World Electric Vehicle Journal

Article

Effect of Having Solar Panels on the Probability of Owning Battery Electric Vehicle

Mats Gezelius and Reza Mortazavi *

Department of Economics, Dalarna University, 79188 Falun, Sweden; mgz@du.se
* Correspondence: rem@du.se

Abstract: Greenhouse gas emissions, produced by various sectors, including transportation, are significantly impairing the environment and drive climate change. Battery electric vehicles are increasingly seen as a way to alleviate these problems, but they must be charged with electricity produced through environmentally friendly methods. This paper investigates a possible relationship between battery electric vehicles and solar photovoltaic panels using ENABLE.EU household survey data from ten European countries in autumn 2017–spring 2018. Based on the estimates from a recursive bivariate probit model, it is found that the probability that a household owns a battery electric vehicle increases significantly if said household owns solar photovoltaic panels. This suggests that a policy encouraging the home charging of battery electric vehicles using solar photovoltaic panels that includes an energy storage facility could speed up the transition to the use of these vehicles.

Keywords: battery electric vehicle; binary choice; random utility model; recursive bivariate probit; solar photovoltaic panels

check for updates

Citation: Gezelius, M.; Mortazavi, R. Effect of Having Solar Panels on the Probability of Owning Battery Electric Vehicle. *World Electr. Veh. J.* **2022**, *13*, 125. https://doi.org/10.3390/wevj13070125

Academic Editor: Joeri Van Mierlo

Received: 2 June 2022
Accepted: 4 July 2022
Published: 7 July 2022

1. Introduction

The use of private cars for everyday transportation is something we value and is often necessary, in the absence of substitutes. However, it is also a source of severe greenhouse gas (GHG) emissions. Many countries have, for this reason, established comprehensive policy programs to initiate a transition to fossil-free vehicles [1]. So far, the market diffusion of electric vehicles has not reached the governmental objectives in most countries [2]. However, with increasing individual environmental insight, the improved performance of electric vehicles and government subsidies, the demand is rising fast, and consequently so is the demand for electricity. As a decrease in electricity produced from non-renewable sources is also a necessity to decrease GHG emissions and most of the renewable energy sources give an intermittent flow of electricity to the grid, the electricity system might sometimes be unable to respond to the demand. These asymmetries in energy production must somehow be mitigated. The possibility to successfully confront this problem differ between countries. If there is not enough hydropower available, only fossil and nuclear energy sources can be used. This raises the question of how the future electricity system should be designed [3,4].

At the same time, there has been an increased popularity of installing solar photovoltaic panels (PV) on the roof of detached houses for heating, cooling, and other private electricity consumption requirements. If households could be incentivized to increase their electricity production by installing additional or more efficient PV to be able to charge their battery electric vehicles (BEV), this could be a part of the solution for future electricity provisions. For this to become a reality, both policy and technological issues must be solved. The present solution to connect PV to the grid and thereby mitigate the differences in PV production and individual consumption does not solve the overall complication with the increased fraction of intermittent electricity production. One solution could be to combine PVs with an energy storage facility [5,6].

The purpose of this paper is to empirically investigate whether having solar photovoltaic panels (PV) increases the probability of the household owning battery electric vehicles (BEV). To the best of the authors' knowledge, this relationship has not previously been investigated. Our hypothesis is that having PV increases the probability of owning a BEV. Comprehensive survey data from ten European countries are used to gain more knowledge about issues related to the choices of owning a BEV and the ownership of PV [7]. These data contain information on household choices of BEV and PV, household, and home characteristics. The theoretical point of departure is the random utility framework, which assumes that the decision makers act rationally and make choices that maximize their utilities [8,9]. The randomness, from the observer's point of view, is due to the unobserved factors that influence the choice. Econometrically, since the choice of BEV is binary, a simple binary logit or probit model could be used to estimate the influence of explanatory variables, such as PV, among others. However, the PV variable itself is a binary variable and endogenous since it is correlated with the unobserved random factors. This issue is dealt with by estimating a recursive bivariate probit model.

Although technical solutions are mentioned in this paper, they are merely examples that are assumed to give functional solutions. Furthermore, the policy implications that are discussed must be seen as general since the prerequisites in different countries are different. Moreover, in this paper, it is assumed that the direction of the effect, if any, goes from having solar panels to owning an electric car. However, this effect could be the other way around. The data used in this study are from a cross-sectional survey. Using data with a time series dimension would make it possible to investigate the direction of this possible effect further.

The remainder of the paper is organized as follows: In Section 2, relevant literature on preferences and choices of vehicles and how PV energy could be stored and used for charging is reviewed. The theoretical framework for this study is the random utility model, which is presented in Section 3. Section 4 describes the data used. Econometric specification is described in Section 5 and the results are discussed in Section 6. Concluding remarks and issues for future research are given in Section 7.

2. Literature Review

Choosing between an electric car and a car with a combustion engine depends on individual preferences and faced constraints. Factors that influence preferences can be varied, such as economic, practical, emotional, or environmental factors [10]. The governments of several countries, with the aim to limit GHG emissions, try to adjust their policies and give incentives for choosing less polluting behaviors. However, policies can affect non-targeted motorists in unexpected ways according to the authors of [1]. They raise the question of whether the efficiency of a policy might suffer if such an outcome arises. They present a model for evaluating the effects of transportation policy. Based on data from Norway, they find that economic incentives have a larger impact than mechanisms based on social preferences. Moreover, their results indicate that the taxation of pollution has a better effect than subsidizing purchases of electric vehicles. Taxation decreases congestion and the total number of vehicles, while subsidies might have the opposite effect. The authors of [11] look at the total cost of ownership of a vehicle's lifetime and apply their model to Italian data. They focus on the variables urban driving, possibility for home charging and total distance travelled. Their results suggest that the possibility of home charging has a large impact on the total cost of ownership and combined with urban driving the costs for an electric vehicle are competitive. This, however, is an exception. In urban areas, fewer inhabitants have access to parking lots with the possibility for home charging. The study [11] further points to the fact that electric vehicles suffer from high initial costs and therefore conclude, contradictory to the reference [1], that subsidies might be of importance for a shift towards electric vehicles.

The study [2] investigates preferences for electric vehicles in South Korea with a discrete choice model. Preferences tend to depend on the current car and driving habits.

They advocate the idea that a wider range of different BEV models appealing to various tastes could increase market diffusion. The need for an increase in charging options is also pointed out by them as an important choice variable. The authors of [12] include electric vehicle knowledge in their model. With data from a stated preference survey from Italy in 2017, they find that with increased knowledge and experience of electric vehicles, the order of the choice attributes changes towards being more homogenous with the one for combustion engine vehicles. However, like [2], they emphasize that the major concern among consumers is the range uncertainty and undeveloped charging station net, particularly for those who do not have access to private parking and charging facilities.

The most important factor for the environment is the source of the power that runs vehicles, regardless of type. Electricity generated from oil or carbon cannot be seen as better than the direct use of fossil fuel in a vehicle [5]. The increased demand for electricity, from both industry and the electrification of the transportation system, must thereby be satisfied with renewable energy sources, as well as the existent demand. Both wind and solar energy-based electricity give intermittent outputs and have to be moderated in some way. Reference [3] suggests a three-layer energy management model that effectively matches consumption from the loading of electric vehicles with renewable energy production. Halted vehicles, connected to the grid, would thereby get access to best-price charging based upon the expected near-future energy production, consumption, and departure time. Another suggestion comes from the authors of [4]. They discuss the possibility of using electric vehicles connected to the power grid to balance the electricity system. Their aim is to find a way to mitigate hydropeaking, which might occur when hydropower is used for balancing the grid. If vehicles not in use are connected to the grid, they might be used for both storage when production is larger than the demand and to provide electricity back to the grid when production does not meet the demand. However, this solution requires a much larger BEV fleet than there is currently and the use of electric vehicles for power storage might harm the battery capacity in the long run.

The study [6] investigates the possibility to reduce governmental spending on PV subsidies with energy storage policies. Their position is that, with proper tariff schemes and policies for the self-consumption of energy, the battery storage of PV-generated energy could be profitable for homeowners, with a lower cost to society than with PV subsidies. With adequate battery storage, less energy is needed to be transferred over the grid to and from PV owners. An alternative storage option is advocated by [5]. They propound an idea with hydrogen fuel cells for storing excess energy from PV and wind at charging stations along highways. The fuel cells will then be used to charge the batteries of electric vehicles when the renewable energy sources give no or insignificant power. This could be a possible solution for the problem of charging possibilities, one of the major problems preventing BEV adoption among consumers according to [2,12]. The stations must, however, be built, and charging must be sufficiently fast to satisfy potential BEV drivers.

Vehicle attributes that drive or impede the choice of using a BEV have been widely discussed in the literature [10]. The possibility for home charging is an important driver for lowering the total cost of ownership of a BEV [11]. Different types of electricity storage systems for renewable energy have also begun to be discussed. If energy is produced with PV and stored until needed, as suggested by the authors of [6], this could further reduce costs and to some extent mitigate the variability of renewable energy. However, the relationship between PV and BEV charging has, to the best of the authors' knowledge, not been properly investigated and it will be the aim of this paper to find out the magnitude of this correlation. Policy implications will be discussed hereafter.

3. Theoretical Framework

The theoretical foundation of the empirical analysis in this paper is the well-known random utility model since the choice of a new vehicle for the household is discrete [8]. In these cases, choices can be seen as probabilistic and utility as random, which is consistent with consumer choice theory [9]. The utility of each discrete alternative can be characterized as the sum of a systematic, observable, component and a random, unobservable, component, $U_{in} = V_{in} + \varepsilon_{in}$. Then, the probability of a certain choice is:

$$\begin{aligned} P(i|C_n) &= \Pr[U_{in} > U_{jn}],\ for\ all\ j \in C_n \\ &= \Pr[V_{in} + \varepsilon_{in} > V_{jn} + \varepsilon_{jn}] \\ &= \Pr[\varepsilon_{jn} - \varepsilon_{in} < V_{in} - V_{jn}] \end{aligned}, \tag{1}$$

Equation (1) implies that the probability that individual n chooses alternative i from the choice set C_n, that he or she confronts, is the same as the probability that, all else being equal, the utility from alternative i, U_{in}, gives the greatest utility compared to all other alternatives. The maximization of utility is subject to budget constraints, which means that choice depends on income and prices. These and other observed variables are included in the mentioned systematic component, so that $V_{in} = x'_{in}\beta$, where x is a vector of variables and β is a vector of parameters to be estimated. The model does not imply that choices are made at random but reflects the unobservable differences in individual taste for the alternatives, which for the observer can be perceived as random [8]. The utility then becomes a random variable with a probability distribution. Different assumptions about the distribution of this random variable require different models such as logit or probit [9].

When a choice is made in a group, for example, a household, the utility is the sum of the individuals' utility [13]:

$$U_{ih} = \omega_a V_{ia} + (1 - \omega_a)V_{ib} + \varepsilon_{ih},\ 0 \le \omega_a \le 1, \tag{2}$$

where ω_a reflects the fraction of influence on the decision for individual a, and U_{ih} is the total utility for the household from alternative i [13]. When a choice comes with high stakes, as in the case of purchasing a vehicle, the decision maker might try to minimize regret rather than maximize utility [14]. Regret is the risk that some attribute performs better in a non-chosen alternative than in the chosen alternative. In a group situation, regret minimization is often found to be the behavior of the decision maker with a high influence over the specific choice and the group maximizes the utility with the choice of the alternative that has the smallest weighted regret [13]:

$$U^R_{ih} = \omega_a(-R_{ia}) + (1 - \omega_a)(-R_{ib}) + \varepsilon_{ih},\ 0 \le \omega_a \le 1, \tag{3}$$

This expression is U_{ih} in (2) but with utility replaced by the individual regret R_i. This can be seen as the influential decision maker includes the possibility of future criticism from other members in the household. If the choice is binary, the outcome will be identical [15]. The dataset used in this paper contains only information from one respondent in each household; however, the aspects of group and regret when evaluating variables and interpreting their effects are considered.

Regarding the choice of car, such as a BEV, the utility function can be thought of as a function of individual or household-specific variables such as various socio-economic factors, preferences, and car-specific characteristics such as cost [16,17]. In the context of this paper, we only observed a binary variable taking the value 1 whether the household has a BEV and 0 otherwise, so we have a simple binary choice when the household owns a BEV if $U_{BEV} = V_{BEV} + \varepsilon_{BEV} > 0$ and $U_{BEV} > U_{Other}$; i.e., the utility achieved by purchasing a BEV is greater than the utility achieved by purchasing any other type of car. As mentioned above, the systematic part V_{BEV} can be seen as a function of a vector of observable variables x and parameters β. Assuming a linear relationship, it can be written as $V_{BEV} = x'\beta$. One complication arises when a variable in the x vector is endogenous. For example, the main explanatory variable of interest in this study, whether the household has solar photovoltaic panels (PV), may be endogenous in the sense that it may be correlated with the error term, for example, expectations about the future cost of electricity. A way to deal with this issue is to estimate a system of two simultaneous equations, more specifically, a recursive bivariate probit model [18]. The explicit specification is described later in the econometric specification section.

4. Data

The dataset used in this paper comes from a European Union survey: 'Enabling the Energy Union through understanding the drivers of individual and collective energy choices in Europe' (www.enable-eu.com, accessed on 2 December 2020) [7]. This set consists of data from eleven European countries, Bulgaria, France, Germany, Hungary, Italy, Norway, Poland, Serbia, Spain, Ukraine, and the United Kingdom, and is made up of 11,265 observations of households. Data were collected by interviewers between November 2017 and February 2018, except in France, Norway, and the UK, where online surveys were used. The survey was not specifically made for the present study but merely gives the possibility to empirically assess whether the probability of the household owning battery electric vehicles (BEV) is influenced by having solar photovoltaic panels (PV).

The data of interest are what type of vehicle a responding household has and whether they have a solar photovoltaic (PV) system installed for generating electricity. In Table 1, the number and percentage of the responding households that have an electric vehicle and/or a solar photovoltaic system are shown by country. Electric vehicles are divided into battery electric vehicles (BEV), which are the fully non-polluting alternative, and hybrid electric vehicles (HEV), which also have a combustion engine for propulsion and to load the batteries.

Table 1. Share of electric vehicle and solar panels.

Country	N	BEV	%	HEV	%	PV	%
Bulgaria	1000	15	1.50	15	1.50	6	0.60
France	1500	44	2.93	71	4.73	51	3.40
Germany	711	18	2.53	12	1.69	17	2.39
Hungary	1022	0	0.00	7	0.68	3	0.29
Italy	1025	11	1.07	15	1.46	27	2.63
Norway	1221	76	6.22	94	7.70	10	0.82
Poland	1000	3	0.30	0	0.00	11	1.10
Serbia	1000	1	0.10	5	0.50	0	0
Spain	760	1	0.13	9	1.18	4	0.53
Ukraine	1011	3	0.30	5	0.49	6	0.59
UK	1015	24	2.36	46	4.53	54	5.32
Total	11,265	196	1.74	279	2.48	189	1.68

The data material makes no difference among HEVs that have the possibility to charge their batteries from the grid and those who only have the possibility to recharge with the combustion engine. This provides a reason to set the border for environmentally friendly vehicles between BEV and HEV and not treat them together as a single variable. The fraction of these variables is very small and, for some countries, even zero. Norway has the largest proportion of electric vehicles, 6.22 percent BEV and 7.7 percent HEV. This is not surprising as Norway has had a comprehensive policy program to increase the share of electric vehicles [1]. France, Germany, and the United Kingdom are three other countries with observable shares of BEV, 2.93, 2.53 and 2.36 percent, respectively. All the other countries have below or around 1 percent shares of BEV, except Bulgaria, where all BEV owners are also registered for an HEV. This raises the possibility of misspecification in the Bulgarian data. As this possible misspecification is in the dependent variable the Bulgarian data are dropped out from the dataset. The presence of solar photovoltaic systems is also infrequent, being the most common in the UK with 5.32 percent. For France, Germany, and Italy, the shares are 3.40, 2.39 and 2.63, respectively. In all other countries, the share is less than or around one percent. Note that these data were collected in autumn 2017–spring 2018.

The information in the dataset provides potential control variables such as the type, size and age of the respondents' home, as well as their income and education level. Table 2 presents a description of the variables and summary statistics.

Table 2. Variables' description and summary statistics.

Variables	Definition	Mean	S.D.	Min	Max
BEV	Binary, 1 if has BEV	0.02	0.13	0	1
PV	Binary, 1 if has PV	0.02	0.13	0	1
Male	Binary, 1 if Male	0.46	0.50	0	1
Education level	Ordinal, (1 = below primary, 5 = PhD)	3.24	0.70	1	5
Age	Age of the respondent	49.53	17.20	18	96
Extra car	Binary, 1 if has an extra car	0.26	0.44	0	1
Subsidy	Binary, 1 if received subsidy for BEV	0.00	0.03	0	1
Tax reduction	Binary, 1 if received reduction for BEV	0.00	0.03	0	1
Wage	Ordinal, (1 = lowest bracket, 10 = highest bracket)	4.58	2.64	1	10
Perceived income	Ordinal, (1 = Living comfortably on present income, 4 = Finding it very difficult to cope on present income)	2.29	0.86	1	4
House Size	Ordinal, (1 = less than 42 square meters, 6 = Larger than 200 square meters)	3.22	1.25	1	6
House age	Ordinal, (1 = if built before 1950, 8 = if built 2010 to 2016)	4.03	2.01	1	8
House type	Binary, 1 if single-family dwelling, 0 if multi-family dwelling	0.56	0.50	0	1
Smart meter	Binary, 1 if has the device	0.22	0.42	0	1
A1	Binary, 1 if answered yes to: You have bought a new car and its low fuel consumption was an important factor in your choice.	0.16	0.37	0	1
A2	Binary, 1 if answered yes to: You regularly use environmentally friendly alternatives to using your private car such as walking, biking, taking public transport or car-sharing.	0.27	0.44	0	1
A3	Binary, 1 if answered yes to: When buying new household appliance, e.g., washing machine or fridge, you choose it mainly because it was more energy efficient than other models.	0.48	0.50	0	1
A4	Binary, 1 if answered yes to: You have switched to an energy supplier which offers a greater share of energy from renewable sources than your previous one.	0.06	0.24	0	1
B1	Extent of agreement to: I am not willing to do anything about the environment if others don't do the same, 1 if strongly disagree, 4 if strongly agree.	1.96	0.85	1	4
B2	Extent of agreement to: Environmental impacts are frequently overstated, 1 if strongly disagree, 4 if strongly agree.	2.16	0.88	1	4
B3	Extent of agreement to: Environmental issues should be dealt with primarily by future generations, 1 if strongly disagree, 4 if strongly agree.	2.05	0.92	1	4
B4	Extent of agreement to: I am willing to make compromises in my current lifestyle for the benefit of the environment, 1 if strongly disagree, 4 if strongly agree.	3.06	0.72	1	4
B5	Extent of agreement to: Policies introduced by the government to address environmental issues should not cost me extra money, 1 if strongly disagree, 4 if strongly agree.	3.10	0.81	1	4
B6	Extent of agreement to: Environmental issues will be resolved in any case through technical progress, 1 if strongly disagree, 4 if strongly agree.	2.47	0.85	1	4
B7	Extent of agreement to: Protecting the environment is a means of stimulating economic growth, 1 if strongly disagree, 4 if strongly agree.	2.93	0.76	1	4

N is varying from N = 6200 to N = 11,175 depending on the number of missing observations for each variable.

Very few respondents, 0.07%, received financial subsidy or tax reduction (0.08%) for purchasing electric cars in these data. These are important policy variables to control for. However, in the final estimation sample, there was no one who had received a subsidy and only two cases where a tax reduction was granted for purchasing a BEV, so they are not included in the final model estimations.

To ensure the comparability of countries, wage is divided into intervals adapted to the purchasing power in each country. However, the wage variable suffers from the 'refuse to answer' problem, which is quite severe and close to 25 percent of the answers. Education level could serve as a proxy for wage. Education level is coded into five categories in ascending order, from below primary to PhD. An alternative variable is the respondents' perceived ability to cope on their household income. This is answered on a four-grade scale, from 'living comfortably ... ' to 'finding it very difficult ... '. Other individual-specific variables are gender and the year the respondent was born based on which the age is calculated.

The type of house variable provides information on whether the household lives in a single- or multi-family dwelling. For the age of house, it was determined if the house was built before 1950 or after 2010, with 10-year steps in between, amounting to a total of eight steps. The size of house divides homes into six categories, from less than 42 square meters to more than 200 square meters.

A smart meter collects information about energy consumption patterns. These consumption patterns are communicated to the consumers and give them the possibility to improve their energy-saving behavior. The data material contains information on whether a household has access to a smart meter in their home for electricity, gas, and heating energy consumption.

The dataset includes questions about the respondents' attitudes towards environmental issues, opinions about policy and stated actions. For the questions related to attitudes, labelled B1–B7 in Table 2, the respondents are expected to give answers on a four-point scale, from strongly disagree to strongly agree, with seven different statements. There is a wide range of opinion questions, from supportiveness for different environmental policies to seriousness if problems are caused by traffic. These questions were only asked to respondents in some countries and are to be discussed further with the estimation results. Finally, there are four stated action questions, labelled A1–A4 in Table 2, where the respondents answer whether they have taken some environmental action. Detailed descriptive statistics and an interpretation for the attitude and stated actions questions are available in the Appendix A.

5. Econometric Specification

As mentioned earlier, the probability of choosing an electric vehicle can be expected to increase if the cost for owning it decreases. One variable that decreases this cost is the possibility of home charging [11]. Furthermore, it may also be reasonable to assume that an owner of an electric vehicle has some kind of environmental preferences and would prefer the needed electricity to have been generated in an environmentally friendly way from renewable sources. A cost-effective way to ensure oneself of the production method is to use electricity from one's own solar photovoltaic panels. Hence, we hypothesize that having your own solar photovoltaic panels increases the probability of owning an electric car. Note that both these two variables are binary (0,1) variables. The relationship between the two could be estimated by any kind of binary-limited dependent variable model such as binary logit or probit. However, there is an issue of endogeneity here since having your own solar photovoltaic panels may be correlated with unobserved factors that influence the choice of owning an electric car. An approach that may be used in these cases, i.e., when the model contains an endogenous binary variable, is to estimate the relationship using a recursive bivariate probit model [18]. The model can be written as:

$$y_1^* = x_1'\beta_1 + \gamma y_2 + \varepsilon_1 \quad y_1 = 1\ if\ y_1^* > 0, \quad 0\ otherwise\ , \tag{4}$$

$$y_2^* = x_2'\beta_2 + \varepsilon_2 \quad y_2 = 1\ if\ y_2^* > 0, \quad 0\ otherwise\ , \tag{5}$$

y_1^* and y_2^* represent unobserved latent variables that are positive when the utility of choosing an electric car and solar panels is maximized; i.e., BEV and PV binary variables both take the value 1. ε_1 and ε_2 are random error terms that are jointly distributed conditional on the x_1 and x_2 vectors of explanatory variables that may share some common elements. The error terms are assumed to have zero mean and are possibly correlated [18]. β_1 and β_2 are vectors of the parameters to be estimated. γ indicates the influence of having solar panels on the choice of owning an electric car. If the error terms are correlated, the two binary outcomes are endogenously determined.

The data material includes a range of variables which can potentially explain the choice of BEV and PV. Table 2 provides descriptive statistics and variable descriptions. Even though the ongoing cost for a BEV is lower than for a traditional vehicle, a BEV comes with a higher initial investment cost than a corresponding vehicle with a combustion engine [11]. If vehicle buyers are not able to calculate the lifetime cost of a vehicle, this implies that a household's wealth and income level might have some effect on their choice of purchasing a BEV [10]. However, the wage variable in the dataset suffers severely from the 'refuse to answer' problem. Two variables are included in the model that can act as proxy for income, education level and the respondents' perceived ability to cope on their current income. Education level might also reflect other important aspects for the choice of vehicle, such as attitudes towards technological progress.

Whether a household is a single- or multi-family dwelling can affect the possibility for home charging and thereby lowering the operating costs for a BEV [11]. The size of the home may influence the choice of having PV and vehicle type. A larger home could suggest a higher economic ability to afford these or children and an increased concern about the future. If a home is equipped with a smart meter, this could also increase the probability for environmentally friendly behavioral changes in other areas, such as the choice of installing PV and owning a BEV.

From a consumer's point of view, one major shortcoming of BEV is that they call for a behavioral change for some types of journeys. Limitations in the range and charging possibilities can be perceived as impediments to spontaneous weekend trips, as an example. On the other hand, the everyday use for commuting and other local transportation are not affected by these limitations in a decisive way, particularly if home charging is an available option. This implies that a BEV might be more arduous to adopt for a one-vehicle household than a household with access to more than one vehicle [10]. A household of course has the possibility to own more than one additional vehicle. However, does each additional vehicle contribute equally to the decrease in possible regret for the choice of purchasing a BEV? A dummy variable that indicates if a household owns more than one car is included in the models.

The main variable of interest is solar photovoltaic panels. A household that owns PV can be assumed to have a combination of environmental and technological preferences that increases the probability for choosing a BEV due to the possibility for home charging with environmentally friendly, self-produced and low-cost energy [11]. The above knowledge on the energy field which could facilitate understanding the possible drawback of owning a BEV and its solutions [12]. This variable is the dependent variable in Equation (5), the second equation in the system.

Three models were estimated and the results are presented in Table 3. The first model is a basic model, including only household and house-specific variables. In the second model, the stated actions variables are added. The variable A1 is in response to the statement: You have bought a new car and its low fuel consumption was an important factor in your choice, is yes (1) or no (0). The variable A2 is in response to the statement: You regularly use environmental-friendly alternatives to using your private car such as walking, biking, taking public transport or car-sharing, is yes (1) or no (0). These two variables are only used in the first equation in the bivariate model, Equation (4), because they are directly related to the choice of transportation mode.

Table 3. Estimation results from the bivariate probit model.

	Basic	SE	Actions	SE	Attitudes	SE
BEV Equation						
Solar panel	2.924 ***	(0.314)	2.605 ***	(0.363)	2.328 ***	(0.391)
Male	0.146	(0.110)	0.132	(0.116)	0.075	(0.122)
Education level	−0.047	(0.079)	−0.047	(0.083)	−0.070	(0.087)
Age	−0.009 **	(0.003)	−0.010 ***	(0.004)	−0.009 **	(0.004)
Extra car	1.124 ***	(0.141)	1.076 ***	(0.150)	1.196 ***	(0.160)
Perceived income	0.113 *	(0.065)	0.146 **	(0.069)	0.164 **	(0.073)
A1			0.524 ***	(0.116)	0.641 ***	(0.125)
A2			0.327 ***	(0.114)	0.482 ***	(0.127)
B1					0.202 ***	(0.074)
B2					0.029	(0.079)
B3					0.073	(0.076)
B4					−0.135	(0.087)
B5					−0.208 ***	(0.074)
B6					0.096	(0.080)
B7					−0.005	(0.080)
Constant	−2.593 ***	(0.380)	−2.909 ***	(0.409)	−2.903 ***	(0.591)
Solar panel equation						
House type	0.283 **	(0.128)	0.259 *	(0.132)	0.219	(0.137)
House age	0.044 **	(0.022)	0.043 *	(0.022)	0.045 *	(0.023)
House size	0.081 *	(0.043)	0.082 *	(0.044)	0.087 *	(0.046)
Smart meter	0.599 ***	(0.099)	0.550 ***	(0.102)	0.460 ***	(0.108)
Male	−0.033	(0.096)	−0.016	(0.098)	−0.029	(0.102)
Education level	0.266 ***	(0.066)	0.249 ***	(0.068)	0.229 ***	(0.070)
Age	−0.003	(0.003)	−0.003	(0.003)	−0.002	(0.003)
Perceived income	−0.213 ***	(0.063)	−0.202 ***	(0.065)	−0.228 ***	(0.069)
A3			0.031	(0.100)	0.175	(0.109)
A4			0.453 ***	(0.131)	0.416 ***	(0.137)
B1					0.122 *	(0.064)
B2					0.174 ***	(0.066)
B3					0.106 *	(0.062)
B4					0.202 **	(0.082)
B5					−0.146 **	(0.063)
B6					0.007	(0.068)
B7					−0.014	(0.068)
Constant	−3.139 ***	(0.380)	−3.170 ***	(0.390)	−4.217 ***	(0.537)
Rho (ρ)	−0.86 ***	(0.090)	−0.75 ***	(0.123)	−0.72 ***	(0.137)
N	3692		3692		3692	
Log likelihood	−627		−606		−573	
Wald	chi2(14) = 416.8 p < 0.0001		chi2(18) = 334.5 p < 0.0001		chi2(32) = 350.6 p < 0.0001	
AIC	1288		1254		1217	
BIC	1394		1385		1434	
LR-test of Rho (ρ)	chi2(1) = 13.0 p < 0.0003		chi2(1) = 10.9 p < 0.0010		chi2(1) = 9.6 p < 0.0019	
Score test	chi2(9) = 9.5 p < 0.3928		chi2(9) = 8.9 p < 0.4554		chi2(9) = 13.9 p < 0.1256	

*, **, and *** indicate statistical significance at 10, 5 and 1 percent levels, respectively. As mentioned in the main text, since some stated action questions were not asked to respondents in some countries, the estimation sample was reduced to 3692 observations to be able to compare the models equally. However, the basic model was also estimated based on the full sample, but the results are very similar to the ones reported here.

The variable A3 is in response to the statement: When buying new household appliance e.g., washing machine or fridge, you choose it mainly because it was more energy efficient than other models, is yes (1) or no (0). The variable A4 is in response to the statement: You have switched to an energy supplier which offers a greater share of energy from renewable sources than your previous one, is yes (1) or no (0). These two variables are only used in the second equation in the system, Equation (5), because they are more related to actions that indicate willingness to save energy and use environmentally friendly sources of it. Stated action questions (A1–A4) were not asked in Italy and Spain, and the last question was not asked in Hungary and Norway. This led to a reduction in the final estimation sample.

In the third model, a group of attitudinal, opinion and behavioral variables were added to both Equations (4) and (5). One of these variables is particularly interesting since it can be interpreted as measuring a kind of conditional adherence to social norms. This variable, labelled B1, measures the extent of agreement to the statement: I am not willing to do anything about the environment if others don't do the same. It takes the value 1 if one strongly disagrees, 2 if disagree, 3 if agree and 4 if strongly agree.

There is a strand of literature that is about how norms, social and personal, influence individual behavior [19]. The role of norms has been investigated in economics research, for example, in the fields of waste recycling [20,21] and the valuation of environmental amenities [22]. This literature finds evidence that norms and motivation matter for individual choices. This implies that individuals have preferences for being responsible and conform to socially acceptable norms; i.e., the utility function mentioned earlier also depends on the willingness to act responsibly from, say, an environmental point of view. One may also argue that some economic behaviors may present an image of acting responsibly to others, for example, by installing solar panels and/or driving an electric car. Moreover, how other people behave might have an impact on how responsibly one behaves.

6. Results

The estimation results are reported in Table 3. In all models, the estimates of ρ are statistically significant (one percent level). According to the likelihood ratio test statistics, the null hypothesis that $\rho = 0$ in all three models can confidently be rejected. This indicates that estimating the models using a bivariate probit is more appropriate than estimating Equations (4) and (5) separately. The likelihood ratio test presented at the bottom of Table 3 confirms this. Additionally, Murphy's scores of normality [23,24] were calculated and are presented at the bottom of the same table. According to this goodness-of-fit test, the bivariate normal distribution assumption cannot be rejected for any of the models. All models show a good fit individually according to the Wald test. The more general models with stated action and attitude variables included show a better fit according to the log likelihood value and AIC and BIC (Akaike and Bayesian information criteria).

There are no major differences regarding the coefficient estimates across the three models. The attitude questions were asked in all countries but had a significant loss of response which lowered the number of observations in the estimation sample. The reasons for non-responses was unfortunately not investigated further. The stated action questions were not asked in Italy and Spain, further decreasing the number of observations in the estimation sample.

The coefficient estimates in Table 3 can only be interpreted in terms of whether an explanatory variable influences the probability of events such as BEV taking the value 1 or PV taking the value 1 or both and whether this influence is positive or negative or insignificant. Later, the marginal effects are reported, which informs about the effects sizes. Note that the variables that are included in the model, for example, education level and perceived income, are categorical but ordinal. These could have been used in the model as dummy variables; however, since the focus is to examine the correlation between PV and BEV and the other variables are used as controls and to ensure that the number of parameters does not become very large, these are treated as interval variables. (The models were also estimated using dummies for different levels of these variables. The results did not change much in general and, in particular, the correlation between BEV and PV was still positive and significant.)

In all models, having solar panel positively and significantly correlates with having BEV. Gender does not correlate with having BEV, neither directly nor indirectly through the solar panel equation. Education level correlates positively and significantly with having solar panels but, interestingly, not directly with having a BEV. Age has a small significant negative correlation with having a BEV but not with having solar panels. Having an extra car in the household correlates positively and significantly with having a BEV.

Income was measured in two different ways in the data. One was the actual income bracket and one used a subjective method, the perceived income described earlier. The former had too many missing observations but correlates significantly with the latter, so it was decided to use the latter as an explanatory variable. This income variable shows mixed effects. It correlates significantly and positively (the signs of the coefficients are negative; however, note that the variable is coded as 1 = Living comfortably on present income, 4 = Finding it very difficult to cope on present income) with having solar panels. However, it correlates in the other direction with having a BEV, at the 5% significance level, in the models when stated actions and attitudes are present as additional explanatory variables.

The respondents' answers to the attitude questions were given on a four-point scale, from strongly disagree to strongly agree, responding to different statements about environmental attitudes. If BEV owners bought their vehicles for the sake of the environment, they are expected to agree or disagree to the statements more frequently than the other respondents. The interpretation of the influence of the associated variables on the questions follows below.

'I am not willing to do anything about the environment if others don't do the same.'

The estimated coefficient for the associated variable, B1, is positive and significant in the BV equation. This means that the higher the degree of agreement, the higher the probability of having a BEV, which contradicts the idea of BEV owners taking some own environmental responsibility. Perhaps BEV owners might have bought their vehicle for reasons other than environmental issues.

'Environmental impacts are frequently overstated.'

The estimated coefficient for the associated variable, B2, is insignificant in the BV equation but positive and significant in the PV equation. This means that the higher the degree of agreement, the higher the probability of having PV, which contradicts the idea of PV owners being especially environmentally oriented. Again, perhaps PV owners might have installed solar panels for reasons other than environmental issues.

'Environmental issues should be dealt with primarily by future generations.'

Generally, respondents disagreed with this statement. The estimated coefficient for the associated variable, B3, is insignificant in the BEV equation, but positively correlates with PV at the 10% significance level. This means that the higher the degree of agreement, the higher is the probability of having PV, which also contradicts the idea of that owners are especially environmentally oriented.

'I am willing to make compromises in my current lifestyle for the benefit of the environment.'

The implication of owning a BEV is that you need to alter your driving behaviors compared to when driving a vehicle with a combustion engine. The estimated coefficient for B4 is insignificant in the BEV equation. The coefficient is insignificant in the BEV equation, but positively correlates with PV at the 5% significance level. This means that the higher the degree of agreement, the higher the probability of having PV, which is in accordance with the idea of PV owners being especially environmentally oriented.

'Policies introduced by the government to address environmental issues should not cost me extra money.'

The estimated coefficient for the associated variable, B5, is negative and statistically significant in the BEV equation, which is consistent with the expectations. BEV owners have spent money on a car with a higher price than a corresponding car with a combustion engine to address environmental issues. Perhaps another interpretation may be that the higher the degree of disagreement with this statement, the higher the likelihood of taking responsibility in acting in an environmentally friendly way. The sign is also negative and statistically significant in the PV equation, which may be interpreted in the same way.

'Environmental issues will be resolved in any case through technical progress.'

The estimated coefficient for B6 is statistically insignificant in both equations. The answers from all respondents are evenly distributed, with an emphasis on the mid-answers (see the Appendix A). BEV and PV owners could be expected to have a little more faith in the technical progress, and a positive sign.

'Protecting the environment is a means of stimulating economic growth.'

The estimated coefficient for B7 is statistically insignificant in both equations. One's opinion about the relationship between protecting the environment and economic growth apparently does not have an influence on either BEV or PV.

'You have bought a new car and its low fuel consumption was an important factor in your choice.'

The associated variable, A1, correlates positively and significantly with the choice of BEV. BEV owners seem to be more concerned about fuel consumption than the average household. Whether this is for economic or environmental reasons is not possible to know. It might imply that households are able to evaluate future savings from operating costs but could as well be that they want to have less of an environmental impact.

'You regularly use environmental-friendly alternatives to using your private car such as walking, biking, taking public transport or car-sharing.'

The coefficient for the associated variable, A2, is positive and statistically significant. This indicates that BEV owners act in a more environmentally friendly way than the average respondent in other situations. Not only this, but having a BEV allows one to be able to continue driving in good conscience. There may also be an issue of the phrasing of the question itself which may lead to somewhat biased answers.

'When buying new household appliance e.g., washing machine or fridge, you choose it mainly because it was more energy efficient than other models.'

The estimated coefficient for the associated variable, A3, is not statistically significant. In terms of household appliances, PV owners seem not to be particularly concerned about energy efficiency.

'You have switched to an energy supplier which offers a greater share of energy from renewable sources than your previous one.'

The associated variable, A4, correlates positively and significantly with the choice of PV. This may be interpreted as the environmentally friendly production of energy is a motivating for PV owners.

As stated earlier, the results in Table 3 only show possible positive or negative statistical correlations between the explanatory variables and the binary choice variables, i.e., whether changes in any explanatory variables lead to changes in the probabilities of having BEV and PV. However, we also need to estimate marginal effects, i.e., by how much a unit change in an explanatory variable changes these probabilities. There are several types of marginal effects that can be derived from a bivariate probit model. Here, the interest lies in how the conditional mean of BEV changes with a unit change in an explanatory variable, with all else being equal. Greene [18,25] derives these marginal effects. In Equation (4), the first equation of the system, the total marginal effect of a unit change in an explanatory variable is the sum of a direct effect and an indirect effect. The direct effect is the change in the probability of BEV = 1 due to a unit change in an explanatory variable that is only used in the first equation, Equation (4). The indirect effect is the effect of a unit change in an explanatory variable in the second equation in the system, Equation (5), on the probability of PV = 1, which in turn changes the probability of BEV = 1.

Table 4 presents some of these marginal effects. We are mainly interested in the effect of the PV on the conditional expectation. This effect is significant at the 1% level and equal to 0.34, which can be interpreted as, all else being equal, having solar panel increases the probability of having a BEV by 34 percentage points, on average. An extra car in the household increases the probability of having a BEV by 4.7 percentage points.

Table 4. Marginal effects on the probability that a BEV is chosen.

Variable	Direct	Indirect	Total	SE
Solar panel	0.3425		0.3425 ***	0.1196
Male	0.0022	−0.0005	0.0022	0.0046
Education level	−0.0025	0.0037	0.0011	0.0032
Age	−0.0003	−0.0000	−0.0003 ***	0.0001
Extra car	0.0470		0.0470 ***	0.0067
Perceived income	0.0059	−0.0037	0.0022	0.0031
House type		0.0033	0.0033	0.0023
House age		0.0007	0.0007	0.0005
House size		0.0014	0.0014	0.0009
Smart meter		0.0089	0.0089 **	0.0038

, * indicate statistical significance at 10, 5 and 1 percent levels, respectively. The marginal effects of the stated action variables and attitude variables are not reported since the interpretation and implication are not straight forward. The marginal effects on the probability that solar panels have been installed are not reported because the main interest is the effects on the choice of BEV.

Note, however, that these results are based on the particular dataset used which has a low share of BEV and PV users. If a similar survey was conducted now, the shares of both BV and PV would be greater. The precise magnitude of the marginal effects, particularly, by how much the probability of owning a BEV changes if household has installed PV, would likely be different. The purpose of the present study is not to present a precise estimate of this effect. Indeed, we acknowledge that to estimate a causal effect, an explicit research design would be required. However, our results suggest a significant association between owning BEV and PV.

7. Discussion and Concluding Remarks

In a future with a constantly increasing demand for electricity and a likewise increased need for electricity to be produced via environmentally friendly methods, all expedient energy-production sources must be involved. One small but nevertheless important possible contribution to the energy system is discussed in this paper in the context of a consumer type that can be expected to have an increased demand for electricity. Based on survey data in ten European countries from ENABLE.EU [7], a significant connection between household-produced electricity by PV and the ownership of a BEV has been established. The results from a recursive bivariate probit model suggest that the probability of owning a battery electric car increases by about 30 percentage points when the household has solar panels. This link may have a very good potential to evolve, especially in countries with higher market diffusion. However, PV produces energy in daytime, while home charging BEV can be expected to take place mostly at night. Home charging is an important part in lowering the total costs of ownership that might help to increase the market diffusion of BEV [11]. If BEV owners, as suggested in this paper, produce their own 'fuel', they must provide the electricity to the grid in the daytime and then buy it back when charging overnight. To counteract this complication, different energy storage solutions have been suggested, such as batteries [6] or fuel cells [5]. Energy storage technology (ES) is of course of minor importance and is hereafter called electricity storage.

ES is not only beneficial for the individual PV owner. With an increased share of intermittent green energy production in a country, the need for expedient mitigating measures of the electricity system increases correspondently. The government should therefore be concerned with establishing a policy framework that give households incentive to adopt a PV–ES facility for home charging their BEV. Taking this one step further, a charging station of the type suggested by the authors of [5] could be jointly owned by a group of households with individual PV and a common ES. In rural areas, charging could be offered to visitors through charging facilities and thereby increase the overall charging possibility in rural areas [2]. People who agree to joint ownership do not have to own a BEV to benefit from the arrangement; the demand for electricity exists regardless of whether the household owns a BEV or not. One positive side effect will arise in that BEV knowledge is likely to increase among the collaborating households and this is expected to increase the probability that the household chooses a BEV as their next car. The study [12] also finds evidence that electric vehicle knowledge has an impact on the future choice of vehicle.

Many countries have set up ambitious goals of reducing emissions from both transport and energy-producing activities. Different policy instruments may be used to achieve these goals. The coordination of policy instruments has potential to induce more effects. The results of this study show a strong link between access to solar panels and owning a battery electric car. This implies that policies such as subsidizing solar panel installation or using a subsidy for purchasing an electric car may be an effective way to facilitate the transition to an energy system with a higher degree of renewable energy production and transport with less pollution. At the same time there may be policies in place, for example, a tax on producing electricity from solar panels, that act as a disincentive for investing in the technology.

Households that increase their solar panel area to generate more energy to charge their car might be one part of the solution to the lack of electricity in the future. Furthermore, this could give positive side effects such as jointly owned ES facilities that increase the charging possibilities for visitors in rural areas and spreading of BEV knowledge. Policy, however, needs to be designed to give incentives and resources for such arrangements.

Further research should be conducted that can give advice for more country-specific policy frameworks. This could entail, for example, tariff policies or regulations of joint ownership. With the disparate prerequisites each country faces, both in terms of present policies, cultural aspects, and the possibilities for energy production, this must be taken care of with a good sense of local knowledge and understanding of specific conditions. Furthermore, a limitation of this study and an issue for future research is that the data used in this study are not the results from an explicit research design to examine the causal relation between the ownership of electric car and solar panels. In this paper, it was assumed that the direction of the effect, if any, goes from having solar panels to owning an electric car. The direction of the effect could be the other way around. A cross-sectional set of data were used in the present study. Data with a time series dimension could make it possible to investigate this issue further.

Author Contributions: M.G.: Conceptualization, literature review, data management, formal analysis, writing original draft and editing. R.M.: Formal analysis, writing and editing. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data used in this study are publicly available at http://www.enable-eu.com/dataset-on-households-energy-use-now-available/ (accessed on 2 December 2020).

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

The dataset includes the stated action questions described below in Table A1. The questions were not asked in Italy and Spain, and the last question was not asked in Hungary and Norway either. The expected answers from BEV owners are described below.

Table A1. Stated action questions.

Name	Statement	Yes	Percent	N
A1	You have bought a new car and its low fuel consumption was an important factor in your choice.	1422	16.77	8480
A2	You regularly use environmental-friendly alternatives to using your private car such as walking, biking, taking public transport or car-sharing.	2466	29.08	8480
A3	When buying new household appliance e.g., washing machine or fridge, you choose it mainly because it was more energy efficient than other models.	4101	48.36	8480
A4	When buying new household appliance e.g., washing machine or fridge, you choose it mainly because it was more energy efficient than other models. You have switched to an energy supplier which offers a greater share of energy from renewable sources than your previous one.	377	6.04	6237

A1—*'You have bought a new car and its low fuel consumption was an important factor in your choice.'*

Seventeen percent of the respondents answered yes. BEV owners can be expected to have factored in the lower fuel consumption in their decision to purchase a BEV for both economic and environmental reasons. They are expected to have answered yes more frequently.

A2—*'You regularly use environmental-friendly alternatives to using your private car such as walking, biking, taking public transport or car-sharing.'*

Twenty-nine percent of the respondents answered yes. There is no obvious direction for the BEV owners' answers. They might want to use their emission-free vehicles as much as possible, as they choose even more environmentally friendly alternatives when possible.

A3—*'When buying new household appliance e.g., washing machine or fridge, you choose it mainly because it was more energy efficient than other models.'*

Forty-eight percent of the respondents answered yes. There is no reason to expect BEV/PV owners differ from non-BEV/PV owners in this regard.

A4—*'You have switched to an energy supplier which offers a greater share of energy from renewable sources than your previous one.'*

Six percent of the respondents answered yes.

The dataset includes the attitudinal questions described below in Table A2. The questions were asked in all countries, but not all respondents gave an answer. The expected answers of BEW owners are described below.

Table A2. How much do you agree with the following statements?

Name	Question	Strongly Disagree	Disagree	Agree	Strongly Agree	N
B1	I am not willing to do anything about the environment if others don't do the same.	3194 32.76%	4319 44.29%	1678 17.21%	560 5.74%	9751
B2	Environmental impacts are frequently overstated.	2335 24.70%	3958 41.87%	2454 25.96%	706 7.47%	9453
B3	Environmental issues should be dealt with primarily by future generations.	3092 31.64%	3926 40.18%	1919 19.64%	835 8.54%	9772
B4	I am willing to make compromises in my current lifestyle for the benefit of the environment.	341 3.55%	1167 12.14%	5676 59.06%	2426 25.24%	9610
B5	Policies introduced by the government to address environmental issues should not cost me extra money.	378 4.00%	1535 16.24%	4325 45.76%	3214 34.00%	9452
B6	Environmental issues will be resolved in any case through technical progress.	1136 12.97%	3312 37.82%	3344 38.19%	965 11.02%	8757
B7	Protecting the environment is a means of stimulating economic growth.	438 5.10%	1502 17.49%	4861 56.61%	1786 17.86%	8587

Percentages of correctly given answers.

B1—*'I am not willing to do anything about the environment if others don´t do the same.'*

Seventy-seven percent of the respondents disagree or strongly disagree with this statement. BEV owners are early adopters and have already done something for the environment without expecting others to do the same; they should be expected to disagree even more frequent.

B2—*'Environmental impacts are frequently overstated.'*

Sixty-six percent of the respondents disagree or strongly disagree with this statement. There is no reason why BEV owners should differ from the population in this statement.

B3—*'Environmental issues should be dealt with primarily by future generations.'*

About 72 percent of the respondents disagree or strongly disagree with this statement. If BEV owners have bought their vehicles for environmental issues, they should disagree more frequently.

B4—*'I am willing to make compromises in my current lifestyle for the benefit of the environment.'*

Eighty-four percent of the respondents agree or strongly agree with this statement. BEV owners have made lifestyle changes to adopt their vehicles and should agree more frequently. The agreement rate in the population is, however, rather high already.

B5—*'Policies introduced by the government to address environmental issues should not cost me extra money.'*

Eighty percent of the respondents agree or strongly agree with this statement. BEV owners have made an investment in an expensive BEV. Although, this is often subsidized by governmental policy. They should agree less frequently than the total population.

B6—*'Environmental issues will be resolved in any case through technical progress.'*

This statement has an even distribution in terms of the answers from respondents. BEV owners should be expected to agree more frequently seeing as though a BEV is a technical solution for the problem of emissions from vehicles.

B7—*'Protecting the environment is a means of stimulating economic growth.'*

Seventy-four percent of the respondents agree or strongly agree with this statement.

References

1. Kverndokk, S.; Figenbaum, E.; Hovi, J. Would my driving pattern change if my neighbor were to buy av emission-free car? *Resour. Energy Econ.* **2020**, *60*, 101153. [CrossRef]
2. Kim, J.; Seung, H.; Lee, J.; Ahn, J. Asymetric preference and loss aversoin for electric vehicles: The reference-dependent choice model capturing different preference directions. *Energy Econ.* **2020**, *86*, 104666. [CrossRef]
3. Shi, C.; Luo, J. EV Energy Management Strategies Considering Renewable Energy Consumption and Load Smoothing. In Proceedings of the IEEE Sustainable Power and Energy Conference (iSPEC), Bejing, China, 24 November 2019; pp. 1897–1902. [CrossRef]
4. Román, A.; Garcia de Jalón, D.; Alonso, C. Could future electric vehicle energy storage be used for hydropeakong mitigation? An eight-country viability analysis. *Resour. Conserv. Recycl.* **2019**, *149*, 760–777. [CrossRef]
5. Singh, A.; Letha, S.S. Emerging energy sources for electric vehicle charging station. *Environ. Dev. Sustain.* **2019**, *21*, 2043–2082. [CrossRef]
6. Zakeri, B.; Cross, S.; Dodds, P.E.; Gissey, G.C. Policy options for enhancing economic profitability of residential solar photovoltaic with battery energy storage. *Appl. Energy* **2021**, *290*, 116679. [CrossRef]
7. Enabling the Energy Union. ENABLE.EU Dataset—Survey of Households. 2018. Available online: http://www.enable-eu.com/dataset-on-households-energy-use-now-available/ (accessed on 2 December 2020).
8. McFadden, D. Conditional logit analysis of qualitative choice behavior. In *Frontiers in Econometrics*; Zarembka, P., Ed.; Academic Press: New York, NY, USA, 1974; pp. 105–142.
9. Ben-Akiva, M.; Lerman, S.R. *Discrete Choice Analysis: Theory and Application to Travel Demand*; MIT Press: Cambridge, MA, USA, 1985.
10. Rezvani, Z.; Jansson, J.; Bodin, J. Advances in consumer electric vehicle adoption reserch: A rewiev and research agenda. *Transp. Res. Part D* **2015**, *34*, 122–136. [CrossRef]
11. Scorrano, M.; Danielis, R.; Giansoldati, M. Dissecting the total cost of ownership of fully electric cars in Italy: The impact of annual distance travelled, home charging and urban driving. *Res. Transp. Econ.* **2020**, *80*, 100799. [CrossRef]

12. Giansoldati, M.; Rotaris, L.; Scorrano, M.; Danielis, R. Does electric car knowledge influence car choice? Evidence from a hybrid choice model. *Res. Transp. Econ.* **2020**, *80*, 100826. [CrossRef]
13. Beck, M.J.; Chorus, C.G.; Rose, J.M.; Hensher, D.A. Vehicle Purchasing Behaviour of Individuals and Groups. Regret or Reward? *J. Transp. Econ. Policy* **2013**, *47*, 475–492.
14. Hensher, D.A.; Greene, W.H.; Chorus, C.G. Random regret minimization of random utility maximization: An explanatory analysis in the context of automobile choice. *J. Adv. Transp.* **2013**, *47*, 667–678. [CrossRef]
15. Chorus, C.G.; Arentze, T.A.; Timmermans, H.J. Spatial Choice: A Matter of Utility or Regret? *Environ. Plann. B Plann. Des.* **2009**, *36*, 538–551. [CrossRef]
16. Berry, S.T.; Levinsohn, J.; Pakes, A. Automobile prices in market equilibrium. *Econometrica* **1995**, *63*, 841–890. [CrossRef]
17. Beresteanu, A.; Li, S. Gasoline Prices, Government Support, and the Demand for Hybrid Vehicles in the United States. *Int. Econ. Rev.* **2011**, *52*, 161–182. [CrossRef]
18. Greene, W.H. *Econometric Analysis*; Pearson: Boston, MA, USA, 2012.
19. Schwartz, S.H. Moral decision making and behavior. In *Altruism and Helping Behavior*; Macauley, J., Berkowitz, L., Eds.; Academic Press: New York, NY, USA, 1970; pp. 127–141.
20. Hage, O.; Söderholm, P.; Berglund, C. Norms and economic motivation in household recycling: Empirical evidence from Sweden. *Resour. Conserv. Recycl.* **2009**, *53*, 155–165. [CrossRef]
21. Halvorsen, B. Effects of norms and opportunity cost of time on household recycling. *Land Econ.* **2008**, *84*, 501–516. [CrossRef]
22. Börger, T.; Hattam, C. Motivations matter: Behavioural determinants of preferences for remote and unfamiliar environmental goods. *Ecol. Econ.* **2017**, *131*, 64–74. [CrossRef]
23. Murphy, A. Score tests of normality in bivariate probit models. *Econ. Lett.* **2007**, *95*, 374–379. [CrossRef]
24. Chiburis, R.C. *Score Tests of Normality in Bivariate Probit Models: Comment and Implementation*; Working Paper; University of Texas at Austin: Austin, TX, USA, 2009.
25. Greene, W.H. *Marginal Effects in the Bivariate Probit Model*; Working Paper Series EC-96-11; New York University, Department of Economics: New York, NY, USA, 1996.