CAN RENEWABLE ENERGY BE FINANCED WITH HIGHER ELECTRICITY PRICES? EVIDENCE FROM SPAIN.

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The aim of this paper is to assess willingness to pay for renewable energy electricity. We used a choice experiment to elicit willingness-to-pay for different electricity service attributes: renewable sources (wind, solar and biomass) and the regional origin of the electricity with data from a survey conducted in Spain in 2010. Findings indicate that a majority of consumers are not willing to pay a premium for increases in the renewable component of their electricity mix. Moreover, they would only accept an increase of the renewable mix at a discount for two of the three renewable sources considered (wind and biomass). On the contrary people are willing to pay for increases in the share of solar energy in the electricity mix of their supplier and generating electricity in the region rather than importing it. However, preferences are heterogeneous and individuals are classified in two groups according to whether renewable sources are important for them. The group of individuals more willing to pay for renewable shows higher environmental concerns, positive attitudes towards renewable energy, higher intention to use renewable electricity even at higher prices, more environmental friendly behavior and higher involvement with environmental practices than the group of less willing to pay.

Can renewable energy be financed with higher electricity prices? Evidence from Spain.

1. Introduction

Climate change is considered among the most serious threats to humankind as it will responsible for very serious impacts on growth and development (Stern, 2007). Greenhouse gas (GHG) emissions have been identified as one of the main reasons behind climate change and their reduction has been set as a priority all over the world. In 2008, the European Union (EU) committed itself to reduce the greenhouse gas emissions of 20% by 2020 compared to 1990 levels (CEPS, 2008). The power sector, accounting for about one-third of Europe's total energy-related GHG emissions, must play an important role in the EU' efforts to achieve its GHG reductions goals. The use of renewable energy sources in the production of electricity is one the technological and societal paths to achieve this goal. The EU, in its 2009 Directive on the promotion of the use of energy from renewable sources (EC, 2009), agreed to establish mandatory targets for an overall 20% share of renewable energy source of all energy consumption by 2020[1]. Moreover, renewable energy sources contribute also to the diversification of energy supply, the promotion of local generation and the reduction dependence on a limited number of energy sources (i.e. oil).

Significant advances have been made in the development of renewable energy, resulting in a remarkable increase in their supply, however the expansion of the share of renewable source in the electricity mix is limited, among other issues, by the higher cost of production[2]. However, as Stern (2007) pointed out, if the overall cost and risks of climate change were taken into account, the benefits of reducing GHG far outweigh the costs. Conventional energy production, emitting GHG

[1] The overall 20% target has been translated into individual targets for each Member State (e.g. 20% for Spain; 30% for Denmark).
[2] Production costs refer to financial costs.

emissions in the process, has thus external costs that are not taken into account. If these external costs were taken into account, the total cost of conventional energy production would be higher, thus making renewable energy (which does not emit GHG) more profitable.

The percentage for electricity from renewable energy sources in gross electricity consumption in 2007 was 15.5% for the EU27 and 20% for Spain (European Commission, 2010). These figures indicate the high potential of Spain to produce energy from renewable, mainly wind and solar power due to the country's geography and climatic conditions. At the same time, the electricity price for households (all taxes included) in 2007 was for the EU27 14.51 €/kWh and in Spain 11.31 €/kWh (Eurostat, 2010). Therefore, although Spain is in a good position to fulfil the EU 2020 goals for renewable energy, further developments in renewable energy generation could be undertaken if public attitudes and willingness to pay for higher renewable energy source in the electricity mix is detected. This is the aim of the paper to analyse citizen willingness to pay for renewable energy electricity.

Several studies have been conducted to analyze either attitudes towards renewable energy or the willingness to pay for renewable energy programs or investments (Hanley and Nevin, 1999; Batley *et al.,* 2001; Bang *et al.,* 2000; Alvarez-Farizo and Hanley, 2002; Rowlands *et al.,* 2003; Goosling *et al.,* 2005; Whitehead and Cherry, 2007; Hansla *et al.,* 2008; Koundouri *et al.,* 2009; Ek, 2005; Bergmann *et al.,* 2008; Dimitropoulos and Kontoleon, 2009; Scarpa and Willis, 2010; Zografakis *et al.,* 2010). However, a limited number of empirical studies have been carried out to study the willingness to pay for electricity from renewable sources. Most of them have found a positive WTP for renewable electricity but while some of them elicit WTP for generic renewable energy (Zarnikau, 2003; Nomura and Akai, 2004; Wiser, 2007; Bollino, 2009) or renewable energy from a specific source such as wind or forest biomass (Champs and Bishop, 2001; Soliño *et al.,* 2009), few of them assess the WTP for renewable energy considering a broader scope of attributes and or sources which may provide it (Goett *et al.,* 2000; Roe *et al.,* 2001; Bergmann *et al.,* 2006; Borchers *et al.,* 2007; Longo *et al.,* 2008)[3].

Bergmann *et al.* (2006) and Longo *et al.* (2008) assess willingness to pay for environmental and social attributes of electricity from renewable sources (wildlife, pollution, GHG emissions, employment generated, etc.) using a choice experiment in Scotland and England, respectively. In addition to environmental and social attributes of the electricity supply, Goett *et al.* (2000), Roe *et al.* (2001) and Borchers *et al.* (2007) added to the choice set other issues such as contract terms, source mix, quantity generated by renewable energy, customer services or community base of the supplier, in their choice experiments in the USA. Our work would relate to these last three studies but provides additional input to the issue of consumer valuation of renewable energy sources in two different ways. First, we attempt to overcome the limitation pointed out by Roe *et al.* (2001) for their study, namely estimating willingness to pay for changes in a single renewable or fossil fuel energy source. For this we extend the approach followed by Goett *et al.* (2000) and Borchers *et al.* (2007). These studies assess the WTP for different sources of renewable energy defining a single attribute for the type of source and for the quantity of electrical usage generated by all of them together. Each of the energy sources (wind, solar, biomass, etc.) are taken as different levels of a "*type of source*" attribute. By contrast, in our case, each individual renewable energy source (i.e. wind, solar and biomass) are considered as different attributes and their level is defined as the percentage of the total electrical use generated by the specific source. The *status quo* option corresponds with the current mix of renewable sources available for respondents in their utility contract and this allows interpreting willingness-to-pay estimates as increases in the electricity bill. This approach allows us to estimate the utility for each of the energy sources in relation

[3] See Menegaki (2008) for a comparative revision of renewable energy valuation studies

to the utility for the current electricity generation mix. Second, the study is conducted in a different geographical and regulatory setting, thus providing insights to the debate on how to implement the transition to a low carbon energy mix.

To achieve our goal, assess willingness to pay for renewable energy electricity, we use a choice experiment to elicit people' willingness to pay for different electricity service attributes being the different renewable sources (wind, solar and biomass) together with the regional origin of the electricity the attributes to be value. The choice experiment was delivered to a representative sample of electricity users in the city of Zaragoza (Spain) during July 2010. The paper is structured as follows. Section 2 presents the methodology and section 3 the survey and choice experiment design. Section 4 describes the data collection and in section 5 the results and main economic implications are presented. Section 6 provides some conclusions.

2. Stated preference theory and choice experiment

The theoretical model is based on the Lancastrian consumer theory of utility maximization (Lancaster, 1966), and consumers' preferences for attributes are modeled within a random utility framework (McFadden, 1974). Lancaster (1966) proposes that the total utility associated with the provision of a good can be decomposed into separate utilities for their component characteristics or attributes. However, this utility is known to the individual but not to the researcher. The researcher observes some attributes of the alternatives but some components of the individual utility are unobservable and are treated as stochastic (Random Utility Theory). Thus, the utility is taken as a random variable where the utility from the n^{th} individual facing a choice among j alternatives within choice set J in each of t choice occasions can be represented as,

$$U_{njt} = \beta'_n x_{njt} + \varepsilon_{njt} \quad (1)$$

where β_n is the vector of parameters which deviates from the population mean β by the deviation parameters η_n, x_{njt} is a vector of explanatory variables that are observed by the analyst in choice occasion *t* and and ε_{njt} is an unobserved random term that is distributed following an extreme value type I (Gumbel) distribution, i.i.d. over alternatives and independent of $\beta_n^{'} x_{njt}$, that is known by the individual but unobserved and random from the researcher's perspective. Instead of assuming homogenous preferences, leading to a conditional logit model, we assume that preferences are heterogeneous, in other words, individuals differ from each other in terms of taste intensity (η_n). Then, we developed a Random Parameters Logit Model (RPL) considering a panel structure to take into account the fact that four choices were made by each individual (Train, 2003). The results of the RPL model provide estimated parameters for each individual in the sample, reflecting the fact that consumers have heterogeneous preferences. However additional modeling issues need to be taken into account to assure that results are robust. In particular correlations across utilities, across taste parameters and discontinuous preferences are investigated.

2.1. Correlation across utilities

In our application, the choice experiment design consists of two hypothetical alternatives and a *status quo* situation describing the current electricity mix. Because the *status quo* is actually experienced by the consumer while the experimental options are hypothetical, the utilities of the latter are likely to be more correlated between them than with the *status quo*. In effect, the experimental alternatives share an extra error component, which is missing in the utility of the *status quo* alternative (Scarpa *et al.,* 2007). Scarpa *et al.,* (2005) found, using a different empirical application, that there is a systematic effect of the *status quo* on choice selection. Moreover, using Monte Carlo simulation they compare the performance of different random utility models addressing this effect and find that a mixed logit error component model is more robust to possible mis-specification than others (e.g. nested logit). Thus, we also estimate an Error Component Mixed Logit to test whether correlation across utilities exist.

2.2. Correlation across taste parameters

In the standard RPL taste parameters are assumed to be random but independently distributed from each other. However, depending on the attributes under study, we can expect that some attributes may be inter-dependent. To take this into account, the correlation structure of β_n is assumed to follow a multivariate normal distribution (normal with vector mean μ and variance-covariance matrix Ω). If at least some of the estimates for elements of the Cholesky matrix C (where C'C= Ω) show statistical significance, then the data are supportive of dependence across tastes (Scarpa and Del Giudice, 2004).

2.3. Discontinuous preferences

A basic assumption within the discrete choice experiment framework is that of substitutability between the attributes used to describe the alternatives in the choice set. This implies that respondents make trade-offs between all attributes across each of the alternatives, and are expected to choose their most preferred alternative without ignoring attributes in the choice set (Campbell *et al.,* 2008). Ignoring attributes in the choice set implies non-compensatory behaviour because no matter how much an attribute level is improved—if the attribute itself is ignored by the respondent—then such improvement will fail to compensate for worsening in the levels of other attributes (Spash 2000; Rekola 2003; Sælensminde 2002; Lockwood 1996). Therefore, without continuity, there is no trade-off between two different attributes, a key issue when computing the marginal rate of substitution between the attributes. With discontinuous preferences, the marginal rate of substitution can be derived from the estimated parameters at the sampled population level, but it is not computable for individual respondents who do not make trade-offs between the attributes.

Discontinuous preferences are likely to be an indication that there are some attributes within the choice set that are not relevant to certain respondents. These respondents are indifferent with respect to the attributes in the choice set which they ignore[4]. Respondents with discontinuous preferences are typically identified in one of the two ways: *i)* using follow-up questions or *ii)* inspecting the actual choices made by respondents to determine whether the respondent consistently chose alternatives which were best with respect to one particular attribute. In our case, the first method has been applied. Discontinuous preferences have been taken into account introducing additional variables in the specification of the utility function. A dummy variable representing whether or not the attribute was considered by the respondent is added for each of the non-monetary attributes. These dummy variables have been introduced in a multiplicative way through interaction terms with the attributes in the utility function. The variables have been defined based on the respondents' response to the follow-up question.

3. Survey design

3.1. Questionnaire design

The questionnaire used in the study was developed building on the information gathered from *i)* an interview to experts on energy matters; *ii)* two consumer's focus groups; and *iii)* a pilot test involving 20 respondents. As an initial phase of our research, a total of ten experts on renewable energy participated in an

[4] There is a range of other factors that may give rise to discontinuous preferences in discrete choice experiments: *i)* the choice tasks require a significant cognitive effort; *ii)* cognitive ability of the respondent; *iii)* the strength of attitudes, beliefs, or dispositions that the respondent holds; and *iv)* other demographic, social and economic characteristics of the respondent.

interview to understand the current trends on key issues related to renewable energy developments. The interviews were conducted using a semi-structured questionnaire that included four blocks of open questions for discussion: *i)* characteristics and current situation of electricity from renewable sources, *ii)* estimates of future renewable energy sources and degree of compliance with targets set by the European Union and Spain, *iii)* production costs of electricity from renewable sources and, *iv)* consumer attitudes towards renewable energy sources. These interviews were conducted with experts from three geographical scopes (European Union, Spain and the region of Aragon) and three different economic agents: producers, distributors and operators (public and private). Results from these interviews were used to establish the group of questions to be included in the consumer questionnaire and to develop a first draft with both, closed and opened questions. A focus group of 14 individuals was used to refine the closed questions, to develop the opened ones and to establish the most important attributes of the electricity service. With this input, a second draft questionnaire was developed which was tested with a new focus group of 15 consumers. This second focus group also provided additional information on the most important electricity service attributes. With this information a new questionnaire was developed and validated using a pilot survey of 20 consumers to test for understanding and interview length.

In the questionnaire, respondents were first asked a screening question on whether he or she was the responsible person for paying the electricity bill in his or hers household. The interview was only conducted if a positive answer was provided to this question. Selected respondents were asked about their electricity provider and the current cost of their monthly electric service. They were also asked questions related to their knowledge and attitudes about and towards renewable energy, their concern with environmental issues, socio-demographic characteristics (i.e. gender, family size and composition, age, educational level, income range) and different lifestyles. The questionnaire also contains the choice experiment question and the follow-up question for preference discontinuity defined in the next section.

3.2. Experimental design

The first step to implement a choice experiment is to choose the attributes and levels to be used. The selected attributes should be relevant to the problem under analysis, realistic, believable and easy to understand by the average respondent (Bateman *et al.,* 2002; Bergmann *et al.,* 2006). To meet these requirements, results from the previous expert interviews and consumers' focus groups are very relevant. As we want to understand consumers' demand for electricity, in the expert interviews and the consumers' focus groups, respondents were asked to indicate the characteristics of the electricity service that they value the most. The characteristic mentioned by most people was the price. The second most important characteristic was the renewable origin of the electricity and the third the geographic origin. Some respondents also mentioned the quality of the service but as many different issues were associated with this concept (regular supply, customer service, good information, etc.) we could not design a single attribute to capture all of them. Therefore, besides price, the selected attributes for the choice experiment are the different renewable electricity sources (wind, solar and biomass) and the geographic origin of the electricity. All the attributes were defined using four levels, except for the geographic origin that has two levels. Table 1 shows the attributes and the levels used.

To allow responding the question posted by the paper's title, the payment vehicle selected was the price of kilowatt hour (kWh) in the electricity bill. At the time of the survey, the price per kWh in Spain for households was 0.14 €. The increments from this price were set using an increase of approximately 25% per level to reach a highest level with a price double the current one (0.17 €/kWh; 0.21 €/kWh; 2.24 €/kWh and 0.28€/kWh). To define the levels of the different renewable electricity sources we start from the current Spanish electricity mix. The *status quo* in 2010 was: 26% of renewable (13% from wind power; 10%, from hydro-electric; 2% from solar and 1% from biomass) and 74% from non-renewable sources. In addition to the *status quo*, the levels have been set based on the different decarbonisation scenarios of the power sector considered in the Roadmap 2050 (www.roadmap2050.eu). The Roadmap 2050 project provides an extensive technical, economic and policy analysis of different scenarios of electricity from renewable sources to achieve a low-carbon economy in Europe, meeting the long-term objective of reducing total greenhouse gas emissions by 90% in 2050. The different scenarios, defined as percentage of electricity from renewable source, are: 40%, 60% and 80%. Based on the Roadmap predictions for each of the renewable sources and the results obtained from the expert interviews describe above, we assume four different increases from the *status quo* percentages to define the levels. For wind energy, it is assumed that in the future the percentage in the mix of electricity will be double; this sets the highest level of the attribute (26%). Sequential increases representing approximately 20% of increment from the previous levels have been assumed to calculate the values for the different levels (16%; 18%; 21%; and 26%). For solar power, the RoadMap forecasts an increase to a maximum of 19% of total supply. In our study, we have set the highest level of the attribute to 18%. Intermediate levels have been designed assuming increases of 200% with regards to the level below (6%; 10%; 14%; and 18%). Finally, although the current share for biomass at EU level is 8% and projections show a share of up to 12%, the degree of uptake and its development prospects in Spain are less promising. Therefore, assumptions have been taken from the expert interviews which foresee a maximum contribution from biomass of 6% of the total electricity mix. Then, the previous levels have been increase by 100% to get the four levels of the attribute (2%; 3%; 5% and 6%). Last, the attribute geographic origin has two levels: electricity produced in the region of Aragón or unknown origin of the electricity.

A description of the experiment was presented to participants, indicating the selected attributes and levels for each of the electricity supply options. Choice sets include three alternatives: two unlabeled alternatives consisting of the different designed electricity supply options and the *status quo* corresponding to the actual price per kWh, electricity mix and geographic origin. The choice sets were presented using graphical aids as shown in Figure 1.

The choice set design was created following Street and Burgess (2007). As we want to estimate main effects only, using an orthogonal main effect plan (OMEP) to construct the profiles in the first option results in an optimal choice set design (Street *et al.,* 2005). The second option in the choice sets is then created adding one of the generators suggested by Street and Burgess, (2007). The orthogonal main effect plan has been calculated from SPSS orthoplan resulting in 32 profiles. We used these 32 profiles to obtain the ones for the second option using one of the generators deriving from the suggested difference vector (1, 1, 1, 1, 1) by Street and Burgess (2007) for 5 attributes with 4, 4, ,4 ,4 and 2 levels, respectively, and two alternatives. We obtain 32 pairs and this design is 94.91% D-efficient. To avoid fatigue effects associated with multiple scenario valuation tasks, the 32 choice sets were randomly split into 8 blocks of four choices. Thus, each respondent was asked to make four choices.

As mentioned this study also considers preference discontinuity and thus a follow-up question was introduced to test whether respondents paid attention to all attributes or just a sub-sample of them. For this, respondents were asked to indicate the attributes they have taken into account when making their choices in the experiment.

4. Data Collection

Data was collected from a survey conducted in Zaragoza, a medium-sized town located in northwest Spain, during July 2010. Target respondents were adults who receive and are responsible for paying an electric bill because this is the payment vehicle of the experiment and the questionnaire was delivered face-to-face. A stratified random sample of consumers was made on the basis of district and age. Sample size was set at 400, resulting in a sampling error of ±5%, and a confidence level of 95.5% when estimating proportions (p=q=0.5; k=2). Interviewers selected and approached individuals randomly, asking them one screening question: whether they are the responsible for paying an electricity bill. In the case of a negative response, interviewers randomly selected another customer belonging to a given age group, until they obtained a positive response.

Summary statistics for the characteristics of the sample are presented in table 2. About half of respondents were female (53%) with an average age of 46 years and living in households of 3 people. Approximately 30% of respondents stated that their household monthly net income was between € 1,500 and € 2,500 and had university studies. 11% of households had children less than six years old, and 20% of households included elderly individuals.

5. Results

5.1 Estimated utility parameters and willingness to pay

In the final specification of the utility function in addition to the attributes, an alternative-specific constant associated with the *status quo* (ASC) was introduced. The utility function is then specified as follows:

$$U_{njt} = ASC + \beta_1 PRICE_{njt} + \beta_2 WIND_{njt} + \beta_3 SOLAR_{njt} + \beta_4 BIOMASS_{njt} + \beta_5 REGION_{njt} + \varepsilon_{njt}$$

where, *J* denotes each of the three options available in the choice set and ASC is a dummy variable describing the *status quo* alternative. The price variable represents the kWh price levels given to consumers for each electricity supply option. The variable representing the different renewable sources (WIND, SOLAR and BIOMASS) are the different percentage levels of contribution to the electricity mix given to consumers (Table 1). The geographic origin is an effect-coded variable (REGION). As we assume that renewable energy electricity is considered a desired good by consumers it is expected that the ASC would be negative and significant, indicating that consumers will obtain greater utility from the designed alternatives (A and B) than from the *status quo*[5]. All coefficients are allowed to be random following a normal distribution, but only those with significant standard deviation are maintained random in the presented results. Price is expected to have a negative impact on utility while the effects of the other variables are the focus of interest here. All estimations were conducted using NLOGIT 4.0.

Four models have been estimated to select the one that best fits our data. The first model presented (Table 3, Model 1) is a Random Parameters Logit Model (RPL) using a panel data structure to take into account the fact that each individual made four choices (Train 2003). For the estimation of the RPL model, we used 500 Halton draws rather than random draws since the former provides a more efficient simulation for the RPL.

The results of the RPL model provide estimated parameters for each individual in the sample, reflecting the fact that consumers have heterogeneous preferences. However, it does not take into account that the design alternatives share an extra error component that is missing in the utility of the *status quo*. In order to correct for these differences in correlations we also estimate an Error Component Random Parameters Model (ECRPL) (Table 3, Model 2). In addition, to test whether taste parameters are correlated, we have also estimated a model assuming that the

[5] All options have higher levels of renewable sources in the energy mix than the *status quo*.

correlation structure of β_n follows a multivariate normal distribution (normal with vector mean μ and variance-covariance matrix Ω). However, only one diagonal value in the Cholesky matrix was statistically significant different from zero indicating that random parameters are not correlated. Because, the Wald statistic for the standard deviation for the BIOMASS parameter indicates that the dispersion around the mean estimate is not statistically different from zero, we estimated model 2 assuming that the BIOMASS has a fixed coefficient (Table 3, Model 3).

To test which of the different assumed specifications is preferred, first, we look at the log-likelihood ratio and the pseudo R^2 values. The log-likelihood ratio and the pseudo R^2 reach their best values in model 2 and model 3. Moreover, we observe that σ_ε for the alternative specific constant is statistically significant, corroborating that an error component model must be specified. Thus, model 3 is the one used for further analysis because all the estimated parameters are statistically significant. This last model is then modified to take into account the fact that some respondents could have discontinuous preferences because they ignore specific attributes when they make choices in the experiment. Model 4 is then a ECRPL with the addition of four dummies variables, one per non-monetary attribute, which take value one if the respondent took this attribute into account when making its choices and zero, otherwise[6]. Both models are statistically significant taken into account the χ^2 . The log-likelihood function is -1,199 for model 3 and -1,174 for model 4, indicating a better model fit for the model that takes into account the discontinuous preferences.

Results are discussed with reference to models 3 and 4. The *status quo* alternative specific constant was found to be negative and significant in both models indicating that the respondents found the "current situation" less desirable than the designed alternatives. The estimated coefficient for PRICE is, as expected,

[6] The percentage of respondents that ignore each of the attributes are: 18.25% for price; 84.25% for wind; 87% for solar; 95.75% for biomass and 65.25% for region

negative for both models and of similar value. The estimated coefficients in model 4 for the interaction terms with the dummies variables are statistically significant different from zero for all the attributes except for BIOMASS. The equality to zero of the estimated coefficient for the interaction term for BIOMASS indicates that the value attached by both groups of respondents, those who take into account this attribute and those who ignore them, to this attribute is the same. This is also confirmed by the fact that respondents present homogenous preferences towards the BIOMASS attribute. On the other hand, respondents' valuation to the rest of attributes differs between the two groups and they present heterogeneous preferences. For WIND, while the utility for respondents who ignore the attribute is negative (-0.0771), for respondents who take this attribute in take is positive (0.0785) [7]. For SOLAR, utility for both groups of respondents are positive but the value attached to this attribute for respondents who take into account the attribute is higher (0.1408). The same happens for the REGION attribute, the utility for respondents who consider the attribute is higher (0.7357) than for respondents who ignore it (0.1616).

The best way to see these differences is through the analysis of the willingness to pay for the attributes. Table 4 shows the marginal WTP estimates derived from model 4. Mean WTP and their statistically significance are calculated by dividing the parameters for the non-monetary attribute over the price and multiplied by minus one. We have also calculated the percentage in relation to the current price, 0.14 € per kWh and the monthly estimates based on the average usage of 200 kWh for a Spanish family with two adults and two children under six years of age.

[7] The estimated parameter for the isolate attribute (WIND, SOLAR, BIOMASS) corresponds to the value for the respondent who ignores the attribute. To calculate the one for respondent who consider the attribute we add the estimated parameter for the interaction with the dummy for the discontinuous preferences (WIND*$DCON_W$ and SOLAR*$DCON_S$, respectively).

Although a majority of the respondents declared that they did not consider one or more of the attributes of the electricity supply options, results show that they are indeed making choices that do take into account these attributes (i.e. the coefficient for the isolated attribute is significantly different from zero). Thus modeling preference discontinuity by setting the parameters to zero is not adequate and might lead to wrong policy implications[8]. Besides this methodological insight, the most significant finding is that results show that a majority of consumers are not willing to pay additional costs for increases in the renewable component of their electricity mix. Moreover, they would only accept an increase of the renewable mix at a discount for two of the three renewable sources considered (wind and biomass). On the contrary people are indeed willing to pay for increases in the share of solar energy in the electricity mix of their supplier and generating electricity in the region rather than importing it.

This does not mean that there is no niche market for the promotion of renewable energy via higher electricity prices. The first niche market refers to solar energy. For this energy source even those segments of the population who declare not to pay attention to the size of solar energy in the energy mix would be willing to pay an increase of 2.2% in the price per kWh for an increase in the share of solar in the supply energy mix. This percentage more than doubles in the case of those consumers who declare that take into account the solar origin of the electricity mix in their decisions. The second niche market is that of those respondents that declare paying attention to the presence of the wind source in the electricity mix of their supply. Although reduced in number (around 15% of total population, see footnote 3) they do show a significant WTP for the wind renewable origin of their electricity (2.6%). Therefore energy suppliers would be interested in knowing who these consumers are and public authorities in understanding what makes a

[8] These estimates have been conducted and are not here. For example, the coefficient for BIOMASS is positive but not significant and that for WIND is only marginally significant (90%) and positive. Thus this alternative modeling provides more information on who and how values renewable energy in their electricity mix.

consumer take into account the renewable origin of his or hers electricity mix. The following section explores who are these consumers.

5.2. Who values renewable energy electricity?

Results indicate that respondents who ignore the electricity source attributes present lower WTP than the respondents who stated they took these attributes into account in the choice made in the experiment. For policy analysis it would be important to profile both groups of respondents, as this would provide information on the best way to enhance the consumption of renewable electricity in Spain. To do that, first, we grouped respondents in two segments according to whether they took into account at least one of the renewable sources attributes (wind, solar or biomass) when make their decisions in the choice experiment. We named the segment of respondent who ignores these attributes as less willingness to pay segment and the segment who takes into account at least one of these attributes as higher willingness to pay segment. Second, we test whether differences between segments exists according to different personal characteristics (socio-demographic and economic, environmental concern, attitudes towards renewable electricity, intention to use renewable electricity, environmentally friendly behavior and involvement).

Environmental concerns were measured asking respondents to rank, using a five-point scale, their concern regarding different environmental issues: air pollution, generation of municipal waste, water pollution and climate change. Attitudes towards renewable electricity were measured asking respondents to rate their degree of agreement in a five-point scale with different characteristics of renewable energy: impact on waste generation, decreasing oil dependency and greenhouse gas emissions, etc. Respondent were also asked whether they probably or definitely would use renewable electricity, even if electricity prices would increase. To derive environmental friendly behavior, respondents were asked if they undertook a number of actions that would result in decreased energy consumption. These include reducing car use, substituting common light bulbs with energy-savings bulbs, insulating their house, efficient use of air-conditioning and heating and buying low consumption appliances. To measure environmental involvement, respondents were also asked whether they participate in an environmental organization, separated the garbage, saved water, avoided buying products that damage the environment, consumed organic products or participated in environmental conservation practices.

To check whether differences between the two segments exist t-test or Pearson chi-square tests are used. Table 5 presents mean/percentage for both segments and the corresponding t-test or chi-square test along with the p-values for the personal characteristics found statistically different between the two segments.

Results indicate that none of the socio-demographic and economic characteristics of the consumer are statistically different between both segments. On the other hand, several other characteristics have been found statistically significant which allow defining the profile for the two segments. In general, the higher willingn to pay segment shows higher environmental concerns; has more positive attitudes towards renewable energy; higher intention to use renewable electricity, even at higher prices; more environmental friendly behavior and a higher degree of involvement with environmental practices. Thus, traditional socio-demographic and economic characteristics do not differ between the two segments while other consumers personal characteristic more related with environmental issues are the ones that profiles the two segments.

6. Conclusions

This study presents the results of a choice experiment which elicits individuals' willingness-to-pay for different renewable sources in the electricity generation mix. The results presented show that with the exception of solar energy, further support to renewable via increases in electricity prices does not seem to be a way forward to promote their supply. However, this is complemented by the fact that there is some niche market to obtain additional revenue from green energy. At this moment in time this niche market is quite restricted in terms of size for wind and biomass, however market reward for solar energy can be obtained via higher prices.

In addition, raising awareness would be one of the first steps to increase the valuation of renewable energy. When consumers take into account this attributes their valuation increase. However as the percentages of people considering the attributes is still very low, this might only happen to a limited extent.

One should consider these results with some caution. First Aragón is a region with a very high presence of wind energy both in production and consumption (nearly half of the renewable energy electricity is generated by wind) and this might explain some of the negative preference for further increases. Second, there is no knowledge regarding biomass as a source for electricity generation and therefore preferences should be treated with caution. Third, the survey was conducted in times when there was a strong political discussion regarding increases in electricity prices (a price increase of 10% was finally agreed and implemented as of January 2011). Therefore, these results cannot be said to be showing that people do not want renewable energy, but that they are not willing to undergo additional price increases. It cannot be disregarded that they would use part of their current energy bill to pay for it and not for nuclear and/or coal subsidies. An additional avenue for research would be to assess whether the estimated WTP, together with eventual income from CO2 emission savings would cover or not the additional generation costs.

References

Alvarez-Farizo, B., Hanley, N., 2002. "Using conjoint analysis to quantify public preferences over the environmental impacts of wind farms. An example from Spain," *Energy Policy*, 30(2), 107-116,

Bang, H.-K., Ellinger, A.E., Hadjimarcou, J., Traichal, P.A., 2000. Consumer Concern, Knowledge, Belief, and Attitude towards Renewable Energy: An Application of the Reasoned Action Theory. *Psychology & Marketing* 17, 449-468.

Bateman, I.J., Carson, R.T., Day, B., Hanemann, M., Hanley, N., Hett, T., Jones-Lee, M., Loomes, G., Maourato, S., Özdemiroglu, E., Pearce, D., Sugden, R., Swason, J., 2002. *Economic Valuation with Stated Preference Techniques: A Manual*. Edward Elgar, Cheltenham.

Batley, S.L., Colbourne, D., Fleming, P.D., Urwin, P., 2001. Citizen versus consumer: challenges in the UK green power market. *Energy Policy* 29, 479-487.

Bergmann, A., Hanly, N., Wright, R., 2006. Valuing the attributes of renewable energy investments. *Energy Policy* 34, 1004-1014.

Bergmann, A., Colombo, S., Hanley, N., 2008. Rural versus urban preferences for renewable energy developments. *Ecological Economics* 65(3), 616-625.

Bollino, C.A., 2009. The Willingness to Pay for Renewable Energy Sources: The Case of Italy with Socio-demographic Determinants. *The Energy Journal* 30, 81-96.

Borchers, A.M., Duke, J.M., Parsons, G.R., 2007. Does willingness to pay for green energy differ by source? *Energy Policy* 35, 3327-3334.

Campbell, D., Hutchinson, W.G., Scarpa, R., 2008. Incorporating Discontinuous Preferences into the Analysis of Discrete Choice Experiments. *Environmental & Resource Economics* 41, 401-417.

CEPS, 2008. *The future of European electricity. Choices before 2020.* Centre for European Policy Studies Policy Brief 164, Brussels. www.ceps.be/ceps/download/1512.

Champ, P.A., Bishop, R.C., 2001. Donation Payment Mechanisms and Contingent Valuation: An Empirical Study of Hypothetical Bias. *Environmental and Resource Economics* 19, 383-402.

Dimitropoulos, A., Kontoleon, A., 2009. Assessing the determinants of local acceptability of wind-farm investment: A choice experiment in the Greek Aegean Islands. *Energy Policy* 37, 1842-1854.

Ek, K., 2005. Public and private attitudes towards "green" electricity: the case of Swedish wind power. *Energy Policy* 33, 1677-1689.

European Commission, 2009. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.

European Commission, 2010a. EU energy and transport in figures 2010. http://ec.europa.eu/energy/publications/statistics/doc/2010_energy_transport_figures.pdf.

Eurostat, 2010b. Data in focus 46/2010. http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB7KS-QA-10-046/EN/KS-QA-10-046-EN.PDF.

Goett, A.A., Hudson, K., Train, K.E., 2000. Customers' Choice Among Retail Energy Suppliers: The Willingness-to-Pay for Service Attributes. *The Energy Journal* 21, 1-28.

Gossling, S., Kunkel, T., Schumacher, K., Heck, N., Birkemeyer, J., Froese, J., Naber, N., Schiermann, E., 2005. A target group-specific approach to "green" power retailing: students as consumers of renewable energy. *Renewable and Sustainable Energy Reviews* 9, 69-83.

Hanley, N., Nevin, C., 1999. Appraising renewable energy developments in remote communities: the case of the North Assynt Estate, Scotland. *Energy Policy* 27, 527-547.

Hansla, A., Gamble, A., Juliusson, A., Gärling, T., 2008. Psychological determinants of attitude towards and willingness to pay for green electricity. *Energy Policy* 36, 768-774.

Koundouri, P., Kountouris, Y., Remoundou, K., 2009. Valuing a wind farm construction: A contingent valuation study in Greece. *Energy Policy* 37, 1939-1944.

Lancaster, K., 1966. A new approach to consumer theory. *Journal of Political Economy* 74, 132-137.

Lockwood, M., 1996. Non-compensatory preference structures in non-market valuation of natural area policy. *Australian Journal of Agricultural Economics* 40, 73-87.

Longo, A., Markandya, A., Petrucci, M., 2008. The internalization of externalities in the production of electricity: Willingness to pay for the attributes of a policy for renewable energy. *Ecological Economics* 67(1), 140-152.

McFadden, D., 1974. Conditional logit analysis of qualitative choice behavior., In *Frontiers in Econometrics*, Paul Zarembka, ed. Academic Press, New York, pp. 105-142.

Menegaki, A., 2008. Valuation for renewable energy: A comparative review. *Renewable and Sustainable Energy Reviews* 12, 2422-2437.

Nomura, N., Akai, M., 2004. Willingness to pay for green electricity in Japan as estimated through contingent valuation method. *Applied Energy* 78, 453-463.

Rekola, M., 2003. Lexicographic preferences in contingent valuation: a theoretical framework with illustrations. *Land Economics* 79(2), 277-291.

Roe, B., Teisl, M.R., Levy, A., Russell, M., 2001. US consumers' willlingness to pay for green electricity. *Energy Policy* 29, 917-925.

Rowlands, I.H., Scott, D., Parker, P., 2003. Consumers and green electricity: profiling potentical purchasers. *Business Strategy and the Environment* 12, 36-48.

Saelensmide, K., 2002. The impact of choice inconsistencies in stated choice studies. *Environmental & Resource Economics* 23, 403-420.

Scarpa, R., Del Giudice, T., 2004. Market segmentation via mixed logit: extra-virgin olive oil in urban Italy. *Journal of Agricultural and Food Industrial Organization* 2 article 7.

Scarpa, R., Ferrini, S., Willis, K.G., 2005. Performance of error component models for status quo effects in choice experiments, in: Scarpa, R., Alberini A. (eds.) (Ed.), *Applications of Simulations Methods in Environmental and Resource Economics*. Springer, pp. 247-274.

Scarpa, R., Campbell, D., Hutchinson, G., 2007. Benefit estimates for landscape improvements: sequential Bayesian design and respondents rationality in a choice experiment*. Land Economics* 83(4), 617-634.

Scarpa, R., Willis, K., 2010. Willingness-to-pay for renewable energy: Primary and discretionary choice of British households' for micro-generation technologies. *Energy Economics* 32, 129-136.

Spash, C.L., 2000. Ecosystems, contingent valuation and ethics: the case of wetland re-creation. *Ecological Economics* 34, 195-215.

Soliño, M., Vázquez, M.X., Prada, A., 2009. Social demand for electricity from forest biomass in Spain: Does payment periodicity affect the willingness to pay? *Energy Policy* 37, 531-540.

Stern, N., 2007. The *Economics of Climate Change: The Stern Review*. Cambridge University Press, Cambridge, UK.

Street, D., Burgess, L., Louviere, J., 2005. Quick and easy sets: Constructing optimal and nearly optimal stated choice experiment. *International Journal of Research in Marketing* 22, 459-470.

Street, D., Burgess, L., 2007. *The construction of optimal stated choice experiments.* John Wiley & Sons Inc. New Jersey.

Train, K., 2003. *Discrete Choice Methods with Simulation*. Cambridge University Press, Cambridge (UK).

Whitehead, J.C., Cherry, T.L., 2007. Willingness to pay for a Green Energy program: A comparison of ex-ante and ex-post hypothetical bias mitigation approaches. *Resource and Energy Economics* 29, 247-261.

Wiser, R.H., 2007. Using contingent valuation to explore willingness to pay for renewable energy: A comparison of collective and voluntary payment vehicles. *Ecological Economics* 62, 419-432.

Zarnikau, J., 2003. Consumer demand for 'green power' and energy efficienty. *Energy Policy* 31, 1661-1672.

Zografakis, N., Sifaki, E., Pagalou, M., Kinitaki, G., Psarakis, V., Tsagarakis, K.P., 2010. Assessment of public acceptance and willingness to pay for renewable energy sources in Crete. *Renewable and Sustainable Energy Reviews* 14, 1088-1095.

TABLES AND FIGURES

Figure 1. Sample choice set

	1 - Bloque 1	Opción A	Opción B	Situación actual
€	Precio kw/hora	0,21 €	0,24 €	Precio actual 0,14 €
	% electricidad generada por energía EÓLICA	18%	21%	13%
	% electricidad generada por energía SOLAR	6%	10%	2%
	% electricidad generada por BIOMASA	5%	6%	1%
	Lugar de generación de la electricidad renovable	Aragón	No especificado	No especificado
	Elegiría:	Opción A ☐	Opción B ☐	Ni opción A ni B ☐

Table 1. - Attributes and levels used in the choice design

Attributes	Levels	*Status quo*
Price (€ per kWh)	0.17; 0.21; 0.24 and 0.28	0.14
% of electricity from wind	16%; 18%; 21%; and 26%	13%
% of electricity from solar	6%; 10%; 14%; and 18%	2%
% of electricity from biomass	2%; 3%; 5%; and 6%	1%
Region of origin	Regional (Aragon) Unknown origin	Unknown origin

Table 2. Sample characterization

Variable	*% unless stated otherwise*
Gender	
Male	47.25
Female	52.75
Age (Average from total sample)	46.70
Education of respondent	
Elementary School (1)	18.50
High School (2)	29.75
University (3)	51.75
Average Household monthly net Income	
Below 600 Euro	4.25
Between 600 and 1,500 Euro	15.75
Between 1,501 and 2,500 Euro	29.50
Between 2,501 and 3,500 Euro	17.75
Between 3,501 and 4,500 Euro	11.75
More than 4,500 Euro	21.00
Household Size (Average from total sample)	3.10
Household with children less than 6 years old (1=Yes)	11.0
Household with adults more than 65 years old (1=Yes)	20.0

Table 3. Results for different model specifications of the choice experiment.

	Model 1	Model 2	Model 3	Model 4
Mean Values				
ASC	-2.8417	-2.0857	-1.9651	-2.0799
	(-8.52)	(-4.19)	(-4.04)	(-4.23)
PRICE	-26.1670	-22.2042	-22.004	-21.7189
	(-11.72)	(-11.47)	(-11.56)	(-11.19)
WIND	-0.0753	-0.0431	-0.0426	-0.0771
	(-2.80)	(-1.97)	(-1.97)	(-2.99)
WIND*$DCON_W$				0.1556
				(3.18)
SOLAR	-0.0192	0.0780	0.0760	0.0654
	(-0.72)	(5.05)	(4.72)	(3.64)
SOLAR*$DCON_S$				0.0754
				(1.93)
BIOMASS	-0.1519	-0.1010	-0.0870	-0.0956
	(-2.52)	(-2.20)	(-2.18)	(-2.25)
BIOMASS*$DCON_B$				N.S.
REGION	0.5069	0.4275	0.4228	0.1616
	(6.58)	(6.50)	(6.72)	(2.12)
REGION*$DCON_R$				0.5741
				(5.14)
Standard deviations of parameter distributions				
WIND	0.2030	0.1353	0.1363	0.1322
	(5.71)	(3.72)	(4.07)	(3.92)
SOLAR	0.3320	0.071	0.0866	0.0810
	(10.56)	(2.19)	(2.90)	(2.86)
BIOMASS	0.4400	0.1907	N.S.	N.S.
	(5.04)	(1.52)		
REGION	0.8032	0.5738	0.5384	0.4571
	(7.17)	(6.64)	(6.39)	(4.92)
Standard deviation of the latent random effect				
σ		5.84	5.62	5.26
		(9.44)	(9.55)	(9.22)
N	4,800	4,800	4,800	4,800
Log likelihood	-1,270	-1,199	-1,199	-1,176
χ^2	974.28	1,117	1,117	1,162
Pseudo R^2	0.275	0.315	0.315	0.328

t-values in brackets

Table 4. Mean estimates WTP (€/kWh)

	WTP	t-test	WTP as % of current kWh price	Monthly WTP (€)#
Respondents who ignore the attribute				
Wind	-0.0036	-3.33**	-2.5	-0.71
Solar	0.0030	3.69**	2.2	0.60
Biomass	-0.0044	-2.43**	-3.1	-0.88
Region	0.0074	2.14**	5.3	1.49
Respondents who consider the attribute				
Wind	0.0036	1.93*	2.6	0.72
Solar	0.0065	3.91**	4.6	1.30
Region	0.0339	8.50**	24.2	6.78

Assuming a monthly consumption of 200 kWh

** (*) Statistically significant at 5% (10%) level.

Table 5. Segments characterization

Characteristics	Segment Less willing to pay	Segment Higher willing to pay	t-test/chi-square (p-value)
Enviromental concerns			
Air pollution	3.69	3.88	-1.76 (0.007)
Generation of municipal waste	3.56	3.78	-1.77 (0.076)
Water polution	3.77	4.39	-5.11 (0.000)
Climate change	3.73	4.14	-2.82 (0.005)
Attitudes towards renewable energy			
Generates waste that needs special treatment	2.14	2.47	-2.72 (0.007)
Diminishes the dependence from fossil fuels	3.69	3.87	-1.55 (0.12)
Reduces Greenhouse Gas Emissions	1.98	2.41	-3.85 (0.000)
Intention to use renewable electricity even at higher prices	48.6%	64.9%	6.64 (0.010)
Environmentally friendly behavior			
Efficient use of air-conditioning heating	74.3%	85.7%	4.5 (0.034)
Insulating their house	49.2%	70.1%	10.9 (0.001)
Environmental involvement			
Membership in environmental organizations	5.7%	13.0%	4.97 (0.005)
Dispose waste taking into account recycling	76.5%	90.9%	7.88 (0.005)
Avoid buying products with high environmental impact	29.1%	39.0%	2.82 (0.093)
Consume organic products	15.5%	29.9%	8.63 (0.003)
Participate in environmental conservation practices	34.4%	53.3%	9.41 (0.002)