Centre for Energy Policy and Economics
Swiss Federal Institute of Technology Zurich

CANADIAN Building Energy End-Use DATA AND ANALYSIS CENTRE
CBEEDAC commercial • residential • institutional

SEEC
Surrey Energy Economics Centre

3rd International Workshop on Empirical Methods in Energy Economics (EMEE2010)

Surrey Energy Economics Centre (SEEC)
University of Surrey, UK
24th – 25th June 2010

NOTE:

The following Abstract and/or Paper is *Work in Progress* for presentation and discussion at the EMEE2010 workshop. It therefore must not be referred to without the consent of the author(s).

Sponsored by:

bp

BIEE
British Institute of Energy Economics

Department of Economics
UNIVERSITY OF SURREY

Eliciting Public Support for Greening the Electricity Mix Using Random Parameter Techniques

Peter Grösche [a*] and Carsten Schröder [b]

[a] Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI)

[b] Christian-Albrechts-University of Kiel

Abstract

With its commitment to double the share of renewables in electricity generation to at least 30% by 2020, the German government has embarked on a costly policy course whose public support remains an open empirical question. Building on ample household survey data, we trace peoples' willingness-to-pay (WTP) for various fuel mixes in electricity generation, and capture preference heterogeneity among respondents using random parameter techniques. Based on our estimates, we infer price premia that can be charged for specific electricity mixes while ensuring that a majority of people still supports the policy. Despite that people's WTP for electricity is positively correlated with the share of renewables in electricity generation, our results imply that the financial scope for subsidizing renewables is virtually exhausted.

Key words: green electricity, willingness-to-pay, preference heterogeneity, policy evaluation

---

* Corresponding author. RWI, Hohenzollernstr. 1-3, 45128 Essen, Germany
Phone: +49 201 81490, Fax: +49 201 8149 200, Email: peter.groesche@rwi-essen.de.

Both authors are deeply grateful for valuable comments and suggestions by Manuel Frondel and Colin Vance.

1 Introduction

Increasing the share of renewables in a nation's energy portfolio is a prominent topic in today's debate on how to mitigate climate change and how to reduce import dependency on fossil fuels. Germany, for instance, aims at increasing the share of renewables in electricity generation to 30% by 2020, and provides a feed-in tariff in order to encourage the production of green electricity. Electricity consumers fund this subsidy by means of a levy on top of its electricity price. According to the German Government, the consumer bears about 4.5 billion Euro in 2008, and a levy of 1.1 Euro-Cent per kilowatt-hour (ct/kWh) was raised (BMU 2007, 2008). Not only that the levy more than doubled since 2004, the funding is expected to rise to 8.2 billion Euro in 2010 (TSO 2009).

Numerous empirical studies have examined the extent to which people are willing to pay price premia for green electricity, and have found a substantial market potential.[1] However, these studies typically consider a situation in which consumers act as sovereigns and people are free to decide whether to consume green electricity. By contrast, the German feed-in tariff commits *all* private consumers to pay for a continually increasing share of renewables in the electricity mix – a policy that must not necessarily be approved by society.

This paper provides insights into the voter's preferences for renewables. Building on data from a large-scale survey among several thousand households in Germany, this paper traces peoples' willingness-to-pay (WTP) for specific mixes of fossil fuels, renewables, and nuclear power in electricity generation. Using random-parameter techniques within a hedonic regression framework, we estimate household-specific WTP as a function of the electricity mix, thereby capturing various degrees of heterogeneity across households. We assess people's approval for a subsidy schedule by juxtaposing estimated WTP figures for a spe-

[1]See amongst others, Fouquet (1998), Eikeland (1998), Goett et al. (2000), Batley et al. (2001), Roe et al. (2001), Zarnikau (2003), Menges et al. (2005), Bollino (2009), Scarpa and Willis (2010). Menegaki (2008) provides a comprehensive review of the recent literature.

cific electricity mix with rising scales of the levy. By these means, we elicit what cost might be imposed on the population for a specific electricity mix such that a majority of people would still endorse that policy. Our results stress an actual dilemma for the energy policy: despite the fact that most people obviously dislike nuclear fuels in electricity generation, their willingness-to-pay for assisting renewables is limited. Thus, finding the right balance between the charged levy and a sustainable electricity mix might become a challenging task.

The following Section 2 describes the design of our survey, the survey instrument and the sample. Descriptives of consumers' WTP as well as regression results follow in Section 3. These results serve for investigating voters' preferences for two green policies scenarios considered in Section 4. Possible limitations of an empirical framework using stated preferences are discussed in Section 5. Section 6 finally concludes.

2 Survey Design and Sample

Lancaster (1966) emphasizes that goods purchased in the market are not always the immediate source of utility, but that people derive utility from the array of characteristics inherent in the particular good. Following Rosen (1974), we postulate that a consumer's WTP is linked to the characteristics of the good via a bid function. Along these lines, we assume that an individual i evaluates the good electricity by its underlying fuel mix and specify the bid function:

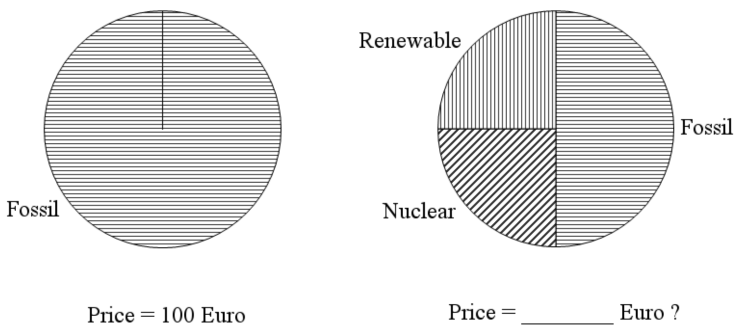
$$\text{WTP}_i = f\left(\text{fossil, renewable, nuclear}\right), \tag{1}$$

with the shares of fossil fuels(coal, oil, gas), renewable energy technologies (wind, photovoltaic, water), and nuclear power as the elements in the electricity fuel mix.

We have acquired our data by surveying households from a commercially maintained online panel. A set of socio-economic and demographic background

Figure 1: Stylized Survey Pie Chart

What is the monetary amount that you would be willing to pay at most for the contract shown on the right hand side, given that electricity generated entirely from fossil fuels costs €100?



information is also available. Each panel household is equipped with a "set-top-box" connecting the household's TV with the internet. Respondents can fill in the questionnaire using a remote control.

Each survey participant is confronted with five hypothetical electricity contracts, differing in the fuel shares in electricity generation, and is asked to state his individual WTP for a contract with a specific fuel mix. Pie charts appear on the television screen that depict alternative mixes (see Figure 1). Underneath the pie charts, respondents state their WTP for the contract in a pre-specified field.[2] As a valuation benchmark, we offer people a contract with 100% fossil fuels, and normalize its price to €100. Deviations in stated WTP from this benchmark can be interpreted as either price premia or deductions associated with a specific variation in the fuel mix.

While in total 14 contracts are available (including the benchmark contract), we limit the evaluation task for each respondent to five randomly drawn alter-

[2]We refrain from restricting WTP assessments to a too narrow range, instead, we allow for responses in the range between €0 and €9 999.

Table 1: Pool of Electricity Contracts

		Renewable share				
		0%	25%	50%	75%	100%
	0%	(Benchmark)				
Nuclear share	25%					
	50%		Fossil = 25%			
	75%					

natives. The grey-shaded area in Table 1 illustrates the set of contracts. The random draws avoid that the responses might be sensitive to order effects (Clark and Friesen 2008) that may result in a sequence of valuation tasks in which only nested alternatives are presented.[3]

Nearly 3,000 households have participated in our survey in 2008. As our participants face five different evaluation tasks, our data exhibits a panel structure. Not all households have provided five WTP assessments, and we end up with an unbalanced panel of 14,532 observations with about 1,000 responses for each hypothetical contract.[4]

Sample characteristics are given in Table 2. Because the questionnaire was addressed to the person who contributes most to the household income (the "household head"), the sample consists mainly of males. About 37 percent of the respondents have at least a high school degree and are about 50 years old. The typical participating household has a disposable equivalent income of €1,550 per month, and includes, on average, 1.83 adults and 0.45 children.[5]

[3]For instance, an order effect is likely to occur while asking a participant to value at first a contract with 25 percent renewables, and subsequently a contract with 50 percent.

[4]We obtained on average 4.7 assessments per household, and checked the sensitivity of our results with respect to households with less than five assessments. Re-estimating our models conditional on the subsample of households which provide all five evaluation task demonstrates robust results.

[5]We have chosen the equivalent income as the income variable to make household incomes

Table 2: Sample Description

		Number/percentage of households	
Region	Western Germany	2,329	79%
	Eastern Germany	619	21%
Gender	Male	2,144	73%
	Female	804	27%
Education	High-school degree	1,105	37%
	Below high-school degree	1,843	63%
		Mean	Std.dev.
Equivalent income[3] (€)		1,550	707
Age		49.5	13.4
Number of adults in the household		1.83	0.73
Number of children in the household		0.45	0.82

3 Empirical Analysis

Table 3 summarizes descriptive statistics of WTP across the contracts evaluated by the respondents. The contracts appear row-wise. For example, the topmost row offers a contract with a mix of 75 percent fossil fuels and 25 percent renewables.

Table 3 reveals two regularities. First, WTP tends to rise with the share of renewables in the electricity mix, indicating a preference for green electricity generation. For example, with sequentially replacing fossil fuels by renewables and holding the nuclear share constant – as e.g. from row nine to eleven – yields a rising WTP, both in means and medians. Second, the figures in rows 1, 6, 10 and 13 suggest that the WTP tends to be decreasing with the share of nuclear power, indicating that nuclear fuels are perceived as an economic 'bad' that lowers

comparable across households of different size and composition. Equivalent income is computed by deflating the household's income by an index $I = 1 + 0.5 \times (\text{number of adults} - 1) + 0.3 \times$ number of children, which takes into account the number of adults and children living in the household unit. Specifically, equivalent income is computed as Income$/I$.

Table 3: Summary of WTP Responses

Fossil Fuels	Share in % Renew-ables	Nuclear Power	No. of Observations	WTP Response in € Mean	Std.Dev	Median
75	25	0	1,008	97	29.7	100
50	50	0	1,056	101	30.8	100
25	75	0	1,031	106	32.9	102
0	100	0	1,084	112	37.2	110
75	0	25	1,063	85	30.4	85
50	25	25	1,090	91	29.5	100
25	50	25	1,048	96	29.5	100
0	75	25	1,058	99	34.6	100
50	0	50	1,054	81	30.3	80
25	25	50	1,061	87	32.0	90
0	50	50	1,055	92	30.6	100
25	0	75	951	76	33.4	80
0	25	75	1,088	81	33.8	80

Means, standard deviations, and medians in full €.

the utility of the typical consumer. The standard deviations, however, indicate substantial preference heterogeneity among respondents.

Using rank-sum tests for trends across ordered groups (Cuzick 1985), we test for differences in stated WTP across fuel mixes. Holding the nuclear share constant, the tests confirm a significant increase in WTP with a rising share of renewables. In a like manner, holding the share of renewables constant, the tests confirm a significant decrease in stated WTP as the nuclear share increases.

3.1 Econometric Specification

Random-parameter techniques offer the required flexibility to cope with preference heterogeneity by allowing for the estimation of personalized regression coefficients $\beta_{ik} := \beta_k + u_{ik}$. The random deviations u_{ik} measure the deviation of individual i from the mean taste β_k for a specific fuel k. Hence, β_{ik} depicts an individual slope coefficient, and we assume that the u_{ik} are normally distributed in the population, with a zero mean and an unknown standard deviation.

We model the individual WTP response for contract $j = 1, \ldots, 13$ in linear form:

$$\text{WTP}_{ij} = \alpha + \sum_k (\beta_k + u_{ik}) x_{jk} + \boldsymbol{z}_i' \boldsymbol{\delta} + v_i + \varepsilon_{ij}, \tag{2}$$

where x_{jk} captures the mix of the k fuels in contract j. We include the share of renewables and the share of nuclear fuels in x_{jk}, but drop the share of fossil fuels because of collinearity reasons.[6] An interaction term *Renewable* $\times$ *Nuclear* captures possible interdependencies of preferences for renewables and nuclear fuels. The vector $\boldsymbol{z}_i$ contains the household's equivalent income, the household's size, and a binary variable that indicates whether a household lives in the east of Germany, and $\boldsymbol{\delta}$ is an unknown parameter vector. The random effect v_i serves to shift the regression line up or down according to the individual household.

We refer to equation (2) – our most flexible specification – as Model 1, and test the sensitivity of our results with respect to nested, less flexible specifications. To this end, we re-estimate the random-parameter specification, but constrain the individual preferences to equal the mean taste, i.e. we invoke $u_{ik} = 0$ for all k and every individual. We refer to this specification as Model 2. Finally, in our third specification we further exclude the household characteristics included in $\boldsymbol{z}_i$ from the analysis (i.e. $\boldsymbol{\delta} = \mathbf{0}$).

3.2 Results

The upper panel of Table 4 shows the coefficient estimates and respective standard errors (*s.e.*) pertaining to Models 1-3, along with the standard deviations for the random parameters. At the bottom of Table 4, likelihood-ratio test statistics are shown, clearly indicating that the random-parameter specifications of Model 1

[6]Note that the sum of fuel shares adds up to unity and the share of fossil fuels is therefore a linear combination of the renewables and nuclear fuels.

Table 4: Summary of Regression Results

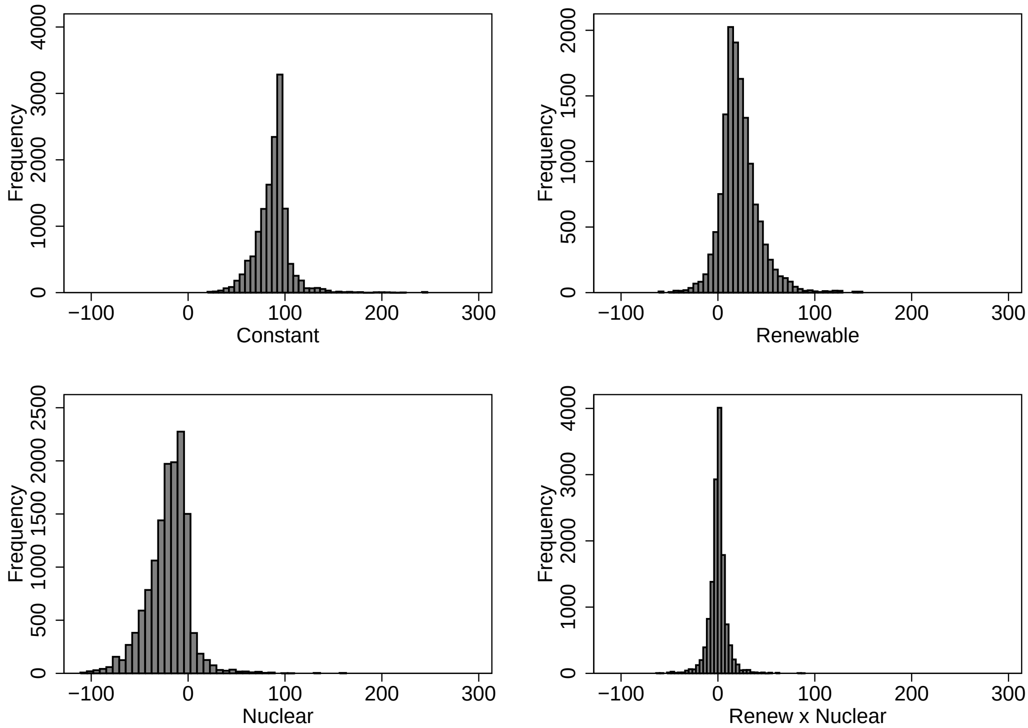
	Model 1		Model 2		Model 3	
	Coefficient	*s.e.*	Coefficient	*s.e.*	Coefficient	*s.e.*
Constant	87.978**	1.869	88.561**	1.904	90.263**	0.771
Renewable	22.234**	1.025	22.142**	0.973	22.163**	0.973
Nuclear	−20.101**	1.283	−19.870**	1.265	−19.851**	1.265
Renewable×Nuclear	0.047	2.903	0.271	3.102	0.212	3.102
Household Size	−0.429	0.480	−0.496	0.479	–	–
East	−2.349	1.265	−3.054*	1.267	–	–
Income	0.003**	0.001	0.002**	0.001	–	–
Log-Likelihood	-63,306		-63,989		-63,999	
	Standard deviation for random parameters					
	Std.Dev	*s.e*	Std.Dev	*s.e.*	Std.Dev	*s.e.*
Constant	32.389**	0.994	25.526**	0.405	25.628**	0.407
Renewable	28.497**	0.774	–	–	–	–
Nuclear	22.356**	0.373	–	–	–	–
Renewable×Nuclear	33.677**	5.418	–	–	–	–
	Likelihood-Ratio Tests					
	Model 2 nested in Model 1		Model 3 nested in Model 2			
parameter restrictions	3		3			
$2 \times \Delta$Log-Likelihood	1366		20			

**significant at the 1% level, *significant at the 5% level. Critical value for model comparison: $\chi^2_{0.99}(df = 3) = 11.35$.

provides superior model fit. In what follows, we will therefore concentrate our discussion on Model 1.

The marginal WTP is increasing in the share of renewables, as suggested by the descriptives of the previous section. Relative to the benchmark contract that solely includes fossil fuels, an increase of the share of renewables by one unit – that is, from 0% to 100% – raises the WTP by 22.23%. On the other hand, increasing the share of nuclear fuels in the electricity mix yields a substantial decrease in average WTP. All the reported standard deviations for the random parameters distributions are highly significant (see the middle panel of Table 4),

Figure 2: Empirical Coefficient Distributions for Model 1



indicating that the u_{ik} vary substantially among individuals. In other words, there is substantial heterogeneity with respect to individual preferences.

Turning to the personal characteristics vector $\boldsymbol{z}_i$, the estimated coefficients for the household size and the East dummy lack statistical significance in Model 1. The coefficient for income appears significant, but the effect, however, is very small. Income is thus only of little importance for explaining variation in WTP: if the equivalent income would increase by on average €100, the average WTP would increase by only 0.3%.[7]

Figure 2 provides histograms illustrating the empirical distributions of the respondent-specific intercepts and slopes. Substantial differences in the individual slope coefficients pertaining to the renewables and nuclear fuel shares exist.

[7]See Wiser (2006), Bergmann et al. (2006) or Zarnikau (2003) for supportive evidence.

For instance, while the mean individual slope-coefficient β_{ik} for renewables is 22.234 (median=19.971), the respective histogram illustrates considerable variation among households. For about 8.5% of the respondents the respective coefficient even falls below zero, hence, their preferences for renewables are associated with a reduced WTP compared to the benchmark. The histogram pertaining to the nuclear share shows a similar variation. While the mean individual slope-coefficient for nuclear power is -20.101 (median=-18.581), about 9.5% of the respondents exhibit preferences associated with a positive β_{ik}. A closer inspection of whether a positive β_{ik} for nuclear power implies a negative coefficient for renewables reveals, however, that only 54 respondents exhibit such a preference pattern.

A specific strength of the random parameter specification of Model 1 is corroborated in the histograms for the interaction $Renewable \times Nuclear$. The respective histogram shows a rather symmetrical empirical coefficient distribution centered around zero. While the mean coefficient therefore appears statistically insignificant, since half of the probability mass fall on either side of zero, the *individual* coefficient might be nevertheless of statistical significance.

4 Evaluating Energy Policy Options

The lion's share of Germany's electricity generation in 2008 relied on fossil fuels, while renewables accounted for some 15% and about 23% came from nuclear power (BMWi 2009:19).[8] Every household paid a levy of 1.10 ct per consumed kWh to fund the feed-in tariff regime for renewables. This levy is included in the average consumer electricity price of 21.43 ct/kWh (BMU 2009, BMWi 2009:35-37), and the consumer price without levy therefore amounts to 20.33 ct/kWh.

[8]We add the share of "other fuels" to the share of fossil fuels in the following analysis. "Other fuels" are non-renewable waste or large hydropower plants, accounting for 4% of the electricity generation. These energy sources do not serve as a stimulus variable in our survey. As they neither incorporate a technical risk, like the nuclear option, nor do they receive public financial support, it appears reasonable to treat them like a fossil fuel.

Table 5: Electricity Mix Scenarios

	Scenario: $s =$	0	15	30a	30b
	Fossil	69.5	62	54.5	62
Fuel Share in %	Nuclear	30.5	23	15.5	8
	Renewable	0	15	30	30
Consumer price	ct/kWh	20.33	21.43	–	–
Levy	ct/kWh	0	1.1	–	–

4.1 Assessment and Scenario Set-Up

We define four scenarios $s \in \{0, 15, 30a, 30b\}$, each linked to a specific fuel mix in the electricity generation. Details of the different scenarios are depicted in Table 5. The scenario $s = 15$ refers to the fuel mix of 2008 in the electricity generation, exhibiting a share of 15% renewables and associated with an average consumer price $p + t^{15}$ of 21.43 ct/kWh (including a levy of $t^{15} = 1.1$ ct/kWh). Scenario $s = 0$ illustrates a hypothetical situation in which the renewables share is removed from the electricity mix. An equal increase of both the fossil and the nuclear share compensates this modification such that the fuel shares again sum to unity. Because no levy would be charged in scenario $s = 0$, the consumer price p^0 amount to 20.33 ct/kWh.

The two hypothetical scenarios $30a$ and $30b$ both refer to the commitment of the German government. Compared to scenario $s = 15$, we increase the renewables share by 15 percentage points in scenario $30a$ at equal expense of the shares from the other two fuels. In scenario $30b$, the rise in the renewables share is compensated by an identical reduction of the nuclear share while the fossil share remains unaffected.

Whether a household favors one fuel mix relative to another depends on the respective consumer surplus. Relative changes in consumer surpluses (ΔCS) can be captured by

$$\Delta CS_i^s = \frac{\text{WTP}^s}{\text{WTP}^0} - \frac{p + t^s}{p}. \tag{3}$$

While p refers to the consumer net price for electricity, t^s denotes the levy associated with the share of renewables in the fuel mix. Whereas the first term in (3) captures the increase in WTP by passing from $s = 0$ to $s \neq 0$, the second term captures the increase in the consumer price due to the levy. Household i prefers situation $s \neq 0$ to $s = 0$ if ΔCS is positive in Equation (3), that is the relative rise in the household's individual WTP outperforms the relative price increase due to the levy. By requiring $\Delta CS_i^s \geq 0$ and rearranging Equation (3), we obtain an upper bound for the levy that might be charged such that household i still prefers $s \neq 0$ to $s = 0$:

$$p \left(\frac{\text{WTP}^s}{\text{WTP}^0} \right) - p \geq t^s \tag{4}$$

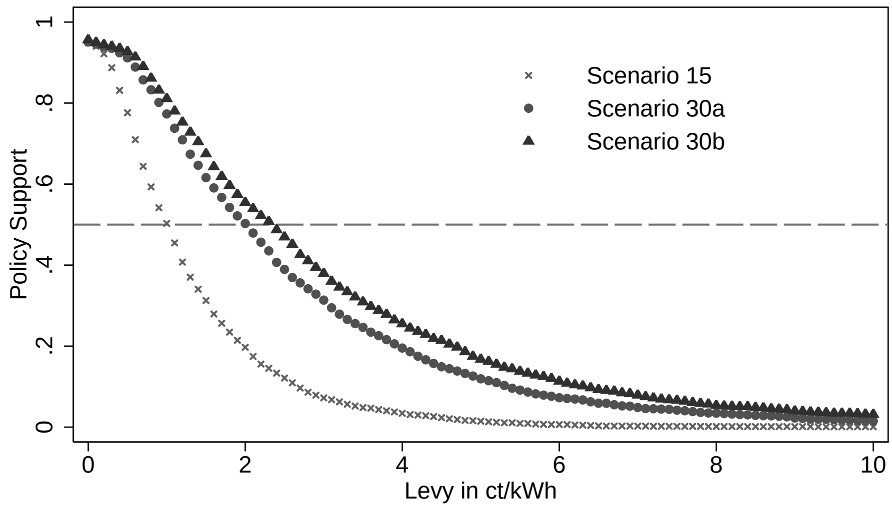
Our econometric results render the preference structure for every single sample household. In order to derive representative population statistics, we weight each sample household by its frequency weight times the number of adults (persons of age 18 and older) living in that household.[9] Against this backdrop, we quantify the levy that is maximally chargeable such that the median voter still maintains an improvement in consumer surplus ($\Delta CS > 0$ in Equation (3)).

4.2 Scenario Outcomes

Using the preference structure inferred from Model 1, Figure 3 illustrates the public support as a function of the levy. The ordinate renders the share of people who are willing-to-pay at least the respectively charged levy, and the horizontal dashed line marks the share of 50% of people. If the marker of an associated scenario falls below the horizontal line, the respective levy will be no longer

[9] In this regard, it is a minor assumption that we assume identical preferences for all adult persons in a sampled household.

Figure 3: Policy Support for Levy Charge



accepted by the majority of people. For instance, the downward sloping line pertaining to scenario $s = 15$ shows a rapidly falling acceptance of subsidizing renewables as the levy increases.

Note that our survey was conducted in 2008 while scenario $s = 15$ renders the German electricity fuel mix of 2008. Our results show for this scenario that the median voter would have accepted a levy of 1.02 ct/kWh in order to promote the respective green electricity generation. By contrast, with 47% of the voters, slightly less than the majority would have also endorsed the actual charged levy of 1.1 ct/kWh in 2008. Similar findings are reported in Batley et al. (2001) for UK and Bollino (2009) for Italy, whose results demonstrate that consumers' WTP for green electricity is too low to meet the respective Government's green electricity commitment for 2010. Scarpa and Willis (2010) provide WTP estimates from UK households for micro-systems to generate green electricity, indicating that the average WTP falls well below the typical investment cost.

Both scenarios for 2020 provide valuable information with respect to the scope of the levy that might be charged for a future fuel mix. The public support is highest in $s = 30b$ where the renewable share is extended solely at the expense of nuclear fuels: 50% of the people would accept a levy of at most 2.37 ct/kWh to subsidize green electricity. In scenario $s = 30a$ the extension of renewables reduces the contribution of nuclear and fossil fuels alike, and nuclear fuels would still contribute more than 15% to the electricity supply. The median voter would accept in that scenario a levy of at most 2.03 ct/kWh. The public acceptance vanishes in both scenarios if the charged levy would exceed 6 ct/kWh.

The policy implications of our results are straightforward but also challenging. On the one hand, the German population strongly dislikes nuclear fuels in the electricity generation. On the other hand, substituting nuclear fuels by renewable energy is only a possible option if the associated levy will not increase too much, since peoples' acceptance of such a policy has its (financial) limits. The challenging task is to find a balance between greening the electricity mix and not escalating subsidy spending. Germany's feed-in-tariff scheme promotes various renewable energy technologies, but lacks a mechanism to limit the public spending. By contrast, the far a particular technology is from a competitive level, the larger is its subsidy. Consequently, total subsidy spending rose dramatically in the last few years, with expected total cost for the consumer of 8.2 billions of Euro in 2010. To fund these cost a levy of 2.047 ct/kWh will be charged (TSO 2009), associated with an estimated renewables share of about 18%.[10] Note that this levy is already close to the maximal chargeable value of 2.37 ct/kWh.

[10] In Germany, the transmission network operators serve as fund-raiser for the subsidy, and announce in late autumn the charged levy for the respective next coming year. The levy for 2010 was announced mid of October 2009. See http://www.eeg-kwk.net for further information.

5 Possible Limitations of Stated-Preferences Approaches

Inherent in the nature of surveys is the absence of a mechanism that ensures that rational agents have an incentive to reveal preferences truthfully. Though Hanemann (1994:37) emphasizes that "there is no reason why observing people's behavior and asking them about behavioral intentions and motives should be mutually exclusive", there is still a debate whether survey respondents "mean what they say" (Bertrand and Mullainathan 2001).[11] In our case, for example, not revealing the true WTP has no immediate negative consequences for respondents as contracts provided had been hypothetical. The lack of financial consequences might tempt the respondents to de-emphasize the associated cost and therefore stating too high WTP (Goett et al. 2000:27). On the contrary, Carson et al. (1996) review more than 600 studies, and demonstrate that stated preference tasks typically average about 90% of the corresponding revealed valuation. Apparently, stated preference even underestimate the benchmark of revealed valuation slightly.

A reliable exposure of preferences requires that stated preferences remain stable between evaluation tasks (Hanemann 1994). To investigate whether this is the case, we have confronted all our respondents with a further assessment problem: each respondent was presented five attributes of electricity contracts, including the *absence of nuclear fuels* in electricity generation and electricity generation using *renewables*. The participants were asked to rank these attributes with respect to desirability, with the highest rank indicating the most important attribute.[12] Preferences remain stable if WTP statements and responses in the additional assessment task are consistent, meaning e.g. that a strong preference for green fuels

[11] Diamond and Hausman (1994), Ajzen et al. (1996), Diamond (1996), and Smith and Osborne (1996) investigate the information content of contingent valuation survey. For case studies, see also Cummings and Taylor (1999), List (2001), Loomis et al. (1997) or Neill et al. (1994).

[12] See the appendix for further details.

is reflected by a high individual regression coefficient for the share of renewables, and is also associated with a high rank for the attribute “electricity generated from renewables”. A consistent preference representation for renewables therefore requires a positive correlation between the individual regression coefficient and the attribute’s rank. By contrast, a preference against nuclear fuels is consistently reflected in a low individual regression coefficient for the nuclear share, accompanied by a high rank of the attribute “nuclear-free electricity generation”. We thus expect a negative correlation between the individual regression coefficient for nuclear fuels and the respective attribute.

Indeed, Spearman rank correlation coefficients exhibit the expected signs and are highly significant. The rank correlation between the individual parameter for the share of green electricity and the rank for the contract attribute “electricity generation from renewables” is 0.2814 and significant at the level $p < 0.001$. Likewise, the Spearman rank correlation between the individual parameter for the share of nuclear fuels and the rank for the absence of nuclear fuels in electricity generation amounts to -0.3050 at $p < 0.001$. This supporting evidence let us believe that our WTP estimates and the derived policy implications might serve as a good proxy for the true underlying population preferences.

6 Summary and Conclusion

The German government has committed to increase the renewables share in electricity generation to at least 30% until 2020, and has stipulated a feed-in tariff regime to encourage green electricity generation. This subsidy is financed by a levy on top of the consumer electricity price, amounting to 1.1 ct/kWh in 2008. While, ultimatively, these subsidies have to be borne by the electricity consumers, it is an open question as to whether policy makers act in accord with the preferences of the voting majority. This paper provides insights into the people’s preferences for greening the electricity mix and renders guidance for policy makers against the backdrop of the green electricity commitment for 2020.

To elicit peoples' preferences for different fuels in the electricity generation, we have used a large-scale household survey, and have captured preference heterogeneity among the respondents by applying random-parameter regression techniques within a hedonic approach. Our results suggest that the large majority of our respondents has a positive WTP for renewables, and a negative WTP for nuclear fuels, both characterized by a substantial variability across respondents.

Using these WTP estimates, we gauge the maximally chargeable levy for a specific fuel mix, such that at least 50% of the voting population in Germany would approve that policy. We have evaluated different scenarios, one of which consists of the actual fuel mix of 2008. We find that the majority of the voting population has a WTP below the actually charged levy of 1.1 ct/kWh. We further determine the maximally chargeable levy for two hypothetical future electricity mixes, both characterized by a share of 30% renewables. If renewable energy solely substitutes nuclear fuels, the charged levy should not exceed 2.37 ct/kWh in order to ensure the approval of the voters' majority. The maximally chargeable levy decreases slightly to 2.37 ct/kWh if nuclear fuels still contributes a sizeable share to the fuel mix.

While an increase of the renewables share in electricity generation thus expands the chargeable levy, our results also indicate that an upper limit for the support of renewables may be reached. In particular, with an estimated renewables share of about 18% in 2010, a levy of already 2.047 ct/kWh will be charged – an amount already close to the maximum chargeable levy of 2.37 ct/kWh. While the current feed-in tariff fosters many generation techniques irrespective of its price competitiveness, a reasonable policy redesign must therefore amplify its efforts in making the future promotion of green electricity less cost-intensive.

References

Ajzen, I., T.C. Brown, and L.H. Rosenthal (1996), Information Bias in Contingency Valuation: Effects of Personal Relevance, Quality of Information, and Motivational Orientation, *Journal of Environmental Economics and Management*, Vol.30:43-57.

Batley, S.L., D. Colbourne, P.D. Fleming, and P. Urwin (2001), Citizen versus Consumer: Challenges in the UK Green Power Market, *Energy Policy*, Vol.29:479-487.

Bergmann, A., N. Hanley, and R. Wright (2006), Valuing the Attributes of Renewable Energy Investment, *Energy Policy*, Vol.34:1004-1014.

Bertrand, M., and S. Mullainathan (2001), Do People Mean What They Say? Implications for Subjective Survey Data, *The American Economic Review - Papers and Proceedings*, Vol.91:67-72.

BMU (2008), *Aktualisierung von Kapitel 13 (Besondere Ausgleichsregelung - § 16 EEG) des EEG-Erfahrungsberichts vom 07.11. 2007*, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, April 2008, Berlin. Internet: `http://www.bmu.de/gesetze/doc/41335.php`.

BMU (2007), *Erfahrungsbericht 2007 zum Erneuerbaren-Energien-Gesetz*, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, November 2007 Berlin. Internet: `http://www.bmu.de/erneuerbare_energien/downloads/doc/40342.php`.

BMWi (2009), *Energie in Deutschland: Trends und Hintergründe zur Energieversorgung in Deutschland*, Federal Ministry for Economics and Technology, April 2009, Berlin. Internet: `http://www.bmwi.de/BMWi/Navigation/Service/publikationen,did=251954.html`.

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

Carson, R.T., N.E. Flores, K.M. Martin, and J.L. Wright (1996), Contingent Valuation and Revealed Preference Methodologies: Comparing the Estimates for Quasi-Public Goods, *Land Economics*, Vol.72:80-99.

Clark, J., and L. Friesen (2008), The Causes of Order Effects in Contingent Valuation Surveys: An Experimental Investigation, *Journal of Environmental Economics and Management*, Vol.56:195-206.

Cummings, R.G., and L.O. Taylor (1999), Unbiased Value Estimates for Environmental Goods: A Cheap Talk Design for the Contingent Valuation Method, *The American Economic Review*, Vol.89:649-666.

Cuzick, J. (1985), A Wilcoxon-Type Test for Trend, *Statistics in Medicine*, Vol.4:87-90.

Diamond, P. (1996), Testing the Internal Consistency of Contingent Valuation Surveys, *Journal of Environmental Economics and Management*, Vol.30:337-347.

Diamond, P.A., and J.A. Hausman (1994), Contingent Valuation: Is Some Number Better than No Number?, *Journal of Economic Perspectives*, Vol.8:45-64.

Eikeland, P.O. (1998), Electricity Market Liberalization and Environment Performance: Norway and the UK, *Energy Policy*, Vol.26:917-927.

Fouquet, R. (1998), The United Kingdom Demand for Renewable Electricity in a Liberalized Market, *Energy Policy*, Vol.26:281-293.

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

Hanemann, W.M. (1994), Valuing the Environment Through Contingent Valuation, *The Journal of Economic Perspectives*, Vol.8:19-43.

Lancaster, K.J. (1966), A New Approach to Consumer Theory, *Journal of Political Economy*, Vol.74:132-157.

List, J.A. (2001), Do Explicit Warnings Eliminate the Hypothetical Bias in Elicitation Procedures? Evidence from Field Auction Experiments, *The American Economic Review*, Vol.91:1498-1507.

Loomis, J., T. Brown, B. Lucero, and G. Peterson (1997), Evaluating the Validity of the Dichotomous Choice Question Format in Contingent Valuation, *Environmental and Resource Economics*, Vol.10:109-123.

Menges, R., C. Schröder, and S. Traub (2005), Altruism, Warm Glow and the Willingness-to-Donate for Green Electricity: An Artefactual Field Experiment, *Environmental and Resource Economics*, Vol.31:431-458.

Menegaki, A. (2008), Valuation for Renewable Energy: A Comparative Review, *Renewable and Sustainable Energy Reviews*, Vol.12:2422-2437.

NEILL, H.R., R.G. CUMMINGS, P.T. GANDERTON, G.W. HARRISON, AND T. MCGUCKIN (1994), Hypothetical Surveys and Real Economic Commitments, *Land Economics*, Vol.70:145-154.

ROE, B., M.F. TEISL, A. LEVY, AND M. RUSSEL (2001), US Consumers' Willingness to Pay for Green Electricity, *Energy Policy*, Vol.29:917-925.

ROSEN, S. (1974), Hedonic Prices and Implicit Markets: Product Differentiation in Perfect Competition, *Journal of Political Economy*, Vol.82:34-55.

SCARPA, R., AND K. WILLIS (2010), Willingness-to-Pay for Renewable Energy: Primary and Discretionary Choice of British Households' for Micro-Generation Technologies, *Energy Economics*, Vol.32:129-136.

SMITH, V.K., AND L.L. OSBORNE (1996), Do Contingent Valuation Estimates Pass a 'Scope' Test, *Journal of Environmental Economics and Management*, Vol.31:287-301.

TSO (2009), *Prognose der EEG-Umlage 2010 nach AusglMechV Prognosekonzept und Berechnung der ÜNB - Stand 15.10.2009*, Transmission System Operators in Germany, Internet: `http://www.eeg-kwk.net`.

WISER, R. (2006), Using Contingent Valuation to Explore Willingness to Pay for Renewable Energy: A Comparison of Collective and Voluntary Payment Vehicles, *Ecological Economics*, Vol.62:419-432.

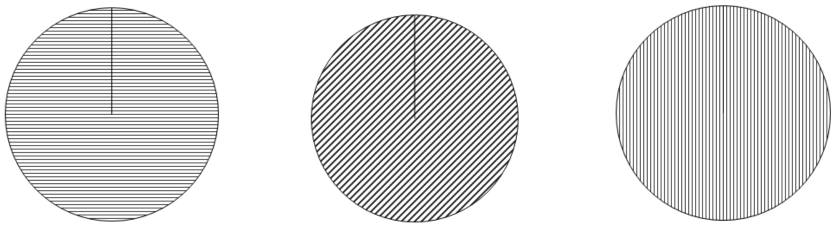
ZARNIKAU, J. (2003), Consumer Demand for 'Green Power' and Energy Efficiency, *Energy Policy*, Vol.31:1661-1672.

Appendix: Survey Questionnaire

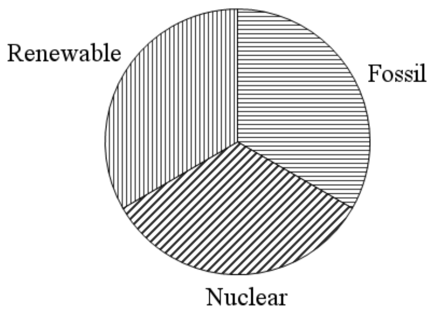
Eliciting Respondent's WTP

Electricity can be generated using different types of energy: fossil fuels (coal, oil and gas), renewables (wind, solar energy, waterpower), and nuclear power. Thus, it is possible that a household consumes electricity solely generated from

fossil fuels nuclear power renewables.



Yet, a household can also consume electricity generated from a mix of fuels, for example electricity might be generated from all three fuels in equal proportion:

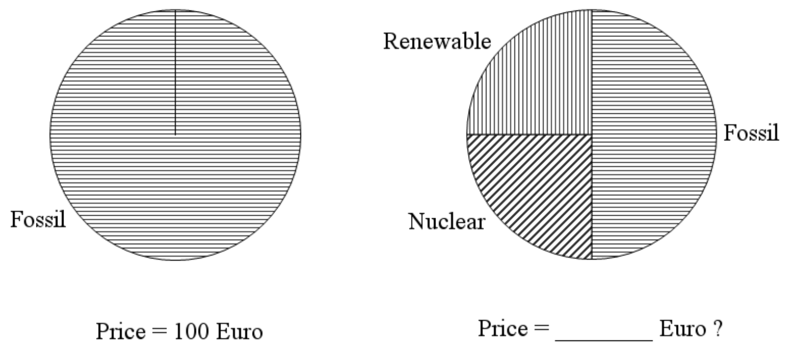


In the following, we will show you several electricity contracts, which only differ in the composition as to whether the three fuels (fossil, renewable, nuclear) contribute to its generation. We would like to ask you about how much you would be willing-to-pay for contracting the respective offer. As a comparison, assume that a benchmark contract, where electricity is entirely generated from fossil fuels (coal, oil, and gas), is available at a price of €100.

Example. The price of the benchmark contract (electricity entirely generated from fossil fuels) is €100. If you are willing-to-pay at most, say, €70 for an alternative contract, please state '70' in the empty box. If you are willing-to-pay at most, say, €180 for the alternative contract, please state '180' in the empty box. Of course, all other values are feasible.

In the following, the benchmark contract (electricity entirely generated from fossil fuels and with a price of €100) will always appear at the left part of your screen. The right part of your screen will show an alternative contract, where electricity is generated using different shares of the three fuels (fossil, renewable, nuclear).

> *What is the monetary amount that you would be willing to pay at most for the contract shown on the right hand side, given that electricity generated entirely from fossil fuels costs €100?*



[**Technical note.** Each respondent had to state her willingness-to-pay for five alternative contracts, drawn randomly from a set of 13 different contracts. All values between 0 and 9999 monetary units were feasible.]

Eliciting Respondent's Attribute Rankings

If you think about your own supply with electricity, which of the following product attributes is the most important for you?

- reasonable electricity price
- nuclear-free electricity generation
- electricity generated from renewable energy such as water, wind, and photovoltaics
- price guarantee
- short term of notice

And from the remaining attributes?

[Technical note. After respondents have chosen the most important attribute, a new computer screen occurred where the remaining four (three, etc.) attributes were provided.]