE’), a higher share of neutrals (47%) and fewer individuals in favor of nuclear energy in the country. Notably, in both segments, the share of neutral responses is substantial. Overall, segment 1 consists of respondents more favorable towards nuclear

energy. In contrast, in segment 2, around half of the respondents are indifferent and almost 2 in 5 indicate an opposing attitude.

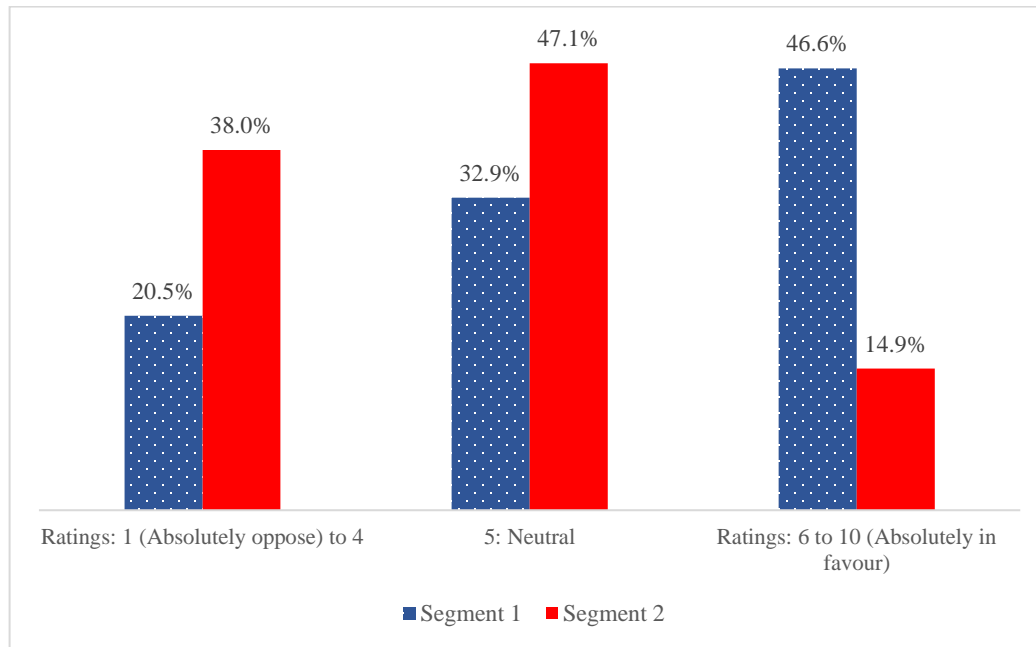


Figure 5: Views towards nuclear energy in the UAE by segment

4.3 Factor analysis on perceived risks and benefits of nuclear energy

In this section we conduct factor analysis to confirm the existence of the latent constructs ‘Perceived risks’ and ‘Perceived benefits’ and to test whether transient residents perceive more benefits as opposed to risks arising from nuclear energy. Table 7 presents the resulting factor loadings and uniqueness’ values (Appendix C provides details on the econometrics of factor analysis).

Table 7. Perceived Risks and Benefits: Factor loadings and uniqueness by question

ξ : Risks			ξ : Benefits		
	Factor Loadings	Uniqueness		Factor Loadings	Uniqueness
Catastrophic accidents	0.83	0.30	Atmospheric emission reduction	0.68	0.53
Threats to the environment	0.87	0.24	Less reliance on fossil fuels	0.73	0.45
Threats to the human health	0.88	0.21	Economic growth	0.79	0.36
Terrorist attacks	0.77	0.40	Energy source diversification	0.74	0.43
Military use of nuclear power	0.75	0.43	Stable/convenient energy prices	0.60	0.63
Risk of nuclear waste disposal accident	0.83	0.30	Technology development	0.66	0.56

Factor loading: it represents the covariance between each item and the construct.

Uniqueness: the variance that is unique to the item considered.

For both constructs, ‘Risks’ and ‘Benefits’, the factor loadings are all positive. Considering perceived risks, most of the variance in the question ‘threats to human health’ is explained by the construct. Instead, with regards to perceived benefits, the item ‘economic growth’ has the smallest uniqueness. Given the factor loadings shown in Table 7 and the answers to each of the items, it is possible to compute a score for each latent factor and for each respondent. The greater the factor loading associated with one item, the greater its weight in the computation of the individual scores. As we observed that expatriates tended to give higher ratings to both

perceived benefits and risks, we computed the differences between benefits and risks' score factors. We refer to this measure as net perceived benefits. This allows to determine whether a given respondent scores greater on the benefits or on the risks. A greater positive difference between benefits and risks is assumed to be associated with a higher degree of acceptance, all else equal.

A series of t-tests have been performed with the aim of assessing whether these differences are significantly higher by specific groups (Table 8). The groups considered are 1) expatriates less satisfied in the UAE, 2) expatriates who indicated the same level of satisfaction in the UAE and in general and 3) expatriates who stated to be more satisfied in the UAE. We also repeated the tests with the subset of expatriates planning to leave the country in the next 10 years (i.e. transient), leading to additional 3 groups according to the level of life satisfaction (bottom three rows in Table 8). Expatriates more satisfied in the UAE and stating to be leaving within the next 10 years are associated with the greatest and positive mean score factor of the net perceived benefits. Instead, expatriates less satisfied in the UAE display a negative value of the difference between the score factors of benefits and risks. This indicates that transient respondents perceive more benefits as opposed to risks arising from nuclear energy, in line with their heightened support towards this energy source.

Table 8 Mean and S.D. of net perceived benefits by group

Segment	Mean	S.D.	Base	Comparison group	Mean	S.D.	Base	T-statistic
Total Expatriates less satisfied	-.154	1.240	592	Else	.066	1.31	1369	3.85
Total Expatriates as satisfied	.025	1.120	727	Else	-.014	1.19	1234	-.726
Total Expatriates more satisfied	.190	1.140	445	Else	-.055	1.17	1516	-3.91
Transient less satisfied	-.174	1.230	295	Else	.062	1.13	443	2.67
Transient as satisfied	-.046	1.140	281	Else	-.022	1.20	457	.265
Transient more satisfied	.252	1.100	162	Else	-.112	1.19	576	-3.49

S.D.: standard deviation.

5 Conclusion

The UAE is in the final stages of developing its first nuclear power programme, which constitutes the first nuclear power station in the Arabian Peninsula, and the first commercial nuclear power station in the Arab World. The UAE's nuclear power program might see the first reactor begin generating electricity by 2020. This is a crucial step in the direction of

fulfilling increasing energy demand and moving towards decarbonizing the energy mix. The UAE has the advantage of learning from past disasters and having resources sufficient to afford world class technology (Sultan 2013). This study analyzed the extent of social acceptance of nuclear energy in the UAE and whether transiency of residence and life satisfaction shape such acceptance.

Part of the findings reveal the presence of support towards nuclear energy implementation in the UAE. First, only 11% would not want the UAE to invest in nuclear. This share is lower if compared to the analogous one found for the UK, amounting to 15%; moreover, it is substantially lower when considering the case of Italy where almost half of the sampled respondents, 45%, would not want the country to invest in nuclear (Contu et al. 2016; Contu and Mourato 2020). In addition, when asked to think about risks of nuclear energy in the UAE as opposed to risks of nuclear energy in general, respondents associated significantly lower risks to nuclear energy implementation in the UAE.

Additional results suggest a more cautious stand towards acceptance of nuclear energy. Only 32% of respondents believe that the risks of nuclear energy are justified by its benefits, including its contribution to limiting climate change. In addition, renewable energy sources obtained a greater share of preferences, with solar and photovoltaic coming top. This shows support towards other plans and investments the government is also undertaking such as the development of a sustainable eco-neighbourhood, Masdar City (Reiche 2010), or Abu Dhabi's goal to generate 7% of its electricity from renewables by 2020 (Reiche 2010), and Dubai's 15% by 2030 (Griffiths and Mills 2016).

Respondents took part in a choice experiment exercise aimed at revealing their valuations of selected attributes of hypothetical nuclear energy projects with no specific

reference to the Barakah site, where the UAE is building four reactors. The resulting economic valuations are in line with those in the stated preference literature. We found that the potential for nuclear energy to reduce GHG emissions is positively valued, as are greater distance from the energy facility (Fimereli 2011) and the provision of public and private benefits (Strazzera et al. 2012). The latent class model findings depict a situation characterized by two distinct segments of preferences: one more in favour of nuclear energy (Segment 1) and the other one more in opposition (Segment 2). Interestingly, respondents who declared an intention to leave the UAE within 10 years and those who appear to be more satisfied with their life in the UAE seem more likely to be associated to the more nuclear energy prone segment (Segment 1). These findings are also supported by the RPL model with heterogeneity decomposition, in which transient respondents and those who are more satisfied with their life in the UAE signal a heightened level of acceptance for nuclear energy.

The results of this study highlight the presence of a link between transient residency and a lower likelihood of opposing nuclear plants developments. It also shows that residents who are more satisfied with their life in the UAE tend to be even more favorable, perceiving more benefits as opposed to risks arising from nuclear energy. This could represent a remarkable advantage for the UAE and countries with large shares of transient residents in their population as it allows considering further nuclear energy developments, exporting electricity to neighboring states and providing expertise to countries willing to embark in a nuclear programme. Results also imply that policies aimed at fostering life satisfaction can influence the way residents view government's initiatives, with positive spillovers in shaping social acceptance towards energy programmes. This is aligned with the findings of Eisasson et al.

(2019). Future research is envisaged to assess social acceptance of nuclear energy across more GCC countries and to explore the effect of transiency of residence and life satisfaction on behaviors and willingness to cooperate in environmental or energy initiatives.

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Appendix A

Table A1. Variables used in the CE econometric models

Choice Experiments- Utility function Variables	Type	Mean	S.D.	Min	Max
ASC	Dichotomous	0.30	0.46	0.00	1.00
Distance 200 Km	Dichotomous	0.17	0.38	0.00	1.00
Distance 100 Km	Dichotomous	0.17	0.37	0.00	1.00
Distance 50 Km	Dichotomous	0.15	0.36	0.00	1.00
Emission Reduction: - 20 %	Dichotomous	0.20	0.40	0.00	1.00
Emission Reduction: - 10 %	Dichotomous	0.26	0.44	0.00	1.00
Parks	Dichotomous	0.34	0.47	0.00	1.00
Bill Reduction	AED/household/year	86.9	140.3	0.00	900
Choice Experiments-Segment membership Variables					
Transient^a	Dichotomous	.38	.48	0.00	1.00
Expat_MS^b	Dichotomous	.23	.42	0.00	1.00

Bill reduction was expressed in percentages in the choice tasks; these values were multiplied times the average annual electricity bill of the sampled respondents in order to obtain the AED/household/year unit.

^aNon-Emiratis who have stated to intend to leave the UAE within 10 years.

^bNon-Emiratis who stated to be more satisfied with their life in the UAE.

Appendix B

B1 Key questions, scales, information presented

This section presents key questions used in this study. Answers to these questions were used to measure latent constructs, both in a confirmatory and exploratory approach, or to support in multivariate analysis as well as serve as predictors.

B1.1 Life satisfaction and transiency of residence

The questions on life satisfaction and transiency of residence are of paramount importance. Two questions on life satisfaction were asked. Respondents were presented with a scale ranging from 1 to 10, where 1 meant ‘Not at all satisfied’ and 10 ‘Extremely satisfied’. They were asked to rate thinking about how satisfied they were with their life in general and, separately, with their life in the UAE. This can be defined as the evaluative account of wellbeing (Dolan and Metcalfe 2012); whilst it can be affected by recall bias, it seems an apt indicator of whether the individual is satisfied in relation to her life in the country, as a whole. In order to measure transiency, we opted for a single question asking the following: ‘How long are you planning to stay in the UAE?’. Possible options were presented as intervals, from ‘less than 3 months’ to ‘more than 10 years’. The minimum was set to take into account the possibility of respondents about to leave the Country due to, for instance, job loss (notice period in the UAE is a minimum of a month according to UAE Labor Law, article 117). We kept the upper option to ‘more than 10 years’ to maintain the list short and reasonable in terms of time period considered.

How long are you **planning to stay in the UAE?**

- Less than 3 months
- 3 – 6 months
- 6 – 12 months
- 1 – 2 years
- 3 – 4 years
- 5 – 6 years
- 7 – 10 years
- More than 10 years
- I do not plan to move out of the UAE
- Other (please specify)
- I do not know

Figure B.1: Question to measure transiency

Please think for a moment about **how satisfied are you with your life**. On a scale from 1 to 10, where 1 means "Not at all satisfied" and 10 means "Extremely satisfied",



Figure B.2: Question to measure life satisfaction

B.1.2 Questions on preferences towards energy sources

Respondents were asked to state how much the country they reside in should invest in different energy sources. This question is adapted from Pidgeon et al. (2008)¹⁵, where instead of an agreement and disagreement scale respondents were asked to pick between invest ‘nothing’ and invest ‘a lot’. Following the pilots, this format seemed to be easier for the respondents to grasp.

In your opinion, how much should the **UAE** invest in...? Please select 'I don't know' if you are not familiar with some of these energy sources.

	Nothing	A little	Some	A lot	I don't know
Oil	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Gas	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
Geothermal	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>
Clean Coal	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>
Traditional Coal	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Solar/Photovoltaic	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Nuclear	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Wind	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
Biomass	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>

Figure B.3: Questions on preference towards energy sources

B.1.3 Perceived risks and benefits of nuclear energy

Figures B.1.4 and B.1.5 show the corresponding screen shown as part of the study. Respondents answered the set of questions on risks and benefits twice: once whilst thinking about nuclear energy in general, and then considering nuclear energy in the UAE. A 5 points

¹⁵ To what extent do you agree or disagree that the following energy sources will make a substantial contribution to reliable and secure supplies of electricity in Britain in the future?

scales for the UAE was used (rather than 7 used in Contu 2018). This reduction was chosen to limit the amount of information to process, given the that respondents were asked to answer twice each set.

In your opinion, how likely are the following **RISKS** associated with nuclear energy **in the UAE**? Nuclear energy in this context is heat, steam and electricity generated by nuclear reactors, fuelled by enriched uranium. The UAE peaceful nuclear energy programme will produce nearly a quarter of the nation's electricity needs by 2020.

	Very unlikely	Unlikely	Neutral	Likely	Very likely
Risk of catastrophic accidents	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Damage/threats to the environment	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Damage/threats to human health	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Terrorist attacks	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Military use of nuclear power	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Nuclear waste disposal accidents	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Figure B.1.4: Questions on perceived risks of nuclear energy

In your opinion, how likely are the following **BENEFITS** associated with nuclear energy **in the UAE**? Nuclear energy in this context is heat, steam and electricity generated by nuclear reactors, fuelled by enriched uranium. The UAE peaceful nuclear energy programme will produce nearly a quarter of the nation's electricity needs by 2020.

	Very unlikely	Unlikely	Neutral	Likely	Very likely
Atmospheric emission reduction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Less reliance on fossil fuels	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Economic growth	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Energy sources diversification	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Stable/convenient energy prices	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Technology development/innovation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Figure B.1.5: Questions on perceived benefits of nuclear energy

Appendix C Statistical and Econometric models

C.1 Analysis of choice experiment data

We measure social acceptance of nuclear energy by means of a choice experiment exercise so as to indirectly measure willingness to accept the construction of nuclear plants in the UAE. This methodology is rooted on the Lancaster's theory of value (Lancaster 1966) and on the Random Utility theory (McFadden 1974). Respondents were presented with pairs of 4 scenarios and in each choice situation they were asked to select their preferred one, or none of them. Each option in each scenario is associated to a set of attributes and levels. Each individual (i) is assumed to evaluate the alternatives (j) and choose the one for which its utility is maximized. In turn, the utility function is divided into a deterministic (V_{ij}) and random component (ε_{ij}):

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

The deterministic component is a function of attributes' matrix \mathbf{x} and the associated preference parameters, represented by the vector of coefficients $\boldsymbol{\beta}$:

$$V_{it,j} = f(\mathbf{x}'_{it,j}\boldsymbol{\beta}) \quad (2)$$

We model preference heterogeneity using two models established in the choice modeling literature: the RPL or mixed logit model (Hensher and Green 2003) and Latent Class model (Boxall and Adamowicz 2002, Greene and Hensher 2003)¹⁶. The former is based on the assumption of a continuous distribution across individuals, namely estimating individual specific effects $\boldsymbol{\beta}_i$, with the choice probabilities as follows:

¹⁶ We also estimated MNL models that assumes preference homogeneity.

$$P_{ijt} = \frac{\exp(x'_{it,j}\beta_i)}{\sum_j \exp(x'_{it,j}\beta_i)} \quad (3)$$

Formally, for each of the K parameters assumed to be continuously distributed, the vector of individual coefficients is as follows:

$$\beta_i = \beta + \Delta z_i + \Gamma m_i \quad (4)$$

where z_i is a vector of individual characteristics affecting the mean of β_i , and Δ indicates the matrix of parameters to be estimated. The random effect m_i has the following expected value and variance:

$$E[m_i]=0, \text{Var}[m_i]=\Sigma=\text{diag}[\sigma_1, \dots, \sigma_k] \quad (5)$$

The analyst has to specify the distribution of the random parameters. Furthermore, Γ represents the lower triangular matrix containing the variances and covariances of the joint distribution of β_i , to be estimated. Given that respondents are engaged in a sequence of choices, the conditional distribution is given by:

$$P_i | m_i = \prod_{t=1}^T P_{it} | m_i \quad (6)$$

In turn, the unconditional probability, obtained by integrating m_i out of the joint probability is as follows:

$$P_i = \int_{m_i} P_i | m_i h(m_i) dm_i \quad (7)$$

where $h(m_i)$ stands for the density of m_i . As normally this integral does not have a close form solution, estimation requires maximizing a simulated log likelihood approach (McFadden and Train 2000):

$$\ln L_s = \sum_{i=1}^N \ln \left[\frac{1}{R} \ln P_i | m_{ir} \right] \quad (8)$$

with \mathbf{m}_{ir} being a simulated draw from the distribution hypothesized, out of the total R draws. The simulation process allows to produce an average over a high number of draws, de facto replacing the continuous integral by summation. This model was estimated with the command MIXLOGIT in STATA, with a minimum of 500 Halton draws set.

Instead, when it comes to the Latent Class model, heterogeneity is modeled in a discrete fashion. The key behavioral model is once again a logit model for discrete choice, but with coefficients β_s being segment specific:

$$P_{it,j|s} = \frac{\exp(\mathbf{x}'_{it,j}\beta_s)}{\sum_j \exp(\mathbf{x}'_{it,j}\beta_s)} \quad (9)$$

The probability of a specific choice being made by the respondent i as $P_{it|s}(j)$. Assuming the T choices are independent given the class allocation, the joint probability of the set of choices is given by:

$$P_{i|s} = \prod_t P_{it|s} \quad (10)$$

With regards to the class assignment, whose outcome needs to be between 0 and 1, a common formulation employed is the multinomial logit:

$$H_{is} = \frac{\exp(\mathbf{z}'_i\theta_s)}{\sum_s \exp(\mathbf{z}'_i\theta_s)} \quad (11)$$

where \mathbf{z}_i represents a set of individual characteristics that might affect class allocation. In order for the model to be identified, the parameters of one of the segments have to be normalized to zero. Furthermore, the unconditional choice probability for each individual is given by:

$$P_i = \sum_s H_{is} P_{i|s} \quad (12)$$

Finally, the log likelihood for the whole sample, to be maximised with respect to β_s and θ_s , is as follows:

$$\ln L = \sum_i^N \ln P_i = \sum_i^N \ln \left[\sum_s^S H_{is} \left(\prod_t^T P_{it|s} \right) \right] \quad (13)$$

The analyst has to specify the number of classes to be estimated. Next, given the goodness of fit, significance of parameters and overall analyst's judgement, the choice of the final model can be made. The latent class models were estimated in Limdep NLOGIT. Different starting values were specified to check for presence of local maxima.

Irrespective of the model estimated, with a linear in parameters utility function, the coefficients estimated directly represent marginal utilities, and their ratio indicates a marginal rate of substitution. When the denominator is the coefficient attached to the monetary attribute, the resulting ratio represents a monetary valuation (MV). Given K attributes and a monetary attribute m, in the context of the MNL model the monetary valuation will be unique for each attribute or level of the same:

$$MV_k = \left| \frac{\beta_k}{\beta_m} \right| \quad (14)$$

Instead, in the context of a latent class model, this will be conditional on a given segment:

$$MV_{k|s} = \left| \frac{\beta_{k|s}}{\beta_{m|s}} \right| \quad (15)$$

C.2 Analysis of psychometric data¹⁷

Perceived risks and benefits are in this study seen as latent factors. These are measured by means of questionnaire items, which then form the inputs of factor analyses. Formally, given

¹⁷Based on Bartholomew et al. (2008).

a set of k items related to a set of constructs, factor analysis involves estimating the following equation for each item i :

$$v_i = \sum_j \lambda_{ij} \xi_j + \delta_i \quad (16)$$

where v_i represents the item, λ_{ij} the factor loadings, ξ_j the latent construct, and δ_i are the specific factors. The model implies the following variances:

$$Var(v_i) = (\sum_j \lambda_{ij}^2) + \theta_{ii} \quad (17)$$

The loadings λ_i can be interpreted as the covariance between each v_i and the latent factor ξ_j . 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. Given the factor loading obtained, it is possible to compute individual scores:

$$\hat{v}_i = \sum_j (\lambda_{ij} / \theta_{ii}) v_i \quad (18)$$