South African attitudes about nuclear power: The case of the nuclear energy expansion

Nomsa Phindile Nkosi and Johane Dikgang

ERSA working paper 726

January 2018

Economic Research Southern Africa (ERSA) is a research programme funded by the National Treasury of South Africa.

South African attitudes about nuclear power: The case of the nuclear energy expansion

Nomsa Phindile Nkosi*and Johane Dikgang‡

January 10, 2018

Abstract

The objective of our study is to investigate households' attitudes and willingness to pay (WTP) for the proposed second nuclear power plant in South Africa. Traditional analysis of such data has tended to ignore zero WTP values. A spike model which explicitly accounts for zero WTP is employed. We also test for effect of distance on WTP. The proximity to the nuclear plant dummy is negative and significant in the probit model, which implies that those who are closer to the plant are more likely to state a zero WTP. The second decision, WTP given positive WTP, modelled with a truncated regression model suggests that putting more distance between residences and the nuclear plant would have little effect on WTP. Therefore, distance is not a relevant predictor of WTP for solving the problem of nuclear-related risk. Nonetheless, the higher WTP for those further from the plant suggests they are more supportive of the plant than those within closer proximity. Higher dependence on electricity is most likely to lead people to be more supportive of the planned plant.

Keywords: distance, nuclear, model, willingness to pay

*Public and Environmental Economics Research Centre (PEERC), School of Economics, University of Johannesburg, South Africa. Email: phindarella@gmail.com

†Corresponding author. Public and Environmental Economics Research Centre (PEERC), School of Economics, University of Johannesburg, South Africa. Tel. +27 (0) 11 559 2017. Email: jdikgang@uj.ac.za.

‡**Acknowledgements.** The Funding from the National Research Fund and the University of Johannesburg Research Committee (URC) internal research grant is gratefully acknowledged.

1 Introduction

Excessive use of fossil fuels is widely acknowledged as one of the main causes of climate change. The energy sector is one of the sectors that make use of fossil fuels. Greenhouse gasses are released during the combustion of fossil fuels, such as coal, oil, and natural gas, to produce electricity. Generating electricity from nuclear reduces pollution externalities hence it is argued by some to be part of a sustainable solution to achieving low-carbon energy options. According to Ertor-Akyazi et al. (2012) since energy security is a critical element in an economy, nuclear energy can play a role in ensuring smooth supply of electricity; it is reliable, and can provide electricity on a larger scale, similar to fossil fuels.

Approximately 7 400 megawatts (MW) of nuclear power is under construction around the world (International Energy Agency, 2015), of which a typical power plant has 1 000 MW capacity. Nuclear power itself is an expensive investment (Liao *et al.*, 2010). There is currently one nuclear power station in South Africa, situated at Koeberg, Cape Town, in the Western Cape province. The government's diversification strategy includes construction of a second nuclear power plant. But past nuclear accidents caused by nuclear waste have resulted in increased opposition to nuclear power.

Households will be expected to contribute towards the capital required to invest in increasing and diversifying the power supply. Given this background, the objectives of our study are to investigate households' attitudes and willingness to pay (WTP) for the proposed nuclear power plant. In this study, the contingent valuation method (CVM) is used to estimate WTP for nuclear power. According to Liao *et al.,* (2010); Ertor-Akyazi *et al.*, (2012), nuclear energy studies eliciting WTP, opinions and preferences have been mostly done in advanced countries, though not in abundance.

No studies evaluating support and WTP for nuclear energy have been done in Africa. This can be attributed to the fact that South Africa is the only country in Africa to have a nuclear power plant (Kessides, 2007). Some other African countries do have plans to build nuclear plants. Given the desire of the South African and other African governments to build power plants, and growing resistance against such plans, it is important to win public acceptance of the expansion and introduction of nuclear power, and of the cost burden.

Electricity is a marketable public good. In other words, it does not fit neatly into either extreme category of a public and a private good. It is subject to political considerations. The electrification programme in South Africa since new democratic era is a good example of government intervention aimed by providing cheap and affordable electricity to all. It is important for

households to participate in the decision-making regarding the type of energy source the government will invest in, since households will be paying for it. Around the world, there are different opinions about different energy sources, so the government needs to be aware of what type of energy source households would prefer. This study sheds light on estimates of WTP for nuclear power. In assessing determinants of the public's WTP for construction of an additional nuclear power plant in South Africa, this study contributes, by generating information, which can be taken into consideration when policies are made.

2 The Nuclear Dilemma

Over 400 nuclear reactors are in operation in 31 countries, providing more than 11 percent of total world electricity. There are currently more than 60 reactors under construction worldwide (World Nuclear Association, 2014). When compared to traditional energy sources such as coal power stations, nuclear power is demonstrably cleaner. Nonetheless, there is mixed support for nuclear, because of the risks associated with it. There are concerns about its safety. Atrocious accidents have arisen from nuclear power, affecting people's health negatively and even resulting in death, as in the recent Fukushima Daiichi accident in Japan. In addition, there are dangers to nuclear waste; it must be stored in a remote location far away from people (Murakami et al., 2015; Zhu et al., 2016; Danzer and Danzer, 2016). For these reasons, there is growing opposition to the expansion of nuclear plants around the world. After the recent Fukushima accident, more safety measures were added, making nuclear power even more expensive (Diaz-Maurin and Kovacic, 2015).

The recent nuclear accident in Japan has resulted in some countries (such as Germany) abandoning their nuclear plans. Some new nuclear projects have been cancelled altogether, with plans to shut down present plants in the near future (International Energy Agency, 2015). According to Visschers et al. (2011), people's emotions have an impact on determining whether something is beneficial or destructive. In the case of nuclear power, past experience of accidents has incited negative feelings towards nuclear. This is evident from how levels of condemnation for nuclear have changed over the years.

The South African government, like those of China, India and France, is in favour of further investment in nuclear power stations. It has announced that it plans to build two more nuclear power stations, in an effort to reduce reliance on coal and reduce carbon emissions. Nuclear power has a large load factor, compared to other power-generating sources. Even though building

a nuclear power station is costly, the cost of the electricity generated from nuclear is low. But although nuclear is considered clean, there are concerns about its safety.

There is strong opposition to nuclear power around the world. The Fukushima accident influenced public opinion negatively; hence, it is even more important for governments to implement corrective measures and transparency during the process, to regain the public's trust in nuclear power. This was done successfully in France, by educating the public about the benefits and the risks of nuclear power (Sun and Zhu, 2014). In South Africa, a survey of public attitudes to nuclear conducted in 2011 by the Human Sciences Research Council (HSRC) showed that South Africans do not have enough information about nuclear energy. Around 40 percent of surveyed participants could not state whether they support nuclear power or not (HSRC, 2012).

3 Background

South Africa is presently the only African country with a commercial nuclear power plant. It has two nuclear reactors, and generates approximately five percent of the country's electricity. The South African government has plans to build another nuclear power station. According to Reuters (2015), South Africa will have new nuclear power plants by 2030. These new plants will cost between R400 billion (US$40 billion) and R1 trillion (US$100 billion) to build.

The plans to build the second nuclear plant are at an advanced stage, with the government (together with Eskom) having identified three possible locations. Bantamsklip in the Western Cape province; Duinefontein, also in the Western Cape, next to the existing Koeberg nuclear plant; and Thyspunt in the Eastern Cape province have been identified as possible sites for construction. An environmental impact assessment was conducted, and named Thyspunt as the preferred location (Eskom, 2010). Eskom (2008) has revealed that three main criteria were used to assess the three sites, namely system reliability, quality of supply, integration considerations, and future generation potential. The reasons for choosing the Thyspunt location are as follows:

- It will ensure supply security for the Eastern Cape, since there is no base-load generation in the area;
- Extensive transmission infrastructure would be necessary for the other sites; it will be easier to transmit power to nearby Port Elizabeth, using

a shorter transmission system of 400kV; and

- This project would be the beginning of more energy projects to come, to develop the area in terms of energy generation.

Overall, the Thyspunt location is deemed more suitable compared to Bantamsklip and Duinefontein due to relatively low construction costs, the ease with which nuclear energy may be fed into the national grid (other locations require long transmission lines), and the fact that Thyspunt has a lower seismic risk than other potential sites (Eskom, 2010).

Since the Western Cape is also well set up in terms of the transmission network, it could be considered for other future nuclear plans. This second nuclear plant will have a capacity of 9 600 MW. The building plans began in 2015; Eskom has secured the site, and the general public does not have access. But as stated, the Thyspunt community is not in favour of this plan because of the nuclear waste and radiation in the event of an accident. Evidence from other countries shows that the after effects of nuclear accidents are costly for the country and the individuals involved.

Danzer and Danzer (2016) state that after the Chernobyl accident, billions of dollars were spent to restore the area and to support the affected individuals. In addition, there are long-term effects that are usually ignored, which include people's mental health and well-being. Anxiety and depression result from thinking about the possibility of having cancer in the future, caused by radiation. These thoughts can make people feel hopeless, resulting in changes in productivity levels and decreased life-satisfaction.

There are also fears that the presence of the proposed nuclear station may negatively affect the local economy. Tourists might choose not to visit the Thyspunt area because of the construction and operation of a nuclear power station. Households are also of the opinion that property prices in the area will go down. Different countries have different opinions on this subject. A drop in house prices depends on a number of factors. According to Fink and Stratmann (2015), government response to a nuclear crisis can influence people negatively or positively, in turn affecting house prices. In Germany, the sudden closure of some nuclear plants within a week after the Fukushima accident resulted into households panicking and selling their houses. Prices near the nuclear plants that are still operating fell by close to five percent, while prices near the closed stations fell by just over 10 percent.

By contrast, in America there was no panic after Fukushima; nuclear plants were not closed suddenly. America's calm response to the Fukushima accident resulted in no noticeable change in house prices. In addition, there was no drastic change of plans for households considering buying houses near

nuclear power stations (Fink and Stratmann, 2015). However, Davis (2011) discovered that when new nuclear plants were built during the 1990s, house prices in the vicinity decreased; though this was unrelated to accidents.

Thyspunt is famous for fishing, destined for international markets. Chokka squid[1] caught there is rated second best in the world. Having nuclear power in the vicinity might negatively affect market perceptions. It is highly likely that some buyers would regard the squid as contaminated, resulting in the loss of foreign revenue and jobs for the local people (Mail and Guardian, 2012). According to Chung and Yeung (2013), in Hong Kong, food security is a concern when it comes to nuclear accidents; careful food inspection is crucial after such an incident.

On the other hand, some residents in the nearby townships not too far from the proposed location are in favour of the nuclear power station, saying it will make the place lively and create both general and technical jobs for the community (Mail and Guardian, 2012). Despite strong opposition among some households in the Thyspunt neighbourhood, the government is going ahead with its plans. For this reason, our main survey was conducted in and around the proposed Thyspunt nuclear site.

4 Literature Review

Erto-Akyazi *et al.* (2012), state that in the 1970s, public disapproval of nuclear was very low, at about 20 percent; but it skyrocketed after the Three Mile Island accident in the US, to over 60 percent, and went up even more after the Ukrainian Chernobyl accident in the late 80s. It got even worse after the Fukushima Daiichi accident in Japan in 2011. According to Park and Ohm, (2014); Sun and Zhu, (2014); Kuramochi, (2015) past nuclear accidents are one of the main reasons for the growing resistance to nuclear energy.

Studies were conducted after these accidents to determine if public opinion and WTP for nuclear energy had changed. A text-mining analysis was conducted in Japan after the accident to get the feeling of what major newspapers in the country supported. Some backed the closure of the nuclear plants, and some were still in support of nuclear, despite the accident. Those against nuclear cited the risk element, and the fact that there had been no public participation. One suggestion was to change energy policy and reforms by including renewable energy in the energy mix and then allowing

[1]The chokka squid (also known as calamari) industry generates around R340 million in foreign revenue per annum (South African Squid Management Industrial Association (SASMIA), 2014).

customers to choose the supplier they prefer. On the other hand, those in favour of nuclear were concerned about the stable power supply associated with nuclear; they were also of the opinion that if nuclear plants were to be shut down, the electricity price would increase. In addition, since Japan is at the forefront internationally in terms of nuclear technology, closing down the plants would affect the country's economic growth negatively, since it exports reactors to other countries. Furthermore, some countries are still embarking on building nuclear plants, for which the reactors may be supplied by Japan (Abe, 2015). This shows how destructive information can affect the views of people who are initially in favour of nuclear, resulting in an upward trend of nuclear resistance (Erto-Akyazi *et al.*, 2012).

Murakami *et al.* (2015) further indicated that the Fukushima accident altered consumers' views about nuclear power, especially in Japan. The study compared the opinions of Japanese and American households regarding nuclear power. Since Fukushima, 65 percent of Japanese respondents' perceptions have changed for the worse. A large number (46 percent) of respondents felt that current nuclear plants should be shut down in the near future, confirming that nuclear is no longer favoured.

On the other hand, the American respondents to the survey were in favour of reducing greenhouse gas emissions, and their perceptions about nuclear were not affected significantly by the accident. Even though on average, supports for nuclear declined, 38 percent of the Americans were of the opinion that nuclear plants could still be built, but with more safety precautions. From the above comparison, it is clear that location matters: those located within close proximity to where the accident occurred have different views about nuclear to those who were never affected. The Japanese respondents were even more willing to pay ($0.72 per month) to reduce nuclear plants by one percent than the Americans ($0.19 per month). However, the Americans also believe that greenhouse gas emissions reduction is possible through increasing green energy investments.

A study in Turkey found that more than half of the surveyed respondents were not in support of nuclear power. This negative outlook on nuclear can be attributed to insufficient knowledge, since Turkey does not have an operative nuclear power station. Alternatively, it may be that the spill over effects of the Chernobyl accident, which negatively affected some parts of Turkey, as well as agricultural production, may have caused resistance to nuclear power in Turkish households (Erto-Akyazi *et al.*, 2012).

After the Fukushima Daiichi accident, public perceptions were analysed in China. Sun and Zhu (2014) estimated WTP for nuclear power in China. Unlike other studies, this study analysed how much households are willing to pay for the location of a nuclear power plant to be far from where they

live. The result was a higher WTP for nuclear plants constructed away from people's residential areas. The study went further, splitting its sample according to those who were knowledgeable about nuclear and those who were not. Knowledgeable people were willing to pay more for construction of nuclear plants further away from their residences than those with limited information. Accordingly, governments should ensure that the public is well informed regarding the subject at hand, in order to make informed decisions.

Visschers *et al.*, (2011) assessed the determinants of nuclear acceptance in Switzerland. Nuclear power contributes around 40 percent of total Swiss energy consumption. The findings show that Swiss people prefer nuclear power, as it is deemed more reliable. This result is in line with Kovacs and Gordelier (2009), who concluded that people residing in countries with many nuclear power plants tend to be in favour of them. Liao *et al.* (2010) assessed people's perceptions and their WTP for nuclear power in Taiwan, with the emphasis on ascertaining whether the benefits of nuclear outweigh its risks. Around 36 percent of the respondents believed nuclear's share of energy in the country should increase, while 33 percent of the sample wanted it to decrease. The remaining 31 percent felt the *status quo* should remain. However, only 21 percent of the people who wanted nuclear expansion had a WTP for this expansion. Moreover, of the ones who wanted the nuclear's share to decrease, only 23 percent indicated WTP for the reduction.

Because of past accidents, a significant proportion of the public is usually not in favour of nuclear power. However, this suggests knowledge gaps pertaining to the costs and benefits of nuclear power. Factual information about nuclear can change an anti-nuclear individual into a nuclear supporter. For example, Gwyneth Cravens, a well-respected author in the United States who wrote a book titled *Power to Save the World: The Truth about Nuclear Energy*, was against nuclear power. After gaining more knowledge, doing site visits, and talking to experts about nuclear, her perceptions changed. She began endorsing nuclear, to the extent that she hopes young children can be taught about the pros and cons of nuclear, so they can grow up to be informed adults and make the right decisions (Shack, 2015).

It is therefore vital that an assessment of people's perceptions about nuclear power and the factors driving those perceptions are better understood. It is vital to win public acceptance of the construction of more nuclear power stations, and of the cost burden. In this study, a user WTP for nuclear power is assessed, as well as whether proximity to a proposed site matters.

The Japanese nuclear energy accident is cited as the main driver for resistance to nuclear energy around the world. Those in favour of nuclear are only so on condition that more safety precaution measures are put in place. Inadequate knowledge of and lack of familiarity with nuclear power also leads

to nuclear opposition. Support for nuclear exists because it generates clean energy, and operating costs are relatively low. However, those further away from nuclear plant locations are more likely to support nuclear plants.

5 Descriptive Statistics

The study was undertaken in the Eastern Cape province, in and around the Thyspunt area proposed for a nuclear power station. Thyspunt is a rocky stretch of coast approximately 12 km West-North-West of Cape St Francis, and 70km South-East of Port Elizabeth. The greater area comprises Cape St Francis, Oyster Bay, Humansdorp, and the popular surfing beach of Jeffrey's Bay. The area's main economic activities include a diverse agricultural offering, which includes dairy and forestry in Humansdorp, fishing and tourism around St Francis Bay, Cape St Francis and Oyster Bay, and surfing in Jeffrey's Bay.

Jeffrey's Bay is widely recognised as South Africa's leading surfing spot, with the world's longest right-hand wave break. Aside from the strong surfing-tourism market it represents, the surfing community has a very pronounced environmental awareness. Considerable efforts have been made to voice objections to the proposed nuclear power station in international surfing-media publications, while a formal petition for boycotts and sponsorship withdrawal has been signed by most of the local surfing market and a number of the top international surfing merchandise brands and their respective surfing figures (Eskom, 2015).

A review of the literature suggests that WTP for protection against nuclear-related risks such as a nuclear accident decreases *ceteris paribus* with distance from the nuclear plant. To test the spatial dimension of responses to the external effects of nuclear power, a survey was also carried out in and around Johannesburg, in Gauteng province, which is 1 150km away from the proposed site. The aim here is to test if there are differences in WTP due to distance. Johannesburg is the country's economic hub. The total sample was 695 respondents, of which 365 were in Johannesburg.

The raw data results are therefore split by province; some respondents were in Thyspunt, Eastern Cape province, and others in Johannesburg, Gauteng province. Households were directly asked to state their attitudes about nuclear energy, which will be an addition to the current electricity produced. Furthermore, they were also informed that the construction of a new nuclear power station would result to increased electricity prices compared to what they are currently paying at that moment for electricity generated by coal.

The follow up question was to elicit an additional amount to their current

electricity bill that they can afford to pay for nuclear power if they support it. On the other hand, if they do not support nuclear power, they could choose to pay for a preferred alternative like an expansion of renewable energy plants in the place of nuclear. Overall, the WTP questions were more about nuclear energy or an alternative energy source, which is renewable energy based on the current energy mix in the country. The current energy mix consists of coal, renewable energy and nuclear power. The baseline electricity source, which mainly consists of coal, did not represent the alternative source since it is not environmentally friendly.

The variables used in the analysis besides the general demographics are described as follows: *Monthly electricity bill* - Electricity consumption is one of the determinants of WTP. Higher electricity consumption may indicate more dependence on electricity, which results in higher WTP for more electricity investments (Guo *et al.*, 2014; Kim *et al.*, 2015). *Proximity* - This is a dummy variable, which represents those that stay near the nuclear site (1) and those that stay far away from the side (0). *Available back-up* - people with electricity back-up like generators. These households may not be willing to pay for additional investment in electricity. They can rather have their back-up electricity ready for when electricity disruptions occur than pay extra for a service that they cannot control and which may be unreliable.

Medical equipment - respondents who depend on electricity for their lives may be willing to pay for stable electricity supply. This may include diabetic medication, which requires refrigeration. *Support for nuclear* - This is a dummy variable whereby 1 represents those in support of nuclear and zero for the ones that do not support nuclear power. *Costly alternative if not supporting nuclear* - Payment for an alternative energy source which is not nuclear or coal (i.e. renewable energy).

The descriptive statistics of the surveyed households are presented in Table 1 below. Where respondents were household members other than the household heads, their responses were interpreted as coming from the heads themselves.

Table 1 shows that a similar share of the people in Gauteng and the Eastern Cape support the proposed nuclear power plan. The two main reasons for supporting nuclear power stated by the households in the survey are that it is deemed reliable, and that it can result in lower electricity prices eventually. However, 12 percent of the Thyspunt sample would rather pay for an alternative energy source than for nuclear power.

A significant proportion of those in support of the plant in the Thyspunt area were supportive because of the job opportunities that would be created: from temporary construction jobs, to permanent power-plant jobs when the plant becomes operational. Unemployment in the area is high; for some

locals, job opportunities outweigh nuclear risks. On the other hand, some members of the community are worried about possible negative social effects during the construction phase, arising from the influx of relatively unskilled workers from neighbouring areas. Some of the workers may remain in the area after the construction, leading to growth in informal housing, affecting the area's sense of place and residents' lifestyles.

In Johannesburg, some respondents made reference to the Koeberg power station - particularly, the fact that it has been in operation for years with no problems. They have faith that nothing disastrous will come of the proposed nuclear plant in terms of safety. This is echoed by Visschers *et al.* (2011); Ertor-Akyazi *et al.* (2012); and Park and Ohms' (2014) findings, which showed that trusting that authorities are able to operate the plant safely results in more social acceptance.

In both provinces, the households had to state their reasons for not supporting nuclear power. The main reason cited was the risk inherent in the transportation and disposal of nuclear waste. Zweifel, Schneider and Wyss (2005) argue that being located at a great distance from a nuclear plant does not necessarily protect households from that risk. Radioactive waste and spent fuel are produced at nuclear plants, from where they may be transported to any disposal site, nation-wide. This suggests that there is increased exposure to the risk associated with nuclear waste in the vicinity of the plant.

According to Hartmann *et al.* (2013), being aware of nuclear risk results in opposition to nuclear; and that was shown in our survey, since many of those opposing nuclear referred to what has happened in other countries. The same sentiment is echoed by Chio *et al.* (2000), who state that the media publicising an event has a huge impact on how households view it. Abe (2015) argues that the negative aspects of the Fukushima accidents were broadcast extensively, which contributed to negative perceptions about nuclear. Being exposed to such information may result in the recipient preferring another, less hazardous energy source. This is evident in Japan, where those against nuclear are promoting the inclusion of renewable energy in the energy diversification strategy.

The second reason for not supporting nuclear in Gauteng is the fact that constructing a nuclear power plant is costly. In the Eastern Cape, the second most important reason for condemning nuclear was that construction in Thyspunt would change the wave structure in Jeffrey's Bay, which would have a detrimental impact on tourism. Additionally, the fact that most countries are moving away from nuclear is a compelling reason for South Africa to rather consider exploring other options that are cheaper and safer than nuclear, such as renewable energy. A follow-up question was posed to re-

spondents who did not support nuclear - whether they would rather pay for another, preferred alternative.

In Gauteng, nine percent of the 25 percent that do not support nuclear are willing to pay for an alternative energy source, even if it is more expensive; while in the Eastern Cape, 12 percent of the 26 percent that do not support nuclear are willing to pay more for another, safer energy source. It is clear that more people in the Eastern Cape who do not support nuclear are prepared to pay for an alternative energy source instead than in Gauteng.

Since Eskom has not been reliable regarding information about and frequency of power cuts, a question was posed to ascertain whether households have ever thought of setting up an independent power source in the future, to offset the power supply problem. Approximately 43 percent of the respondents were planning to invest in their own household energy generation; 35 percent had never thought about doing it; and 21 percent said they might consider it. The limiting factor is budget constraints; some respondents reported that if they had enough money to set up an independent power source, they would certainly do so.

6 Empirical Result for Willingness to Pay for Nuclear Plant

A spike model is employed to analyse the determinants of not having a WTP for nuclear power. The first decision is modelled with a binary probit model, where the dependent variable is equal to one if WTP is positive. The second decision, WTP given positive WTP, is modelled with a truncated regression model[2] (i.e. neither the dependent nor the independent variable is known if the threshold criterion is not met) or a regression model on positive WTP.

As a large number of respondents stated zero WTP for nuclear, it is vital that we analyse the determinants of these zero WTP responses. That is why this analysis is carried out in two parts, using the spike model for the zero WTP responses, and the truncated regression for the positive WTP responses. Most studies have used the probit model to get rid of zero responses and only analyse the positive responses, but Kriström (1997) proposed a spike model to cater for cases where zero or negative WTP is stated.

Direct estimation of the WTP distribution is such that the specific WTP distrubition has a probability mass at zero.

[2]Note that with censored variables, all of the observations are in the dataset, but we do not know the 'true' values of some of them. With truncation, some of the observations are not included in the analysis, because of the value of the variable (Carlsson, 2008).

$$F_{wtp}(t) = \begin{matrix} 0 if t < 0 \\ p if t = 0 \\ G_{wtp}(t) if t > 0 \end{matrix} \quad E[WTP] = \int_0^{\infty} (1 - F_{wtp}(t) dt \tag{1}$$

Where $F_{wtp}(t)$ is a cumulative function of the respondents not willing to pay the t amount, p represents (0, 1), $F_{wtp}(t)$ is a continuous and increasing function, such that $F_{wtp}(t) = 0 = t$and $\lim_t$ to infinity is $F_{wtp}(t) = 1$.

To be clear what WTP we are discussing here, we have the mean WTP for the whole sample and the mean WTP for the restricted sample. Note that E(WTP)=Pr(zeroWTP)*0+E(WTP|WTP>0)*Pr(WTP>0). Furthermore, when analyzing the second stage we should make sure to apply a relevant model: A model that restricts WTP to be non-negative.

The risks associated with nuclear power, such as accidents and waste disposal, are often cited by those who are against nuclear power plants. A significant number of people around the world shun nuclear power for these reasons, and that attitude is evident in this study as well. One might therefore expect people who live in Thyspunt and surrounding areas - who are most likely to be worst affected, should an accident occur - to be less supportive of the proposed plant. This implies that we expect the distance dummy (i.e. 1 for Thyspunt residents, and 0 for distant [Johannesburg] respondents) to be negatively signed and significant. If that is the case, it means that putting more distance between the plant and residences would increase support for nuclear.

A large number of respondents supported the nuclear plan, but stated zero WTP towards nuclear. In some cases, supporting a good does not necessarily mean the individual would also pay for it; in extreme cases, a negative WTP may be stated, when a good is detrimental to a person's welfare. Presumably, a respondent who states zero WTP thinks the government should be the one funding the project.

In the truncated regression, proximity is tested using a dummy variable to differentiate between those who reside in close proximity to the proposed nuclear plant site, and those who reside further away. In Table 2 below, we assess the determinants of WTP for the proposed second nuclear power plant.

By running a two-part model, our analysis allows a proportion of the sample to have zero WTP, which is realistic in many cases. Our strategy is first to analyse the probability of zero WTP using a binary probit model, where the dependent variable is equal to 1 if WTP is zero. The second step entails analysing the WTP for WTP>0 with a truncated regression model.

The proximity to the nuclear plant dummy is negative and significant in the probit model, which implies that those who are closer to the plant are more unlikely to state a zero WTP. The other variables that are negatively signed and significant are male dummy, availability of backup power, and children under 18 years. This implies that males (relative to females) are most unlikely to state a zero WTP. This means that females are more likely to state zero WTP for nuclear than males, since the male dummy variable is negative and significant. This was expected, because women are seen as usually more sensitive than males, and are not expected to take risks where nuclear is concerned. For example, according to Bromet (2012), after the Fukushima accident, pregnant women who had been exposed to the radiation were asked to terminate their pregnancies. Furthermore, 10 years after the accident, women who had been affected by radiation had mental problems, including depression and stress. These suggest that women are exposed to more physical danger than men are.

The unlikeliness if stating a zero WTP also applies to households that already have back-up power such as generators, and households with children under 18 years. Households with young children are most unlikely to state a zero WTP for nuclear power.

On the other hand, the higher the amount spent on the electricity bill, the more likely people are to be willing to pay zero, which is logical given the significant amount already spent on the utility bill. This shows that households that rely on electricity may support nuclear power, but state zero WTP for other reasons, which may include affordability. They may think the electricity price is already high, and are of the opinion that they cannot afford to pay more for nuclear power. Households with medical equipment that requires electricity are most likely to be WTP zero. This may be due to budget constraints, as they are already spending a significant proportion of their budgets on medical expenses. One might think that because they depend on electricity, they would be unlikely to state a zero WTP towards nuclear power, but in this case they are not willing to pay. This also applies to older people, those in formal jobs, and the self-employed.

The coefficient of distance to the nuclear plant in the truncated model is a significant determinant of WTP>0, which is in contradiction to the sample WTP descriptive. Males are more pessimistic about a nuclear plant, which is reflected in their lower WTP compared to their female counterparts. The finding that having a higher electricity bill is likely to predict higher WTP may be due to the higher dependence on electricity of those households. The highest electricity bill paid by households in the survey was R7000 ($583.33), those households with higher electricity usage can have a WTP to safeguard their own stable electricity supply.

Given that those who are self-employed may run home-based businesses, which are heavily dependent on reliable supply of electricity, it is not surprising that they view the proposed nuclear plant favourably.

The marginal effects after running the truncated model show that if the electricity bill increases by one unit, the conditional WTP increases by 0.0001 units. Self-employed and males' conditional WTP figures are 0.60 units higher and 0.28 units lower respectively. Table 3 below compares responses concerning WTP for the proposed nuclear power.

Gauteng households are prepared to pay R124.28 ($10.37) in support of the proposed nuclear plant, while households in and around the proposed site in the Eastern Cape are willing to pay significantly less (R70.47/$5.87). This is in line with the argument in the literature that WTP for coverage against the risks of a nuclear accident decreases with distance from the plant. We therefore conclude that for geographical reasons, households further away from the nuclear power plant are more supportive, as they are not directly exposed to the risk associated with nuclear plants.

7 Discussion

A picture that emerges from the whole sample is that most respondents are in favour of the construction of the country's second nuclear power plant. On average, an overwhelming 74 percent of the whole sample supports the proposed second nuclear power plant. Overall, South African households are becoming increasingly reliant on electricity; and the fact that the country has never experienced a nuclear accident may perhaps be the reason for the general support for a plan to secure the national grid.

The support emanates from the fact that the new plant will increase the country's electricity generation capacity, which would increase electricity reliability and the possibility of lower electricity prices. Support also stems from the prospects of job creation in the area due to the construction of the plant. The main concern from those not in support concerns nuclear waste (which can be detrimental to people's health), the negative impact nuclear might have on tourism in the area, and the possibility of falling house prices.

The modelling results suggest that putting more distance between residences and the nuclear plant would have little effect on WTP. This implies that distance effect does not matter as far as the WTP for nuclear plant is concerned. This may be because South Africa has had a nuclear plant for a very long time, and has not experienced a nuclear accident. Therefore, distance is not a relevant predictor of WTP for solving the problem of nuclear-related risk. Higher dependence on electricity is most likely to lead

people to be more supportive of the planned plant.

Pessimistic males are willing to pay significantly less than females. This is in line with the findings of studies such as Zweifel, Schneider and Wyss (2005), which stated that females were more concerned with the well-being of future generations than males. In that study, females were found to be willing to pay more than twice as much as males for additional insurance coverage and solving the waste disposal problem.

It is interesting that self-employed people support the plan. According to Kim *et al.* (2014), this suggests that the most important thing for them is a reliable power supply. They may trust that no accidents will occur, given proper management of the plant.

8 Conclusions

There is information asymmetry when it comes to nuclear power. In the survey, it was evident that most people are not well informed about nuclear as additional explanatory information had to be provided when asking questions. More information must be provided to educate households about the pros and cons of nuclear, and about the reasons the government is considering investing in nuclear power to diversify the electricity mix, as well as the reasons of those strongly against nuclear. According to Zhu *et al.* (2016), when there is no concrete nuclear power knowledge and trust in the government, people can end up believing negative things that they are exposed to, and that can result into nuclear power opposition.

Furthermore, the public must be included in the decision-making regarding nuclear power (Abe, 2015). Participation must start from the planning process to make it easier for the public to accept the project. Chung and Yeung (2013) pointed that if the Japanese government had been more transparent, the damage from the Fukushima disaster would have been minimised. It is even more shocking that more than 50 percent of the Hong Kong population do not know about the appropriate safety precautions or exit areas, should a nuclear accident occur. Given that figure, one would think other countries might have the same shortfalls that would need to be addressed by a government embarking on building nuclear plants - as South Africa is.

Distance to the nuclear power station is statistically insignificant in the truncated regression. This implies that the distance between the householders' residences and the power plant does not affect the risk associated with nuclear power generation; hence the distance dummy does not influence WTP. Nonetheless, the higher WTP for those further from the plant suggests they are more supportive of the plant than those in closer proximity. Future

researchers should investigate whether risk perceptions are more important in determining how much people are willing to pay to support nuclear plants, despite the risks associated with them. Moreover, we recommend the use of more complex approaches such as choice modelling, as it would generate much richer data than CV surveys.

References

[1] Abe, Y., 2015. The nuclear power debate after Fukushima: a text-mining analysis of Japanese newspapers. *Contemporary Japan, 27(2)*, pp.89-110.

[2] Bromet, E.J., Mental health consequences of the Chernobyl disaster. *Journal of Radiological Protection, 71*, pp.71-75.

[3] Chung, W., Yeung, I.M.H. 2013. Attitudes of Hong Kong residents toward the Daya Bay nuclear power plant. *Energy Policy, 62*, pp. 1172-1186.

[4] Danzer, A.M., Danzer, N. 2016. The long-run consequences of Chernobyl: Evidence on subjective well-being, mental health and welfare. *Journal of Public Economics. 135*, pp. 47-60.

[5] Davis, L.W. 2011. The effect of power plants on local housing prices and rents. *Review of Economics and Statistics, 93(3)*, pp. 1391-1402.

[6] Diaz-Maurin, F., Kovacic, Z. 2015. The unresolved controversy over nuclear power: A new approach from complexity theory. *Global Environmental Change, 31*, pp. 207-216.

[7] Ertor-Akyazi, P., Adaman, F., Ozkaynak, B., Zenginobuz, U. 2012. Citizens' preferences on nuclear and renewable energy source: Evidence from Turkey. *Energy Policy, 47*, pp. 309-320.

[8] Eskom. 2010. Environmental impact assessment (EIA) for a proposed nuclear power station and associated infrastructure. http://www.eskom.co.za/OurCompany/SustainableDevelopment/ EnvironmentalImpactAssessments/Documents/DEIR_APP_D6_Public_Meet_Presentation_10.04.13_Oyster_Bay1.pdf. (Accessed 30 May 2016).

[9] Eskom. 2010. Nuclear 1 - Comparison between Thyspunt, Bantamsklip and Koeberg sites.

http://projects.gibb.co.za/portals/3/projects/201104%20N1%20DEIR/27.%20APP%20E2%20to%20E30%20Specialist%20Reports/Rev%20DEIR%20APP%20E28%20Eskom%20Grid%20Planning%20Report.pdf. (Accessed 30 May 2016).

[10] Eskom. 2014. Eskom Company Information. http://www.eskom.co.za/OurCompany/CompanyInformation/Pages/Company_Information_1.aspx. (Accessed 30 May 2016).

[11] Eskom. 2015. Draft environmental impact report. http://www.eskom.co.za/OurCompany/SustainableDevelopment/EnvironmentalImpactAssessments/Documents/Nuclear1RevDEIRv2/PhysicalBiophysicalEnvironment.pdf. (Accessed 30 May 2016).

[12] Eskom. 2015. Medupi Power Station Project. http://www.eskom.co.za/Whatweredoing/NewBuild/MedupiPowerStation/Pages/Medupi_Power_Station_Project.aspx. (Accessed 30 May 2016).

[13] Fink, A., Stratmann, T., 2015. US housing prices and the Fukushima nuclear accident. *Journal of Economic Behaviour and Organization, 117*, pp. 309-326.

[14] Gelo, D., Koch, S.F. 2015. Contingent valuation of community forestry programs in Ethiopia: Controlling for preference anomalies in double-bounded CVM. *Ecological Economics, 114*, pp. 79-89.

[15] Hartmann, P., Apaolaza, V., D'Souza, C., Echebarria, C., Barrutia, J.M. 2013. Nuclear power threats, public opposition and green electricity adoption: Effects of threat belief appraisal and fear arousal. *Energy Policy, 62*, pp. 1366-1376.

[16] Human Sciences Research Council. 2012. Heart of the matter: Nuclear attitudes in South Africa. http://www.hsrc.ac.za/en/review/june-2012/heart-of-the-matter-nuclear-attitudes-in-south-africa. (Accessed 11 May 2015).

[17] International Energy Agency. 2015. Energy and Climate Change. https://www.iea.org/publications/freepublications/publication/WEO2015SpecialReportonEnergyandClimateChange.pdf

[18] Kessides, I.N., Bogetic, Z., Maurer, L. 2007. Current and forthcoming issues in the South African electricity sector. World Bank Policy Research.

[19] Kovacs, P., Gordelier, S. 2009. Nuclear power and the public. *Nuclear Energy Agency News, 27(1)*, pp.4-7.

[20] Kriström, B. 1997. Spike models in contingent valuation. *American Journal of Agricultural Economics, 79 (3)*, pp. 1013-1023.

[21] Kuramochi, T. 2015. Review of energy and climate change policy developments in Japan before and after Fukushima. *Renewable Energy Reviews, 43*, pp. 1320-1332.

[22] Liao, S., Tseng, W., Chen, C. 2010. Eliciting public preference for nuclear energy against the backdrop of global warming. *Energy Policy, 38*, pp. 7054-7069.

[23] Mail and Guardian. 2012. There goes the neighbourhood and here comes nuclear. http://mg.co.za/article/2012-12-21-00-there-goes-the-neighbourhoodand-here-comes-nuclear. (Accessed 30 May 2016).

[24] Murakami, K., Ida, T., Tanaka, M., Friedman, L. 2015. Consumers' willingness to pay for renewable and nuclear energy: A comparative analysis between the US and Japan. *Energy Economics, 50*, pp. 178-189.

[25] Park, E., Ohm, J.Y. 2014. Factors influencing the public intention to use renewable energy technologies in South Korea: Effects of the Fukushima nuclear accident. *Energy Policy, 65*, pp. 198-211.

[26] Reuters. 2016. Russia, China front runner in South Africa's nuclear project-source. http://www.reuters.com/article/safrica-nuclear-idUSL8N15Q3MN. (Accessed 4 April 2016).

[27] Shack, H. 2015. Gwyneth Cravens: Why nuclear power should play a greater role in the response to climate change. *Bulletin of the Atomic Scientists, 71(6)*, pp. 45-51.

[28] Sun, C. Zhu, X. 2014. Evaluating the public perceptions of nuclear power in China: Evidence from a contingent valuation survey. *Energy Policy 69*, pp. 397-405.

[29] Sundt, S., Rehdanz, K. 2015. Consumers' willingness to pay for green electricity: A meta-analysis of the literature. *Energy Economics, 51*, pp. 1-8.

[30] Visschers, V.H.M., Keller, C., Siegrist, M. 2011. Climate change benefits and energy supply. *Energy Policy, 39(6)*, pp. 3621-3629.

[31] World Nuclear Association. 2014. Nuclear power in the world today. http://www.world-nuclear.org/info/Current-and-Future-Generation/Nuclear-Power-in-the-World-Today/. (Accessed 30 May 2016).

[32] Zhu, W., Wei, J., Zhao, D. 2016. Anti-nuclear behavioural intentions: The role of perceived knowledge, information processing and risk perception. *Energy Policy, 88*, pp. 168-177.

[33] Zweifel, P., Schneider, Y., Wyss, C., 2005. Spatial effects in Willingness-to-Pay: The case of nuclear risks. http://www.energiestiftung.ch/files/downloads/energiethemen-atomenergie-kosten/2uni_zh_zweifel-schneider-2007.pdf. (Accessed 30 May 2016).

Table 1: Descriptive statistics for support of proposed second nuclear power plant

Variable	Thyspunt, Eastern Cape	Johannesburg, Gauteng	Total Sample
	Mean	**Mean**	**Mean**
Support for nuclear	0.73 (0.45)	0.75 (0.43)	0.74 (0.44)
Monthly electricity bill amount	R640.50 ($53.37)	R1 189.64 ($99.14)	R928.90 ($77.41)
Costly alternative if not supporting nuclear	0.12 (0.33)	0.09 (0.29)	0.11 (0.31)
Available backup	0.13 (0.34)	0.17 (0.38)	0.15 (0.36)
Medical equipment	0.15 (0.36)	0.13 (0.34)	0.14 (0.35)
Males	0.49 (0.50)	0.59 (0.49)	0.54 (0.50)
Age	36.83 (11.01)	34.22 (12.32)	35.98 (11.06)
Household size	4.00 (2.02)	3.61 (1.76)	3.81 (1.89)
Kids under 18 years	0.61 (0.49)	0.53 (0.50)	0.57 (0.50)
Education	12.83 (3.34)	14.50 (3.61)	13.71 (3.85)
Annual household income	R143 257.60 ($11 938.13)	R282 465.80 ($23 538.82)	R217 934.80 ($18 161.23)
Employed	0.75 (0.43)	0.62 (0.49)	0.68 (0.47)
Student	0.03 (0.18)	0.07 (0.25)	0.05 (0.22)
Self-employed	0.10 (0.30)	0.20 (0.40)	0.15 (0.36)
Retired	0.02 (0.14)	0.03 (0.16)	0.02 (0.15)

Note: Standard Deviation and dollar values (in monthly electricity bill amount and annual household income) in parentheses

Table 2: Determinants of WTP for nuclear power plant using a spike model

	Spike Regression Probit (WTP = 0)	Truncated Regression	Marginal Effects
Monthly electricity bill	0.0007 *** (0.00008)	0.0004 *** (0.00008)	0.0004 *** (0.00008)
Proximity	-1.65 *** (0.10)	-0.15 (0.12)	-0.15 (0.12)
Available backup	-0.48 ** (0.19)	0.19 (0.15)	0.19 (0.15)
Medical equipment	0.20 *** (-3.32)	0.06 (0.16)	0.06 (0.16)
Male dummy	-0.43 *** (0.06)	-0.28 ** (0.11)	-0.28 ** (0.11)
Age	0.01 * (0.003)	0.005 (0.01)	0.00 (0.01)
Household size	0.01 (0.02)	0.04 (0.03)	0.04 (0.03)
Children under 18 years	-0.15 ** (0.07)	0.07 (0.13)	0.07 (0.13)
Education years	0.0005 (0.01)	0.01 (0.02)	0.01 (0.02)
Log income	-0.01 (0.04)	0.06 (0.08)	0.06 (0.08)
Employed	0.19 ** (0.10)	0.36 (0.22)	0.36 (0.22)
Student	0.08 (0.16)	0.35 (0.31)	0.35 (0.31)
Self-employed	0.28 ** (0.13)	0.6 ** (0.27)	0.60 ** (0.27)
Retired	-0.01 (0.24)	0.59 (0.38)	0.59 (0.38)
_cons	2.26 *** (0.42)	2.97 *** (0.91)	
Log likelihood	-972.012	-535.10	
Number of households	695	695	695
Number of obs.	11 040	362	
Prob. > chi2	0.00	0.00	

Note: Standard errors in parentheses
* p < 0.10; ** p< 0.05; *** p < 0.01

Table 3: WTP for Thyspunt nuclear power plant

Sample	Mean WTP	Standard Deviation	Median WTP	Minimum	Maximum	Share of Zero WTP
Thyspunt	R70.47 ($5.87)	131.76	2.00	0.00	1200.00	0.24
Johannesburg	R124.28 ($10.37)	260.47	20.00	0.00	2250.00	0.24
Whole Sample	R98.73 ($8.23)	211.04	10.00	0.00	2250.00	0.48