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IMPACT OF BELIEFS ABOUT NEGATIVE EFFECTS OF WIND TURBINES ON PREFERENCE HETEROGENEITY REGARDING RENEWABLE ENERGY DEVELOPMENT IN POLAND

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Impact of beliefs about negative effects of wind turbines on preference heterogeneity regarding renewable energy development in Poland

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Abstract: We investigate individuals' preferences for renewable energy development in Poland. Our main objective is to examine whether preferences for avoiding externalities from renewable energy development near respondents' place of residence are influenced by their personal beliefs about the negative effects of wind turbine activity. We focus on attitudes towards wind power because it has had the most dynamic development among all renewable energy sources in Poland. To elicit values on avoiding renewable energy externalities, we use a choice experiment (CE) approach. To conduct our analysis we applied a theoretically robust econometric approach, the hybrid mixed logit model. From our analysis of data from a large sample of the Polish population, we find that beliefs about wind turbine have distinct negative effects on respondents' preferences concerning renewable energy development. Respondents who generally have an opinion about potential wind turbine effects would like to have input on renewable energy development in their neighbourhood. Latent beliefs that wind power is not harmful enhance respondents' preferences for implementing a wind energy project and enhance preferences against solar power development. These beliefs appears to be significantly correlated with respondents' marginal utility of money.

Keywords: beliefs about negative effects, choice experiment, preference heterogeneity, renewable energy externalities, stated preferences

JEL codes: D12, H41, Q48, Q51

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1. Introduction

Although renewable energy production contributes to the decrease of greenhouse gas emissions, there are also negative effects associated with it. These effects may generate strong opposition within the general public against developing production of renewable energy sources. From scientific and policy points of view, understanding the nature of this opposition is important. The opposition can be based on well-reasoned judgements or on beliefs without scientific bases, such as the generation of wind power having negative impacts on human health. A better understanding of which negative effects are the most important for the general public may improve the information base for decision-makers to design renewable energy development in more effective and socially acceptable ways.

Public acceptance of renewable energy technologies has been increasingly investigated in the literature. Non-market valuation studies have often been used to estimate the value of renewable energy construction characteristics (e.g., see Kuondouri et al. 2009; Dimitropoulos and Kontolen 2009; Rijnsoever et al. 2015) or to investigate preferences about locating renewable energy production sites (REPS) (e.g., see Bergmann et al. 2006; Ladenburg and Dubgaard 2007; Ek and Persson 2014). Most of this analysis pertains to wind power, which is the second most important source of renewable energy generation worldwide and is expected to increase significantly in the near future.

Wind power development is associated with various negative effects such as undesirable appearance, noise pollution, and adverse impacts on wildlife, particularly birds. Based on their meta-analysis study of the non-market valuation literature on wind power production impacts, Mattmann et al. (2016) conclude that the visual aspects of wind turbines are the most important factor affecting individuals' welfare. Jones (2009), Mroczek and Kurpas (2014), and Mariel et al. (2015), among others, suggest a link between concerns about wind farms' negative consequences on birds and the social acceptance of these installations. In their qualitative study, Delicado et al. (2016) confirm that people perceive noise as one of the most important negative effects of wind turbines, but only a few of their respondents linked noise pollution to their health status. Results from Mroczek et al. (2015) suggest that psychological factors are important in evaluating the harmful effects of wind farms on human health. The authors investigated Health-Related Quality of Life index ratings among respondents living in the vicinity of windmills. Respondents who expected that their financial situation would improve through wind farm development rated their health status as better.

In this study, we investigate individuals' preferences for renewable energy development in Poland. Our main objective is to examine whether preferences for avoiding externalities from renewable energy development in the vicinity of respondents' place of residence are influenced by personal beliefs about the negative effects of wind turbines. We focus on attitudes towards wind power because it has had the most dynamic development among all renewable energy sources in Poland (almost 70-fold increase) in the last decade (PEWA 2017). Local populations have staged numerous protests against the expansion of wind farms in recent years, arguing that wind power has negative effects on human health, the appearance of the landscape, the quality of life in the vicinity of wind turbines, and the environment.

To elicit values of avoiding renewable energy externalities, we use a choice experiment (CE) approach. The CE is a non-market valuation method based on the consumer theory of Lancaster (1966) which posits that any good can be described in terms of its attributes. When people make choices between different bundles of attributes, they express their preferences. Subsequently, based on the observed choices, it is possible to infer which attributes significantly influenced the choices and to derive a marginal rate of substitution between those attributes. If one of the attributes is a price or a cost, then the marginal rate of substitution between a nonmonetary and a monetary attribute provides a marginal willingness to pay (WTP) for the nonmonetary attribute. To the best of our knowledge, no studies have investigated the impact of individuals' beliefs about negative wind turbines effects on their preferences regarding renewable energy development.

To carry out our analysis, we apply a theoretically robust econometric approach, the hybrid mixed logit (HMXL) model (Ben-Akiva et al. 2002), which allows examining individuals' preferences regarding renewable energy development within a random utility framework. HMXL is a structural model that incorporates a choice component from a CE and a non-choice component that provides measurement of latent variables. Beliefs, which are often directly measured in studies, are actually unobservable and can only be approximated through various indicators. The HMXL approach avoids the problem of measurement error, which may be present when stated measures are directly included in the choice model as explanatory variables (e.g., see Thomson and Kempton 2018).

In our study latent variables are based on self-reported beliefs about different negative effects of wind turbines. In the study, respondents were asked to indicate the strength of their beliefs about the negative effects on a Likert scale, but they also had the opportunity to indicate a lack of opinion about the issue. Our applied methodology allows us to separately investigate

being willing to reveal/having opinions about the negative effects of wind turbines and believing in them.

The remaining article is structured as follows. The next section briefly describes energy production in Poland. In section 3, the applied methodology is described. Section 4 elaborates the survey structure, the design, and data collection, while Section 5 reports the results. Section 6 discusses the results and offers some recommendations for energy policy.

2. Background information

Electricity in Poland is mostly generated from coal. In 2015 conventional power plants, based on hard coal and lignite, generated over 83% of electricity produced in the country, whereas renewable resources accounted for 13% of electricity production (GUS 2017). Among these renewable energy sources, the most important was wind. In 2015, wind turbines accounted for 48% of renewable energy production in Poland (GUS 2017). In terms of wind capacity installed, Poland is in seventh place among EU countries. In terms of the dynamics of wind energy development, with a total of 1145 MW in new onshore capacity installed, Poland was second in Europe after Germany in 2015 (PWEA 2016). Energy production from biomass accounted for 40% of renewable energy production, and its share has been decreasing in recent years. Compared with the previously mentioned energy sources, solar energy production in Poland is negligible. At the end of 2015, it accounted for only 0.3% of energy production from REPS.

Table 1: Renewable energy installation in Poland at the end of 2015

Type of installation	Quantity	Power (MW)
Wind power-stations	1003	4254
Biomass power-stations	36	1033
Photovoltaic power-stations	225	51

Source: Energy Regulatory Office (as of December 2015).

The expansion of wind farms has caused numerous protests by local populations in recent years, leading to the creation of several associations opposing the development of wind energy in Poland. The controversies most frequently pertain to the impact that wind turbines have on human health and the environment. Although numerous protests occurred, they did not attract a large number of people on a national scale.

3. Survey

3.1. Survey structure and data collection

The survey used in the current study had five main sections. The first section provided respondents with general information about wind, solar, and biomass energy and collected data on respondents' exposure to REPS and their general attitude towards them. Pictures and graphical illustration supported the text. Section 2 presented the choice tasks. For each task, respondents were asked to choose their preferred option from among several alternatives regarding the development of REPS within 10 km of their place of residence. The choice sets, which were presented in a randomized order, contained both increases and decreases in the household's monthly energy bill, according to the experimental design (see Section 4.2). In section 3, individuals' financial risk preferences were elicited.¹ Section 4 contained attitudinal statements, including those concerning respondents' beliefs about the negative effects of wind turbines. Socio-demographic variables were requested in the last section.

The survey took place in January 2016. The sample was representative of the Polish population in terms of age, gender, community size, and geographical location. In total, 800 face-to-face interviews were conducted using the computer-assisted personal interviewing (CAPI) system by a professional polling agency. The questionnaire was tested for understandability with students from the Faculty of Economic Sciences at the University of Warsaw and people from the general public. Additionally, the discrete choice part of the survey was tested earlier in a survey in Germany (see Oehlmann und Meyerhoff 2016). The final sample used for analysis consisted of 744 respondents, after exclusion of respondents who chose the same column in all presented choice tasks both in the CE and in the risk preferences elicitation part. Table 2 reports the basic socio-demographics characteristic of the analysed sample.

¹ The influence of risk preferences on respondents' WTP for the renewable energy development in Poland is a subject of the different study (see Bartczak et al. 2017).

Table 2: Descriptive statistics of the sample characteristics

	Share	Mean	Median	Min	Max
Women	53%				
Age		49	50	19	86
Education					
- Primary	37%				
- Secondary	35%				
- High	28%				
Net monthly individual income in zł*		1965	1500	500	15000

Note: * Number of respondents, N = 744; 13% of those respondents did not reveal their income. Nominal exchange rate in January 2016: 1 EUR = 4.36 PLN.

3.2. Attributes and experimental design

The CE was introduced as follows:

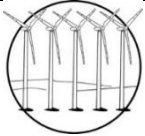
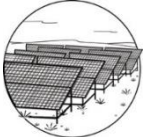
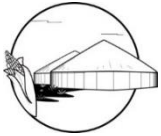
Renewable energies as well as the electricity grid will be expanded in Poland. In the following choice sets, you can choose among different alternatives for renewable energy development. Please think of REPs being built within 10 km of your place of residence. If you live in a large city, please consider the surrounding area of your city. You can choose among the following alternatives:

- *Electricity from wind energy (wind farms),*
- *Electricity from solar energy (solar fields),*
- *Electricity from biomass (biogas power stations),*
- *I do not care about the type of renewable energy generation (you do not have any opinion on the type of renewable energy which will be developed within 10 km of your place of residence).*

Each choice set comprised four labelled alternatives. The first three referred to the development of wind, solar, and biomass energy sites within 10 km of a respondent's place of residence. The definitions and pictograms used to describe renewable energy sources are presented in Table 2. The fourth alternative (future status quo, FSQ) indicated that a respondent did not care about the renewable energy extension in their neighbourhood and the attribute

levels presented in this option were acceptable to them (see also Figure 1). The CE design was adopted from the project EnergyEFFAR.²

Table 3: Renewable energy: definitions and pictograms

Type	Definition	Pictogram
Wind energy	Electricity generation with single wind turbines and wind farms exclusively onshore	
Solar energy	Electricity generation with photovoltaic system in the open landscape	
Biomass	Electricity generation with biogas and biomass from the cultivation of, for example, corn	

In the CE we used five attributes related to renewable energy externalities and a monetary attribute. Non-monetary attributes were related to the minimum distance of REFS to the edge of a respondent's town/place of residence, the size and number of REFS, and the 'protection of landscape view', which pertained to the share of the landscape in the 10 km surroundings which will not be used for renewable energy development in the future. Additionally one attribute related to transition lines (whether the new lines should be built overhead or underground). The monetary attribute took the form of a surcharge or a rebate on respondents' current energy bills. As Aravena et al. (2014) reported, the effect on the electricity price paid by consumers due to the introduction of new sources of energy generation or the reduction in the probability of future power outages is often uncertain. In the CE we used both increases and decreases in the electricity bills to depict the uncertainty about the effect of new sources of energy generation on the current price level. The FSQ had a cost of zero. Table 4 shows the full list of attributes and their levels used in the experimental design.

² Project "Efficient and fair allocation of renewable energy production at the national level" funded by the Federal Ministry of Education and Research in Germany.

Table 4: CE attributes and levels

Attribute	Attribute label	Attribute level
Minimum distance to residential areas	Distance	300 m, 600 m, 900 m (FSQ), 1600 m, 2500 m
Size of renewable energy production sites	REPS size	Small, medium (FSQ), large*
Number of renewable energy production sites	REPS number	1, 2, 3 (FSQ), 4, 5
Share of landscape not used for renewable energy expansion	Landscape	10%, 20%, 30% (FSQ), 40%, 50%
High-voltage transmission lines	HVTL	Overhead (FSQ), underground
Monthly surcharge or rebate to energy bill (annually) in EUR	Cost	-10 (-120), -5(-60), 0 (FSQ), +2(24), +7 (84), +14(168), +23(276)

* For the wind energy alternative, small was defined as 5–10 turbines, medium as 18–25 turbines, and large as 35–50 turbines. In the case of the solar energy alternative, 0.5–5 hectares, 20–40 hectares, and 60–100 hectares indicated small, medium, and large, respectively. For the biomass energy alternative, small meant 1–3 fermentation tanks; medium, 5–8 fermentation tanks; and large, 15–25 fermentation tanks.

The choice sets were created using a Bayesian efficient design applying the C-error optimization criterion (Scarpa and Rose 2008). The final design comprised 24 choice sets that were blocked into four subsets of each six sets. The order of choice sets was randomized as was the order of the first three labelled alternatives. We ensured that each choice set and each alternative were presented in every position a comparable number of times. In each choice set, respondents were asked to choose which alternative they would prefer within a 10 km radius of their place of residence. Figure 1 shows an example choice set.

Figure 1: Example of a choice set

	Electricity from wind	Electricity from biomass	Electricity from solar	“Do not care”
Minimum distance to residential areas	600 m	2500 m	300 m	900 m
Size of renewable energy production sites	large (35–50 turbines)	large (15–25 fermentation tanks)	small (0.5–5 hectares)	medium
Number of renewable energy production sites	4	5	5	3
Share of landscape not used for renewable energy expansion	20%	50%	10%	30%
High-voltage transmission lines	underground	underground	overhead	overhead
Monthly surcharge or rebate to energy bill (annually)	+14 EUR (+168 EUR)	–5 EUR (–60 EUR)	+14 EUR (+ 168 EUR)	0 EUR
I prefer	☐	☐	☐	☐

3.3. Beliefs about negative effects of wind turbines

We collected respondents’ beliefs about negative effects of wind turbine activity in follow-up questions. We asked them to express their level of agreement or disagreement with four statements referring to different potential negative wind turbines effects:

- *Wind turbine activity is harmful to human health.,*
- *Wind turbine activity is burdensome for local residents.*
- *Wind turbines destroy landscape.*
- *Wind turbine activity is harmful to animals and/or cultivation.*

These statements were chosen based on results from the in-depth interviews with a selected number of people. In the main survey, respondents were asked to assess each statement on a 4-point Likert scale that included responses: ‘I definitely disagree’, ‘I disagree’, ‘I agree’ and ‘I definitely agree’. Responses were coded from 1 to 4, with higher numbers corresponding to greater agreement with the statement. Respondents could declare that they did not have an opinion, but this option was not shown in the answer scale. These responses were coded by interviewers separately. According to Willis et al. (1994) and Kroh (2006), for example, ‘I don’t

know' can be considered valid information about respondents' indecision. Respondents who give this answer more frequently might be less informed or aware of the object under study (e.g., see Faulkenberry and Mason 1978; Dolnicar and Rossiter 2009) or less interested in the topic (Krosnick 2002). Additionally, as Manisera and Zuccolotto (2014) pointed out, 'I don't know' choices can arise from item difficulty/complexity. We did not present a non-opinion option in the answer scale to avoid discouraging some respondents from doing the cognitive work necessary to report the true opinions that they do hold (e.g., see Krosnik et al. 2002; Willis 2008).

4. Methodology

To analyse our data we employ a hybrid mixed logit model in order to incorporate individuals' attitudes regarding wind power external effects into a random utility framework. Hybrid choice models (HCMs) are very flexible tools that provide a link between behavioural sciences (e.g., psychology) and fields based on estimation such as engineering and economics (Ben-Akiva et al. 2002). Although the initial formulation of the model involved a more general class of the models, the most widely used specification is the one connecting a choice model, such as mixed logit (Revelt and Train 1998), with the Multiple Indicators and Multiple Causes model (Jöreskog and Goldberger 1975).³ This specification uses latent variables to simultaneously explain individuals' choices and individuals' answers to attitudinal questions, usually measured on a Likert scale. Most of the applications of this framework to date appear in the transportation literature (e.g., Johansson et al. 2006; Daly et al. 2012; Daziano and Bolduc 2013). Applications of HCMs in the environmental literature include valuation of water quality improvements (Hess and Beharry-Borg 2012) and analyses of preferences for flood risk policies (Dekker et al. 2012) and land management (Mariel et al., 2015)). Most relevant for this study is work by Mariel et al. (2015) who incorporate a pro-wind power attitude into choice models to explain individuals' preferences for characteristics of wind farms. Their results indicate that preference heterogeneity is indeed partly driven by individuals' attitudes. As estimation of HCMs is computationally intensive and they can be reduced to simpler discrete choice models, it is debated whether the gains from those models justify the increased effort (Mariel and Meyerhoff 2016). Vij and Walker (2016) analyse the possible advantages of employing a hybrid framework and provided general criteria for assessing whether its use is justified.

³ These are frequently referred to as Integrated Choice Latent Variables models.

In the current setting, we use HMXL to decompose preference heterogeneity for renewable energy development. Specifically, we are interested in how much preferences are driven by individuals' attitudes and beliefs about external effects generated by wind energy.⁴ This topic would be hard to investigate without the HCM framework as the alternative would be to directly incorporate answers to the attitudinal questions into the model. That approach would likely cause a measurement bias issue as answers to those questions are instead functions of real attitudes and not their direct measures. The issue is avoided in HMXL by directly incorporating measurement error into the model (Budziński and Czajkowski, 2017). In addition, in many cases there are numerous indicators describing one psychological factor which can lead to a large number of estimable parameters in the model, collinearity, and difficulty with the interpretation of results; an HCM avoids these issues. HMXL used in this study consists of two parts: a discrete choice model and measurement equations.⁵

4.1. Discrete choice model

The theoretical foundation for the discrete choice model is random utility theory, which assumes that the utility a person derives depends on observed characteristics and unobserved idiosyncrasies, represented by a stochastic component (McFadden, 1974). As a result, individual i 's utility resulting from choosing alternative j in choice set t can be expressed as

$$V_{ijt} = \beta_i \mathbf{X}_{ijt} + \varepsilon_{ijt}, \quad (1)$$

where $\mathbf{X}_{ijt}$ is a vector of attributes, β_i is a vector of individual-specific parameters, and ε_{ijt} is a stochastic component allowing for factors not observed by the econometrician to affect individuals' utility and choices.

We assume that heterogeneity of preferences, described by the distribution of individual-specific parameters, β_i , depends on latent variables, which correspond to individuals' attitudes. The functional form of this dependence may vary due to distributional assumptions. If an individual's parameter for the k -th attribute is assumed to be normally distributed, it will be specified as follows:

$$\beta_{ik} = \alpha_{1k} LV_{1i} + \alpha_{2k} LV_{2i} + \beta_{ik}^*, \quad (2)$$

whereas if it is assumed to be log-normally distributed, it would be

⁴ We use only wind energy as we consider it to be the most familiar renewable energy type in Poland, and, therefore, individuals are more likely to have well-formed attitudes towards it.

⁵ Most HCMs have a third part, structural equations, in which latent variables are explained by socio-demographic characteristics. We did not include it here as most variables were not highly significant, and it did not change obtained results and inference.

$$\beta_{ik} = \exp(\alpha_{1k}LV_{1i} + \alpha_{2k}LV_{2i} + \beta_{ik}^*). \quad (3)$$

In both cases β_{ik}^* denotes the unexplained part of heterogeneity distributed normally with mean and standard deviation to be estimated, and LV_{1i} and LV_{2i} denote latent variables which are assumed to follow normal distribution with zero mean and unit standard deviation.⁶ As a result, the conditional probability of individual i 's choices, $\mathbf{y}_i$, is given by

$$P(\mathbf{y}_i | \beta_i^*, LV_{1i}, LV_{2i}) = \prod_{t=1}^T \sum_j y_{ijt} \frac{\exp(\beta_i \mathbf{X}_{ijt})}{\sum_l \exp(\beta_i \mathbf{X}_{ilt})}. \quad (4)$$

4.2. Measurement equations

One of the key purposes for including latent variables in the choice model is that they describe various psychological factors. These factors usually cannot be measured in a direct way, unlike other individual characteristics, such as age and gender. Instead, a researcher must use various attitudinal questions in a survey, the responses to which could be expected to be determined by the latent variables.

The model choice for the measurement equations depends on the particular application.⁷ In this study we included responses to four questions regarding the potential negative effects of wind turbines, which were measured on a 4-point Likert scale. Respondents also had the opportunity to state 'I don't know', if they did not want to answer a particular question. Therefore, each measurement equation is modelled as a two-step process. Consider l -th measurement equation and denote by K_{il} a variable which takes one if an individual chooses the 'I don't know' option, and zero otherwise. We model it with a binary probit model:

$$P(K_{il} | LV_{1i}, LV_{2i}) = K_{il} \Phi(\lambda_{1l} + \lambda_{2l}LV_{1i} + \lambda_{3l}LV_{2i}) + (1 - K_{il})(1 - \Phi(\lambda_{1l} + \lambda_{2l}LV_{1i} + \lambda_{3l}LV_{2i})), \quad (5)$$

where $\Phi(\cdot)$ denotes cumulative distribution function of normal distribution. Then, if $K_{il} = 0$, we denote an individual's answer to the l -th attitudinal question as I_{il} , which we then model by using ordered probit:

$$P(I_{il} | LV_{1i}, LV_{2i}) = \sum_{k=1}^4 \mathbf{1}\{I_{il} = k\} (\Phi(\delta_{kl} - \gamma_{1l}LV_{1i} - \gamma_{2l}LV_{2i}) - \Phi(\delta_{k-1l} - \gamma_{1l}LV_{1i} - \gamma_{2l}LV_{2i})), \quad (6)$$

⁶ Standard deviation is normalized for the identification (Raveau et al. 2012).

⁷ Many early hybrid choice model applications used a simple, linear regression even in cases where the dependent variable was clearly ordered (Daly et al., 2012).

where $\delta_{1l} < \delta_{2l} < \dots < \delta_{4l}$, are thresholds to be estimated⁸ and $\mathbf{1}\{\cdot\}$ denotes an indicator function which is equal to one if the condition in parentheses is fulfilled and zero otherwise. The probability of an answer that individual gave to the l -th attitudinal question is then given by

$$P(I_{il}, K_{il} | LV_{1i}, LV_{2i}) = (1 - K_{il}) P(I_{il} | LV_{1i}, LV_{2i}) P(K_{il} | LV_{1i}, LV_{2i}) + K_{il} P(K_{il} | LV_{1i}, LV_{2i}). \quad (7)$$

Finally, after combining equations (4) and (7) we obtain the full-information likelihood function for the HMXL model:

$$L_i = \int P(\mathbf{y}_i | \beta_i^*, LV_{1i}, LV_{2i}) \left[\prod_l P(I_{il}, K_{il} | LV_{1i}, LV_{2i}) \right] \times \\ \times f(\beta_i^*, LV_{1i}, LV_{2i}) d(\beta_i^*, LV_{1i}, LV_{2i}). \quad (8)$$

As random disturbances β_i^* , as well as latent variables are not directly observed; they must be integrated out of the conditional likelihood, with $f(\beta_i^*, LV_{1i}, LV_{2i})$ being a density function. This multidimensional integral can be approximated using a simulated maximum likelihood approach – we use 2000 Sobol draws with random linear scramble and random digital shift to make approximation more precise (Czajkowski and Budziński, 2015). As can be seen, we use one-step estimation. This approach has two main advantages over the two-step method; first, it is more efficient and, second, it allows for identification of more flexible specifications as it has more degrees of freedom.

5. Results

5.1. Descriptive statistics

The results show that the majority (88%) of respondents support the development of renewable energy in Poland, while a notable minority advocate for conventional energy. Collected information regarding respondents' experience with REPS indicates that 91% encountered wind turbines, whereas 33% have wind energy sites within 10 km of their place of residence.

In general, beliefs about the negative effects of wind turbine activity were not deeply rooted among the respondents. The majority of respondents did not agree with statements that wind turbine activity is harmful to human health, destroy landscape, or can negatively affect the environment (see Table 5). For the analysed sample, the biggest disadvantage of wind turbine activity was that windmills, in respondents' opinion, can be a nuisance (e.g., noise) for local residents.

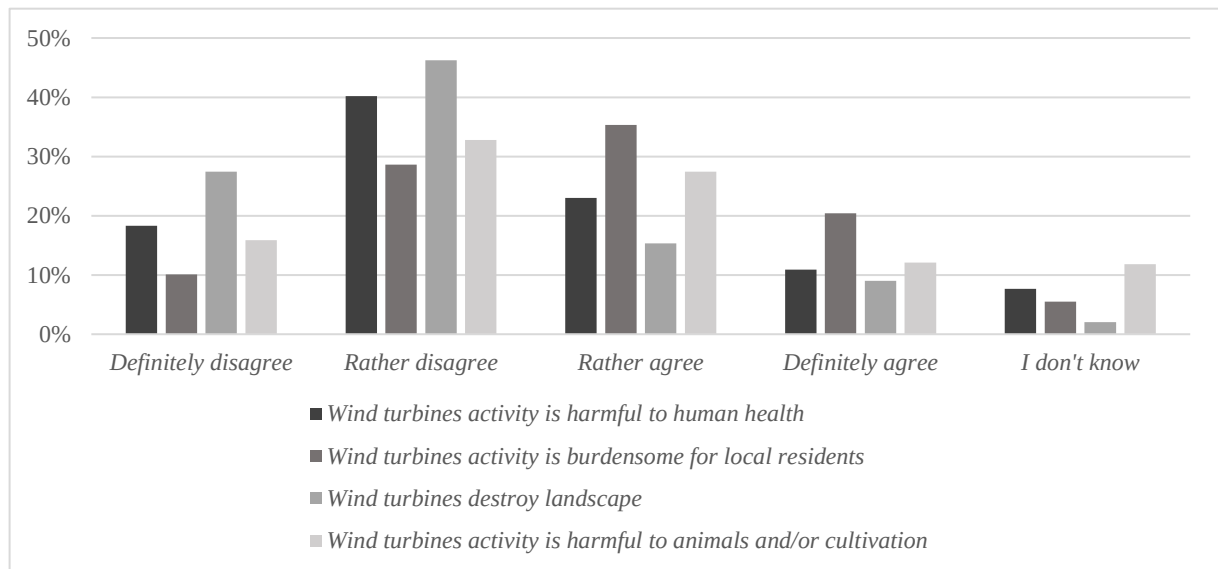
⁸ It is assumed that: $\delta_{0l} = -\infty, \delta_{4l} = \infty$

Table 5: Statistics of beliefs about negative effects of wind turbines.

Statements	Mean	St. dev.	Median
<i>Wind turbine activity is harmful to human health</i>	2.29	0.91	2
<i>Wind turbine activity is burdensome for local residents</i>	2.70	0.93	3
<i>Wind turbines destroy landscape</i>	2.06	0.90	2
<i>Wind turbine activity is harmful to animals and/or cultivation</i>	2.41	0.94	2

Note: We use a Likert scale, where 1 indicates strong disagreement, and 4, strong agreement with the statement.

The results also suggest that the lack of opinion decreases with familiarity of the effect (see Figure 2). The lowest number of ‘I don’t know’ answers occurred when respondents were asked about the effect of wind turbines on the landscape – the highest when they were asked to assess the impact on animals and/or cultivation. In other words, respondents were cautious in judging the most complex issues.

Figure 2: Distribution of the responses to wind turbine negative effects statements

5.1. Estimation results

The HMXL consists of two parts: a discrete CE component and measurement equations. Results from the discrete CE component of the model are presented in Table 7, and results from the measurement component are shown in Tables 8 and 9. Table 10 contains the model diagnostics.

Overall, the model is highly significant (see Table 10), and the signs of the parameters for attributes are generally as expected (see Table 7). The results indicate that on average,

respondents would like to have input on renewable energy extension in their neighbourhood. The significance and signs of alternative-specific constants (ASCs) indicate that, all else held constant, the respondents would prefer solar power over wind power and wind power over electricity from biogas in the 10 km surrounding their place of residence.

The results also suggest that people generally want REPS to be further from their place of residence as opposed to nearby. This finding aligns with what many other studies on externalities have found, especially for wind power (e.g., see Knapp and Ladenburg 2015). The probability of choosing an alternative is significantly and positively influenced by the size of area in respondents' neighbourhood not used for renewable energy expansion and by building new high-voltage transmission lines underground. These findings are in line with results by Des Rosiers (2002) and Navrud et al. (2008), for example. Coefficients for the cost attribute denote the parameters of log-normal distribution, and they are both highly significant. The rest of the attributes (i.e., the size and the number of REPS) do not seem to influence the average respondent's choices. Relatively large and significant standard deviations indicate the presence of substantial unobserved preference heterogeneity in the model, which justifies the use of the mixed logit specification.

Table 7: Discrete choice component

	Discrete choice component					
			<i>interaction with</i>			
			<i>LV_{WT_not harmful}</i>		<i>LV_{having opinion}</i>	
	coefficient	st. error	coefficient	st. error	coefficient	st. error
Mean						
ASC_wind energy	1.8679***	0.3572	0.6766**	0.3348	3.4516***	0.4623
ASC_solar energy	3.8948***	0.3646	-0.7855**	0.3710	4.7965***	0.4070
ASC_biomass energy	0.6441*	0.3802	-0.4365	0.3368	3.7902***	0.4706
Distance	0.3771***	0.0664	-0.1370**	0.0691	0.0630	0.1048
REPS size_medium	0.0643	0.1511	0.0189	0.1549	-0.4076*	0.2174
REPS size_large	-0.1152	0.1786	0.0092	0.1670	-0.2545	0.2527
REPS number	0.0066	0.0530	-0.0122	0.0502	-0.0713	0.0740
Landscape	0.7328*	0.3747	-0.3917	0.3896	-0.6128	0.6358
HVTL	0.2522**	0.1069	0.1617	0.1051	0.2212	0.1568
Cost	-3.1015***	0.1001	0.1787**	0.0789	-0.0382	0.1269
Standard deviation						

ASC_wind energy	3.9578***	0.4319
ASC_solar energy	2.2990***	0.4656
ASC_biomass energy	2.4738***	0.4057
Distance	0.5981***	0.0991
REPS size_medium	0.5623***	0.1894
REPS size_large	1.0320***	0.2737
REPS number	0.3416***	0.0887
Landscape	3.5027***	0.7965
HV transmission lines	0.9675***	0.2110
Cost	1.3586***	0.1028

Note: ***, **, * indicate 1%, 5% and 10% significance level, respectively.

With regard to the main objectives of our study, the measurement equations show that latent variables capture intrinsic beliefs about the negative impacts of wind turbine activity. Both latent variables are related to having opinions on wind turbines' external effects (see Table 8). Higher values of these variables increase the probability of giving an assessment on the potential effects of wind turbines. However, the first latent variable effect compared to the second is a bit higher (in the absolute values) in the case of health, disturbance, and environmental externalities, and lower in the case of landscape externality – an assessment which is probably the least burdensome for respondents.

Additionally, the first latent variable $LV_{WT_not\ harmful}$ can be associated with a belief that wind energy generation is not harmful. High values of $LV_{WT_not\ harmful}$ are related to stronger stated beliefs that wind turbine activity does not cause negative effects (see Table 9). This effect is the weakest in the case of landscape externalities. The visual effect is probably the most known from amount all wind turbine external effects. The vast majority of respondents stated that they encountered wind turbines. The impact of the second latent variable $LV_{having\ opinion}$ is not significant on all four attitudinal concerning beliefs about the negative effects of wind turbine activity (see Table 9).

Table 8: Measurement component – the first step: Opinions vs. lack of opinions about potential wind turbines external effects (binary probit: 1 = ‘I don’t know’; 0 = otherwise)

Measurement equation	1		2		3		4	
Depended variable:	Health externality		Disturbance externality		Landscape externality		Environmental externality	
	coeff.	st. err.	coeff.	st. err.	coeff.	st. err.	coeff.	st. err.
$LV_{WT_not\ harmful}$	-0.5185***	0.1291	-0.5054***	0.1638	-0.7497***	0.3274	-0.4937**	0.1322
$LV_{having\ opinion}$	-0.4011***	0.1541	-0.4255***	0.1447	-1.3639***	0.5359	-0.3578**	0.1191
Cutoff 1	1.7035***	0.1206	1.9101***	0.1312	3.7707***	0.9731	1.3851***	0.0969

Note: ***, ** indicate 1% and 5% significance level, respectively.

Table 9: Measurement component – the second step: Attitudinal statements about potential wind turbines external effects (ordered probit: 1 = strong disagreement and 4 = strong agreement with the statement)

Measurement equation	5		6		7		8	
Depended variable:	Health externality		Disturbance externality		Landscape externality		Environmental externality	
	coeff.	st. err.	coeff.	st. err.	coeff.	st. err.	coeff.	st. err.
$LV_{WT_not\ harmful}$	-1.4427***	0.1070	-1.7292***	0.1398	-0.6676***	0.0602	-1.4773***	0.1214
$LV_{having\ opinion}$	-0.2118	0.1307	-0.2264	0.1528	0.0758	0.0794	-0.0963	0.1351
Cutoff 1	-1.5203***	0.1127	-2.5090***	0.1787	-0.6998***	0.0666	-1.7051***	0.1314
Cutoff 2	0.4748	0.3094	-0.5115	0.6284	0.7944**	0.3755	0.0793	0.3412
Cutoff 3	1.9261**	0.8339	1.4194	1.0414	1.5814***	0.4099	1.7639***	0.3603

Note: ***, ** indicate 1% and 5% significance level, respectively.

The influence of unobserved beliefs about the negative impacts of wind turbines activity on stated preferences in the CE component is revealed by interactions of the latent variables with the means of preference parameters (see Table 7). The significant and positive coefficient of interaction of $LV_{WT_not\ harmful}$ with ASC for wind energy indicates that respondents with less belief about the negative effects of wind turbine activity are more in favour of wind power development in Poland over the FSQ. On the other hand, they reveal stronger preferences against solar power development. Additionally, we observe that respondents who are less convinced about wind turbine external effects do not mind having REPS closer to their place of residence. Regarding the cost attribute its interaction with $LV_{WT_not\ harmful}$ is significant and positive, indicating that respondents who do not believe in the negative effects of wind turbine

activity are more sensitive to cost and, as a result, their WTP for avoiding potential negative REPs external impacts is generally lower⁹.

The significant and positive coefficients of the interaction of $LV_{having\ opinion}$ with ASCs for wind, solar, and biomass energy development suggest that respondents who generally have an opinion about potential wind turbine effects (i.e., they either agree or disagree that such effects exist) would like to have input on the renewable energy development in their neighbourhood. They could be more interested in the subject and/or be more informed about it.

Table 10: Model diagnostic

LL at convergence	-7380.60
LL at constant(s) only	-10614.73
McFadden's pseudo-R ²	0.3047
Ben-Akiva-Lerman's pseudo-R ²	0.4705
AIC/ <i>n</i>	3.3591
BIC/ <i>n</i>	3.5270
<i>n</i> (observations)	4464
<i>r</i> (respondents)	744
<i>k</i> (parameters)	117

We also calculate a median WTP which gives the implied monetary valuation of changes in attributes.¹⁰ In the case of continuous attributes (*Distance*, *REPS number*, and *Landscape*), a positive median WTP indicates how much respondents would be willing to pay for a unit change of the given attribute; whereas, in the case of discrete attributes, it indicates how much the respondents would be willing to pay for a change from its base level. As shown in Table 11, the respondents display a positive WTP for development of wind and solar power compared to FSQ, and they are willing to pay to have energy production sources farther away from their place of residence and to protect the landscape in their neighbourhood from those investments. The respondents also revealed positive WTP for building new transmission lines underground.

⁹ The cost parameter is log-normally distributed. The effect of this attribute is calculated as a value of natural exponential function.

¹⁰ The median WTP was simulated in a two-step procedure. In the first step, model parameters are drawn from normal distribution, with mean equal to their estimated values, and covariance matrix equal to inverse of hessian. In the second step, conditional on the draw from the first step, random parameters and latent variables are drawn from their assumed distributions. Then, WTP is calculated as a ratio of parameter for given attribute and the cost (as per equations (2) and (3)). In the first step we generate 20,000 draws and for each of them we generate 10,000 draws in the second step. The median is then calculated over 10,000 draws, and 20,000 draws from the first step are used to obtain confidence intervals.

Table 11: MWTP estimates in PLN per month per household

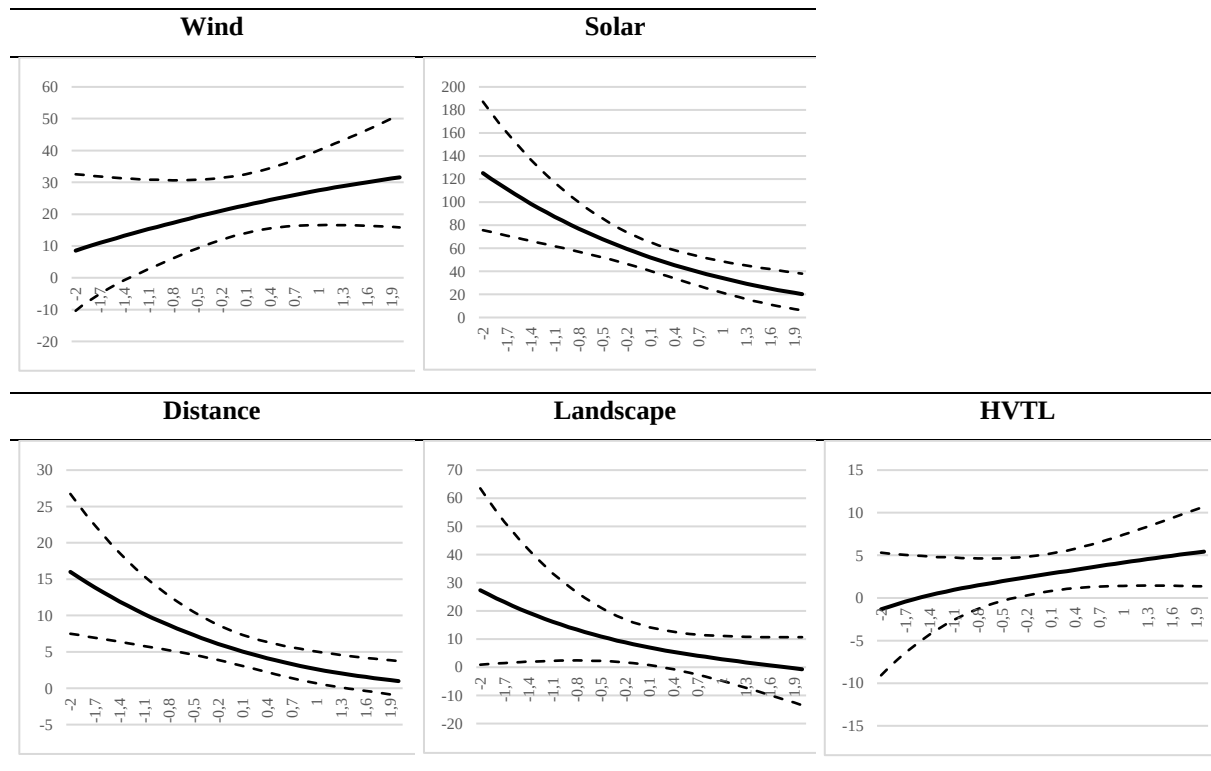
	Median	St. error
ASC_wind energy	21.80***	5.60
ASC_solar energy	54.44***	7.73
ASC_biomass energy	7.04	4.66
Distance (in km)	5.37***	1.35
REPS size_medium	0.73	1.70
REPS size_large	-1.39	2.11
REPS number	0.07	0.56
Landscape (in %)	7.49*	4.29
HV transmission lines	2.66**	1.31

Note: ***, **, * indicate 1%, 5% and 10% significance level, respectively. Nominal exchange rate in January 2016: 1 Euro=4.36 PLN.

To illustrate the differences in preferences between respondents with different levels of beliefs about wind turbine negative effects, we simulate the median WTP and its 90% confidence interval associated with our choice attributes for respondents with different levels of $LV_{WT_not\ harmful}$.¹¹ The results for significant WTPs are provided in Figure 2.

¹¹ The mean of the $LV_{WT_not\ harmful}$ is normalized to zero.

Figure 2. MWTP (PLN) of respondents with varying strength of the latent beliefs that wind energy does not cause negative effects



6. Conclusions

Renewable energy production in Poland is relatively new, and its development has caused controversies among Poles. For example, the expansion of wind farms in recent years has prompted numerous protests by local populations, leading to the creation of several associations that oppose the development of wind energy in Poland. The controversies have most frequently pertained to the impact that wind turbines have on human health and on the environment.

In this paper we shed light on whether heterogeneity in the preferences concerning renewable energy extension in Poland might be explained by the beliefs about negative effects of wind turbines, which are the predominant source of renewable energy generation in the country. We adopted a hybrid choice modelling framework that used respondents' statements on their perceptions about different types of negative effects of wind turbines as their latent beliefs on wind turbines externalities. We analysed how these beliefs correlated with respondents' stated preferences about how the development of renewable energy should look in their neighbourhood. Our measurement of beliefs differs from approaches prevalent in previous studies in that respondents could choose the option 'I do not know', aside from the standard response scale for each of their statements. We separately analysed the effect of having

opinions about wind turbine external effects and beliefs that wind energy generates negative effects. Kroh (2006) and Iannario et al. (2017), among others, claimed that ‘I do not know’ as an answer provides valid information about respondents’ indecision. Including ‘I do not know’ options shows that it is acceptable to have no opinion, and respondents are not forced to provide a definite answer.

Analysing data from a large sample of the Polish population, we find distinctive effects of beliefs about the negative effects of wind turbines on respondents’ preferences concerning renewable energy development. Respondents who generally had an opinion about potential wind turbines effects would like to have input on the renewable energy development in their neighbourhood. This belief enhances respondents’ preferences for implementing a renewable energy project (wind turbines, solar energy, or energy from biomass), rather than sticking with the status quo. The latent beliefs that wind power is not harmful enhanced respondents’ preferences for implementing a wind energy project and enhanced preferences against solar power development. This belief appears to be significantly correlated with respondents’ marginal utility of money. Not believing in the negative effects of wind turbine activity increases sensitivity to cost, while simultaneously lowering respondents’ willingness to pay to avoid renewable energy externalities.

Additionally, our survey revealed that most respondents do not agree that wind turbine activity is harmful to human health or destroys the landscape. This argument was used during protests against wind turbines expansion; however, it should be emphasized that although these protests were numerous, they did not attract a lot of people. Nevertheless, many politicians tend to see local protest groups as representing the common interest of society. These protests have contributed to changes in regulations on renewable energy production in Poland (Sokołowski 2017). In 2016, the Polish government implemented very restrictive legislation on wind power that have already drastically slowed investments in this sector.

To our knowledge, this study is the first to investigate the impact of individuals’ beliefs about negative effects of wind turbines on their preferences regarding renewable energy development. More research is needed to investigate the generalizability of these results.

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