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

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Peter Grösche and Carsten Schröder[1]

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Abstract

With its commitment to double the share of renewable fuels in electricity generation to at least 30% by 2020, the German government has embarked on a potentially costly policy course whose public support remains an open empirical question. Building on household survey data, in this paper 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 trace out the locus that links the premia charged for specific electricity mixes with the fraction of people supporting the policy. Albeit people's WTP for a certain fuel mix in electricity generation is positively correlated to the renewable fuel share, our results imply that the current surcharge effectively exhausts the financial scope for subsidizing renewable fuels.

JEL Classification: C23, H23, Q48

Keywords: Green electricity; willingness-to-pay; preference heterogeneity; policy evaluation

December 2010

1 Peter Grösche, RWI; Carsten Schröder, University of Kiel and DIW Berlin. *– The authors gratefully acknowledge the helpful comments and suggestions by Manuel Frondel, Christoph M. Schmidt. We also would like to thank Massimo Filippini and the participants of the 3rd International Workshop on Empirical Methods in Energy Economics, held at the University of Surrey (UK). Lisei Joost and Moritz Seidel provided valuable research assistance.* *– All correspondence to Peter Grösche, RWI, Hohenzollernstr. 1–3, 45128 Essen, Germany, E-Mail: peter.groesche@rwi-essen.de.*

1 Introduction

Increasing the share of renewable fuels in the energy mix is a prominent topic in today's debate on how to mitigate climate change and how to reduce import dependency on fossil fuels. Germany aims at increasing the share of renewable fuels in electricity generation to 30% in 2020, and provides a feed-in tariff in order to encourage the production of green electricity. This subsidy is paid by the electricity consumer by means of a levy on top of its electricity price. According to the German Government, a levy of 1.1 euro-cent per kilowatt-hour (ct/kWh) was raised in 2008, while the levy more than doubled since 2004 (BMU 2007, 2008).

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* consumers to pay for a certain economy-wide electricity mix, in which the share of renewable fuels continually increases.

While this political decision triggers the market outcome in terms of a specific electricity mix associated with a specific levy, people must not necessarily approve this policy. The question arises to what extent the population consents on this financial obligation. Against this backdrop, this paper aims at assessing the maximal levy that can be charged for a specific electricity mix in Germany, such that a majority of people eligible to vote would approve the political commitment. We analyze in the retrospective for 2008 whether the policy maker have acted on behalf of their voters; we further consider two future green electricity scenarios – which are both in line with the national target of 30% green electricity – and

[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.

provide insights into the voter's preferences for reasons of political guidance.

Building on data from a large-scale survey among several thousand households in Germany, we trace peoples' willingness-to-pay (WTP) for specific mixes of fossil, renewable, and nuclear fuels in electricity generation. Using random parameter econometric techniques within a hedonic regression framework, we estimate household-specific WTP as a function of the electricity mix, and thereby capture various degrees of heterogeneity between the households. Using these results, we proceed with calculating people's WTP within the respectively considered situation, and juxtapose the WTP figures 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 eligible to vote 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 renewable fuels is also limited. Thus, finding the right balance between the charged levy and a sustainable electricity mix might become a challenging task.

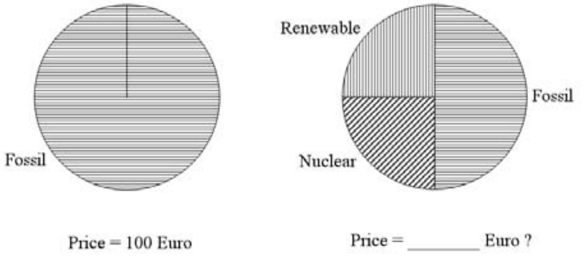
The remainder of the paper reads as follows. The following Section 2 describes the design of our survey, the survey instrument and the sample. Descriptives of respondents' WTP as well as regression results follow in Section 3. These results serve for investigating voters' preferences for two green policies 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. Along these lines, we postulate that a consumer's WTP is linked to the characteristics of the good via a bid

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?



function. We assume that an individual i evaluates the good electricity by its underlying fuel mix and specify the bid function:

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

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

We have acquired our data by surveying households from an online panel, for which the survey institute recruits the households in a complex multi-stage procedure and ensures that the panel is representative for the German population. A set of socio-economic and demographic background information is automatically stored within the system. 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.

Several formats have been suggested to elicit WTP in surveys, each possessing specific weaknesses and strengths (see Frew et al. 2003). Formats suggested in previous literatures include open-ended formats such as ours, close-ended formats, payment scale, and bidding/bargaining formats.[2] We have chosen an open-ended format to avoid ex-ante restriction of responses and anchoring effects: contracts were assigned no offer values and responses were allowed to vary in a broad range between €0 and €9,999. A potential drawback of such a format is its failure to provide subjects with a clue as to plausible values. Other approaches such as the closed-ended format give more guidance to the survey participants. The choice of the predetermined values, however, is a normative judgment provided by the researcher, and responses may be sensitive to the predetermined values. Moreover, since electricity is a good that respondents know from daily experience, we believe that ill-considered valuations are not a too large burden in our analysis. Another potential drawback of the open-ended format is the possible occurrence of protest bids in the data, meaning respondents that either give a zero value to a good that has actually a value or assign an obvious invalid high value to the good (Halstead et al. 1992). However, as our empirical analysis will show below, protest bids are not of importance in our data.

In the survey, each survey participant is presented with five hypothetical electricity contracts, differing in the fuel shares contributing to the 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. We lack information about the actual individual electricity consumption and the corresponding cost. To avoid people stating a monetary amount that is inflated by their individual electricity consumption, which would yield incomparable responses from households with different consumption, we provide people a mental anchor point by choosing a benchmark

[2] In case of the open-ended format, each subject reports her own WTP. Responses are unbounded and there is no predetermined offer value. In case of the payment scale format, all subjects chose a value from the same pre-specified and ordered list. In case of the closed-ended format, respondents are required to make an accept/reject choice at predetermined offer values. In case of bidding/bargaining formats, the researcher suggests WTP values that the respondents accept or reject.

Table 1: Pool of Electricity Contracts

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

contract with 100% fossil fuels, and normalize its price to 100 monetary units. Deviations in stated WTP from this benchmark can be interpreted as 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 alternatives. The grey-shaded area in Table 1 illustrates the set of contracts.[3] The ordering in which these five contracts are presented to the respondents may affect respondents' bids. For example, showing initially a contract with e.g. 25% renewables in the fuel mix followed by an evaluation task with 50% renewables may give rise to a specific WTP pattern. This is the so-called 'ordering effect' (Bateman and Langford 1997, Clark and Friesen 2008). Empirical evidence on the presence of ordering effects in contingent valuation studies is mixed (Boyle et al. 1993). To minimize ordering-related biases, we randomize the draws from the set of available contracts. Accordingly, each possible sequence of evaluation tasks that can be constructed from Table 1 has the same chance to been drawn, and the probability that the same sequence will occur twice is extremely low. Thus, even if respondents' later bids are influenced by the its initial bid, ordering effects should not play a role at the sample level.

[3]A stepwise variation of fuel shares has also been implemented in Menges et al. (2005).

Table 2: Sample Breakdown

		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 (€)		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

About 2,948 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 (on average: 4.7 assessments per household), and we end up with an unbalanced panel of 14,532 observations with about 1,000 responses for each hypothetical contract.

Sample characteristics are given in Table 2. About 79% of the sample households live in western Germany, which is conform with the regional distribution of the German population described by official census data. 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. Average age is about 50 years. The typical participating household has a disposable equivalent income of €1,550 per month, and consists on average of 1.83 adults and 0.45 children.[4]

[4] We chose the equivalent income as the income variable to make household incomes comparable across households of different size or structure. Equivalent income is computed by deflating the household's income by an index $I = 1 + 0.5 \times (\text{number of adults} - 1) + 0.3 \times \text{number of children}$, that takes into account the number of adults and children living in the household unit. The index is the so-called 'OECD modified equivalence scale'. Equivalent income is computed as Income/I.

3 Empirical Results

3.1 Descriptive Statistics

The upper panel of Figure 2 provides descriptive statistics for the WTP responses while in the lower panel boxplots illustrate the distributions of the responses for every evaluated contract. Both panels exhibit the same structure: The topmost row refers to a contract with a mix of 75 percent fossil fuels, zero percent nuclear fuels and 25 percent renewable fuels. In the three adjacent rows, the nuclear share is held constant while the renewable share is increased in 25 percent steps. In the rows five to eight (nine to eleven; twelve to thirteen), the nuclear share is held constant at 25 percent and, again, the renewable share is increased.

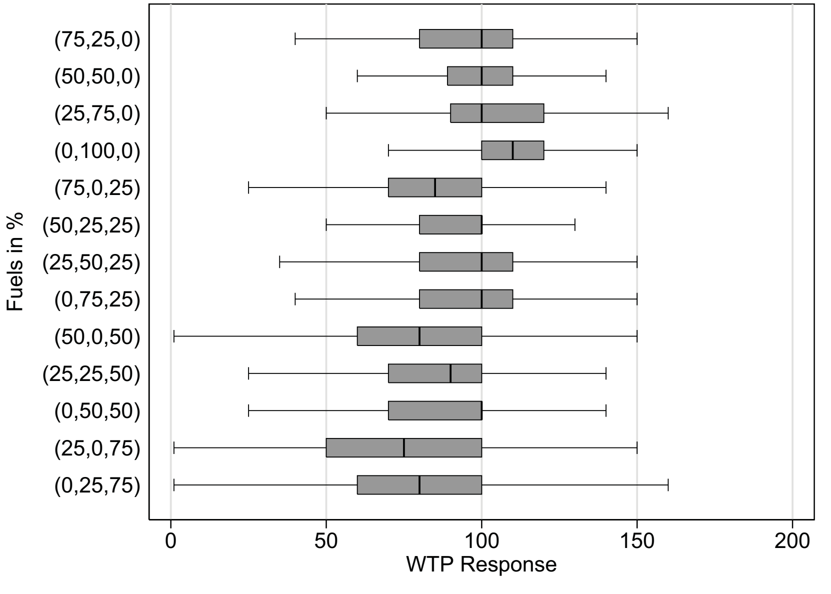
Figure 2 reveals two regularities. First, WTP tends to rise in the share of renewable fuels in the electricity mix. Take, for example, the rows nine to eleven, where fossil fuel is sequentially replaced by renewable fuel, keeping the nuclear share constant at 50 percent. Both the descriptive statistics and the boxplots depict that WTP rises in the share of green electricity, indicating a preference for green electricity generation. On the other hand, the figures in rows 1, 6, 10 and 13 suggest that the WTP tends to be decreasing in the nuclear share, indicating that nuclear fuels are perceived as an economic 'bad', lowering the utility of the typical consumer. 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 renewable fuels. In a like manner, holding the share of renewable fuels constant, the tests confirm a significant decrease in stated WTP as the nuclear share increases.

In our survey, we have chosen an open-ended format. Inherent in its nature is the problem that respondents may feel tempted to protest specific contracts being presented, meaning that respondents reject a specific electricity mix by

Figure 2: Outline of WTP Responses

Share in % Fossil Fuels	Share in % Renew-ables	Share in % Nuclear Power	No. of Observations	WTP Response in € Mean	WTP Response in € Std.Dev	WTP Response in € 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 €.



responding a WTP of '0'. However, Figure 2 reveals that the number of protest bids in our data is small. This can also bee seen from Figure A.1 in the Appendix, which illustrates the empirical distribution of WTP responses by means of contract-specific histograms. These histograms also convey another relevant piece of information. In the survey instructions, we explained the assessment problem to the respondents using two examples for which we have imbedded fictitious arbitrarily selected WTP statements of 70 and 180 Euro. These two numbers may serve as an anchor, so that respondents' bids may cluster around these values. The histograms in Figure A.1, however, do not indicate the presence of such an effect.

3.2 Econometric Analysis

3.2.1 Estimation Method

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:

$$\text{WTP}_{ij} = \alpha + \sum_k (\beta_k + u_{ik}) x_{jk} + \sum_l \delta_l z_{il} + v_i + \varepsilon_{ij}, \tag{2}$$

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.[5] An interaction term $Renewable \times Nuclear$

[5]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.

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. By controlling for the socioeconomic background of the households, we aim at assessing some of the preference heterogeneity among clusters of households with respect to the fuel mix. 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 second 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. $\boldsymbol{\delta} = \mathbf{0}$).

3.2.2 Econometric Results

The results from our three regression models are summarized in Table 3, reporting the results for model 1 in the first and the second column, for model 2 in columns three and four, and for model 3 in the remaining columns. The upper panel of Table 3 reflects the coefficient estimates and respective standard errors ($s.e.$). The middle panel reports the standard deviations for the random parameters in the respective models. The lower panel of Table 3 depicts likelihood-ratio statistics, clearly indicating that the random parameter specifications of model 1 provides a flexibility that boosts the model fit. In the following we will therefore concentrate the discussion on model 1.

The WTP is increasing in the share of renewable fuels, as suggested by the descriptives of the previous section. Compared to the benchmark contract with

Table 3: 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
Renewables	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
Renewables×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
Renewables	28.497^{**}	0.774				
Nuclear	22.356^{**}	0.373				
Renewables×Nuclear	33.677^{**}	5.418				

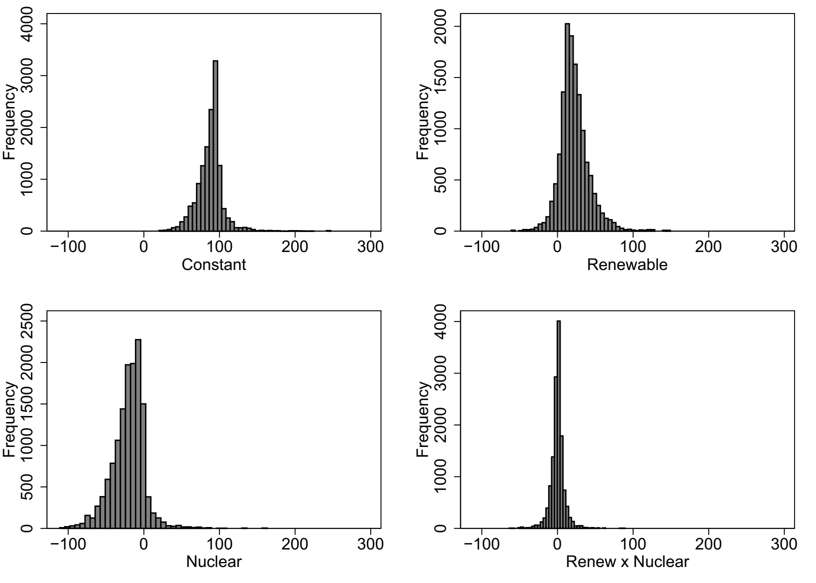
	Likelihood-Ratio Tests	
	Model 2 nested in Model 1	Model 3 nested in Model 2
parameter restrictions	3	3
$2 \times \Delta$Log-Likelihood	1366	20

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

pure fossil fuels, increasing the share of renewable fuels from zero to one by one – meaning switching from zero 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 3), indicating that the u_i vary substantially among individuals. In other words, we observe considerable preference heterogeneity concerning the assessment of the various fuels.

Turning to the personal characteristics vector $\boldsymbol{z}_i$, we find that larger house-

Figure 3: Empirical Coefficient Distributions for Model 1



holds and respondents living in the former East of Germany generally want to pay less, though both estimated coefficients lack statistical significance.[6] Finally, WTP is slightly rising in equivalent household income.[7]

Figure 3 provides histograms illustrating the empirical distributions of the respondent-specific intercepts and slopes. In sum, the figures reconfirm our previous conclusions of a positive marginal WTP for green electricity, and a negative marginal WTP for the nuclear fuel share. However, substantial differences in the individual slope coefficients pertaining to the renewable and fossil fuel shares exist. For instance, several individual slope coefficients for 'Nuclear' fall below a

[6] A preference divide between the two former parts of Germany has also been found in other areas. For example, Alesina and Fuchs-Schündeln (2007) find such an effect to be present in evaluations of public social policies that entail redistribution.

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

value of −60, compared to a grand mean of −20.101. The coefficient of 'Renewables' exhibits a similar variation.

A specific strength of the random parameter specification of model 1 is corroborated in the histograms for the interaction *Renewables* × *Nuclear*. The respective histogram shows a rather symmetrical empirical coefficient distribution with large tails, but 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

Renewable fuels accounted for some 15% in Germany's gross electricity generation in 2008, while about 23% came from nuclear fuels. With almost 60% the lion's share of Germany's electricity generation relies on fossil fuels, while the remaining 2% were generated using "other fuels" (BMWi 2010:19).[8] The German government aims at redesigning the energy system towards an economic, sustainable and secure energy supply. A German particularity is the nuclear phase-out on which the government and the electricity producer had agreed upon in 2002. While this agreement is still in force, there is a lively and ongoing discussion about a possible recurrence of nuclear energy in power generation.

Renewables shall become the most important fuels in the future electricity mix. The German government has committed to enhance the renewable share in domestic electricity generation to at least 30% in 2020. In order to assist the generation of green electricity, Germany provides a feed-in tariff regime. In

[8]These "other fuels" are non-renewable waste or large hydropower plants. These fuels 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. We hence add their share to the share of fossil fuels in the following analysis.

2008, the total subsidy payments amount to 8.7 bn Euros and are expected to reach 12.7 bn Euros in 2010. Selling the generated green electricity at the market yields sales revenues but since the feed-in tariff exceeds the market price by a large amount (depending on the renewable technology),[9] a difference remains for which every household in Germany is committed to pay a levy. In 2008, a levy of 1.1 ct per consumed kWh was raised, while the average consumer electricity price amounts to 21.43 ct/kWh (BMU 2008, BMWi 2009:35-37). Hence, the consumer price "net" of the levy amounts to 20.33 ct/kWh. Between 2008 and 2010 the total subsidy spending rose by almost 46%, and the levy charged in 2010 amounts to 2.047 ct/kWh.

4.1 Assessment and Scenario Set-Up

Whether a household favors one fuel mix – associated with a respective levy – relative to another mix (and another levy), depends on the respectively achieved consumer surplus. Relative changes in consumer surpluses (ΔCS) can be captured by

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

where $s \in \{0, 15, 30a, 30b\}$ denotes scenarios linked to a specific fuel mix in the electricity generation (see below). 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), meaning that the relative rise in the household's individual WTP outperforms the relative price increase due to the levy. By requiring $\Delta CS_i^s \geq 0$

[9] For further details see the respective German act on the priority treatment of renewable energies ("Erneuerbare Energien Gesetz").

Table 4: Electricity Mix Scenarios

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

and rearranging Equation (3), we obtain an upper bound for the levy

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

that might be charged, such that household i still prefers $s \neq 0$ to $s = 0$.

Details of the four different scenarios s are depicted in Table 4. The scenario $s = 15$ refers to the "status-quo" fuel mix of 2008 in the electricity generation, exhibiting a share of 15% renewable fuels 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). The scenario $s = 0$ illustrates a hypothetical situation with zero renewable fuels in the electricity mix. The 15% renewables of the status-quo scenario are equally assigned to the shares of fossil and nuclear fuels. Because no levy would be charged in such a situation, the consumer price p^0 equals the "net" price of 20.33 ct/kWh. By comparing scenario $s = 15$ to $s = 0$ – meaning that we analyze what fraction of people exhibits a positive expression in Equation (3) – we might provide an answer to whether today's policy is supported by a majority of people eligible to vote.

The two hypothetical scenarios $30a$ and $30b$ both refer to the commitment of the German government to increase the share of renewable fuels in the electricity generation to 30% until 2020. While we increase the renewable-fuel share by 15 percent points in scenario $30a$ (compared to the "status-quo") at equal expense of the shares from the other two fuels, fossil and nuclear, the rise in the renewable share in scenario $30b$ causes a 1:1 reduction of the nuclear share. Against this backdrop, we quantify the maximal levy levels chargeable, such that still a majority of people supports the policy.

Our econometric results render the preference structure for every single sample household, providing the information on whether household i maintains a positive ΔCS_i^s in Equation (3). In order to derive representative population statistics, we weight each sample household by the household's frequency weight. The frequency weights extrapolate the sample households in order to best fit the German micro-census statistics, and consider three household characteristics for extrapolation: monthly household net income, household size, and region of residence (Germany's 16 federal states).[10] In a second step, we multiply every (weighted) household by its number of adults (age 18 and older) and end up with the number of potential voters in the household. In this regard, it is a minor assumption that we assume identical preferences for all adult persons in a sampled household.[11]

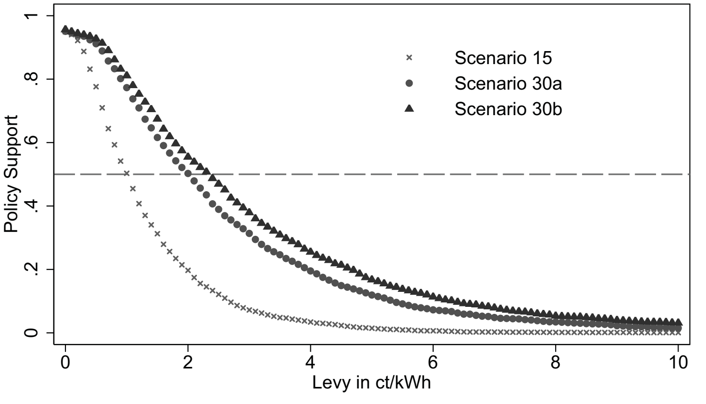
4.2 Scenario Outcomes

Using the preference structure inferred from model 1, Figure 4 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 accepted by the majority of people. For instance, the downward sloping line pertaining to scenario $s = 15$ shows a rapidly falling acceptance of subsidizing

[10] The frequency weights are derived using the software 'Adjust' (for further information see Merz (1994)), which relies on an entropy based minimum information loss principle. The software incorporates a numerical solution by means of a modified Newton-Raphson procedure with a global exponential approximation.

[11] As a referee noted, there is a difference between a registered and a typical voter. We lack information about the voting behavior of our sample households. Therefore our results reflect the preferences in the population eligible to vote and not the actual outcome of an election.

Figure 4: Policy Support for Levy Charge



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, only 47% of the voters would have also endorsed the actual charged levy of 1.1 ct/kwh in 2008, meaning that the policy barely had the support of the majority of people. Similar findings are reported in Batley et al. (2001) for UK and Bollino (2009) for Italy, whose results demonstrate that consumer's 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.

The dotted and the triangular line refer to the scenarios $s = 30a$ and $s = 30b$, respectively. Both scenarios enlarge the share of renewable fuels in the electricity generation and 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 renewable fuels are extended only 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 renewable fuels reduces the contribution of nuclear and fossil fuels, 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 and challenging. On the one hand, the German population strongly dislikes nuclear fuels in the electricity generation. On the other hand, substituting nuclear by renewable fuels is only a possible option if the associated levy won't increase too much, since the peoples' acceptance of such a policy has its (financial) limits. The challenging task is to find a balance between greening the electricity mix and the verification not to escalate the subsidy spending. Germany's feed-in-tariff promotes various renewable fuels but lacks a mechanism to limit the public spending. Consequently, already in 2010 a levy 2.047 ct/kWh will be charged – associated with an estimated renewable fuel share of about 18%.

5 Possible Limitations of Stated-Preferences Approaches

Stated preference approaches have the central advantage that the survey question can be designed in a way that it directly addresses the research question, even if the market design prevents inference from revealed preference data. In our case, for instance, both the levy and the electricity mix are triggered by a political decision and therefore given to the consumer. Consequently, data on the revealed demand of green electricity do not reflect consumer preferences, meaning that a revealed preference approach is not feasible.

Inherent in the nature of surveys, however, 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).[12] In our case, for example, not revealing the true WTP has no immediate negative consequences for respondents as contracts provided had been hypothetical, and stated WTP levels had no financial consequences. In the absence of opportunity costs, however, "customers can have a tendency to de-emphasize price, since they do not actually have to pay the price" (Goett et al. 2000:27). The difference between stated and revealed values is referred to as "hypothetical bias."

Carson et al. (1996) review more than 600 studies, and demonstrate that stated preference tasks typically average about 90% of the corresponding revealed valuation, hence, slightly underestimate the benchmark of revealed valuation. Murphy et al. (2005) conduct an econometric meta-analysis of hypothetical bias, and found evidence of a positive but small bias. They conclude that hypothetical bias "may not be as significant a problem in stated preference analyses as is often thought" (Murphy et al. 2005:323). Along these lines, studies from the recreational choice literature have often found no statistically significant differences between demand functions derived from revealed and hypothetical data.[13] With respect to green electricity, Champ and Bishop (2001) and Poe et al. (2002) provide evidence that a hypothetical character of the evaluation task yields a pos-

[12] 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).

[13] See Alberini et al. (2007) for a review of related literature; a more pessimistic view is expressed in Harrison and Rutström (2008).

itive bias, meaning that hypothetical values overstate actual (revealed) values. Though we cannot ensure that our WTP estimates overstate the " true" values, such a pattern would even strengthen our results: if our respondents would actually pay less than stated, the public support for any level of the charged levy would decrease. Then, our results should be conceived as an upper bound for the underlying population preferences.

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. More precisely, each respondent was presented five attributes of electricity contracts, including the *absence of nuclear fuels* in electricity generation and electricity generation using *renewable fuels.* The participants were asked to rank these attributes with respect to desirability, with the largest rank indicating the most important attribute (see the Appendix for further details). Preferences remain stable if responses in both survey parts are consistent, meaning e.g. that a strong preference for green fuels is associated with a high individual regression coefficient, and also a high rank for the attribute "electricity generated from renewable fuels". A consistent representation of preference for renewable fuels would therefore require 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 Spearman rank correlation coefficient between the individual parameter for the share of green electricity and the rank for the contract attribute "electricity generation from renewable fuels" 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 $p < 0.001$.

6 Conclusion

The German government has committed to increase the share of renewable fuels in electricity generation to at least 30% until 2020, and provides a feed-in tariff 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 the cost of the subsidy scheme is shifted to the consumer due to a political decision, it is an open question whether the policy maker act on behalf of 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 green electricity commitment for 2020.

In a first step, we use a large-scale household survey to elicit peoples' preferences for different fuels in the electricity generation. We capture preference heterogeneity among the respondents by applying random parameter regression techniques within a hedonic approach. Our results suggest that the majority of our respondents has a positive WTP for renewable, and a negative WTP for nuclear fuels, both characterized by a substantial variability.

Using these WTP estimates we gauge in a second step the maximal chargeable levy for a specific fuel mix, such that a majority of people would approve that policy. We evaluate three different scenarios, one of which consists of the actual fuel mix of 2008. We find that the actual charged levy of 1.1 ct/kWh exceeds the WTP for slightly more than 50% of the population, meaning that the actual policy barely has the support of the majority of voters. We further determine the maximal chargeable levy for two hypothetical future fuel mixes, both characterized by a share of 30% renewables but different shares of nuclear fuels. According to our results, the charged levy should not exceed 2.03 ct/kWh in order to ensure the approval of the voters' majority. If the renewable fuels predominantly substitute nuclear fuels, the maximum chargeable levy increases slightly to 2.37 ct/kWh.

An increase of the share of renewable fuels in electricity generation thus expands the chargeable levy. However, our results also stress that the possible financial scope to support renewable fuels is basically exhausted. In particular, a levy of 2.047 ct/kWh will be charged already in 2010 – an amount close to the maximum chargeable levy of 2.37 ct/kWh – while the estimated renewable share of 2010 amount only to about 18%. As a consequence, energy policy must amplify its efforts in making the future promotion of green electricity less cost intensive. While the current feed-in tariff fosters many generation techniques – even if they are far from any price competitive level – a reasonable policy redesign might initiate some extent of competition between renewable generation techniques. A possible approach would encompass, for instance, a bidding scheme, meaning the introduction of an upper bound for the annually subsidy spending, and the supported generation techniques have to compete for these scare financial resources.

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Appendix

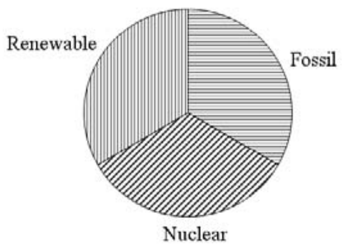
Survey Questionnaire

Eliciting Respondent's WTP

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

fossil fuels nuclear fuels renewable fuels.

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:

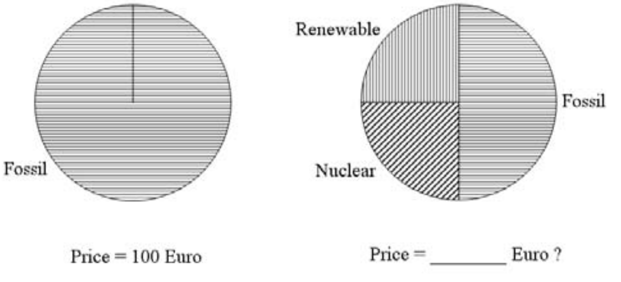


In the following, we will show you several electricity contracts, which only differ in the composition as to whether the three fuels (fossil, renewable, nuclear) contribute to its generation. We would like to ask you about how much you would be willing-to-pay for contracting the respective offer. As 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?

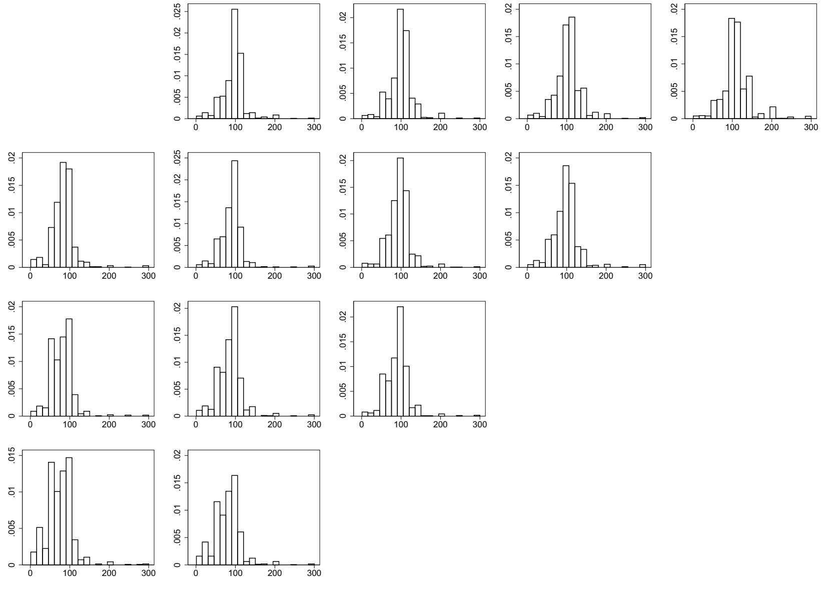
- reasonable electricity price
- nuclear-free electricity generation
- electricity generated from renewable fuels such as water, wind, and photovoltaics
- price guarantee
- short term of notice

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.]

Contract-specific Distributions of Responses

Figure A.1: Histograms of willingness-to-pay



Note. Figure has the same structure as Table 1. From left to right: Share of renewable fuels rises from 0 percent to 100 percent (25 percentage steps). From top to bottom: Share of nuclear fuels rises from 0 percent to 75 percent (25 percentage steps). The abscissa gives the willingness-to-pay in Euro. The ordinate gives the density.