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Heterogeneous preferences toward landscape externalities of wind turbines – combining choices and attitudes in a hybrid model

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ABSTRACT

Expanding the share of renewable energy sources might substantially increase externalities as, for example, wind turbines may disturb the landscape and negatively affect biodiversity. This paper investigates the public's sensitivities towards these externalities by using discrete choice experiments and shows how preferences differ across inhabitants of our study region. As a further insight into the sources for these variations, a hybrid choice model is employed in order to incorporate individuals' latent attitudes in the estimated model. Our latent class structure allocates individuals to classes according to underlying latent attitudes that also influence the answers to attitudinal questions. We show that these underlying attitudes are a function of a number of socio-demographic characteristics, with young people, men with low income and those living closer to turbines having a stronger pro-wind power generation attitude. The inclusion of the attitudes in the class allocation component of the latent class model leads to a richer picture of people's valuations, revealing, for example, antagonistic preferences of two distinct groups of respondents, i.e. advocates and opponents of wind power generation.

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1. Introduction

Expanding the share of renewable energy sources is a central element of the climate and energy policy of the Federal German Government [12]. The stated target is to produce 30% of the electricity from renewable sources. This goal was reiterated after the accident at the nuclear power plant of Fukushima in 2011 resulting in a strategy that aims at transforming the whole energy system. This transition, called *Energiewende in Germany,* pursues the aims of lowering greenhouse gas emissions by 80% to 95% by 2050 and of fully phasing out the use of nuclear power by 2022. In order to achieve this objective it is planned to constantly increase the share of renewable energy sources and growing energy efficiency [13].

Among the sources of renewable energy available in Germany, onshore wind power is of great importance. In 2013, an additional capacity of 2997 MW was installed onshore. This is, as in previous years, a renewed increase of the capacity growth of onshore wind power [14]. In total, the installed capacity in 2013 was 33,757 MW for onshore wind power (offshore: 903 MW), with wind producing

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34.4% of the electricity supply from renewable energy resources in 2013; renewables provided altogether 152.6 billion kilowatt hours. This underlines the important role wind power is playing as part of the transformation process of the energy system in Germany. On the other hand, particularly wind turbines are said to cause so called landscape externalities, among them negative impacts on the landscape by disturbing scenic views or negatively affecting biodiversity (e.g., [26,2,34]). Therefore, an increasing share of onshore wind power in future is also likely to result in increasing externalities. Additionally, increasing electricity production from renewables both on- and offshore requires new transmission lines, also causing new externalities (e.g., [30,29]). Thus, land use conflicts are likely to increase, especially in densely populated countries such as Germany and knowledge of the extent of the externalities can help to mitigate or even solve these conflicts. In a recent study in Sweden, Ek and Persson [19] discuss how results from discrete choice experiments can be used to support decision making concerning the question of where and how to place turbines in order to minimise externalities at the societal level.

The objective of this paper is, therefore, to similarly investigate the externalities of wind turbines using a discrete choice experiment, but to employ a still rarely used hybrid choice model combining preferences and attitudes. This is based on our hypothesis that attitudes are a key factor in driving people's sensitivities. The basic choice model methodology, now frequently applied in environmental valuation, involves the generation and analysis of choice data through constructing a hypothetical market via surveys. The data from these hypothetical choice scenarios (stated choice) are usually analysed by models based on the classical Random Utility Theory in which an individual is assumed to maximise his/her utility. The utility of an alternative is generally a function of attributes of the alternative and observable characteristics of the individual such as socio-demographics. A big effort has been made in the literature to model differences across individuals in taste parameters, i.e. the sensitivities of an individual to changes in the attributes, either in a deterministic or a random way (e.g., [35,36]). Recently, additional information coming from responses to attitudinal questions has been used to shed light on taste differences in a hybrid choice modelling framework set out by Ben-Akiva et al. [4,5]. Incorporating underlying attitudes potentially plays a substantial role in explaining choices in discrete choice experiments as they further inform models about differences among individuals and their valuations [21,23].

We follow this stream of literature based on the recognition that individuals' preferences are not only driven by attributes and observable characteristics but are also related to individuals' attitudes and perceptions. A suitable and widely used way to collect data on attitudes or perceptions is to show a number of attitudinal statements asking respondents to indicate their degree of agreement [16,17]. An example for incorporating attitudes into the analysis of discrete choice data was recently presented by Yoo and Ready [38]. They used a series of 23 questions to measure respondents' attitudes toward renewable energy and renewable energy policy. Their motivation for using attitudinal data was that they are a potentially important source of preference heterogeneity. Thus, they use principle component analysis to identify a limited set of dimensions, three components in the end, and incorporate them subsequently in their choice models. However, authors in favour of the hybrid model (e.g., [4,5]) question whether responses to attitudinal questions should be included directly as error free explanatory variables in a model. They argue that it is crucial to account for the latent nature of attitudes as answers are merely an indicator of true underlying attitudes and adding the responses directly could potentially lead to an endogeneity bias. Hence, this article not only aims at determining the landscape externalities of wind turbines but also aims at additionally incorporating individuals' attitudes toward wind power generation in a hybrid choice model. These models have seen only very limited exposure in the fields of environmental and resource economics, with Hess and Beharry-Borg [21] potentially giving the first application.

The present study adds to the literature a novel approach by specifying a latent class (LC) model that captures taste heterogeneity and simultaneously allocates individuals to classes according to underlying attitudes that also influence the answers to a number of attitudinal questions. To the best of our knowledge this modelling approach, a Hybrid Latent Class (HLC) model, has not been used in environmental valuation before. Breffle et al. [9] presented a joint latent class model combining attitudinal data with choice data, and their model is also motivated by the assumption that using attitudinal data in addition to choice data provides an opportunity to enhance the understanding of preference heterogeneity. However, their approach to link choices and attitudes differs significantly from the HLC model presented here and fails to create the full linkage allowed for in our model, as explained towards the end of our paper. The paper is organised as follows. Section 2 presents a literature review on hybrid choice models, Section 3 describes the case study and Section 4 defines the model to be used. Section 5 contains the main results and, finally, Section 6 draws some conclusions on the hybrid choice model application.

2. Hybrid choice models

The first studies making use of responses to statements aimed at capturing environmental attitudes directly incorporated these responses as explanatory variables in the utility specification (among others, [27,31]). These responses are, however, indicators of underlying attitudes rather than a direct measure of attitudes. Therefore, they are likely to suffer from measurement error, which is amplified by the widespread use of categorical formats such as Likert scale. Additionally, these responses may be correlated with other unobserved factors, causing correlation between the modelled and random components of utility, potentially leading to endogeneity bias [4,5,8]. As a response to this situation, hybrid choice models have been developed over the last fifteen years, with key developments by Ben-Akiva et al. [4,5] and Bolduc et al. [8].

These models specify latent variables to explain unobserved attitudes and other psychological constructs. In the resulting Integrated Choice and Latent Variable (ICLV) models, the latent variables, which are functions of socio-demographics and an error term, are used both in the choice model and in a separate measurement model used to explain answers to follow up questions. These models have seen a gradual uptake in applications across various fields in the last few years. As an example, in a transport application, Abou-Zeid et al. [1] use the model to incorporate individuals' attitudes towards travel into a choice model using data on two car alternatives which differed in terms of travel times, travel costs, and number of speed cameras. The starting idea was that a traveller with the perception that public transport is uncomfortable (car-lover) is likely to be more sensitive to the time and cost changes associated with public transport trips. The value of time associated with public transport is therefore expected to be different for this traveller in comparison to another traveller who has a positive perception of public transport.

In an application from environmental valuation, Hess and Beharry-Borg [21] analyse the non-market values for improvements to coastal water quality in Tobago. Their model includes ten attributes of which nine are interacted with the latent variable representing respondents' attitudes towards coastal water quality protection. Similar to the previous study, the authors conclude that the latent attitude can be used to explain both the stated choices and the responses to the attitudinal questions. As a result, they find