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Abstract

We propose a behaviorally sound model capable of simulating choice set generation for car renewal. It appears at an upper layer of a choice model of a new car. Our model sheds light on potential latent demand for electric cars.
We develop a hierarchical latent variable approach to model consideration for electric and plug-in hybrid electric vehicles in car renewal. It drives the observed outcomes that regard how much an individual would account or not for electric cars when planning to renew one. We model it as a latent factor that is defined as a linear combination of attitudes and perceptions. In our application, respondents are asked to whether they would consider or not a 100% electric and a plug-in hybrid electric vehicle.
Attitudes and perceptions are also latent factors. These are additional variables that we model. They here are of three types: range anxiety, environmental concerns, and perception about compatibility of use in everyday life. They are measured through a series of questions that concern barriers and motivations to adoption of electric cars. For each of them, respondents are asked to rate on a 5 points Likert scale. We use data from the 2012 Nissan-Renault Alliance survey for application. It covers 5 European countries (France, Germany, Italia, Spain, UK). The sample size is about 5000 observations. In addition to observed outcomes that we model, we have information about individuals, structures of their households, the current cars they own and the way they use them (driven mileages).
The measurement model takes the form of a mixed multivariate ordered Logit model. We discuss identification conditions to uncover the structural parameters of our system. It is estimated by maximization of the associated simulated log-likelihood function. Estimates live up to our expectations and are in line with existing literature.

Keywords

Electric vehicle, plug-in hybrid electric vehicle, probabilistic choice set generation, latent

variables, multivariate ordered logit

1 Introduction

Electric vehicle technology improved significantly these last decades. The range of electric vehicles increased. Power and comfort specifications are also in line with conventional cars. The European electric car market progressed: 65 199 personal car were registered in Europe in 2014, an increase of 60,9% over 2013, France and Norway being the two biggest consumers [1]. Nevertheless, the number of sales of this type of vehicle remains low compared to the sales of traditional vehicles. Electric vehicles represent only 3.2% of 2013 car market in France [2]. It is expected that this trend will continue during the years. Indeed, the political will is to reduce greenhouse gas emissions significantly as it is considered as a determinant of climate change. For example, in France, the transportation sector represent 27 percent of the greenhouse gas emitted in 2011 with 132,5 MteqCO2 (toxic equivalency CO2) [3]. People will be more and more encouraged, thanks to incentives, to consider electric cars as an alternative.

The process leading to a choice during a decision process is directly influenced by attitudes, preferences and perceptions (McFadden (1998)). Concerning car, those issues are characterized by advantages or drawbacks associated to electric technology. For example cheaper fuel and lower operating costs will not have the same impact on decision-making process compared to higher purchasing price. Attitudes and preferences are not directly observable, they are usually measured by indicators of individuals' opinions and represented by latent constructs (Walker (2001)).

There is some literature focusing on probabilistic choice set generation framework for personal (Brownstone *et al.* (1994)) and commercial fleets (Crane (1996)). Concerning traditional car renewal, Berri (2012) shows consumer behavior is mainly influenced by vehicles' characteristics. For new technology, Welzel and Schramm-klein (2013) highlight that early adopters are influenced by dimensions called perceived innovation characteristics (relative advantage, compatibility, ease of use, triability, visibility). Only few papers deal with probabilistic choice set generation related to new alternatives (Glerum *et al.* (2013)), which is our contribution in this paper. It is a cross-cutting issue in relation to a broader issue that is to predict the behavior of consumers when faced with new technologies. The objective is to create a model with latent variable capable of forecasting consideration for electric vehicles during car-renewal among European countries.

The rest of the article is structured as follows, Section 2 presents the literature review. Section 3

[1] `http://www.notre-planete.info/actualites/4207-ventes-voitures-electriques-France-Europe`
[2] `actu-environnement.com/ae/news/vehicules-electriques-marche-en-progression-20430.php4`
[3] `developpement-durable.gouv.fr/Transports,34304.html`

describes the mathematical framework that will be used in order to build a model capable of simulating choice set generation for car renewal. Section 4 describes the case study and the dataset used. Section 5 contains a discussion of the main results that have been found.

2 Literature review

The paper aims at developing a model capable of forecasting demand for clean-fuel vehicle, and especially for electric vehicle. This is a relatively new issue. Indeed, the existing literature provide a lot of paper about choice making process concerning conventional cars but only few are dealing with this issue and electric technology.

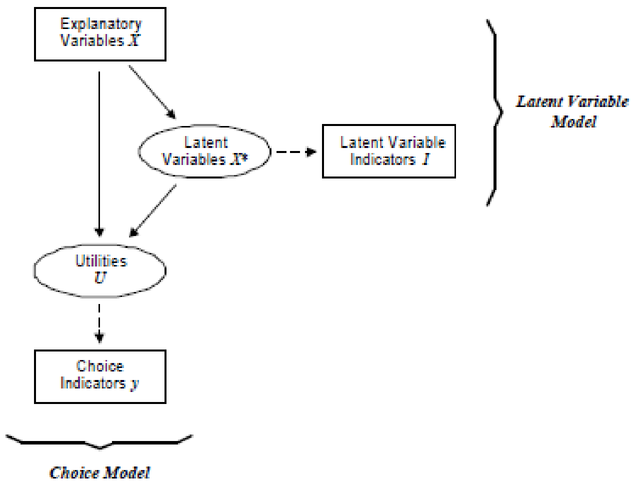
The first to study this subject are Brownstone *et al.* (1994) and Crane (1996) when commercial electric vehicle was at its infancy. They presented the theoretical framework and the first results about the introduction of new technology within the Californian car market for personal car or commercial fleet. It turns that exogenous factors concerning the principal characteristics of vehicle have an impact on the consumer choice. Globally and as expected they are identical to conventional vehicle as fuel price, operating cost, incentives or performances.
At that time, electric vehicles were really rare, expensive and not attractive at all compared to fuel cars. But in the recent years, the electric technology improved and became more competitive with conventional cars in terms of comfort and performances. Recently, Berri (2012) shows that attributes related to car use, such as the level of pollution, the frequency of station, operating costs or the range also influence the consumer behavior.
In view of the pronounced popularity of the population for the environmental issue, car manufacturers then created a vehicle range especially dedicated to clean-fuel vehicle in order to gain potential consumer. It is important for them to know the target population that is likely to buy these vehicles. The use of stated preference survey allows to get more information about consumers. With this information, several researchers highlight that the socio-economic factors such as the gender, the household income or the origin of the respondent are parameters explaining the choice concerning clean-fuel vehicle. Welzel and Schramm-klein (2013) seek to define early adopter groups by establishing consumer behavior influencing variables for a German sample. It turns that attitudes are both influencing by knowledge about the technology, social norm and perceived innovation characteristics. Moreover, consumers can be assigned to three different groups (early adopter, second user and refusing electric) depending on their socio-economics factors and attitudes. Glerum *et al.* (2013) assessed and defined attitudes, the parameters involved and their influence on the consumer's purchase behavior for Switzerland. This assessment was made using a hybrid choice model (Ben-Akiva *et al.* (2002)). Two attitudes were pointed out: pro-leasing and pro-convenience attitude, each of them depend on the socio-economic characteristics of the respondent.

This paper builds up on existing literature and propose a model to forecast consideration for electric vehicles in car renewal based on individual latent attitudes and observed characteristics.

3 Methodology

This section develops the mathematical framework used in order to model consideration for electric vehicles. Literature suggests that attitudes of the consumer have an important impact on the purchasing choice (Ben-Akiva *et al.* (2002)). They can be integrated into a discrete choice model using the hybrid choice model framework (see Fig. 1). The model integrates two components, the latent variable model and the choice model presented in Sections 3.1 and 3.2. Model identification and estimation are discussed in Sections 3.3 and 3.4. Each equation presented in this section represent an individual n facing alternatives i. For the sake of clarity, we drop out subscript n.

Figure 1: Integrated Choice and Latent Variable Model



Source: Walker (2001)

3.1 Latent variable model

This model explains specific attitudes affecting respondents choice by socio-economic characteristics or vehicle attributes. For each of this j attitudinal dimensions, a latent variable model is defined as: The structural equation of a latent variable F_j^* is specified as follows.

$$F_j^* = \sum_i \beta_{j,i} \cdot X_{j,i} + l_j \cdot \omega_j, \qquad i = 1, \ldots, n \tag{1}$$

Where $X_{j,i}$ are socio-economic characteristics of a respondent, $\beta_{j,i}$ and l_j are parameters to estimate. $\omega_j \sim \mathcal{N}(0,1)$ is a random variable. The latent variables F_j^* are not directly observable. They can be measured by indicators $I_{j,k}$, expressed on a five-point likert scale. k depends on the number of indicator present in each attitudinal dimension, i.e $k = k(j)$.
The measurement model relates the responses $I_{j,k}$ a respondent gives about his/her opnion that relates to the latent variable F_j^*. Since the responses $I_{j,k}$ are discrete and ordered variables, the measurement model is specified as an ordered logit regression, where $I_{j,k}^*$ are latent variables which represent an underlying continous distribution of $I_{j,k}$.

$$I_{j,k}^* = \omega_k \cdot F_j^* + \alpha_k + \epsilon_k \tag{2}$$

Where ω_k and α_k are parameters to estimate, ϵ_k represent the error term, $\epsilon_k \sim \mathcal{L}(0,1)$. Indicators $I_{j,k}$ are ordered and related to $I_{j,k}^*$ with the following mapping:

$$I_{j,k} = \begin{cases} 1 & \text{if } I_{j,k}^* \leq b_1 \\ 2 & \text{if } b_1 < I_{j,k}^* \leq b_2 \\ 3 & \text{if } b_2 < I_{j,k}^* \leq b_3 \\ 4 & \text{if } b_3 < I_{j,k}^* \leq b_4 \\ 5 & \text{if } b_4 < I_{j,k}^* \end{cases} \tag{3}$$

Probabilities are defined as:

$$\begin{aligned} Pr(I_{j,k} = 1) &= \frac{1}{1 + \exp(\omega_k \cdot F_j^* + \alpha_k - b_1)} \\ Pr(I_{j,k} = 2) &= \frac{1}{1 + \exp(\omega_k \cdot F_j^* + \alpha_k - b_2)} - \frac{1}{1 + \exp(\omega_k \cdot F_j^* + \alpha_k - b_1)} \\ Pr(I_{j,k} = 3) &= \frac{1}{1 + \exp(\omega_k \cdot F_j^* + \alpha_k - b_3)} - \frac{1}{1 + \exp(\omega_k \cdot F_j^* + \alpha_k - b_2)} \\ Pr(I_{j,k} = 4) &= \frac{1}{1 + \exp(\omega_k \cdot F_j^* + \alpha_k - b_4)} - \frac{1}{1 + \exp(\omega_k \cdot F_j^* + \alpha_k - b_3)} \\ Pr(I_{j,k} = 5) &= 1 - \frac{1}{1 + \exp(\omega_k \cdot F_j^* + \alpha_k - b_4)} \end{aligned} \tag{4}$$

3.2 Choice model

In a choice model, an individual n faces alternatives i represented by a utility function U_{in}. In the case of an ordered logit model where the individual has to estimate if one alternative will be considered or not, there exist only one utility function U^* relative to this alternative. The latter directly depends on the latent variables of the j attitudinal dimensions. In those case where electric and plug-in hybrid has to be estimated, there exist two utility functions U^*_{EV} and U^*_{PHEV} (Eqs. (5) and (6)).

$$U^*_{EV} = \sum_j \Pi_\mathrm{j} \cdot F^*_j + \sum_i \beta_i \cdot X_i + \tau^{EV}_k = V_{EV} + \tau^{EV}_k \tag{5}$$

$$U^*_{PHEV} = \sum_l \Delta_\mathrm{l} \cdot F^*_l + \sum_m \beta_m \cdot X_m + \tau^{PHEV}_k = V_{PHEV} + \tau^{PHEV}_k \tag{6}$$

Where X_i and X_m are socio-economic characteristics of the respondent. F^*_j and F^*_l are latent variables as defined earlier. β_i, β_m, Π_j and Δ_l are parameters to estimate. Moreover, Π_j and Π_l represent the part of each attitude j on the respondent's choice. τ^{EV}_k and τ^{PHEV}_k represent the error terms, $\tau^{EV}_k, \tau^{PHEV}_k \sim \mathcal{L}(0,1)$. Choice indicators y_{EV} and y_{PHEV} of each respondent directly depend on utility functions U^*_{EV} and U^*_{PHEV}(see Eqs. (5) and (6)). Considering a binary choice:

$$y_{EV} = \begin{cases} 0 & \text{if } U^*_{EV} \leq b_1 \\ 1 & \text{if } b_1 < U^*_{EV} \end{cases} \tag{7}$$

$$y_{PHEV} = \begin{cases} 0 & \text{if } U^*_{PHEV} \leq b_2 \\ 1 & \text{if } b_2 < U^*_{PHEV} \end{cases} \tag{8}$$

Probabilities are then defined as:

$$\begin{aligned} Pr(y_{EV} = 0) &= \frac{1}{1 + \exp\left(V_{EV} - b_1\right)} \\ Pr(y_{EV} = 1) &= 1 - \frac{1}{1 + \exp\left(V_{EV} - b_1\right)} \end{aligned} \tag{9}$$

$$\begin{aligned} Pr(y_{PHEV} = 0) &= \frac{1}{1 + \exp\left(V_{PHEV} - b_2\right)} \\ Pr(y_{PHEV} = 1) &= 1 - \frac{1}{1 + \exp\left(V_{PHEV} - b_2\right)} \end{aligned} \tag{10}$$

3.3 Model identification

The identification model concern latent variable $I^*_{j,k}$. For each attitudinal dimension j the localization and dispersion factor are fixed for the first indicator.

- dispersion parameter $\omega_1 = 1$
- localization parameter $\alpha_1 = 0$

Moreover, expressions of latent variable do not have constant (no intercept term). That means that all the thresholds are estimated.

Remark: A similar model can be built by adding a constant and normalize one threshold to 0 for all indicators. This method is identical but comport a locational shift.

3.4 Model estimation

Hybrid choice model (HCM) is estimated by using the software Biogeme (Bierlaire (2003)). The individual contribution to the likelihood function is given by the following expression:

$$L_i = \int_{D(F_1^*,F_2^*,F_3^*)} \prod_{j\in\{EV,PHEV\}} P(y_j|F_1^*, F_2^*, F_3^*, \Pi_k, \Delta_k, \boldsymbol{X.}', \boldsymbol{\beta.}') \left[\prod_{q=1}^{3} \left\{ \prod_{t=1}^{T_q} g(I^*_{q,t}|F^*_q, \omega_t, \alpha_t) \cdot f(F^*_q|\boldsymbol{X.}'', \boldsymbol{\beta.}'') \right\} \right] \quad dF^*_q \tag{11}$$

Where y_j is a matrix of individual binary choice concerning consideration of EV and PHEV as powertrain; F_1^*, F_2^* and F_3^* are the structural equations of latent variable; Π_k and Δ_k are proportion of each attitudinal dimension in the respondent choice for each powertrain with $k = 1, 2, 3$; $\boldsymbol{X.}'$ and $\boldsymbol{X.}''$ are vectors of socio-economic attributes of the respondent for the structural equation of latent variables and the choice model; $\boldsymbol{\beta.}'$ and $\boldsymbol{\beta.}''$ are vectors of parameters relative to the structural equation of latent variables and the choice model; T_q represents the number of indicators relative to each latent variable; g and f are the distributions of the indicators and the latent variables; $I^*_{q,t}$ are vectors of indicators relative to latent variable model of each attitudes; F^*_q is the structural equation of latent variable relative to each attitudinal dimension; ω_t and α_t are vectors of parameters relative to the measurement of the latent variable model.

4 Case study

4.1 Data analysis

The data used has been collected by a Renault-Nissan Alliance survey. It was conducted among five European countries (France, Germany, UK, Italy, and Spain) during the month of September 2012. Getting a representative sample of each country studied is a main issue. In order to achieve this, some responses were removed thanks to the screening part of the survey. For example, minor or people older than 75 years, when there is no car in a current household, people professionally related to the automobile industry (advertising/ automotive industries/ journalism), when a household plans to replace their actual car in more than 5 years, when the replacement car will be a used car etc. Information collected is also used to create a personal choice situation. The latter is proposed to the respondent in the second part of the questionnaire and provides stated preferences for each of them. Finally the total sample is about 5000 observations, the distribution between each European country is represented by Table 1. France and Germany approximately represent the half of the sample. The purpose of this paper is to create a

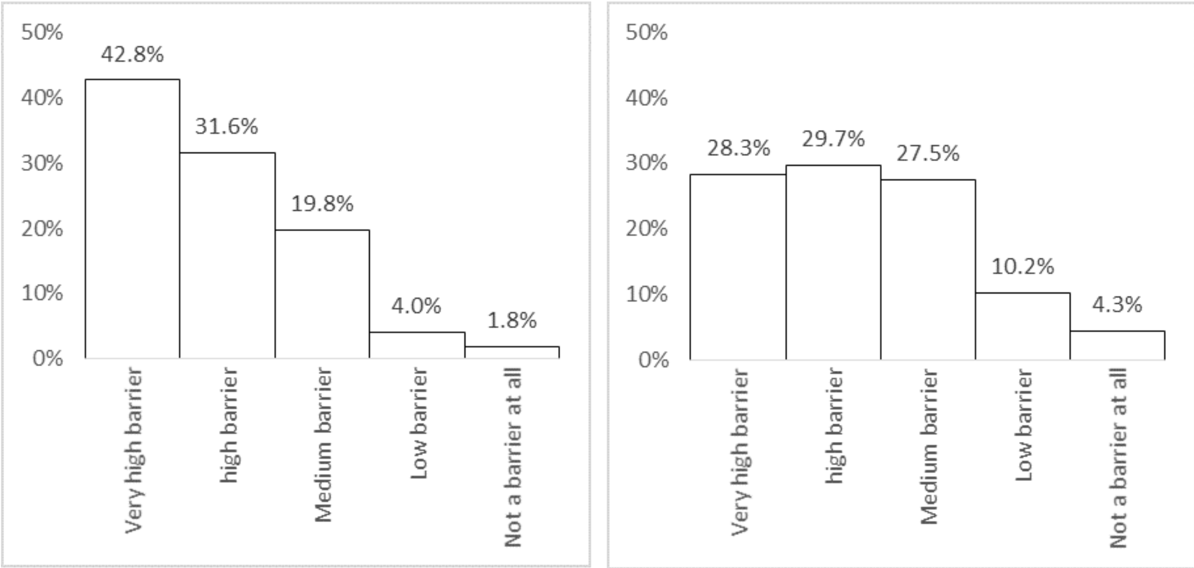
Table 1: Country of origin of respondents

Country	**Population**	**Percentage**
France	1101	21.9%
UK	981	19.5%
Germany	1448	28.9%
Spain	518	10.3%
Italy	971	19.3%
Total	5019	100%

model capable of forecasting consideration for electric vehicles. From the theory presented in Section 3, the opinion statements are going to be used as indicators. They shall come from a series of questions relative to barriers ("Assessment of the barrier to EV") and motivations ("Assessment of the opportunities for EV") that users may have for electric vehicles. For these questions each respondent has to rate each item, using a five-point scale. Hence, barriers are evaluated from 5 (very high barrier) to 1 (not a barrier at all) and opportunities from 1 (very good reason) to 5 (not a good reason). The distribution of respondents' answers to two different questions relative to barrier is represented in Figure 2. Both questions concern the financial aspect of electric vehicles. As expected, those two items are negatively perceived. Despite the closeness of the two questions, the obtained answers are rather different. Indeed, the vehicle

Figure 2: Histograms of the answers to opinion statement Barrier 3 & 7

(a) Barrier 3 "Will be expensive to buy" (b) Barrier 7 "Will be expensive to operate"



price is considered as a very strong barrier by 42.8% of the respondents(Figure 3(a)) instead of responses relatives to running cost are more spread between "medium", "high" and "very high barrier"(Figure 3(b)).

In addition to differences founded between barriers an opportunities, it is important to study differences between populations within the sample. Countries considered by the survey, although close to each other geographically, present big differences. Of Latin origin, French, Italian and Spanish people have culturally more points in common between them compared to with the Germans or the British. This peculiarity influences the lifestyles and the attitudes of the inhabitants of each of the countries. Besides the cultural origins, special characteristics of every country make the differences between respondents larger. Whether it is the demography, the economy, the policy, or even the surface, each of these indicators implies that the inhabitants of every country form a unique entity. Hence their attitudes are also unique, especially concerning car purchase.

This remark can be confirmed by a data analysis, using descriptive statistics (Table 2). This implies socio-economic groups relative to the respondent (gender, age), his household (number of people, number of cars, income) and his car (frequency of usage by week). Results highlight that in average Spanish and Italian are less represented by woman (24%) than other countries (more than 35%), the average age is located between 39 and 48. Concerning the household composition, in average Spanish and Italian are more numerous (more than 3.15) than French, German and British (between 2.5 and 2.8). The number of children is spread between 0.46 and 0.76, Spain having the highest rate and Germany the lowest. The number of car is higher than

1.45 for every country, Italy is the one with more cars per household (1.82). It is also the country with largest frequency of usage with, on average, 6 days a week France is the lowest with only 5.44 days. Finally, the household income is located between category 6 (25 001- 36 000) and 7 (36 001- 42 000) for every country. There exist variations which depend on the economy, level of life and other external factors related to the country studied.

Given that the characteristics of respondents differ according to the origin, it may have an influence on the answers to opinion statements. Then, it may be interesting to verify if there exist differences between countries for a single assessment. For this purpose, Figure 5(a) represents the repartition of responses by country for the barrier assessment 1 "Concern with battery durability" and Figure 5(b) for opportunity assessment 12 "Will be quick to recharge".
The concern with battery durability is a barrier for more than 90% in every case. However, the distribution change depending on the country studied. For example, France considers it at least as a "high barrier" in 78.4% of cases instead of Italy in 58.4%. Globally, the distribution between "medium barrier", "high barrier" and "very high barrier" really depend on the country of the respondent.
The quick load time of the battery is at least an average reason to choose an electric vehicle in almost 90% of cases, only Germany considers it as a "poor reason" or "not a reason at all" in more than 10%. Again, the distribution change depending on the country studied. For example, France considers it at least as a "good reason" in 83.4% of cases instead of Italy in 66.1%. The distribution between "average reason","good reason" and "very good reason" vary from one country to another.
For these two examples, Italian seems to be less categorical and more nuanced about barriers or opportunities of electric vehicles. Hence, the data provided are heterogeneous and dependent on the country of origin of the respondent.

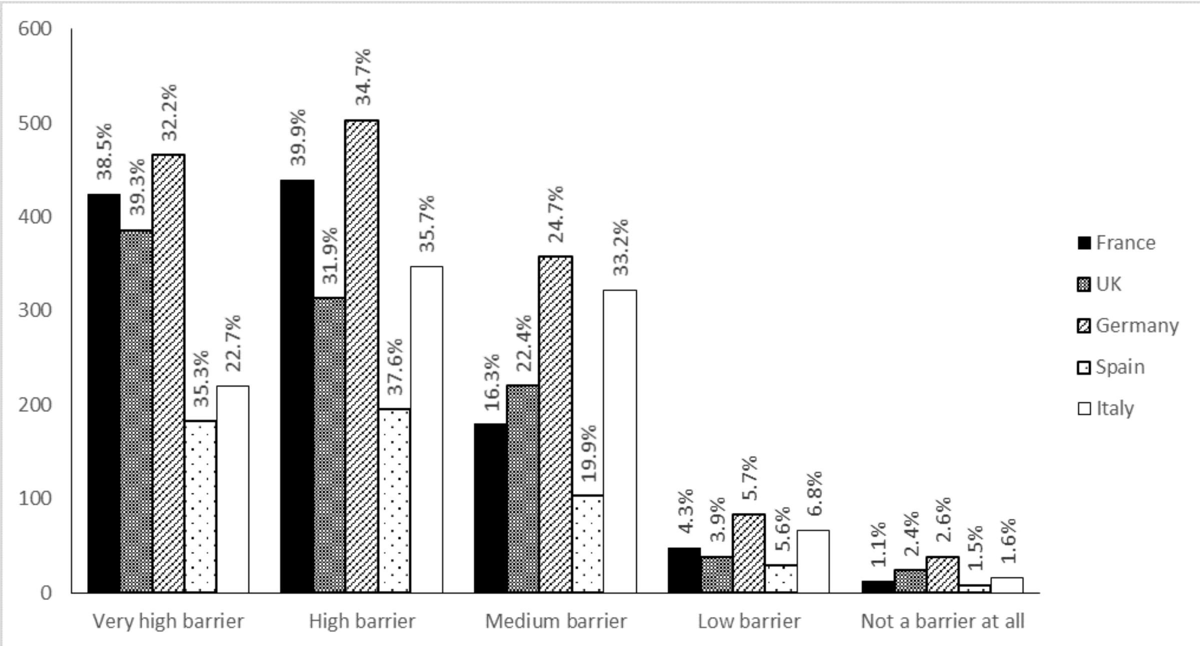
Table 2: Descriptive statistics

	Label	Min.	Max.	Mean	Std. Dev.	Freq.
France	Age	19	73	47.63	12.53	508
	Numb. Pers.	1	7	2.77	1.21	556
	Numb. Child	0	5	0.64	0.93	671
	Numb. Car	1	4	1.63	0.68	509
	Freq.usage (week)	0	7	5.44	1.82	438
UK	Age	18	75	45.53	14.57	479
	Numb. Pers.	1	7	2.80	1.33	498
	Numb. Child	0	4	0.66	0.98	615
	Numb. Car	1	4	1.41	0.61	628
	Freq.usage (week)	0	7	5.67	1.59	364
Germany	Age	18	75	45.93	12.74	668
	Numb. Pers.	1	7	2.52	1.12	846
	Numb. Child	0	4	0.46	0.78	996
	Numb. Car	1	4	1.52	0.66	814
	Freq.usage (week)	0	7	5.82	1.36	447
Spain	Age	19	69	39.84	11.82	279
	Numb. Pers.	1	7	3.26	1.18	293
	Numb. Child	0	5	0.76	0.92	265
	Numb. Car	1	4	1.63	0.68	242
	Freq.usage (week)	0	7	5.61	1.52	203
Italy	Age	18	73	43.69	12.84	467
	Numb. Pers.	1	7	3.16	1.22	583
	Numb. Child	0	5	0.54	0.81	613
	Numb. Car	1	4	1.82	0.74	343
	Freq.usage (week)	0	7	6.00	1.44	262

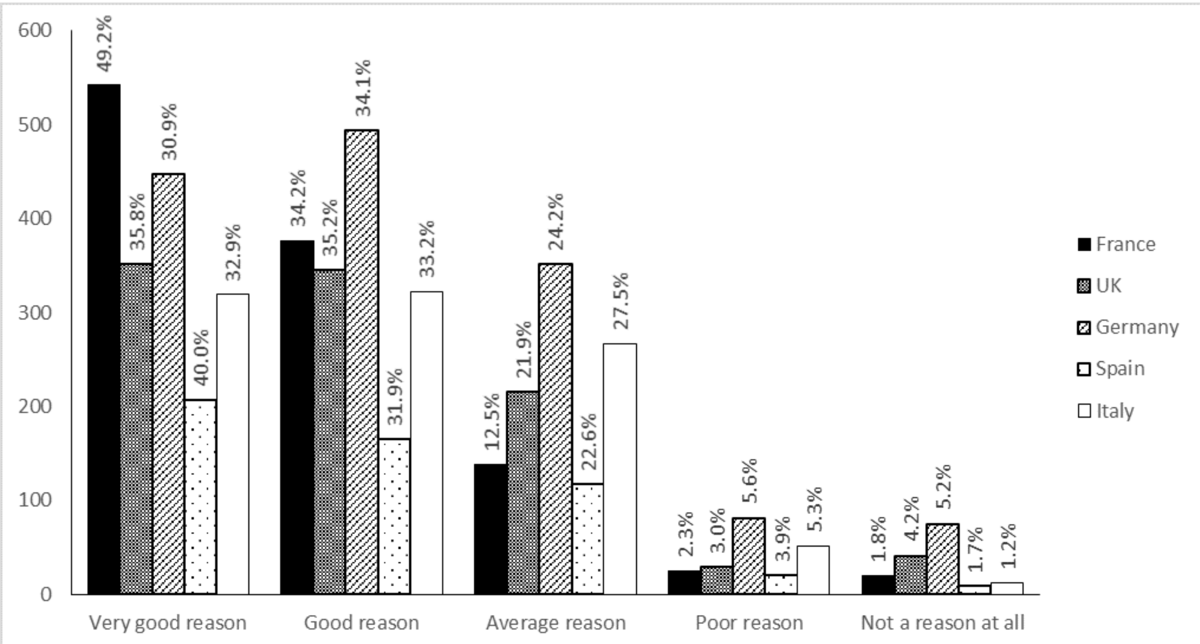
Label		**France**	**UK**	**Germany**	**Spain**	**Italy**
Gender	Male	61.4%	60.8%	64.2%	76.3%	75.7%
	Female	38.6%	39.2%	35.8%	23.7%	24.3%

Figure 4: Histograms of the answers to opinion statement

(a) Barrier 1 "Concern with battery durability"



(b) Opportunity 12 "Will be quick to recharge"



4.2 Application

The process leading to a purchasing choice takes into account variables such as barriers or opportunities in a simultaneous way. Those questions are numerous and varied (see Table 9) and can explain attitudes. In order to create those attitudes a factor analysis is performed on all the questions. This method is a statistical procedure that is conducted to identify groups of related items (called factors). Results show that barriers can be explained with 4 attitudes and opportunities with 3.

Barrier-1: Mistrust against accompanying element of EV
Barrier-2: Fear about the capabilities of electric vehicles
Barrier-3: Anxiety toward EV
Barrier-4: Expensive to maintain

Opportunity-1: Compatibility with daily life
Opportunity-2: Interest in new technologies
Opportunity-3: Environmental friendliness

Table 10 provides the affectation of each assessment to one of the attitude. We choose to reject some subgroup as "Fear about the capabilities of electric vehicles" or "Mistrust against accompanying element of EV". Indeed, nowadays, the product range offered for electric vehicles is quite large. It is possible to find an electric vehicle considered equivalent in terms of performance or comfort to each existing conventional models. Then we kept the attitudes that we considered most pertinent. Thus, we get the following three attitudes:

- A **anxiety attitude (I_1)**, characterizing respondent which are worried about EV and PHEV technology performances (Barrier-3).
- An **environmental friendliness attitude (I_2)**, characterize individuals which are really concerned about environmental issues, who believe that electric vehicles are an efficient solution in order reduce global warming (Opportunity-3).
- A **compatibility with a daily life attitude (I_3)**, represents the people waiting for electric vehicles full integration into their daily lives (Opportunity-1).

We remark that environmental friendliness and compatibility attitudes are measured by responses from questions relating to the assessment of the opportunities for EV. Instead of anxiety attitude which is measured by question relating to the assessment of the barriers to EV.

In order to reduce the number of assessment provided in Table 10 for the three attitudes selected, we decided to select the most appropriate indicators for each of them. Finally, indicators $I_{j,k}$ are defined with the following items:

Anxiety 1 ($I_{1,1}$): Concern with battery durability/life.
Anxiety 2 ($I_{1,2}$): Long time recharge.
Anxiety 3 ($I_{1,3}$): Will have inadequate driving distance on one battery charge.
Anxiety 4 ($I_{1,4}$): Not enough/ adequate recharge stations.
Environmental friendliness 1 ($I_{2,1}$): Will reduce dependency on oil.
Environmental friendliness 2 ($I_{2,2}$): Will generate zero exhaustive emissions.
Environmental friendliness 3 ($I_{2,3}$): Will be the next best thing for the planet.
Compatibility 1 ($I_{3,1}$): Will provide adequate driving range on one charge.
Compatibility 2 ($I_{3,2}$): Will be quick to recharge.
Compatibility 3 ($I_{3,3}$): Adequate charging station will be provided.

For each of this attitudinal dimension a latent variable model is build. The attitudes dimensions and indicators which have just been defined are going to be used to estimate respondents' choices concerning powertrain. Choice is binary: considering 100% electric vehicle (EV) or plug-in electric vehicle (PHEV) as their future power train or not. Responses are relative to the question B5 "Consideration of different powertrain". For this question, each respondent has to indicate, using a 11 point scale, if their consideration for this powertrain is high or low. Hence, consideration is evaluated from 10 (very high barrier) to 0 (not a barrier at all). We transformed these answers into a binary choice:

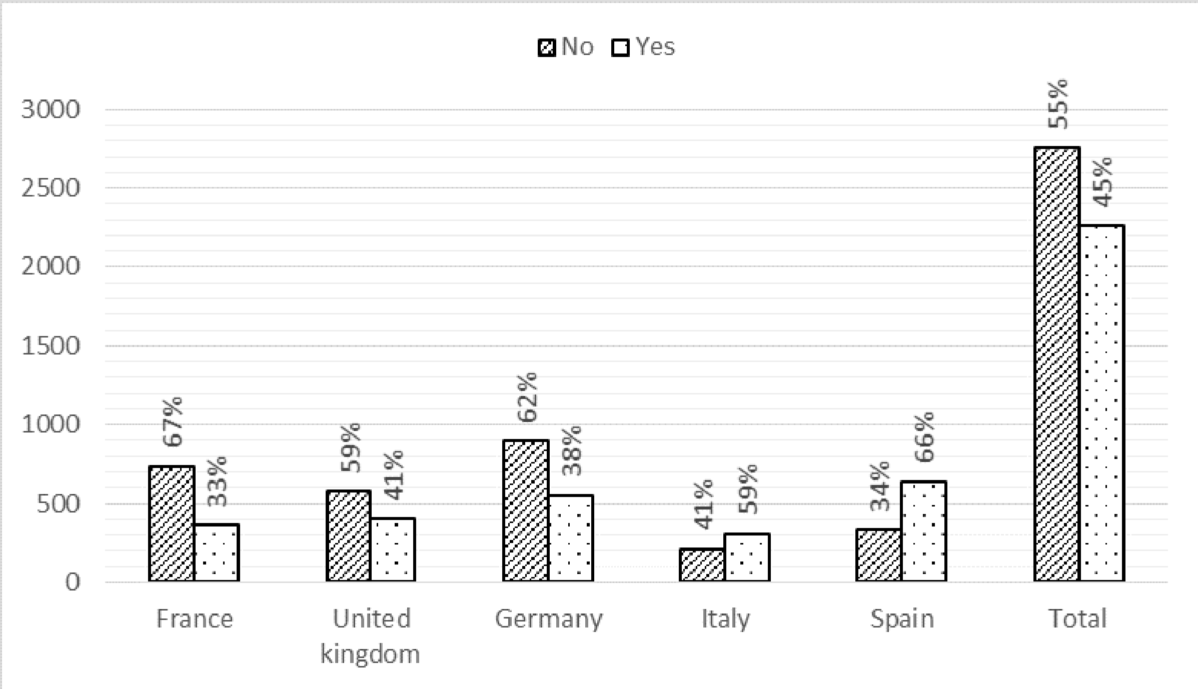
- 0 respondent will not consider an EV (respectively PHEV) if the response is between 0 and 5
- 1 respondent will consider an EV (respectively PHEV) if the response is between 6 and 10

Respondent's answers show that the distribution between "will not consider" and "will consider" depend on the powertrain evaluated. Figure 6. France, Germany and United Kingdom do not support electric vehicle while Italy and Spain do. Globally the sample rejects electric technology at 55% Figure 7(a). Concerning plug-in hybrid electric vehicle, the part of respondent in favor of this technology increase compared to EV. Only France and United Kingdom do not support PHEV. Globally the sample accepts plug-in hybrid technology at 58% Figure 7(b).

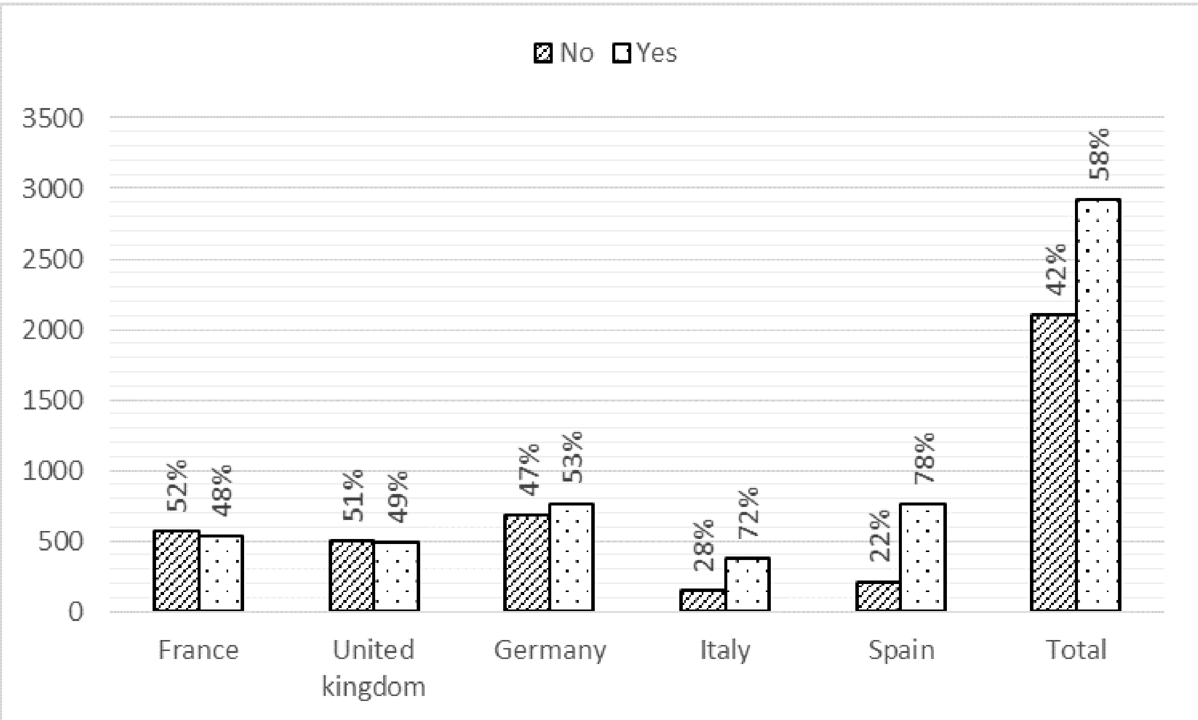
Having noticed the heterogeneousness of the data by country (Section 4.1), it was decided to build a model per country using the same specification for the five European countries (France, Germany, Spain, Italy, UK). The objective is to observe the differences of behavior according to the studied country. It exists two types of variables (Tables 3 and 4): those relative to the latent variable model (Section 3.1) and those relative to the choice model (Section 3.2). The variables

Figure 6: Histograms, for each country, of the binary answers to opinion statement

(a) Consideration of EV



(b) Consideration of PHEV



tested for the latent variable model are the same for all attitudinal dimensions (Table 3) and those tested for the choice model are the same for the two utility functions (Table 4). Concerning attitudinal dimensions and in order to highlights differences between countries, variables tested take into account results of descriptive statistics (Table 2). Moreover, in order to avoid conflicts between the latent variable model and the choice model it is deciding to use different variables for those two models. Most variables have been chosen according to the literature review (Section 1)the data analysis (Section 4.1) and some by intuition.

Remark:Tables 3 and 4 show the latest version of our model. Some variables, not presented here, were tested and rejected due to a lack of significance or coherence. Moreover variables concerning age and mileage are transformed in piecewise linear function.

Table 3: Specification table of latent variable models

Coefficient	Variable	Variable description
β_{Female}	X_{Gender}	1 if the respondent if female 0 if the respondent if male
$\beta_{WithChild}$	X_{Numb_Child}	Number of child in the household
$\beta_{VehMainCar}$	$X_{Vehicle\_Status}$	1 if the vehicle is the main car of the household 0 otherwise
$\beta_{DistCovTot}$	$X_{Distance\_Covered}$	Logarithm of the distance covered by the current vehicle of the household
$\beta_{IndividParkLocationWork}$	$X_{Individual\_Parking\_At\_Work}$	1 if the respondent has an individual parking at work 0 otherwise
$\beta_{CurrVehAutomatic}$	$X_{Curr\_Veh\_Transmission}$	1 if the current vehcile has automatic transmission 0 otherwise
$\beta_{EmployerRespBuying}$	$X_{Employer}$	1 if the employer is responsible of buying (compagny car) 0 otherwise
$\beta_{CurrVehSegmentA}$	$X_{Veh\_Segment}$	1 if the current vehicle belong to segment A 0 otherwise
β_{CSP^+}	X_{CSP^+}	1 if the household belong to high socio-professional category (CSP+) 0 otherwise
$\beta_{Age18-24}$	$X_{18<Age<24}$	1 if the respondent's age is between 18 and 24 0 otherwise
$\beta_{Age25-34}$	$X_{25<Age<34}$	1 if the respondent's age is between 25 and 34 0 otherwise
$\beta_{Age35-49}$	$X_{35<Age<49}$	1 if the respondent's age is between 35 and 49 0 otherwise
$\beta_{Age50-75}$	$X_{50<Age<75}$	1 if the respondent's age is between 50 and 75 0 otherwise
l_j	ω_j	Random variable $\mathcal{N}(0, 1)$

Models were tested with 500 draws. Results are presented by attitudinal dimension for all countries Tables 5 to 7 and 11. The part of each attitude on the respondent's choice are presented by country with the results of the two utility functions in Table 8.

Remark: in order to confirm the robustness of our model we tested France with 1000 draws. It

Table 4: Specification table of choice models

Coefficient	Variable	Variable description
$\Pi_{Anxiety}$	$F^*_{Anxiety}$	Part of the anxiety attitude
$\Pi_{Enviro.friendliness}$	$F^*_{Enviro.friendliness}$	Part of the environmental friendliness attitude
$\Pi_{Compatibility}$	$F^*_{Compatibility}$	Part of the compatibility attitude
$\beta_{Familiarity}$	$X_{Familiarity}$	1 if the respondent know very well or well the powertrain considered 0 otherwise
$\beta_{HeavyTraffic}$	$X_{Drive\_Heavy\_Traffic}$	Estimated frequency (%) of usage for new car in moderate to heavy stop-and-go traffic with frequent stops and long idle waiting
$\beta_{ExpectedMilleage0-16}$	$X_{0<Mileage<16}$	1 if the respondent's expected mileage for the next year is between 0 and 16 km/ay 0 otherwise
$\beta_{ExpectedMilleage17-54}$	$X_{17<Mileage<54}$	1 if the respondent's expected mileage for the next year is between 17 and 54 km/day 0 otherwise
$\beta_{ExpectedMilleage55-91}$	$X_{55<Mileage<91}$	1 if the respondent's expected mileage for the next year is between 55 and 91 km/day 0 otherwise
$\beta_{ExpectedMilleage92-500}$	$X_{92<Mileage<500}$	1 if the respondent's expected mileage for the next year is between 92 and 500 km/day 0 otherwise

turns variables results are very close. The same variable remain significant with the appropriate sign.

Table 5: Estimation results of Anxiety attitude (*Statistical significance> 95%; **Statistical significance> 90%)

	France		Germany		Italy		Spain		UK	
Coefficeint	**Parameter estimate**	**t-test**	**Parameter estimate**	**t-test**	**Parameter estimate**	**t-test**	**Parameter estimate**	**t-test**	**Parameter estimate**	**t-test**
β_{Female}	0.556 *	3.85	-0.0856	-0.78	0.0614	0.35	0.274	1.16	0.196	1.1
$\beta_{WithChild}$	-0.0293	-0.37	-0.0443	-0.57	0.0279	0.29	-0.315 *	-3.06	0.0644	0.69
$\beta_{VehMainCar}$	0.178	1.3	0.128	1.14	0.202	1.36	0.525 *	2.61	0.856 *	4.92
$\beta_{DistCovTot}$	-0.0668	-0.85	0.246 *	3.51	0.214 *	2.23	0.00302	0.03	0.00606	0.06
$\beta_{IndividParkLocationWork}$	-0.524 *	-3.24	-0.0486	-0.34	-0.0494	-0.27	-0.165	-0.72	-1.1 *	-4.09
$\beta_{CurrVehAutomatic}$	-0.808 *	-3.76	-0.00217	-0.01	-0.778 *	-3.42	0.265	0.92	0.458 *	2.22
$\beta_{EmployerRespBuying}$	0.294	0.52	0.338	1.11	1.33 **	1.84	1.72	1.58	1.15 *	2.32
$\beta_{CurrVehSegmentA}$	-0.37 **	-1.88	-0.0601	-0.27	-0.322	-1.5	-0.0095	-0.02	0.812 *	2.81
β_{CSP^+}	-0.271 **	-1.8	-0.207 **	-1.87	-0.00318	-0.02	0.22	1.15	0.0751	0.45
$\beta_{Age18-24}$	-0.00605	-0.06	-0.0845	-1.24	0.106	0.93	-0.0104	-0.08	0.0887	0.79
$\beta_{Age25-34}$	0.0398	1.14	0.0514 **	1.85	-0.00322	-0.1	0.0727 **	1.76	-0.000279	-0.01
$\beta_{Age35-49}$	-0.00161	-0.1	0.0165	1.18	0.0169	0.94	0.041 *	1.99	0.0587 *	2.66
$\beta_{Age50-75}$	0.0589 *	3.55	-0.0156	-1.32	0.00509	0.26	-0.0338	-1	0.0346 **	1.91
l_1	-2.07 *	-19.3	-1.86 *	-21	-2.06 *	-19.51	1.98 *	13.66	2.45 *	19.22
b_1	-6.4 *	-8.13	-4.14 *	-8.22	-4.03 *	-4.74	-4.96 *	-5.43	-4.3 *	-5.38
b_2	-4.23 *	-5.49	-2.54 *	-5.1	-1.79 *	-2.12	-3.06 *	-3.42	-2.71 *	-3.38
b_3	-1.73 *	-2.27	-0.147	-0.3	1.32	1.56	-0.601	-0.68	0.132	0.16
b_4	1.02	1.33	2.16 *	4.34	3.83 *	4.52	1.9 *	2.14	2.54 *	3.14

Table 6: Estimation results of Environmental friendliness attitude (*Statistical significance> 95%; **Statistical significance> 90%)

	France		**Germany**		**Italy**		**Spain**		**UK**	
Coefficeint	**Parameter estimate**	**t-test**	**Parameter estimate**	**t-test**	**Parameter estimate**	**t-test**	**Parameter estimate**	**t-test**	**Parameter estimate**	**t-test**
β_{Female}	1.02 *	4.97	0.0925	0.53	0.23	0.91	0.796 *	2.42	0.0811	0.33
$\beta_{WithChild}$	0.00844	0.07	0.26 *	2.32	0.0195	0.14	-0.126	-0.86	0.488 *	3.91
$\beta_{VehMainCar}$	-0.068	-0.35	0.345 *	2.01	0.354	1.56	0.858 *	3.09	0.347	1.39
$\beta_{DistCovTot}$	-0.0364	-0.31	0.118	1.17	-0.208	-1.49	0.0158	0.11	-0.0183	-0.15
$\beta_{IndividParkLocationWork}$	-0.199	-0.84	0.227	1.11	0.213	0.79	0.376	1.11	-0.297	-0.81
$\beta_{CurrVehAutomatic}$	0.618 *	2	0.239	1.03	0.362	0.96	-0.277	-0.72	0.24	0.89
$\beta_{EmployerRespBuying}$	-0.817	-0.9	-0.994 *	-2.27	-2.19 *	-2.06	1.68	1.2	0.879	1.12
$\beta_{CurrVehSegmentA}$	0.363	1.16	1.12 *	3.32	0.157	0.43	0.752	1.23	1.19 *	2.63
$\beta_{CSP^{+}}$	-0.234	-1.06	0.11	0.65	-0.062	-0.27	0.753 *	2.86	-0.3	-1.22
$\beta_{Age18-24}$	-0.0252	-0.13	-0.0242	-0.21	0.106	0.69	-0.0916	-0.52	0.188	0.95
$\beta_{Age25-34}$	0.0586	1.03	0.00794	0.18	-0.000675	-0.01	-0.0263	-0.44	-0.0465	-0.85
$\beta_{Age35-49}$	0.0372	1.45	-0.0221	-1.11	0.0442	1.63	0.085 *	2.87	-0.0577 *	-2.01
$\beta_{Age50-75}$	-0.0132	-0.61	0.00748	0.41	-0.0276	-0.91	-0.00534	-0.14	0.00359	0.14
l_2	3.15 *	21.16	-2.94 *	-24.43	-3.07 *	-19.72	-2.6 *	-14.02	-3.27 *	-19.53
b_1	-1.84	-1.36	-2.65 *	-3.36	-1.26	-1.12	-1.28	-1.09	-2.43 **	-1.75
b_2	1.44	1.05	-0.0386	-0.05	1.45	1.28	1.65	1.41	0.587	0.42
b_3	4.36 *	3.19	2.59 *	3.3	4.72 *	4.17	4.32 *	3.7	3.67 *	2.63
b_4	6 *	4.36	4.08 *	5.17	6.83 *	5.98	5.6 *	4.74	5.03 *	3.59

Table 7: Estimation results of Compatibility attitude (*Statistical significance> 95%; **Statistical significance> 90%)

	France		**Germany**		**Italy**		**Spain**		**UK**	
Coefficeint	**Parameter estimate**	**t-test**	**Parameter estimate**	**t-test**	**Parameter estimate**	**t-test**	**Parameter estimate**	**t-test**	**Parameter estimate**	**t-test**
β_{Female}	0.434	1.46	-0.333	-1.46	0.273	1.17	0.44	1.26	0.291	0.98
$\beta_{WithChild}$	-0.205	-1.14	0.222	1.41	0.233 **	1.8	-0.177	-1.18	0.255	1.63
$\beta_{VehMainCar}$	0.905 *	3.24	0.156	0.69	0.00559	0.03	1.01 *	3.37	0.535 **	1.73
$\beta_{DistCovTot}$	0.182	1.15	0.329 *	2.22	0.165	1.28	0.179	1.09	0.0679	0.36
$\beta_{IndividParkLocationWork}$	-1.02 *	-2.98	0.0958	0.34	0.0343	0.15	-0.181	-0.53	-1.02 *	-2.4
$\beta_{CurrVehAutomatic}$	0.204	0.42	0.306	0.88	0.0243	0.08	0.55	1.28	0.517	1.42
$\beta_{EmployerRespBuying}$	1.75	1.55	-1.01 **	-1.82	-1.9 *	-2.28	3.18 **	1.65	1.29	1.22
$\beta_{CurrVehSegmentA}$	0.533	1.31	0.852 *	2	0.158	0.6	2.08 *	3.04	1.04 **	1.93
$\beta_{CSP^{+}}$	-0.245	-0.8	0.225	0.96	0.14	0.7	0.719 *	2.53	-0.339	-1.09
$\beta_{Age18-24}$	-0.247	-1.04	-0.0733	-0.4	0.0573	0.39	-0.224	-0.87	0.159	0.5
$\beta_{Age25-34}$	0.213 *	2.56	-0.0733	-1.25	-0.00182	-0.04	0.112 **	1.73	-0.0835	-1.12
$\beta_{Age35-49}$	0.01	0.27	0.0561 **	1.92	0.0481 *	2.04	0.00428	0.14	-0.0182	-0.43
$\beta_{Age50-75}$	-0.0112	-0.37	-0.0621 *	-2.58	-0.0238	-0.96	0.00933	0.21	-0.0118	-0.28
l_2	4.21 *	19.44	-4.15 *	-25.79	2.87 *	19.65	2.76 *	13.32	4.16 *	20.05
b_1	-1.55	-0.98	-2.71 *	-2.16	-3.32 *	-3.15	-1.68	-0.92	-2.57	-1.13
b_2	2.41	1.51	0.511	0.41	-0.337	-0.32	1	0.56	0.978	0.43
b_3	5.68 *	3.54	3.46 *	2.75	2.97 *	2.83	4.14 *	2.29	4.84 *	2.14
b_4	7.26 *	4.49	5.31 *	4.2	5.06 *	4.78	5.86 *	3.23	6.06 *	2.68

Table 8: Estimation results concerning the part of every attitudes in the consideration of EV and PHEV as powertrain (*Statistical significance> 95%; **Statistical significance> 90%)

	France		Germany		Italy		Spain		UK	
Coefficeint	**Parameter estimate**	**t-test**	**Parameter estimate**	**t-test**	**Parameter estimate**	**t-test**	**Parameter estimate**	**t-test**	**Parameter estimate**	**t-test**
$\Pi_{Anxiety}$	-0.429 *	-7.04	-0.505 *	-8.18	-0.327 *	-6.09	-0.444 *	-4.71	-0.426 *	-7.74
$\Pi_{Enviro.friendliness}$	0.205 *	4.89	0.374 *	8.51	0.179 *	4.33	0.0875	1.5	0.348 *	5.94
$\Pi_{Compatibility}$	0.00519	0.15	0.0642 *	2.3	0.0894 *	1.99	0.124 **	1.82	0.0576	1.47
$\beta_{FamilliarityEV}$	1.46 *	7.65	1.05 *	6.59	0.756 *	4.87	1.23 *	4.81	1.51 *	7.71
$\beta_{HeavyTrafficEV}$	0.0119 *	3.06	0.00465	1.27	0.0048	1.19	0.00452	0.76	0.0113 *	2.71
$\beta_{ExpectedMilleageEV0-16}$	0.034	0.96	-0.059 **	-1.91	-0.0171	-0.57	0.0444	1.15	-0.0562 **	-1.74
$\beta_{ExpectedMilleageEV17-54}$	-0.0069	-0.86	0.0188 *	2.66	-0.00605	-0.73	0.00326	0.3	-0.00418	-0.5
$\beta_{ExpectedMilleageEV55-91}$	0.00315	0.44	-0.0023	-0.32	0.00415	0.55	-0.00681	-0.7	0.000681	0.07
$\beta_{ExpectedMilleageEV92-500}$	-0.00146	-0.51	-0.00309	-0.78	-0.000612	-0.12	0.00296	0.67	0.000869	0.12
b_1	1.86 *	2.67	0.425	0.71	-1.16 *	-2.13	0.482	0.64	-0.127	-0.16
$\Delta_{Anxiety}$	-0.274 *	-5.4	-0.254 *	-5.38	-0.198 *	-3.55	-0.394 *	-4.02	-0.264 *	-6.09
$\Delta_{Enviro.friendliness}$	0.226 *	6.04	0.286 *	7.57	0.221 *	4.66	0.1	1.6	0.269 *	5.52
$\Delta_{Compatibility}$	0.0268	0.9	0.108 *	4.22	0.069	1.35	0.232 *	2.92	0.0714 *	2.09
$\beta_{FamilliarityPHEV}$	1.35 *	7.03	1.49 *	8.35	1.42 *	6.31	1.81 *	5.1	1.57 *	7.99
$\beta_{HeavyTrafficPHEV}$	0.0058	1.59	0.00387	1.13	0.00697	1.48	0.00697	1.03	0.00816 *	2.12
$\beta_{ExpectedMilleagePHEV0-16}$	0.0133	0.42	0.00312	0.1	0.00457	0.14	0.0319	0.75	-0.0509 **	-1.71
$\beta_{ExpectedMilleagePHEV17-54}$	-0.00107	-0.14	0.0176 *	2.67	-0.00259	-0.28	0.00556	0.46	0.0157 *	2.02
$\beta_{ExpectedMilleagePHEV55-91}$	0.00397	0.6	-0.00451	-0.65	0.00872	1	-0.00359	-0.33	-0.00391	-0.44
$\beta_{ExpectedMilleagePHEV92-500}$	-0.00473 **	-1.7	-0.0087 *	-2.03	-0.00687	-1.19	0.00282	0.55	-0.00216	-0.33
b_2	0.833	1.37	0.827	1.55	-1.02 **	-1.85	0.000695	0	0.0354	0.06

5 Discussion

This section deals with results obtained in Section 4.2. Results will be provided attitude after attitude before the finale consideration of respondent for EV and PHEV. Concerning attitudinal dimension, in so far as a model per country using the same specification is applied, variables are not significant for each attitude and each country. Anxiety is a barrier evaluated from 5 (very high barrier) to 1 (not a barrier at all), then a variable with a positive sign consider this attitude as a higher barrier and vice versa. Environmental friendliness and compatibility with daily life are opportunity evaluated from 5 (very good reason) to 1 (not a good reason), then a variable with a positive sign consider those attitudes as higher opportunity.

Anxiety attitude Concerning this attitudinal dimension several comments can be made. Generally, women are more fearful about unexpected effects so their anxiety is higher than men. The same explanation is also applicable concerning the main vehicle of households. When this car breaks down, people have difficulties to deal with this situation. Increasing the distance covered also increase the risk of failure, so the distance covered can be a cause of anxiety. Having an individual park location at work decreases this attitude as being a barrier in so far as the respondent do not have to spend extra time on the road finding a parking space. Automatic transmission is a technological improvement compared to manual car. Then, respondent with a current car having an automatic transmission are more confident with EV or PHEV. However, this results do not hold for United-Kingdom were anxiety is higher for automatic cars. People may have not the same trust than elsewhere. Employer often buy more than one vehicle, so their anxiety is higher because the amount of money invested is important. If the respondent has a vehicle that belong to segment A then anxiety seems to be a higher barrier for United-Kingdom. It is difficult to explain this result while this variable is a lower barrier for France. For respondent that belong to the highest socio-professional group anxiety is lower barrier, maybe because they can have more alternatives or means of substitution. For the different age class, the anxiety is a barrier from 25 years old. This can be explained by the familiarity of the respondent with the latest technology. Indeed, people under 30 years old are the first generation born with Internet, thus they adopt a less fearful approach to innovations. Concerning this attitude, it is difficult to explain why, for Spain, having child reduce anxiety toward EV and PHEV.

Environmental friendliness attitude This attitudinal dimension is the one with the less significant parameters. As expected women and respondent with child have higher environmental conscience then consider more this attitude as an opportunity. Also for households with more than one vehicle, the main car emit the major part of greenhouse gas, then EV and

PHEV are good opportunities to be environmental friendly. The same explanation can also be applied when the distance covered by one household increase. Automatic transmission allows reducing fuel consumption for conventional vehicles, then respondent with this vehicle type are more concerned with environmental issues. We thought that, for employers, buying EV or PHEV represent a good opportunity for the company in terms of image. But results show the opposite. We know that the amount of money invested for a company is the main argument in a buying process, then it may exist a bias between environmental conscience of firm and vehicles cost. Segment A typically represents cars build for the city, short, very manageable and with a low consumption. It seems normal that respondents with this vehicle segment consider the environmental aspect as a good opportunity. As expected the socio-professional group sign negative, indeed people with high revenue are generally more concerned with those issues. Concerning the different age class, environmental conscience is a good opportunity for respondents from 35 years old. During this period, people think more about the future and the world they want for their children. This result do not hold for United-Kingdom which have the opposite effect and which is difficult to interpret. For this attitude, the parking location is the only variable insignificant.

Compatibility attitude For this final attitude, compatibility is considered as an opportunity by respondents with child, for the household vehicle main car and the total distance covered. Those results are coherent because a good compatibility allows to simplify the daily life of respondent characterized by those variables. Hence, there are no differences in term of lifestyle between conventional vehicle and EV or PHEV if a good compatibility is founded. If respondent have an individual parking location at work, the compatibility is not an opportunity because he can instal is own equipment if the range provided is too low. While, people that only load vehicle at home needs a greater daily life compatibility. The sign of the variable when employer is responsible of the purchase vary across countries studied and is difficult to interpret. In one hand compatibility can still be biased by the vehicle price which implies a lower opportunity. In another hand it an advantage an implies fewer problems if all vehicles are compatible with their use. Cities are the perfect place to implement facilities for EV and PHEV. Moreover, vehicles of segment A are principally used in cities, then compatibility can be a greater opportunity for this segment. People with high revenue may pay more for new technology, but they want a quality as they expected. Then, for them, compatibility have to be an opportunity. Concerning the age of the respondent, compatibility is a good opportunity for people between 25 and 49 years old. It is during this period that household raised child, travel the most for work or go on holidays. Then a good compatibility is needed. Surprisingly compatibility seems to be a lower opportunity from 50 years old for Germany. Compatibility is not more perceived as an opportunity by women than men. For this attitudinal dimension the vehicle transmission is the only variable not significant for any country.

Consideration of EV and PHEV as powertrain The choice of the car powertrain directly depend on the attitudinal dimension previously explained. Their impact on the choice process are not always significant and their importance can varied according to the country studied. Results shows attitudes almost always have an impact for each countries. Concerning EV, environmental friendliness is not significant for Spain and anxiety for France and United-Kingdom. Concerning PHEV, environmental friendliness is not significant for Spain and anxiety for France and Spain. As expected, in the case of attitude with a robust t-test, anxiety always have a negative impact while environmental friendliness and compatibility a positive. Concerning variables tested, unsurprisingly and correlated by existing literature, the familiarity of the respondent with the technology strongly influence his choice positively. When respondent have enough information about a technology it implies less fear and then they can really consider it as an alternative. Likewise, to a lower level, a high frequency of heavy traffic encourages people to consider those two technologies as an alternative. This type of traffic seems to be the most appropriate for EV and PHEV. Heavy traffic with frequent stop and go directly depend on the three attitudinal dimension previously presented. In one hand in implies greenhouse gas emissions, then EV or PHEV with adequate compatibility in term of driving range increase the attractiveness of those vehicles. In another hand, in those situations, the anxiety of being stuck in traffic jams with inadequate battery durability increase and the attractiveness decrease. Finally, the expected mileage do not always have an impact on the respondent choice. France, Italy and Spain do not consider this variable in their choice. But concerning significant results some comments can be made. Concerning EV, daily distances are inappropriate under 17 miles for Germany and United-Kingdom. Germany is the only country with significant results for a daily distance between 17 and 54 miles. Concerning PHEV, daily distances between 17 and 54 miles seems to be the most appropriate distance for those vehicles. While distances lower than 17 for United-Kingdom or greater than 91 miles for Germany are not evaluated as appropriated by respondents. Those results are coherent with expectations. Indeed, below 17 miles, respondents may think this technology useless and then unappropriated. Higher than 91 miles per day, the anxiety predominate. But between 17 and 54 miles, respondent consider EV and PHEV enough attractive to be an alternative to conventional vehicles.

6 Conclusion

This paper presents a model capable of forecasting choice set generation, concerning the consideration for electric and plug-in electric vehicles in car renewal. Based on the existing literature a hierarchical latent variable approach was developed using attitudes and perceptions about respondent, data were collected by Renault-Nissan Alliance in 2012 among 5 European countries (France, Germany, Italia, Spain and UK). The measurement model takes the form of a mixed multivariate ordered Logit model rated on a 5 points Likert scale.

This research highlights the fact that the origin of the respondent is important aspect, variables are not significant for each attitude and each country. In any event, the respondent choice is directly influenced by latent variables. Both their intensities and their impacts during the decision process may differ. As expected, the anxiety of respondents toward EV and PHEV dissuade people to choose those technologies while environmental conscience and convenience with lifestyle encourage them. Within the utility functions there exists three important and significant variables for which the results are aligned with the existing literature and our expectations. The familiarity of the respondent with the technology concerned influences the choice in favor of EV and PHEV. The type of traffic is an advantage if the vehicle evolves in moderate to heavy stop-and-go with frequent stops. The estimated daily distance covered within the next year differ from the class studied. Concerning a distance lower than 16 miles and greater than 91 miles, EV and PHEV are not considered by respondents. But concerning a daily distance between 17 and 54, these technologies are good alternatives.

Future works include the development of the present model by the incorporation of new variables from data collected by Renault-Nissan alliance but also from additional external data sources. Tastes of respondents are subjective and may vary across a population or a country. So, a phase of investigation about interactions between variables present in the utility functions will be undertaken. Then, using a last part of the survey, we plan to evaluate the average willingness to pay of respondents to consider electric vehicles and plug-in electric vehicles as a future car. This willingness to pay will concern specific features of those new technology vehicles and measure their impacts on the respondent choice.

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A Appendix

Table 9: Assessment of the barriers and opportunities

Barriers to EV	
1	Concern with battery durability/life
2	Long time to recharge
3	Will be expensive to buy
4	Will have inadequate driving distance on one battery charge
5	Not enough/adequate recharge stations
6	Cannot charge at home
7	Will be expensive to operate (charge)
8	Will be expensive to maintain
9	Will use electricity which is not produced ecologically
10	Will have concerns with Aftersales-service & technical support
11	Lack of guarantee / warranty on the battery
12	Lack of ownership of battery / Not sure I own the battery
13	No dealers selling Electric Vehicles in the area where I live
14	Re-sale value will be lower than vehicles with traditional engines
15	Insufficient acceleration or driving performance
16	Lack of confidence in this new technology
17	Smaller boot capacity
18	Limited speed of the vehicle

Opportunities for EV	
1	Will reduce dependency on oil
2	Will generate zero exhaust emissions
3	Will be inexpensive to run
4	Will be the next best thing for the planet
5	Will expect to receive TAX benefits or returns
6	Will be safe to drive
7	Will be the latest technology
8	Will meet my driving performance needs (i.e. acceleration, braking and handling)
9	Will be reliable
10	Will be a practical choice
11	Will provide adequate driving range on one charge
12	Will be quick to recharge
13	Adequate charging stations will be provided
14	Will be cars for people ahead of their times
15	Will be able to re-charge at home

Table 10: Factorial analysis full results

Barriers to EV	Opportunities for EV
Mistrust against accompanying element of EV	**Compatibility with daily life**
Lack of ownership of battery / Not sure I own the battery	Will provide adequate driving range on one charge
Will have concerns with Aftersales-service & technical support	Will be quick to recharge
No dealers selling Electric Vehicles in the area where I live	Will be reliable
Re-sale value will be lower than vehicles with traditional engines	Adequate charging stations will be provided
Will use electricity which is not produced ecologically	Will be inexpensive to run
Lack of confidence in this new technology	Will meet my driving performance needs (i.e. acceleration, braking and handling)
Will be expensive to operate (charge)	Will be able to re-charge at home
Smaller boot capacity	Will be safe to drive
	Will expect to receive TAX benefits or returns
Fear about the capabilities of electric vehicles	Will be a practical choice
Limited speed of the vehicle	
Insufficient acceleration or driving performance	**Interest in new technologies**
	Will be cars for people ahead of their times
Anxiety toward EV	Will be the latest technology
Will have inadequate driving distance on one battery charge	
Not enough/adequate recharge stations	**Environmental friendliness**
Long time to recharge	Will generate zero exhaust emissions
Will be expensive to buy	Will reduce dependency on oil
Concern with battery durability/life	Will be the next best thing for the planet
Lack of guarantee / warranty on the battery	
Cannot charge at home	
Expensive to maintain	
Will be expensive to maintain	

Table 11: Estimates of the parameters of the measurement equations (*Statistical significance> 95%; **Statistical significance> 90%)

		α_k		ω_k			β_k		ν_k			θ_k		η_k	
		Parameter estimate	**t-test**	**Parameter estimate**	**t-test**		**Parameter estimate**	**t-test**	**Parameter estimate**	**t-test**		**Parameter estimate**	**t-test**	**Parameter estimate**	**t-test**
France	$I^*_{1,1}$	0	-	1	-	$I^*_{2,1}$	0	-	1	-	$I^*_{3,1}$	0	-	1	-
	$I^*_{1,2}$	-0.282 **	-1.75	1.13 *	17.61	$I^*_{2,2}$	0.573 *	3.18	1.09 *	22.69	$I^*_{3,2}$	0.0857	0.62	0.977 *	23.55
	$I^*_{1,3}$	0.493	1.28	1.37 *	17.48	$I^*_{2,3}$	0.71 *	5.57	1.01 *	22.91	$I^*_{3,3}$	0.24	0.99	0.889 *	23.39
	$I^*_{1,4}$														
Germany	$I^*_{1,1}$	0	-	1	-	$I^*_{2,1}$	0	-	1	-	$I^*_{3,1}$	0	-	1	-
	$I^*_{1,2}$	0.108	0.82	1.21 *	19.37	$I^*_{2,2}$	0.151 **	1.89	1.02 *	26.57	$I^*_{3,2}$	0.247	1.49	0.886 *	29.5
	$I^*_{1,3}$	0.705 *	2.87	1.47 *	18.85	$I^*_{2,3}$	0.623 *	5.95	0.912 *	26.14	$I^*_{3,3}$	0.736 *	2.81	0.802 *	28.81
	$I^*_{1,4}$	0.199	1.36	1.25 *	19.38										
Italy	$I^*_{1,1}$	0	-	1	-	$I^*_{2,1}$	0	-	1	-	$I^*_{3,1}$	0	-	1	-
	$I^*_{1,2}$	-0.07	-0.51	0.958 *	17.45	$I^*_{2,2}$	0.114	1.03	0.964 *	20.33	$I^*_{3,2}$	0.0529	0.44	1.04 *	20.51
	$I^*_{1,3}$	0.197	1.42	1.05 *	17.85	$I^*_{2,3}$	0.822 *	3.48	0.81 *	19.66	$I^*_{3,3}$	0.132	1.08	1.04 *	20.56
	$I^*_{1,4}$	0.454 *	3.42	1.01 *	17.43										
Spain	$I^*_{1,1}$	0	-	1	-	$I^*_{2,1}$	0	-	1	-	$I^*_{3,1}$	0	-	1	-
	$I^*_{1,2}$	-0.254 **	-1.88	0.987 *	12.04	$I^*_{2,2}$	0.429 *	3.12	0.976 *	14.05	$I^*_{3,2}$	0.311 *	2.2	0.982 *	13.85
	$I^*_{1,3}$	0.229	0.92	1.24 *	12.42	$I^*_{2,3}$	0.671 *	4.89	0.979 *	13.92	$I^*_{3,3}$	0.152	0.82	0.93 *	13.56
	$I^*_{1,4}$	0.453	1.63	1.27 *	12.3										
UK	$I^*_{1,1}$	0	-	1	-	$I^*_{2,1}$	0	-	1	-	$I^*_{3,1}$	0	-	1	-
	$I^*_{1,2}$	-0.17	-1.44	0.952 *	18.8	$I^*_{2,2}$	-0.19 **	-1.92	0.994 *	22.33	$I^*_{3,2}$	-0.0728	-0.56	0.965 *	25.11
	$I^*_{1,3}$	0.0641	0.31	1.22 *	19.12	$I^*_{2,3}$	0.76 *	7.67	0.998 *	22.93	$I^*_{3,3}$	-0.0234	-0.16	0.957 *	25.38
	$I^*_{1,4}$	0.537 *	2.4	1.25 *	18.41										