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# Do the Spanish want biodiesel? A case study in the Catalan transport sector.

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Abstract

In this paper, we analyse the opinions, attitudes and willingness of consumers to pay for biodiesel as an alternative to diesel in Barcelona province. Data were gathered from face-to-face structured questionnaires from 300 diesel car owners/users that regularly purchase fuel. A variation of the traditional choice experiments (CE) was used by excluding the price attribute from the design. In a subsequent contingent valuation (CV) exercise, respondents were asked to state their maximum willingness to pay (WTP) for their preferred choice sets using the "payment card" format. The relative importance of the attributes and levels were calculated by estimating a random parameter logit model. The results demonstrated, contrary to the literature in Spain, that consumers were not willing to pay for biodiesel, especially when its production may negatively affect food prices. The main limitation was that car manufacturers do not recommend its use as it may lead to engine failure. The public authorities are asked to work jointly with the automotive industry to address this drawback.

Key words: Biodiesel, Willingness to pay, Choice Experiment, Contingent Valuation, Catalonia

# 1. Introduction

Renewable energy sources are becoming an increasingly important issue in the political agenda of countries all over the world. They are considered a primary driver of economic progress, enabling countries to reduce energy dependency, achieve goals of sustainability and enhance competitiveness [1]. In the last decades, the global debate on the environment and climate change was primarily focused on the reduction of the emission of CO2, which is considered a major source of the greenhouse gas effect [2]. As a consequence, many countries adopted policies and strategies to diversify their energy sources in many sectors, transport being the most important one. According to Eurostat (Table 1), in 2011, the production of the total renewable energy[1] in the EU 27 has increased significantly, reaching 208,006 thousand tonnes of oil equivalent (TOE). Germany leads the list of the EU countries, followed by France, Spain and Italy.

Table 1. The major producers of biofuels in the EU 27

| | *Total renewable energy* | *Biofuels* | *biodiesel* | *bioethanol* |
|---|---|---|---|---|
| ***EU27*** | 208,006 | 11,455 | 8,112 | 2,746 |
| ***Germany*** | 38,642 | 3,660 | 2,535 | 577 |
| ***France*** | 23,027 | 2,053 | 1,625 | 668 |
| ***Spain*** | 20,677 | 844 | 609 | 368 |
| ***Italy*** | 19,644 | 1,137 | 528 | 119 |

Values are expressed in thousand tonnes of oil equivalent (TOE). Source: Eurostat 2013.

The European transport sector, including the Spanish sector, faces two major challenges. First, it depends greatly on imported energy sources, especially fuel oil, which is one of the fossil fuels that contributes to the increased concentrations of greenhouse gases [3]. This sector accounted for more than 20% of the total EU emissions in 2010 [4]. This situation limits the possibility of meeting the obligations of the Kyoto Protocol and increases the energy dependence of the EU [5]. According to the data from Eurostat, the EU is energy deficient, with energy dependency of 53% in 2010. Second, price volatility, the continuous increase in the prices of fossil fuels, and uncertainties regarding its availability generate concerns for its long term sustainability.

In this context, the Spanish transport sector experienced a significant increase in road infrastructure of approximately 16,000 km in early 2012, behind only the US and China in absolute terms [6], and its greenhouse emissions have increased by 66% since 1990. It is the largest user of final energy, accounting for 40% of the total final consumption [7].Thus,

[1] Following the Eurostat methodology, by total renewable energy we refer to the following: solar energy, solar thermal, biomass and renewable wastes, wood and wood wastes, hydro power, wind power, solar photovoltaic and the tide, waves and ocean.

reducing its emissions is crucial to reducing overall emission. As indicated by [8], the low taxation of car fuels in Spain, which is 20% below the European averages for 2010, the shift of car fleets to diesel [9] due to its low relative price and the consequent increase of problems related to local greenhouse gases in Madrid and Barcelona [10] and [6] make this sector a relevant case study.

Biofuels as a renewable energy source have been viewed for decades as a worthwhile alternative to address these challenges. However, the shift toward this source remains weak [11]. Their total production in the EU27 increased from 7 TOE in 1991 (mainly produced by Austria) to 11,455 TOE. In 2011, Germany was the major European producer of biofuel, followed by France, Italy and Spain (Table 1). Biodiesel represents the major share of biofuel production, reaching 71% (8,112 TOE) of the total EU 27 production. The EU is the world's largest biodiesel producer, representing, on a volume basis, approximately 70% of the total biofuels market share in the transport sector [12]. The largest producer of biodiesel is Germany followed by France, Spain and Italy (Table1).

In the last decade, the production of biofuels, in particular first-generation biofuels, has generated a debate about the impact of production on food prices. The debate regarding the negative effect of biofuels on food security around the world is not quite new. Within this context, there are two clearly differentiated opinions on if and to what extent biofuel production affects feedstock prices. On the one hand, certain studies have stated that biofuels are not responsible for the price increase and volatility of feedstock. [13] concluded that the increases in biofuel production have a non-significant impact on feedstock prices in the case of corn, wheat, barley, sugarcane, rapeseed, soybean and sunflower. [14] and [15] stated that rising feedstock prices are primarily related to other factors, such as oil price developments, financial speculation and the recent strong economic growth of China. However, on the other hand, several studies ([16], [17], [18], [19], [20] and [21]) noted that the food price increases have been mainly the result of the expansion of biofuels. [22] mentioned that the biofuel market expansion had led farmers to produce crops for the biofuels sector, driven by several subsidy programs, at the expense of the local and international food markets. He concluded that the most important factor in the growth of food prices is the large increase in biofuel production in the U.S. and the EU.

In considering the empirical analysis of the relation between biofuel production and feedstock prices, we can analyse two approaches: the first focuses on the supply side of biodiesel. This approach analyses the advantages and shortcomings of the production and its relation to agricultural feedstock and food prices. The second relies on the analysis of the demand side and focuses on the social attitudes and opinions toward biodiesel and the public opinion on its relation to the increase in food prices. The combination of both approaches is necessary to determine the optimal provision of biofuels from a social point of view. In theory, once the optimum is located, the policy authorities will be in a position to design the appropriate instruments to correct the market failures.

In recent years, certain studies have addressed the first approach, especially after the 2008 food price crisis, focusing their analysis on price volatility and the relationship between biodiesel production and food prices [23]. However, there is a scarcity of studies that have focused on the perceptions of society regarding biodiesel production and the opinions and acceptances of the role they play in rising food prices, in particular in Spain. In this context, the main objective of this paper is to analyse consumer opinion and attitudes toward biodiesel as an alternative fuel in Barcelona Province (Spain) and their willingness to pay for it. The importance of using this region as a case study is the high degree of dependence on imported energy sources, the high energy consumption per unit of GDP and the environmental problems caused mainly by the increased GHG emissions from the transport sector [6].

## 2. Literature review

Biofuels are derived from biomass[2], which mainly includes ethanol and biodiesel [24]. There are four known generations of biofuels. The first generation is directly related to a biomass that is generally edible [11] and produced directly from food crops. The most common for ethanol production are corn, sugar beets and sugar cane, while for biodiesel production palm oil, rapeseed and soybean are the main crops. The second generation is produced from non-food crops, such as wood, organic waste (municipal solid wastes) and other food crop waste. The third generation focuses on improvements in the production process of biomass, introducing algae as a principal energy source [25]. The introduction of algae is due to its potential to produce more energy per acre than conventional crops. The fourth generation is similar to the second and third generations with the difference that during the production process, the carbon emission is captured and stored, locking away more carbon than it produces.

The biomass-based fuel may have advantages and disadvantages. From one perspective, biofuels might be manufactured from a wide range of materials, thus improving the recycling efficiency. They are easily renewable as new crops are grown and waste material is collected [26]. Moreover, because they are produced locally, they help reduce the foreign energy dependency and create new jobs in rural areas [27]. They also may provide

[2] As mentioned by the International Energy Agency, biomass is any organic, i.e. decomposing, matter derived from plants or animals available on a renewable basis. Biomass includes wood and agricultural crops, herbaceous and woody energy crops, and municipal organic wastes, as well as manure.

economic incentives for the agricultural sector if the demand for the energy crops increases [28]. Finally, less carbon output and toxins are produced when it is burned in comparison to the fossil fuels. However, biofuels may not be worth producing, especially those from the first generation [29]. Those that are based on raw agricultural material produce negative net energy gains because the carbon footprint (the machinery necessary to cultivate the crops and the plants to produce the fuel) is high. Food prices and shortages may also be affected. As the demand for raw agricultural material grows for biofuel production, it could also raise the prices for the necessary primary food crops [30]. Water demand for biofuel production is also high, both for the irrigation of the crops as well as for the production process of fuel [30].

Within this debate, the regulations for producing biofuels in recent years have undergone remarkable changes. In September 2013, a narrow majority of European Parliament voted that "first generation" biofuels should not exceed 6% of the final energy consumption in transport by 2020, while advanced biofuels should represent at least 2.5% of the energy consumption in transport. These changes affected the Directive 2009/28/EC on the promotion of the use of energy from renewable sources, which set up mandatory targets for its member states of a 20% share of renewable energy in the total energy consumption and a 10% share of energy from renewable sources (primary biofuels) in all forms of transport by 2020. Member states may introduce for themselves the measures that promote biofuel consumption to reach this goal. It is worth mentioning that Spain has set a renewable energy target in the transport sector that is 3.6 points above the 10% binding European objective for 2020 [5].

The renewable energy policy in Spain, with its emphasis on biofuels, progressed in line with other EU counties and presents a response to the main challenges that the Spanish energy sector has faced in the last decades. In the Spanish biofuel market, biodiesel plays a predominant role because the consumption of bioethanol is negligible compared to the USA, which is the case for all European countries [31]. This policy follows both the Renewable Energy Directive (RED) [27] and the Fuel Quality Directive (FQD) [32]. The former involves the need to meet 10 per cent of the transport energy demand from renewable sources by 2020; the latter, to reduce the emissions of the transport fuels by at least 6 per cent by 2020.

In June 2007, Spain imposed mandatory biofuel blending for transport with Law 12/2007. The FQD enabled fuel operators to market B7 and E10, which are blends with a volumetric biodiesel content of 7 per cent and an ethanol content of 10 per cent, respectively. It is worth mentioning that in 2011, biodiesel production in Spain has decreased from 841 TOE in 2010 to 679 TOE as a result of the worldwide economic crisis. Biofuels in Spain are supported due to their joint production with other public goods. The biofuel industry in 2011 was supported with €237 million for ethanol and €1,002 million for biodiesel [26]. Biodiesel consumption was supported with €0.31 per litre and €0.40 per litre for ethanol.

Without presenting an extensive review, fewer studies have focused on the public preferences and the willingness to pay for biodiesel, in particular in Spain. In the US, [33] analysed the preferences of ethanol (E-10 and E-85); [34] also analysed different policies to promote biofuel, and [35] analysed the WTP for biomass ethanol. [36] Analysed factors affecting adoption of biodiesel in China. [37] assessed the determinants factors of the renewable energy choice and [38] studied car users and their WTP for biofuels in Greece. [39] and [40] estimated the WTP for the reduction of air pollution, which is brought about by using biodiesel in the US. In Spain, [41] and [6] focused on the willingness to pay for biodiesel. These studies were conducted in Spain, and their results indicated that although consumers have low levels of knowledge about biodiesel, there is a positive perception of biodiesel due to its environmental impacts, which consequently demonstrated that consumers are willing to pay more for biodiesel than for conventional diesel and are ready to use it.

In this context, our paper attempts to verify these hypotheses especially after the worldwide economic crisis. This study aims to fill the gap in the existing literature by attempting to elicit consumer preferences for biofuels by investigating the WTP for biodiesel in Catalonia (Spain), taking into consideration the current discussions surrounding the development of alternative fuels for transport.

# 3. Material and methods

## *3.1. Data sample and collection*

The data used in this analysis were obtained from 300 face-to-face questionnaires with the drivers/owners of diesel engine vehicles in the Barcelona Province (the city of Barcelona and the suburbs). The population represents consumers over 18 years of age who are car users/owners and thus regularly purchase diesel fuel (Table 2). We follow a quota sampling procedure stratified by age and gender, and the participants are selected randomly. This distribution, however, does not have to be in proportion to the population of Barcelona Province, as we restrict the sample to consumers who own/drive a diesel vehicle. As we are not able to access the total number of diesel vehicles registered in Barcelona Province and the distribution of their drivers by gender and age, we use a proxy variable. The citizens with a driver's licence in the province of Barcelona stratified by age and gender have been used. Nevertheless, this set does not reflect the citizens who drive diesel vehicles in each strata; thus, we correct the strata percentage using the primary information obtained from face-to-face interviews with several authorised car dealers and garages. The final description of the sample is discussed in the results section.

Table 2: Survey technical sheet

| | |
|---|---|
| Population | Residents of province of Barcelona |
| Filter | Drivers of diesel engine vehicle |
| Sample design | Quota sampling stratified by age and gender |
| Selection | Random |
| Date of field work | September/ October 2012 |
| Sample size | 300 |
| Error | $\pm$ 5.66 |
| Control measure | Pilot survey (15 questionnaires) |

A structured questionnaire has been designed to analyse consumer preferences and attitudes towards biodiesel as well as their maximum willingness to pay for it. The questionnaire was divided into several parts:

- In the first part, consumer awareness and knowledge of biodiesel is measured (familiarity with biodiesel, the raw materials to produce biodiesel and the present percentage of biodiesel mixture in the market).
- In the second part, consumers were asked about the use of diesel and biodiesel as a fuel in their cars, the frequency of use, their car's fuel efficiency (l/km), the purchase, the consumption and the year of registration.
- In the third part, respondents were asked to indicate their opinion towards the relation between food and biodiesel and its environmental impact. They were also asked about the alternatives that they would choose if fuel prices continue to rise. The questions were formulated on an 11-point scale ranging from "0 to10", the most understood scale in Spain.
- The fourth part is focused on analysing the most important factors that consumers take into consideration when deciding to refuel their car and their willingness to pay for biodiesel, using an approach that applies the joint use of the choice experiment and the contingent valuation
- The final part contains questions on the socio-demographic characteristics (i.e., gender, family size and composition, age, education level, and income) and other psychographic variables.

### *3.2. The experimental design*

In analysing “complex goods” the choice experiment (CE) is one of the most relevant methods. It involves the characterisation of the product through a series of descriptors that can be combined following an orthogonal fractional factorial design to create different hypothetical scenarios of the product (alternatives). The respondents are faced with several of these scenarios (choice sets) and are asked to select their preferred alternative at different price levels while implicitly making a trade-off between attributes. However, in our approach, we exclude the monetary attribute from the design of the scenarios, and we subsequently ask respondents for their maximum willingness to pay (WTP) following a contingent valuation (CV) exercise. Within the CV, respondents were asked to state their maximum WTP using the “payment card” format, as it combines both the advantages of the open-ended formats (the elicitation of the point information of the WTP) and of the close-ended formats (the ease of the cognitive burden on the interviewees) while minimising the risk of the “starting-price bias” associated with the iterative bidding processes [42]. This procedure is related to the dual response choice experiment (DRCE) design proposed by [43], with the exception that the price in our case was set in a contingent valuation exercise. Asking consumers whether they are willing to purchase the product emphasises the purchasing context, which leads the respondents to focus more on their budget constraints and places more attention on the price. In contrast, in the traditional single-stage CE, the respondents can be driven by reason and logical arguments rather than by price considerations [44]. Figure 1 represents the experimental design used in our study.

| ***Scenario A*** | ***Scenario B*** | ***None of them*** |
|---|---|---|
| Combination of the different levels of the attributes | Combination of the different levels of the attributes | |
| 1. *If you could choose any of the three previous options, which one would you choose?* | | |
| ☐ | ☐ | ☐ |
| 2. *Given your monthly budget constraint and that the average price for “the product” in the last month was X € / unit of the product, choose from the following list of prices::* | | |
| 3. *Of the selected scenarios, your willingness to pay is a maximum of:* | | *___________€/unit* |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **0** | **0.2** | **0.4** | **0.6** | **0.8** | **1.0** | **1.20** | **1.40** | **1.60** | **1.80** | **2.0** |

Figure 1: Example of the choice set

First, individuals are asked to choose their preferred scenario from three possible alternatives. Afterward, the respondents are faced with a “pay/not to pay” decision response mode for the preferred scenario to set their maximum WTP. Introducing this follow-up question allows individuals to approach the information twice regarding their preferences, first by stating what they prefer and subsequently if they are willing to pay for it and if they can afford it. Asking consumers about the maximum willingness to pay in a purchasing context may bring them to a greater emphasis on their budget constraints.

Due to the hypothetical nature of the assessment of the willingness to pay, a standard cheap talk was used in the survey process as proposed by [45] and [46]: “Previous studies indicate that individuals in general respond to surveys differently from the way they act in real life. It is quite common to find that individuals say they are willing to pay higher prices than those that they are really willing to pay. We believe that this is due to the difficulty in calculating the exact impact of these higher expenses on the household economy. It is easy to be generous when in reality one does not need to pay more”.

Applying the previous design to analyse the attributes that consumers take into consideration when he/she refuels and the relative importance of biodiesel, the first and most important step is to identify the attributes and their levels. After reviewing the market conditions in Barcelona Province and the abovementioned literature research on the relevant topic of consumer preferences toward biofuels, four attributes have been selected with their levels:

1) *Type of diesel.* This attribute was straightforward because it is a main objective of the study. According to the available mixtures of biodiesel on the Spanish fuel market, we assess four levels of this attribute, one of them being the conventional diesel and the other three being the mixtures of 10% (B10), 20% (B20) and 30% (B30) biodiesel.
2) *Location of petrol stations*. This attribute takes two levels to demonstrate whether the location of the petrol station affects the decision of the consumers to select the preferred station. We define the two levels as on the “usual route” and “outside the usual route”` for the consumers.
3) *Type of the petrol station*. For the more than 10,000 petrol stations in Spain, we assign two levels for this attribute. The first one is referred to as the “local petrol stations”, which represents the 33.85% that belong to local operators, cooperatives and supermarkets. The other belongs to the “multinational operators”, which represents 66.15% of the total.
4) *Price of the bread*. Due to the potential relation between the feedstock price and biofuels production, we used the price of bread as a proxy variable to analyse this trade-off. [47] mentioned that an increase in the cost of raw materials in the US (vegetable oils) also leads to an increase in the commercial price of bread and breakfast cereals. [48] also noted that biofuel production in the U.S. increases the price of bread among other food products by approximately 10% to 30%. [49] stated that biofuel production in the US had an impact on planted acreage, crop prices, livestock production and retail food costs, leading to an increase in the price of bread and bakery items. Thus, the price of bread was used due to its daily consumption in our case study region and because consumers

are more familiar with its price. In addition, the bread price is also related to cereals as well as to vegetable oils prices. In Spain oil seeds are used to produce biodiesel, the direct effect of increased biodiesel production is likely to be felt on vegetable oil prices but also on cereals crops as both compete for the same agricultural land and thus its production is affected. This attribute will indicate the impact of the potential price increase of bread as a result of increasing biofuel production on consumer decisions to purchase biodiesel. We evaluate the following four levels of this attribute for bread prices: unchanged, might increase by 5%, 10% and 20%.

Our sample was divided into two equal subsamples with 150 consumers each. Both subsamples share all of the survey questions but differ by the number of attributes included in the CE analysis. The choice sets were created using a fractional factorial orthogonal design. For the first sample, we include the first three attributes (type of diesel, location of petrol stations, type of petrol station), leading to eight choice sets that are presented for each participant. For the second subsample, we include the fourth attribute (bread price), obtaining 16 choice sets. This differentiation was made to estimate how the changes in the price of bread can influence the purchasing decision for biodiesel and to compare how the preferences are affected by the presence of this attribute. To avoid the fatigue effects associated with the multiple-scenario valuation tasks, the 16 choice cards were divided into two blocks with eight choice sets each following the factorial blocking procedure.

### *3.3. The econometric modelling*

The choice data obtained from the first question in our experimental design (Figure 1) were analysed using the traditional data treatment of the CE. Thus, following the Random Utility Theory [50], the subjects choose among scenarios according to a utility function with two components: a systematic (i.e., observable) component plus a random term (non-observable by the researcher):

$$U_{in} = V_{in}(X_i, S_n) + \varepsilon_{in} \qquad (1)$$

Where $U_{in}$ is the utility provided by alternative $i$ to subject $n$, $V_{in}$ is the systematic component of the utility, $X_i$ is the vector of attributes of alternative $i$, $S_n$ is the vector of socio-economic characteristics of the respondent $n$, and $\varepsilon_{in}$ is the random term.

To predict the subjects' preferences for the attributes and their levels, it is necessary to define the "probability of choice" that an individual *n* chooses the alternative *i* rather than the alternative $j$ (for any $i$ and $j$ within choice sets $(C)$), which is equivalent to the probability that $U_i$ is greater than $U_j$. Several probabilistic models are available to analyse the choice-stated data from the CE. The Conditional Logit Model (CL) is the basic model whereby the probability that an individual *n* will choose alternative $i$ ($P_{in}$) among other alternatives ($j = 1$ to $J$) of a set $(C)$ is formulated as follows [51]:

$$P_{in} = \frac{e^{\mu V_{in}}}{\sum_{j=1}^{j=J} e^{\mu V_{jn}}} \qquad \forall i \in C \qquad (2)$$

where $\mu$ is a scale parameter that is inversely proportional to the standard deviation of the error terms. Within this model, the $V_{in}$ must be defined. In our case, we follow a separable, additive and linear utility function as follows:

$$V_{in} = \beta_k X_{ik} + \varphi_k X_{ik} + \varepsilon_{in} \qquad (3)$$

where $(\beta_k)$ is a mean effect for each attribute level, $(X_k)$ is the value of attribute $k = 1...K$ in alternative $i$, $(\varphi_k)$ is the standard deviation, and $\varepsilon_{in}$ is the error term. This utility specification leads to the random parameters logit model (RPL)[3], which has been applied in the study because it accounts for the unobserved heterogeneity and allows obtaining the individual-specific parameter estimates. For more details about the CE technique and the RPL model, see among others [52] and [53].

### ***3.4. The relative importance of biodiesel attributes and levels***

From the RPL model estimates in the traditional discrete choice experiment, the marginal rate of substitution (MRS) between attributes is usually calculated. Because one of the attributes is expressed in monetary terms, it is possible to determine the implicit price (IP) of the attributes. However, in this study, we use the marginal utilities estimates $(\beta_k)$ attached to the levels of the attributes to calculate the global utility (i.e., the relative importance) of each attribute $(I_k)$ and their levels $(I_{l_k})$. Regarding the attributes, the ratio of the particular estimate to the sum of all the estimates of a specific attribute is used to reveal its relative importance as follows (Smith, 2005):

[3] We started by estimating a conditional logit model. However, the result of the Hausmann-MacFadden test demonstrates the violation of the IIA property. Thus, we specified the different types of model that relax the IIA, of which the RPL have demonstrated the best goodness of fit.

$$I_k = \frac{\left(\max \beta_k - \min \beta_k\right)}{\sum_{k=1}^{K}\left(\max \beta_k - \min \beta_k\right)} \qquad (4)$$

where $(I_k)$ is the relative importance of the attribute $(k)$; $(\max \beta_k)$ is the maximum utility of the attribute (i.e., the most preferred level), and $(\min \beta_k)$ is the minimum utility (i.e., the least preferred level).

Concerning the levels, it is necessary to distinguish between the positive (preferred) and negative (non-preferred) levels (i.e., the levels with a positive contribution to the utility function with a positive estimate $(\beta_k > 0)$ (hereafter, $\beta_k^+$) and those with negative estimates $(\beta_k < 0)$ (hereafter, $\beta_k^-$). Thus, the relative importance of the preferred levels $(I_{l_k}^+)$ is obtained by $I_{l_k}^+ = \frac{\beta_k^+}{\sum \beta_k^+}$ , and for the non-preferred levels, $(I_{l_k}^-)$ is obtained by $I_{l_k}^- = \frac{\beta_k^-}{\sum \beta_k^-}$ .

### *3.5. The joint use of the CE and CV: decomposing the WTP*

The aim of the joint use of the results of the CE and the CV is to decompose the scenario WTP into the attribute and the attribute levels WTP using their relative importance $(I_k, I_{l_k}^+, I_{l_k}^-)$. Decomposing the value of a “complex good” into different values of their attributes and levels is not new. [54] decomposed the value of complex goods (agricultural multifunctionality and rabbit meat) using the CV and the relative importance of the attributes and levels obtained from the analytical hierarchy process (AHP). However, in their procedure they assumed positive utilities for the attribute levels, which is rather restrictive. Thus, to alleviate this drawback, in this paper we propose the use of the CE instead of the AHP to obtain the relative importance of the attribute and attribute levels. Following the basic model presented by [54], the maximum willingness to pay (WTP) for the shift from “do not choose” to “choose” a preferred scenario can be decomposed into the maximum WTP of their descriptors (i.e., the attributes and attribute levels) using their relative importance (I).

Thus, the WTP for the k-th attribute is given by:

$$WTP_k = I_k \times WTP_{Si} \quad where \quad \sum I_k = 1 \qquad (5)$$

where the $WTP_{Si}$ refers to the willingness to pay for the chosen scenario.

For the attribute levels, we should distinguish between the preferred $(\beta_k^+ > 0)$ and the non-preferred levels $(\beta_k^- < 0)$. In the case of the preferred levels, their WTP $(WTP_{l_k}^+)$ is calculated by multiplying the positive value of the k-th attribute WTP ($WTP_k$) by their relative importance $(I_{l_k}^+)$ as follows:

$$WTP_{l_k}^+ = I_{l_k}^+ \times WTP_k \quad where \quad \sum I_{l_k}^+ = 1 \qquad (6)$$

Similarly, for the non-preferred levels, their willingness to pay $(WTP_{l_k}^-)$ is obtained by multiplying the negative value of the $(WTP_k)$ by their relative importance $(I_{l_k}^-)$

$$WTP_{l_k}^- = I_{l_k}^- \times (-WTP_k) \quad where \quad \sum I_{l_k}^- = 1 \qquad (7)$$

This is because the sum of the positive estimates is equal to the sum of the negative ones $(\sum \beta_k^+ = -\sum \beta_k^-)$, which is a characteristic of the coding effect procedure that is often used for the codification of attributes in the CE, as applied in our case study $(\sum(\beta_k^+ + \beta_k^-) = 0 \Rightarrow \sum \beta_k^+ = -\sum \beta_k^-)$.

# 4. Results and discussion

## *4.1. Sample description*

The sample consisted of 300 diesel car owners/users over 18 years old who regularly purchase fuels. Most of the respondents were male (72, 33%), aged between 30 and 44 years and living in three-member households. More than half of the participants had university-level studies and were employees with an average income between 1000 and 2500€ per month.

The consumers were asked to state how much money they spent on fuels per week and whether they paid for the fuels by themselves. The answers indicated that the majority of respondents paid by themselves, and 53% of respondents spent 1-25€ in fuels per week, while the average consumption is 32.06€ per week. The next questions referred to the year the respondents bought the car and their average fuel consumption per 100 km. Half of the respondents (51.5%) had cars registered after 2006, 37.1% registered their vehicles in the period between 2000 and 2005, while a small percentage of respondents (11.3%) had old cars registered before 1999. The average fuel consumption was 6.49 litres per 100 km.

## *4.2. Attitudes and opinions toward biodiesel*

The actual consumption of biodiesel among respondents was very low, with only 1% of respondents using biodiesel always, and 16% of them using it occasionally. The consumers who have never or almost never used biodiesel were asked to indicate their reasons for such behaviour. The main reason was “not recommended by their vehicle manufacturer” (20.8%) followed by “I had never thought in using it” (20.4%). The fact that biodiesel is not available in most of the petrol stations was also an important reason (18.4%). Although biodiesel is cheaper or approximately the same price to conventional fuel in the area of Barcelona, 12.4 % of the respondents answered that they did not use it because it is more expensive. “I do not trust its reliability” and “I do not think that there is any difference from the conventional” comprise 9.2% and 0.8%, respectively.

Nearly all of the respondents (91.7%) were familiar with the existence of biodiesel. Although the percentage was significantly high, when consumers were asked to indicate two crops that are used for its production, a significant percentage could not indicate any (48.7%). The others mostly stated that biodiesel is produced from corn (16.3%), sunflower oil (11.7%) or rapeseed (10.7%). In this context, the consumers were asked to indicate the percentage of the mixture between conventional diesel and biodiesel allowed in the market in Spain; 18.3% of the respondents answered the question correctly (10-30% of the mixture). However, the majority of the respondents (81.7%) wrongly answered, or they did not know.

Participants were also asked to assess various statements related to certain characteristics of biodiesel. The evaluation was on a scale of 0 “I strongly disagree” to 10 “I strongly agree”. The respondents agreed with the notion that biodiesel releases less pollutants than conventional diesel, with an average of 6.81. They also agreed that biodiesel will make the country less dependent on fossil fuels. However, the respondents did not agree that the number of kilometres travelled using biodiesel is greater than that of conventional diesel, with an average of 4.55.

Finally, the environmental issues related to biodiesel and other renewable energy were analysed. Consumers were asked to rate from 0 to 10 the respect for the environment of the different energy sources. Solar energy and wind energy were evaluated as the most environmentally friendly energy sources, with an average of 8.43 and 8.2, respectively. Hydraulic energy was close, with an average 7.61. However, the respondents evaluated natural gas and biodiesel at a lower range, with 5.57 and 5.44, respectively. The low mean of biodiesel may indicate that consumers do not consider biodiesel as a clear alternative energy source, as it received a lower value than natural gas. The average level of respect for the fossil fuels was 4.2 for conventional diesel and 3.64 for gasoline. Finally, nuclear energy received a 3.14 and thus is considered to be the least satisfactory energy for the environment.

### *4.3. The CE results*

First, we started by checking for the IIA property. The results from the Hausman-McFadden test for both subsamples indicated that the IIA property does not hold for the conditional logit model ($\chi^2$= 32.8752 with a p-value = .0000 for the first subsample and $\chi^2$=67.8044 with a p-value =.0000 for subsample 2). Thus, the RPL model will better fit our data set. Table 3 presents the results of the RPL model for both samples. As can be observed, at the 99% confidence level, we can reject the null hypothesis that all coefficients are jointly equal to zero. We thus do not reject the overall significance of the model. The results exhibited an acceptable range of goodness of fit through McFadden's pseudo-$R^2$ value (0.256 and 0.226, respectively). It also exhibited a satisfactory value of the predicted percentage of the correct classification (78.5% and 76.9%, respectively). For the estimation of the random parameters, we assumed that the attribute coefficients were normally distributed, as they better fit our stated data.

The positive or negative sign of the parameters indicates a positive or negative contribution to the utility function. Thus, in both samples, diesel car users primarily prefer to refuel in their habitual route and at the local petrol station. The results also indicate that in both cases the respondents demonstrate a rejection of biodiesel in all its proposed mixture. This non-acceptance of biodiesel is more accentuated when its production may increase the price of bread. The standard deviations of almost all random parameters are significant, confirming the suitability of the specification of this model to our data.

Table 3: Results of the models' estimation for data with and without information

| ***Estimates*** $\beta$ | ***Random Parameters Logit Model*** | |
|---|---|---|
| | **Sample 1** | **Sample 2** |
| | **Random parameters $\beta_s$** | |
| Type of petrol station (local) | 0.036* | 0.272*** |
| Location (habitual route) | 1.607*** | 0.522*** |
| Biodiesel mixture 1 (10%) | -0.164 | -0.397*** |
| Biodiesel mixture 2 (20%) | -0.423*** | 0.034 |
| Biodiesel mixture 3 (30%) | -0.450** | 0.076 |
| Bread price increase (10%) | - | 0.190 |
| Bread price increase (20%) | - | -0.096 |
| Bread price increase (30%) | - | -1.886*** |
| - | **Non-random parameters $\beta_s$** | |
| Opt-out option | 1.101*** | 1.285*** |
| | **S.D. of random $\beta_s$** | |
| Petrol station type | 1.022*** | 0.198 |
| Location | 1.538*** | 0.659*** |
| Biodiesel mixture 1 (10%) | 1.018*** | 0.541*** |
| Biodiesel mixture 2 (20%) | 0.831*** | 0.426 |

| | | |
|---|---|---|
| Biodiesel mixture 3 (30%) | 1.983*** | 0.654*** |
| Bread price (increase 10%) | - | 0.096 |
| Bread price (increase 20%) | - | 0.398** |
| Bread price (increase 30%) | - | 1.104*** |
| Log-Likelihood (θ) | -955.08 | -1,005.8 |
| Log-Likelihood (0) | -1,283.17 | -1,299.6 |
| Log-Likelihood ratio | 656.18 (0.000) | 587.6 (0.000) |
| Pseudo $R^2$ | 0.256 | 0.226 |
| Predicted % | 78.5% | 76.9% |
| Observations | 3,504 = 146 respondents×8 choice sets × 3 alternatives | 3,576 = 149 respondents×8 choice sets × 3 alternatives |

Significance levels: $^{***}$p<0.01; $^{**}$p<0.05; $^{*}$p< 0.10

To better understand the relative importance of all levels of the attributes, it is important to calculate the utility of the base levels because they are not directly estimated from the model. The coefficients of the reference level of each attribute are obtained following the coding effect procedure. Thus, $\beta_0$ is calculated as $-1\times\beta_P$, where $P$ is the number of the total levels of each attribute. For the significance of the values, we employed the [55] the method for 1000 random repetitions. The results are displayed in Table 4.

Table 4: Utilities of the base levels of the attributes obtained from the RPL

| $\beta_0$ of the base levels of the attributes | *The marginal utility of the base level from the RPL* | |
|---|---|---|
| | Subsample 1 | Subsample 2 |
| Type (Multinational) | -0.036$^{*}$ | -0.272$^{***}$ |
| Location (non-habitual route) | -1.607$^{***}$ | -0.522$^{***}$ |
| Conventional Diesel | 1.038$^{***}$ | 0.287$^{**}$ |
| Bread price (unchanged) | - | 1.791$^{***}$ |

Significance levels: $^{***}$p<0.01; $^{**}$p<0.05; $^{*}$p< 0.10

### ***4.4. The WTP of the attributes and levels***

The relative importance of the attributes and levels are displayed in Table 5. The results indicated that for sample 1, the most important attribute was the ‘location of the petrol station’ followed by the ‘type of diesel’ and the “type of the petrol station”. For sample 2, the respondents demonstrated the same preferences pattern. However, as expected, they exhibited the highest relative importance for “bread price”. These values were used for the decomposition of the WTP of the preferred scenarios into the WTPs of the attributes and levels. As observed, the participants from the first sample demonstrated a willingness to pay 0.81€ for the location of the petrol station, 0.37€ for the type of diesel and a non-significant 0.02€ for the type of petrol station. The participants from sample 2 demonstrated the highest

WTP for the attribute “bread price” (0.79€) followed by the location (0.22€), type of diesel (0.15€) and finally the type of the petrol station (0.12€).

Table 5. The WTP decomposition of attributes using the CE and CV results

| Attributes | ***Sample 1*** | ***Sample 2*** | ***Sample 1*** | ***Sample 2*** | ***Sample 1*** | ***Sample 2*** |
|---|---|---|---|---|---|---|
| | $I_k$ (Relative importance of the attributes) | | $WTP_k$ (Willingness to pay of the Attributes) | | $WTP_{Si}$ (Average value of the WTP of the selected scenario in each choice set) obtained from the CV **(€/litre)** | |
| | $I_k = \frac{(\max \beta_k - \min \beta_k)}{\sum_{k=1}^{K} (\max \beta_k - \min \beta_k)}$ | | $WTP_k = I_k \times WTP_{Si}$ **(€/litre)** | | | |
| Type of petrol station | 0.015 | 0.091*** | 0.02 | 0.12*** | 1.20 | 1.27 |
| Type of diesel | 0.312*** | 0.115*** | 0.37*** | 0.15*** | | |
| Location of petrol station | 0.673*** | 0.175*** | 0.81*** | 0.22*** | | |
| Bread price | **-** | 0.618*** | - | 0.79*** | | |

Significance levels: ***p<0.01; **p<0.05; *p< 0.10

In a subsequent step, the previous WTP values attached to the attributes (i.e. $WTP_k$) were decomposed into the WTPs of their levels. The procedure and the results are exhibited in Table 6. In both samples, participants were willing to pay 0.018€ and 0.116€ for the local petrol station. The respondents also demonstrated a WTP of 0.37€ and 0.106€ for conventional diesel. However, they were not willing to pay a premium for biodiesel and for the different proposed mixture. One of the main factor for such rejection is that car manufacturers do not recommend its use as it may negatively affect the energy efficiency and may cause engine failure [56]. For the location of the petrol station, diesel car users exhibited a WTP of 0.808€ and 0.223€ if the petrol station is located in their habitual route, being the most important level in the first sample. Finally, as expected for the attribute of bread price, the respondents were willing to pay 0.710€ to keep it unchanged (i.e., a 0% increase), being the most important level.

## Table 6. Decomposing the WTP of levels using the CE and CV results

| Levels | | ***Positively valued levels*** $(\beta_k^+)$ | | | | ***Negatively valued levels*** $(\beta_k^-)$ | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | ***Sample 1*** | ***Sample 2*** | ***Sample 1*** | ***Sample 2*** | ***Sample 1*** | ***Sample 2*** | ***Sample 1*** | ***Sample 2*** |
| | | $I_{l_k}^+$ (Relative importance of the positively valued level) | | $WTP_{l_k}^+$ (Willingness to pay of the levels that contribute positively to the utility function, €/litre) | | $I_{l_k}^-$ (Relative importance of the negatively valued level) | | $WTP_{l_k}^-$ (Willingness to pay of the levels that contribute negatively to the utility function, €/litre) | |
| | | $I_{l_k}^+ = \frac{\beta_k^+}{\sum \beta_k^+}$ | | $WTP_{l_k}^+ = I_{l_k}^+ \times WTP_k$ | | $I_{l_k}^- = \frac{\beta_k^-}{\sum \beta_k^-}$ | | $WTP_{l_k}^- = I_{l_k}^- \times (-WTP_k)$ | |
| ***Type of petrol station*** | Multinational | - | - | - | - | 1.00* | 1.00* | -0.018* | -0.116* |
| | Local | 1.00* | 1.00* | 0.018* | 0.116* | - | - | - | - |
| ***Type of Diesel*** | Conventional | 1.00*** | 0.72** | 0.374*** | 0.106** | - | - | - | - |
| | Biodiesel 10% | - | | - | - | 0.16 | 1.00*** | -0.059 | -0.146*** |
| | Biodiesel 20% | - | 0.09 | - | 0.013 | 0.41** | - | -0.152** | - |
| | Biodiesel 30% | - | 0.19 | - | 0.028 | 0.43** | - | -0.162** | - |
| ***Location*** | Habitual route | 1.00*** | 1.00*** | 0.808*** | 0.223*** | - | - | - | - |
| | Non-habitual route | - | - | - | - | 1.00*** | 1.00*** | -0.808*** | -0.223*** |
| ***Bread price*** | Without increase 0% | - | 0.90*** | - | 0.710*** | - | - | - | - |
| | Increase 10% | - | 0.10 | - | 0.075 | - | - | - | - |
| | Increase 20% | - | - | - | - | - | 0.05 | - | -0.038 |
| | Increase 30% | - | - | - | - | - | 0.95*** | - | -0.747*** |

Significance levels: ***p<0.01; **p<0.05; *p< 0.10

## 5. Conclusions

In this study, we assessed the consumer preferences toward biodiesel in the transport sector in Catalonia Spain. The results demonstrated that the Spanish users/owners of diesel cars are not willing to pay for biodiesel, which seems to be rejected in all the mixtures proposed; this result is contrary to the results obtained by [6], who confirmed that consumers are willing to pay 0.08 Euros/litre and [41] who determined that Spanish users of diesel are willing to pay up to 5% over the price of standard diesel.

The data indicated that in Spain, few manufacturers of cars currently accept the use of more than B5, while others do not recommend any level of biodiesel to refuel. Vehicle owners are asked therefore to check the recommendations of the vehicle manufacturer before using biodiesel, particularly if the vehicle is covered by a new vehicle warranty. For instance, Toyota, Mercedes Benz and BMW (with the exception of Germany) among other brands do not recommend the use of biodiesel in their engines. Biodiesel requires certain changes in the engine, such as the use of synthetic plastics. Thus, the term “non-recommended” indicates that any amount of biodiesel can damage the engine, and the owner may lose the car warranty. However, other brands (for instance, Audi, Ford, Honda, Seat…) allow the use of a maximum of 5% of the mixture of biodiesel in their engines.

Although all of the respondents were familiar with the existence of biodiesel, they exhibited a lack of information about its production and its situation in Spain at the moment. They did not consider biodiesel as a clear environmentally friendly alternative energy in the transport sector, and thus more studies are needed in the future. Another significant limitation is the lack of biodiesel availability due to its low market share. At present, there are only 204 petrol stations that offer biodiesel in Spain, which represents a very small portion (approximately 2%) of the total number of petrol stations.

At the methodological level, our approach demonstrated the capacity to decompose the WTP associated with any scenario into the WTPs of its attributes and levels using the relative importance estimated from the CE. However, this approach needs to be validated and compared with the traditional CE, and it is necessary to test the consistency of the results obtained. This point is beyond our objective and will be assessed in future research.

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