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Consumer purchases of energy-efficient cars: How different labelling schemes could affect consumer response to price changes

Ibon Galarraga [a,b,*], Steffen Kallbekken [c], Alessandro Silvestri [a]

[a] Basque Centre for Climate Change (BC3), Alameda Urquijo 4, 4ª, 48008, Bilbao, Spain
[b] Economics for Energy, Doutor Cadaval 2, 3E, 36202, Vigo, Spain
[c] CICERO Center for International Climate and Environmental Research – Oslo, PO Box 1129, Blindern, 0318, Oslo, Norway

A R T I C L E I N F O

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A B S T R A C T

Improved energy efficiency can help reduce pollution, contribute to energy security, and help consumers save money. This paper explores energy labelling schemes as a policy instrument for promoting energy-efficient cars in Spain. Specifically, it explores consumer responses to changes in vehicle prices. We derive the demand responses for two different efficiency labelling schemes: absolute and relative. To that end, we calculate own- and cross-price elasticities of demand for cars with efficiency labels on the Spanish car market. The results show that the elasticities for more efficient cars are in general higher. However, in the specific case of sedans, the elasticities depend on assumptions about how consumers decide which car to purchase. If consumers are concerned about the absolute energy performance of cars independently of other attributes, and thus pay attention to absolute labelling, demand for more efficient cars is more elastic than demand for less efficient cars. If consumers choose the car segment first and then the energy performance, using the relative label, the opposite result is found. The results suggest that both relative and absolute labelling schemes can be useful, depending on how consumers make their decisions. It might also be possible to design a mixed system.

1. Introduction

A wide array of international research assessments, market analyses, institutions and politicians expect improved energy efficiency to deliver greenhouse gas emission reductions, reduced local air pollution, jobs, growth, increased energy security and large financial savings for households, companies and governments. Energy efficiency can unquestionably generate multiple socioeconomic benefits (Ryan and Campbel, 2012). If the goal of limiting global warming to well-below 2 °C, as agreed in the Paris Agreement[1] by the parties to the United Framework Convention on Climate Change (UNFCCC), is to be achieved, the IPCC (2014) envisages investments of as much as US$336 billion over the next two decades in energy efficiency in housing, industry and transportation.

Transportation is one of the sectors where improved energy efficiency is expected to play a key role in meeting climate, environmental, energy and social policy goals. The Fifth Assessment Report of the IPCC finds that "energy efficiency measures through improved vehicle and engine designs have the largest potential for emission reductions in the short term" (Edenhofer et al., 2014).

Investments in energy-efficient goods are lower than expected in light of the potential financial savings that could be made by purchasing more efficient goods (Jaffe et al., 2009; Kounetas and Tsekouras, 2008). This is known as the "energy efficiency paradox". There are many factors that contribute to explaining this phenomenon, such as asymmetric or insufficient information, lack of access to capital, differences between private and social discount rates, principal-agent issues that lead to maximising short-term profit rather than long-term strategic decisions, uncertainty regarding savings compared to certainty regarding costs, and the irreversible nature of the investment required (Abadie and Galarraga, 2012). Other behavioural barriers include the importance of frames or reference points (once a consumer is familiar with a product

* Corresponding author. Basque Centre for Climate Change (BC3), Alameda Urquijo 4, 4ª, 48008, Bilbao, Spain.
E-mail address: ibon.galarraga@bc3research.org (I. Galarraga).

[1] https://unfccc.int/process-and-meetings/the-paris-agreement/what-is-the-paris-agreement For more information on this check Roman de Lara and Galarraga, 2016.

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he/she tends to stick to it and use it as a basis for comparison with other similar products), the use of heuristics[2] and loss aversion (Policy Studies Institute, 2006). If we are to succeed in actually achieving the hypothesised benefits of improved energy efficiency, we need to find ways to help consumers, companies and investors to make purchases that will generate multiple benefits. In many instances, we will need to design smart government interventions, subsidies, regulations or information campaigns to overcome these barriers.

In this paper, we first examine the current situation as regards energy efficiency in the light-duty vehicle market in Spain. We focus on the light-duty vehicle market as a way of approaching the decision-making process of regular citizens in their daily life. In particular, we take into account how different energy efficiency labelling schemes (relative and absolute) can affect people's response to changes in vehicle prices, which in turn could imply different optimal policies to promote the purchasing of efficient vehicles. We explore whether and how the specific design of efficiency labels (relative and absolute) might affect consumer responses to price changes, while acknowledging that price may not be the single most important attribute when deciding to buy a car, but it certainly is a very important one (Lane and Banks, 2010; Orlov and Kallbekken, 2019). Describing motivations and factors affecting the purchase of efficient vehicles is outside the scope of this paper. A wide literature addresses how different factors play a role in the purchasing decision process. For instance, the impact on this process of socio-demographic characteristics, vehicle characteristics, built environment (Bhat et al., 2009; Cao et al., 2006; Choo and Mokhtarian, 2004), brand fidelity (Train and Winston, 2007) and gasoline prices (Mabit, 2014). Moreover, the role of labels has also been discussed in the framework of behavioural economics alongside the concept of nudges (Thaler and Sunstein, 2009). For instance, Codagnone et al., (2016) find that labels influence choices mainly when focusing on fuel economy and running costs rather than emissions.

Second, we calculate the own- and cross-price elasticities of demand in two different frameworks (absolute and relative) reflecting the different aforementioned labelling schemes. It is important to note that, as our analysis follows from the results obtained with the hedonic method in Galarraga et al. (2014), it does not deal with behaviour motivations and the factors affecting the decision process are weights based solely on demand-side and supply-side factors. In other words, using the hedonic method allows us to analyse the energy efficiency attribute while controlling for the rest of attributes of the car, as well as the motivations of consumers.

With this paper, we aim to contribute to the analysis by providing a conceptual discussion on the design of labels and, at the same time, estimate values for elasticities that can be used, in the future, to undertake a full welfare analysis of the effectiveness and efficiency of rebate schemes. The values shown here offer some insights on how label design features may impact policy outcomes, but are not meant to substitute a much-needed in-depth policy evaluation or design analysis.

The rest of paper is structured as follows: Section 2 describes the European Union energy label scheme for cars, and how it is implemented in different ways in different EU Member States. Section 3 provides information on energy efficiency in the Spanish light-duty car market. Section 4 offers some insights with respect to absolute and relative labels. Section 5 describes the model used to estimate elasticities, the so-called Quantity Based Demand System (QBDS). Section 6 presents and discusses the results. The final section is devoted to conclusions and some policy insights.

[2] Heuristics refer to the fact that consumers make limited efforts to consider the benefits and costs of a decision, and instead use mental short-cuts to help them. Having too many choices often prevents consumers from making a decision.

2. EU energy labels for cars and supplementary policies

Energy labels are used as a policy instrument in many countries to convey information to consumers about the characteristics of goods (Lucas and Galarraga, 2015). The information contained in a label should help consumers make more rational choices in the sense of buying goods which consume less energy per service. Energy labels can be a sound choice if consumers hold incorrect beliefs about the energy efficiency of different products (e.g., car models), and if the labels are designed in a way that is effective in influencing consumer choices. Several studies indicate that consumers may indeed hold some incorrect beliefs about energy use, and that their behaviour does not match the predicted rational behaviour. Allcott and Wozny (2014), for instance, find that "US auto consumers are willing to pay just \$0.61 to reduce expected discounted gas expenditures by \$1". This finding may well also be related to risk aversion of consumers. Gerarden et al. (2017) review the causes of this energy efficiency gap and find substantial literature demonstrating the impact on energy choices of, among others, bounded rationality, myopia and inattention phenomena.[3] See Avineri (2012) for a literature review on how different behavioural factors affect decision making in transport.

The EU has mandated energy labels for domestic appliances since 1995. In 1999 this was extended to include cars by Directive (1999)/94/EC, which establishes a mandated labelling scheme under which retailers are required to display certain characteristics of the car such as size, fuel consumption and CO_2 emissions. It is an information labelling scheme.

The same Directive also regulates the use of a voluntary comparative labelling scheme with different categories of energy efficiency (from A, the most efficient, to G, the least efficient) in order to allow consumers to compare car models. The label can also include other information, such as running costs, annual tax costs, the amount of CO_2 emissions and additional attributes of the vehicle. This means that there are major differences between labels in different countries (Brannigan, 2011). In Spain, the Directive was transposed by Royal Decree 837/2002, and today all car retailers have to show both the standard EU label and the comparative label for their vehicles.

The use of the voluntary label has varied from one EU Member State to another mainly due to the lack of specific common requirements. As a consequence, the level of recognition varies substantially, and is higher in those countries which have established the EU Energy Labelling-style format (Carrol et al., 2014). For instance, Codagnone et al. (2013) find that more than half of the respondents of a survey in different European countries were unfamiliar with the label; 40 per cent disagreed with the statement that it was easily recognisable; and 44.5 per cent agreed that car labels were unfamiliar to them. The differences also include the way in which categories of efficiency are calculated.

Some countries have established an absolute labelling scheme for all the cars in the market: the most efficient cars which pollute the least, usually the smallest cars, are labelled A class, while other cars, bigger or less efficient, are labelled B, C, D, E or G. This labelling system is used by most European countries, including France, Belgium, Denmark and the United Kingdom (Brannigan et al., 2011).

Other countries, such as Spain and Germany, have chosen to introduce a relative labelling scheme (Brannigan et al., 2011) where the label of the car depends on how much the fuel consumption and emissions of the car deviates from the average within its market segment (for instance small, mini, small sedan, big sedan, etc.). Hence, the relative label allows consumers to compare energy efficiency within a given car segment, but might make it more difficult to compare efficiency across car segments. In addition, this kind of scheme can sometimes be misleading, as in some cases, larger and heavier vehicles with absolute high emissions can achieve a better relative rating than smaller cars with

[3] See also Ramos et al. (2015).

lower emissions (Carrol et al., 2014).

Policy makers should aim to achieve the most energy-efficient car fleet which consumes as little fuel as possible and pollutes as little as possible at the minimum policy cost. The success of such a policy, however, depends on how well its design matches the process that consumers follow when deciding what car to purchase.

Labelling policy is often supplemented by financial incentives, such as a rebate for the most efficient goods (Galarraga et al., 2013). This is the case in Spain: the PIVE (*Programa de Incentivos al Vehículo Eficiente*) plan was implemented in 2012 (Resolution dated 28th December of 2012) and, as for now, has been renewed until its 8th edition ended in 2016 (Royal Decree 1071/2015). The PIVE subsidises the purchase of cars categorised as class A or B, electric cars, hybrid, and cars which use gas or other alternative fuels. The subsidy is only applicable to cars up to a maximum price of €25,000 (€40,000 if fully electric, hybrid or range-extender vehicles). It consists of a minimum discount of €750 in the price before taxes, which the producer or retailer has to apply, plus a subsidy of at least €750 after taxes financed by public funding earmarked for the PIVE. Not many studies on the impact of such schemes are available. One of the few exceptions is Jiménez et al. (2016), who analyse the impact of a previous version of this plan (Plan, 2000E), which subsidised the purchasing of efficient vehicles based on their emission performance (gr/CO2). They conclude that the plan was inefficient in enhancing the sales of efficient vehicles, as part of the subsidy was absorbed by the increase in vehicles' prices by car manufacturers. However, the PIVE plan specifically refers to the efficiency label. Hence, we contribute to this by analysing how different types of labels (absolute or relative), and their underlying behavioural assumptions, can affect consumer responses to vehicles' price changes. The elasticity values calculated in this paper should allow for further and more complete welfare analysis on the impact of rebate schemes as proposed in Galarraga et al. (2013) and Galarraga et al. (2016).

3. Energy efficiency in the Spanish car market

To the best of our knowledge, there are no official statistics on the energy efficiency class of the new light-duty vehicles sold in the Spanish market. The National Association of Car and Truck Producers (*Asociación Nacional de Fabricantes de Automóviles y Camiones*, ANFAC) offers monthly data on the number of cars sold, but does not collect information on the energy efficiency performance of the cars sold. As a supplement to this information, The Spanish Energy Diversification and Saving Institute (*Instituto de Diversificación y Ahorro Energético*, IDAE) offers a list of the cars and models available and their energy efficiency attributes.

We merge information from these two databases in order to provide a better picture of the energy performance of cars sold in Spain (See Table 1). In 2012, a total of 699,589 cars were sold. We have identified the energy efficiency of 97.5 per cent of these cars. Most of the cars with unknown energy efficiency are sports and luxury cars: Some special models cannot be found in the information provided by IDAE. In some other cases, one car model may have different energy efficiency options depending on other attributes such as power or the type of fuel, i.e., depending on the specific sub-model. In these cases, we have divided the sales of that model proportionately to the number of sub-models in each energy efficiency category that could be found..[4]

Our numbers show that 41 per cent of the cars sold in Spain in 2012 were categorised as very efficient (A class). A- and B-labelled cars make up more than 75 per cent of all cars sold (see Table 1). There are significant differences, however, across car segments. Whether the high sales of efficient cars are a consequence of the current (and previous) PIVE rebate schemes remains to be fully understood. Other factors such as high fuel prices might also have influenced the high proportion of efficient cars sold.

How frequently the labels granted in a labelling scheme are reviewed also has an important effect on the proportion of efficient cars sold. In order to maintain the efficiency of the labelling system, it is necessary to periodically tighten the criteria for the ratings in an attempt to keep up with technological changes (Carrol et al., 2014). In the Spanish case, the formula used to make the classification should be updated annually according to the legislation (Resolution of September 24, 2012).[5]

Most of the cars sold were small (27.8 per cent) or small sedans (27.3 per cent). The share of sport and luxury cars was very low. The proportion of efficient cars varies from one segment to another: for instance, the proportion of Sport, all types of SUV and Big Minivans with class A was very low, while more than half of all small and big sedans were class A. The energy efficiency of SUVs was very low, which can be explained by the limited presence of efficient SUVs on the market.

As the energy efficiency labelling in Spain is relative, it is possible to find small cars labelled B or even C that consume significantly less fuel and emit less CO_2 than bigger cars (in other segments) labelled A. One example is that the Alfa Romeo Mito, which is a small car consuming 4.2 L of fuel per 100 km and emitting 99 g CO_2/km, is labelled B, whereas a big KIA Optima sedan consuming 5.1 L of fuel per 100 km and emitting 133 g CO_2/km, is labelled A. The reason is that the relative labelling scheme provides a comparison only within segments and does not compare performance across segments.

To give an idea of the differences in emission performance and fuel consumption, Fig. 1 shows the distribution for each car segment in the Spanish market. Note that the green box refers to the distribution of cars within the first and second quartiles, while the pink one shows the distribution within the second and the third. The lines denote the minimum and maximum values.

Luxury cars show a significantly greater average consumption and emissions than other segments. They are followed by Sport, SUV and sedan vehicles. The difference between big and small sedans and small cars and minis is not so significant, although the variance is smaller in small cars and minis. However, as relative labelling does not account for these substantial performance differences across segments because it only focuses on best in class within the same segment, the distribution within the same segment can vary significantly compared to the absolute data.

4. Relative vs. absolute labelling

Many factors influence the choice of a car, including income, gender, age, education, household size, the number of drivers in the household, attitudes and driver personality, lifestyle and mobility (Policy Studies Institute, 2006; Prieto and Caemmerer, 2013). For instance, McCarthy and Tey (1998) (in OECD, 2008) find that in the US, demand for energy-efficient cars is greater among women, minorities and younger people, while people with larger incomes tend to select larger, heavier, less efficient cars.

In this paper we explore two schemes for energy efficiency labelling, the relative - used in Spain today - and the absolute - used in several other European countries, and how they perform under two different assumptions about how consumers choose cars. In particular, as relative labels only allow a comparison of vehicles' efficiency *within* the car segment they align with, the assumption is that consumers first decide the car segment and only compare vehicles within the selected segment. The absolute label allows comparing vehicles from any segment,

[4] Each car model usually has several variants or sub-models that could have different efficiency labels depending on other attributes. When this occurs and it was not possible to clearly identify the label, we divide the sales proportionally among the different energy efficiency classes.

[5] The formula for calculating the efficiency of each car in Spain is $a^*e^{(b^*s)}$, where s is the area of the car; e = 2.7183; and a and b are two coefficients. Since 2012, these two coefficients have to be updated annually.

Table 1
Number of cars sold in Spain in 2012 per market segment, and their energy efficiency.

	n. cars	%	% A class	% B class	% Others	Unknown
Small	194,616	27,82%	37,68%	50,70%	11,62%	1,05%
Mini	35,164	5,03%	25,16%	38,39%	36,45%	0,58%
Small Sedan	191,604	27,39%	53,40%	26,11%	20,49%	0,13%
Big Sedan	85,310	12,19%	69,95%	18,75%	11,30%	0,05%
Small Minivan	75,565	10,80%	42,51%	44,16%	13,33%	0,58%
Big Minivan	10,573	1,51%	8,67%	32,16%	59,17%	3,51%
Sport	2176	0,31%	1,30%	21,61%	77,09%	19,90%
Luxury	1581	0,23%	52,16%	40,68%	7,16%	33,08%
Executive	10,806	1,54%	33,98%	46,33%	19,69%	26,37%
Small SUV	30,177	4,31%	2,97%	21,90%	75,13%	2,64%
Medium SUV	52,198	7,46%	5,30%	18,72%	75,98%	1,25%
Big SUV	2757	0,39%	0,00%	0,00%	100,00%	0,40%
Luxury SUV	7062	1,01%	0,00%	31,00%	69,00%	29,51%
TOTAL	**699,589**		**41,07%**	**34,20%**	**24,73%**	**1,53%**

Source: Own calculations using data from IDAE and ANFAC.

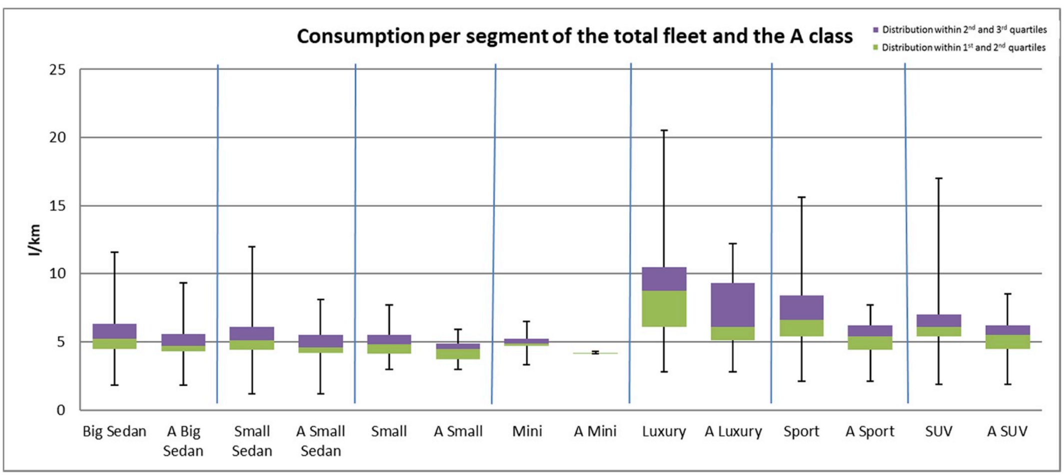

Fig. 1. Consumption per segment of the total fleet and the A classSource
Own work from data from IDAE.

aligning with the absolute label decision framework where consumers compare vehicles from any segment. This is a simplification, as many consumers make decisions using simultaneous or nested processes (Noblet et al., 2006). However, this simplification does fit well with the policy analysis in Brannigan et al. (2011) and serves well to explore the implications of choosing one type of labelling or the other[6]:

Some evidence on a purchasing behaviour reflecting the decision frameworks applied to this study can be found in European Parliament (2010), which considers that consumers go through two rounds in their decision process: First, selecting a vehicle segment and second, applying the additional criteria, namely fuel efficiency, to make their final decision.

Lane and Banks (2010) also find that there is a perceived trade-off between fuel economy and vehicle size, i.e., once consumers have chosen a vehicle segment, they are rarely motivated to search for the most energy-efficient model, as they underestimate the availability of highly-efficient cars in that segment. This fact highlights the importance of, and need for relative labelling to compare the energy efficiency of different models within a car segment. Furthermore, the study suggests that information on which model is "best in class" may be greatly appreciated by consumers.

If consumers use the relative decision process, then policy makers who wish to design an effective policy should aim for a relative energy efficiency labelling system. In fact, Peters et al. (2008) find that consumers show some, but limited, willingness to change behaviour in order to obtain incentives such as rebates, and that relative systems are better suited to implementing policies of this type. The limitation of this policy approach is that the policy does not directly incentivise the purchase of the most efficient cars in the full market, but only the most efficient cars within each segment. This is, of course, an indirect way of achieving an efficient car fleet, and thus reducing fuel consumption and pollutant emissions.

If policy makers wish to supplement their policies with a rebate for purchasing efficient cars within each segment (class A) or taxing the less efficient ones, then obtaining information on the price elasticities of demand (own and cross) for each car segment becomes a very relevant issue.

Many countries have made decisions as to which type of labelling system to introduce, and we wonder whether those decisions are based on any deeper understanding of the decision making process or not, but we have not been able to find any supporting documents to back up these decisions based on our literature search.[7] Future work based on behavioural economics might help answer this question.

Spain has chosen the relative labelling scheme. Although the

[6] As far as we are aware no empirical studies are available to support the type of labelling chosen in EU Member States. If such studies existed, they could have offered some insights on how purchasing decisions are made in each country.

[7] Using the most common online platforms (Web of Science, Google scholar and others).

information provided by manufacturers and retailers shows the fuel consumption and the CO_2 emissions for each vehicle, the labelling scheme does not make it easy to compare across segments. This policy is aimed at consumers who behave consistently with the relative decision-making process. It remains to be seen whether Spanish consumers actually behave in such a way. Even if most of them do, one could argue that an absolute labelling scheme could lead some consumers to change their minds and decide on more efficient (probably smaller) cars. This would, of course, lead to lower energy consumption and CO_2 emissions, but also to lower emissions of other important local pollutants such as particulates (PM), NOx and CO.

In the absence of more complete information about how consumers actually make their decisions, an argument can be made for implementing both absolute and relative labelling schemes in some form of a mixed labelling scheme where consumers can access both types of information. The Swiss labelling scheme offers information on some parameters based on absolute efficiency and also some relative ones. The scheme implemented in the Netherlands also offers both types of information and looks at the weighted average of the average CO_2 emissions of all cars in the same vehicle class (the weight is 75 per cent) and the average CO_2 emissions of all cars in the market (Brannigan et al., 2011). These schemes might give some insights regarding how this can be done effectively.

5. Estimation of price elasticities of demand

For the purpose of this analysis, and in an effort to understand demand responses to price changes, we do not analyse supply-side factors. That is, we only look at the demand side, as it is reasonable to assume an infinitely elastic supply function to account for the fact that if supply cannot meet the demand in the Spanish market, more cars will be imported (Galarraga et al., 2013). This will occur until the total demand is met.

The absence of long-term time series data for the Spanish car market with sufficient detail with respect to labelled versus non-labelled goods means we cannot undertake full elasticity estimates with a traditional demand system analysis. It is precisely under these circumstances that Galarraga et al. (2011) suggest the use of QBDS as applied in this paper as a valid way to provide reliable elasticity estimates.

The QBDS is based in consumer theory and follows the standard structure of demand systems (e.g., Almost Ideal Demand System (AIDS), by Deaton and Muellbauer, 1980). In particular, the QBDS was developed for the analysis of close substitutes as a special case of the well-known linear version of the AIDS (see Galarraga et al., 2011). It is much easier to handle and requires fewer parameters to be known but it operates under two limitations: 1) that the own-price elasticity has to be greater than the income elasticity and 2) that the same income elasticity is assumed for labelled and non-labelled goods. Authors argue that this restricts the use of this model to very close substitutes and labelled vs non-labelled good, which is the case of the analysis presented here (Galarraga et al., 2011). The QBDS model has been applied previously to fair trade, organic and regular coffee markets in the UK (Galarraga and Markandya, 2004) and to labelled and non-labelled dishwashers in the Spanish market (Galarraga et al., 2011). In addition, when comparing the estimates obtained by the application of the linear version of the AIDS and the QBDS to calibrate elasticities, authors conclude that the results obtained from the LA/AIDS model are […] similar to those obtained from the QBDS model, except in the estimates for cross-price elasticities (not estimated by QBDS) of the composite good, which are in any case negligible".

It is assumed that the market for an appliance is divided into two types of appliances: those with a "high label" for energy efficiency and those with a "low label". The rest of the characteristics of the appliances are the same (because we control for them). The following variables are defined:

V_i: demand for quality i (energy efficiency) of good V (appliance) in comparable units. That is:
P_i: price of quality i of good V.
M: total expenditure.
P: aggregate price of good V
w_j: expenditure share of good V.

The demand for quality i of good V can be defined as follows:

$$\frac{V_i}{V} = \beta_i \left(\frac{P_i}{P}\right)^{-\alpha} \tag{1}$$

where $\beta_i \geq 0$ is a constant and $\alpha \geq 0$ is the price sensitivity parameter.

If we now define a price index P as:

$$P = \prod_i P_i^{s_i} \quad \text{where } s_i \geq 0 \text{ and } \sum s_i = 1 \tag{2}$$

And the aggregate demand for all quality types as:

$$V = A\left(\frac{P}{M}\right)^{-\mu} \tag{3}$$

where s_i is the weight for a quality i good in the price index for good V. A>0 is a constant and μ is the expenditure sensitivity parameter for the aggregate demand for the good.

The demand for each quality i for good V is homogenous of degree zero in prices and income.

The price elasticity $\in_{ii}$is given by:

$$\in_{ii} = -\alpha + (\alpha - \mu)s_i \tag{4}$$

While the cross-price elasticity for good i with respect to the price of good j ($\in_{ij}$) is:

$$\in_{ij} = (\alpha - \mu)s_j \tag{5}$$

Finally, note that the Slutsky equation requires:

$$\frac{s_j}{s_i} = \frac{w_j}{w_i} \tag{6}$$

The additivity condition is obtained by differentiating the budget constraint with respect to M.

$$\sum_i w_i e_i = 1 \tag{7}$$

As Galarraga and Markandya (2004) acknowledge, this has the limitation of requiring that quantities be broadly comparable, but the advantage that subgroups of close substitutes are easier to handle, and plausible own- and cross-price elasticities can be derived from limited data.

The QBDS is less demanding than the linear version of AIDS, but it must also meet an additional condition: the income elasticity for close substitute goods must be the same. It is possible to derive the following conditions from the homogeneity constraint:

If $e_i > |e_{ii}|$ then $\sum_j e_{ij} < 0$ for all j≠i. Therefore, at least one of the cross-price elasticities has to be negative and,
If $e_i < |e_{ii}|$ then $\sum_j e_{ij} > 0$ for all j≠I. and thus all the cross-price elasticities could be positive.

This condition could be simplified by the fact that information on the composite good is not required. Having $e_i < |e_{ii}|$which can be further simplified to $\overline{\alpha} > \mu$ suffices to have positive cross-price elasticities for all close substitutes. In short, this implies that the income elasticity of demand has to be smaller than the own-price elasticity of demand of one of the substitute goods in absolute value.

6. Results

In this section, we present the results of the own- and cross-price elasticities of demand. This is useful in terms of policy design in order to understand how prices changes are likely to affect the purchasing of efficient cars in the market. However, to fully understand the effectiveness and efficiency of rebate schemes (or taxes), these values should be used for a full welfare analysis as mentioned earlier and suggested in Galarraga et al. (2013). This is especially true for Spain, in the light of existing evidence on the ineffectiveness and inefficiency of existing labelling-based rebate schemes (see Jiménez et al., 2016 for automobiles and Galarraga et al., 2013 for appliances).

To reflect the distinction between the two types of labels, absolute and relative, we develop our analysis in two different scenarios: in the first case, consumers compare cars across all the segments, while in the second case, the comparison takes place within a given car segment. These have been shaped as two different decision frameworks: absolute and relative. The details in which these distinctions will affect the analysis are explained in the two sections that follow, along with the respective results.

6.1. Own- and cross-price elasticities of demand for cars under an absolute label decision framework

In this framework, consumers who are concerned about energy efficiency search for cars in the whole market (i.e., across all segments) for the model that consumes the least fuel per km (and thus also pollutes the least). In this context, absolute labelling provides the most helpful information. Small and mini type cars labelled as class A are preferred, and demand is lower for the biggest cars, such as sedans. Lane and Banks (2010) find that consumers in the UK value “fuel economy/running costs”, “size/practicability” and “vehicle price” as the three most important factors to take into account when purchasing a new car. Consumers in Norway, however, rate reliability as the most important factor, ahead of safety, price and then fuel consumption (Orlov and Kallbekken, 2019). Note that fuel economy is motivated more by running costs than actual environmental benefits. Therefore, some consumers might consider energy efficiency issues, as it seems they prioritise fuel consumption over other attributes when deciding to buy a car.

If the policy maker wishes to supplement this policy with other policies, such as a rebate system (or taxing the less efficient cars), a subsidy can be paid for the purchase of cars with class A or, alternatively, a tax could be levied on inefficient cars.[8] The expected result of a rebate would be a change in the fleet, with smaller cars replacing bigger ones.

We consider efficient and non-efficient cars as substitute goods to a certain extent. We then use a demand system for close substitutes (the so-called QBDS) to calculate the own-price elasticity for energy-efficient cars and the cross-price elasticities between energy-efficient cars and other cars for Spain.

Before price elasticities can be calculated with the QBDS, it is necessary to know the own elasticity of less efficient (other) cars, the income elasticity of demand for cars and the expenditure shares for both efficient and non-efficient (or less efficient) cars.

Whelan, (2007) estimates an own-price elasticity of −0.34. In a more recent study, De Groote et al. (2016) calculate a price elasticity of −0.8 for the city centre of Amsterdam, arguing this value to be higher due to the presence of close substitutes to the car in the area. Other studies, such as Hymans (1970), provide information on the own-price elasticities for automobiles for short and long periods of time that are much higher. Based on these studies, we use values ranging from −0.35 to −1.2. Matas and Raymond (2008) show that car ownership income elasticity in Spain varied with the size of the municipality and over time. For the year 2000, they estimated a value of 0.548 for large, 0.454 for medium and 0.468 for small municipalities, and with much higher values for consumers owning two cars (ranging from 0.808 to 1.147), and for three or more cars (values from 1.644 to 2.176). Values seem to be declining with time. Guerra (2015) estimates an income elasticity of 0.44 in Mexico City. De Groote et al. (2016) find income elasticity levels to be decreasing for higher-income households, ranging between 1.2 and 0.4 for different income levels. Based on these values, we assume an income elasticity of 0.3, 0.5 and 1. Unfortunately, some of the values found in the literature are the result of research undertaken several years back. This is a limitation for this study, but research from 2014 to 2016 quoted above shows that the elasticity ranges used in this paper fall within the estimates of more recent studies. In addition, some of these estimates do not refer to the case of Spain. However, these two limitations should not represent a caveat of the method itself, which could be re-applied when (if) more recent data becomes available. Recall that the QBDS imposes the mathematical constraint that the income elasticity of both type of cars should be smaller in absolute value than the own-price elasticity of demand for other (O) cars.

The data on expenditure shares for non-efficient cars come from expenditure surveys conducted by the *Instituto Nacional de Estadística* (Spain’s National Office of Statistics) in 2011.[9] We use the price premium estimate of 0.0592 per cent of the average car price found in Galarraga et al. (2014) [10] to calculate the expenditure shares for efficient cars (class A) (we name this good as “A”), non-efficient cars with classes below A (named “O”) and a third good (named “X”), which is a composite that stands for the rest of the goods in the economy.

The expenditure shares are:

$$W_O = 0.009278206 \ W_A = 0.006849049 \ W_X = 0.98387275$$

The QBDS model works as a simplification of the Deaton and Muellbauer (1980) Almost Ideal Demand System (AIDS), except that it is defined in terms of quantity shares rather than expenditure shares. The QBDS is less data-demanding, which is an advantage in these cases. Galarraga et al. (2011) show that results under some assumptions are robust and very similar for both models.

Table 2A,2B,2C shows the results of this estimation under the absolute decision-making hypothesis.

The results suggest that demand for efficient cars (A) is slightly more elastic than demand for non-efficient cars (O). That is, demand for efficient cars decreases (increases) more than demand for non-efficient ones when the price of cars increases (decreases). The cross effects also suggest that changes in the demand for efficient cars are greater than the effect on other, less efficient ones. This difference increases as the price elasticities increase. Note that the results presented here consider only the differences in energy efficiency while keeping all the rest of the attributes of the car constant, i.e., *ceteris paribus*. Therefore,

Table 2A
Own and cross price elasticities of demand QBDS (Income elasticity = 1).

Own O	Cross OA	Own A	Cross AO
−1.1	0.1000	−1.1355	0.1355
−1.2	0.2000	−1.2709	0.2709

[8] It is, of course, also possible to use a rebate that is a combination of both a tax on inefficient cars and a subsidy on the most efficient ones. See for example Langer (2005).

[9] The expenditure share for new cars (07111) in 2012 was 1.61 per cent (INE, 2011).

[10] Note that this premium is a result of a hedonic analysis and consequently refers to the price difference between labelled and non-labelled cars, controlling for the rest of the attributes of the car, i.e. *ceteris paribus*.

Table 2B
Own and cross price elasticities of demand QBDS (Income elasticity = 0.5).

Own O	Cross OA	Own A	Cross AO
−0.55	0.0500	−0.5677	0.0677
−0.85	0.3500	−0.9741	0.4741
−1.1	0.6000	−1.3128	0.8128
−1.2	0.7000	−1.4483	0.9483

Table 2C
Own and cross price elasticities of demand QBDS (Income elasticity = 0.3).

Own O	Cross OA	Own A	Cross AO
−0.35	0.0500	−0.3677	0.0677
−0.45	0.1500	−0.5032	0.2032
−0.55	0.2500	−0.6387	0.3387
−0.85	0.5500	−1.0451	0.7451
−1.1	0.8000	−1.3837	1.0837
−1.2	0.9000	−1.5192	1.2192

when comparing the efficient versus non-efficient cars, we are comparing cars that are exactly equal in size, power, brand and other attributes.

6.2. Own- and cross-price elasticities of demand for cars under a relative label decision framework

In this case, consumers first select a car segment according to their needs or preferences regarding attributes other than energy efficiency, and then incorporate energy efficiency considerations. As an example, take a family who needs a big car with 7 seats. They will select a large car segment first, before (potentially) searching for a fuel efficient car within that segment. This is what Teisl et al. (2004) find in focus groups for the US and Noblet et al. (2006) use the same rationale for their work. Furthermore, Noblet et al. (2006) find that consumers do not react to eco-labelling information even at class or segment level, but only at brand and model level. That is, only after consumers have chosen a brand and model do they incorporate fuel efficiency considerations. This is perhaps the most extreme case of relative decision making, and thus not easy to address. Estimating demand elasticities for specific car brands requires a very rich, comprehensive database of a kind unlikely to become available in the short to medium term.

We repeat the process of calculating the price elasticities of demand for efficient cars and non-efficient ones using the QBDS, but in this case for each car segment. Galarraga et al. (2014) also estimate a different price premium for different car segments with values ranging from 1.5 per cent for sedans to 7.5 per cent for Sport and Luxury cars.

To calculate the expenditure shares, with the knowledge that the share of efficient cars varies from segment to segment, we divide total expenditure by the market share of each segment (data shown in Table 1).[11],[12],[13],[14] As a price difference exists between car segments, this assumption may not always hold. This is a caveat to be acknowledged, but the lack of official statistics requires an assumption to be made at this stage. The resulting expenditure shares are shown in Table 3.

Using this information, elasticities of demand ranging from −0.35 to −1.2 and an income elasticity ranging from 0.3 to 1, we can calculate the price elasticities of demand for each car segment as shown in Tables 4a, 4b and 4c.

The results show that, in the case of sedans, the demand for the most efficient cars (class A) is less elastic than demand for non-efficient cars (O). This result is driven by the fact that the proportion of efficient vehicles in the market is higher than that of non-efficient vehicles for sedans. The range of elasticity values varies significantly in the cases of Mini, Sports and Luxury and SUV vehicles, but in general, the result of efficient vehicles being more elastic holds. A comparative analysis with LA/AIDS leads to basically the same results as shown in Galarraga et al. (2011).

In all but one of the cases the cross-price elasticities AO are greater than cross OA, which means that impacts of changes on prices of the A-labelled car segment affect the demand for less efficient ones much less than in the opposite direction. This is an expected result when the share of non-efficient vehicles is greater than the share of A-labelled ones. The exception to this is the case of A-labelled sedan vehicles with a greater share in this market segment that makes the cross-elasticity AO lower than the cross-OA. That is, in this case, changes in prices in A-labelled cars affect the demand of non-labelled ones more. This effect cannot be noticed when showing values under an absolute decision-making hypothesis because the impacts on the rest of the segments overturn this.

6.3. Caveats

The method presented here has several caveats that need to be recognised. First, ideally, price elasticities in demand, as well as income elasticities, should be estimated from existing detailed market data. However, this information is not available for Spain. The method proposed here might thus be proposed as an alternative for the analysis until richer information becomes available. Consequently, the elasticities calculated in this paper offer some interesting findings on the different impact of pricing policies depending on the specific design of the label, but should be used with caution when it comes to detailed policy design. Instead, these values are useful to undertake a more detailed micro-economic (welfare) analysis to fully analyse effectiveness and efficiency issues. Second, in addition to prices, many other factors are known to affect decision-making processes as mentioned earlier in this paper, so other disciplines such as behavioural economics or psychology may offer complementary insights into the research question. But one should acknowledge that prices are indeed a very important factor, and rebate schemes (and taxes) are precisely designed to act on these. Demand elasticities are an essential part for any detailed welfare analysis. And finally, the assumption of both labelled and non-labelled cars having the same income elasticity can also be a limiting factor to consider. However, and for simplicity, it not uncommon to make such assumptions for welfare analysis. When (and if) detailed information on income elasticities becomes available, the results obtained by the QBDS could easily be compared to the more general LA/AIDS model as mentioned above.

Table 3
Expenditure shares per car segment.

	W_O	W_A	W_X
Sedan	0.0026	0.0038	0.9936
Sport & Luxury	0.0002	0.0001	0.9997
Mini	0.0006	0.0002	0.9992
Small	0.0027	0.0017	0.9955
Minivan	0.0012	0.0008	0.9980
Four-wheel-drive (SUV)	0.0020	0.0001	0.9979

[11] We assume that the expenditure share for each segment is proportional to its share of total sales. Of course, it can be argued that as the price of small cars is lower, our result may overestimate the expenditure share on small cars. We have compared the expenditure shares obtained with those given by average prices and the results do not change much. The share for small cars is a little higher with the second method, whereas that of luxury cars is a little lower. For the rest of the segments the values are quite similar.

[12] For more information see https://ec.europa.eu/clima/policies/transport/vehicles/labelling_en

[13] More recently a new labelling schemes exists for environmental performance of Spanish cars. For more information, see https://sede.dgt.gob.es/es/vehiculos/distintivo-ambiental/

[14] See H2020 project CONSEED (https://www.conseedproject.eu/) for more information on the topic.

Table 4a
Own and cross price elasticities of demand per segment (Income elasticity = 1).

SEDAN				SPORT & LUXURY			
Own O	Cross OA	Own A	Cross AO	Own O	Cross OA	Own A	Cross AO
−1.1	0.1000	−1.0684	0.0684	−1.1	0.1000	−1.2000	0.2000
−1.2	0.2000	−1.1368	0.1368	−1.2	0.2000	−1.4000	0.4000
MINI				**SMALL**			
Own O	Cross OA	Own A	Cross AO	Own O	Cross OA	Own A	Cross AO
−1.1	0.1000	−1.3000	0.3000	−1.1	0.1000	−1.1588	0.1588
−1.2	0.2000	−1.6000	0.6000	−1.2	0.2000	−1.3176	0.3176
MINIVAN				**SUV**			
Own O	Cross OA	Own A	Cross AO	Own O	Cross OA	Own A	Cross AO
−1.1	0.1000	−1.1500	0.1500	−1.1	0.1000	−3.0000	2.0000
−1.2	0.2000	−1.3000	0.3000	−1.2	0.2000	−5.0000	4.0000

Table 4b
Own and cross price elasticities of demand per segment (Income elasticity = 0.5).

SEDAN				SPORT & LUXURY			
Own O	Cross OA	Own A	Cross AO	Own O	Cross OA	Own A	Cross AO
−0.55	0.0500	−0.5342	0.0342	−0.55	0.0500	−0.6000	0.1000
−0.85	0.3500	−0.7395	0.2395	−0.85	0.3500	−1.2000	0.7000
−1.1	0.6000	−0.9105	0.4105	−1.1	0.6000	−1.7000	1.2000
−1.2	0.7000	−0.9789	0.4789	−1.2	0.7000	−1.9000	1.4000
MINI				**SMALL**			
Own O	Cross OA	Own A	Cross AO	Own O	Cross OA	Own A	Cross AO
−0.55	0.0500	−0.6500	0.1500	−0.55	0.0500	−0.5794	0.0794
−0.85	0.3500	−1.5500	1.0500	−0.85	0.3500	−1.0559	0.5559
−1.1	0.6000	−2.3000	1.8000	−1.1	0.6000	−1.4529	0.9529
−1.2	0.7000	−2.6000	2.1000	−1.2	0.7000	−1.6118	1.1118
MINIVAN				**SUV**			
Own O	Cross OA	Own A	Cross AO	Own O	Cross OA	Own A	Cross AO
−0.55	0.0500	−0.5750	0.0750	−0.55	0.0500	−1.5000	1.0000
−0.85	0.3500	−1.0250	0.5250	−0.85	0.3500	−7.5000	7.0000
−1.1	0.6000	−1.4000	0.9000	−1.1	0.6000	−12.5000	12.0000
−1.2	0.7000	−1.5500	1.0500	−1.2	0.7000	−14.5000	14.0000

Table 4c
Own and cross price elasticities of demand per segment (Income elasticity = 0.3).

SEDAN				SPORT & LUXURY			
Own O	Cross OA	Own A	Cross AO	Own O	Cross OA	Own A	Cross AO
−0.35	0.0500	−0.3342	0.0342	−0.35	0.0500	−0.4000	0.1000
−0.45	0.1500	−0.4026	0.1026	−0.45	0.1500	−0.6000	0.3000
−0.55	0.2500	−0.4711	0.1711	−0.55	0.2500	−0.8000	0.5000
−0.85	0.5500	−0.6763	0.3763	−0.85	0.5500	−1.4000	1.1000
−1.1	0.8000	−0.8474	0.5474	−1.1	0.8000	−1.9000	1.6000
−1.2	0.9000	−0.9158	0.6158	−1.2	0.9000	−2.1000	1.8000
MINI				**SMALL**			
Own O	Cross OA	Own A	Cross AO	Own O	Cross OA	Own A	Cross AO
−0.35	0.0500	−0.4500	0.1500	−0.35	0.0500	−0.3794	0.0794
−0.45	0.1500	−0.7500	0.4500	−0.45	0.1500	−0.5382	0.2382
−0.55	0.2500	−1.0500	0.7500	−0.55	0.2500	−0.6971	0.3971
−0.85	0.5500	−1.9500	1.6500	−0.85	0.5500	−1.1735	0.8735
−1.1	0.8000	−2.7000	2.4000	−1.1	0.8000	−1.5706	1.2706
−1.2	0.9000	−3.0000	2.7000	−1.2	0.9000	−1.7294	1.4294
MINIVAN				**SUV**			
Own O	Cross OA	Own A	Cross AO	Own O	Cross OA	Own A	Cross AO
−0.35	0.0500	−0.3750	0.0750	−0.35	0.0500	−1.3000	1.0000
−0.45	0.1500	−0.5250	0.2250	−0.45	0.1500	−3.3000	3.0000
−0.55	0.2500	−0.6750	0.3750	−0.55	0.2500	−5.3000	5.0000
−0.85	0.5500	−1.1250	0.8250	−0.85	0.5500	−11.300	11.0000
−1.1	0.8000	−1.5000	1.2000	−1.1	0.8000	−16.300	16.0000
−1.2	0.9000	−1.6500	1.3500	−1.2	0.9000	−18.300	18.0000

7. Conclusions and policy implications

This paper explores energy labelling schemes as a policy instrument for the promotion of efficient cars in Spain. There are at least two ways of designing a labelling scheme for the car market: absolute and relative labelling schemes. Both target consumers, but they assume different underlying decision-making processes. The relative scheme is likely to be more effective for consumers who decide on other car attributes first (in particular, choosing a segment), and then incorporate energy-efficiency considerations. The absolute scheme targets consumers who place energy-efficiency attributes at the same decision level as other characteristics of the vehicle.

These labels are often used to decide which car models qualify for inclusion in a rebate scheme to incentivise the purchase of more efficient vehicles. This is the case in Spain with the PIVE rebate scheme. It could also be used for designing taxing schemes. In order to fully account for welfare impacts of both rebate and/or taxing policies, the price elasticities of demand must be estimated.

Depending on which scheme is to be promoted, different price elasticities can be calculated. In order to estimate these values, we define two different frameworks for decision-making: absolute and relative. Depending on the framework used, the demand response to changes in prices will be different. This is a very important finding that suggests that consumers should be properly characterised before the decision on the labelling scheme is taken. A mixed scheme might be the most suitable approach, but that does not help to settle the difficult decision of having to design the rebate scheme to favour one type of consumer. Of course, the resulting label should not be so complex as to hinder consumers' understanding of the information provided (European Parliament, 2010).

When we analyse the elasticity values in the absolute- and relative-decision framework, we find some differences in the sensitivity of the own-price and cross-price effects. This has implications for which policies will be the most effective and how to fine-tune them. Note that as demand elasticities depend significantly on market shares and on the level of aggregation, our results are quite sensitive to changes in these two factors. This makes it crucial to conduct further analysis on the way in which consumers make decisions, as it will shed light on how these elasticities should be estimated and what effective pricing policies can be.

With the results shown in this paper, some interesting conclusions can be drawn. When absolute decision is assumed, the elasticities for vehicles with a higher efficiency level are greater than that for less efficient ones. *Ceteris paribus*, this means that pricing policies are likely to be more effective when applied to A-labelled cars, and therefore policies based on pricing systems may have a role to play in incentivising the purchase of more efficient vehicles (or discouraging the purchase of less efficient ones). As mentioned, in the case of sedans, when relative decision is assumed, that is, when consumers choose the car segment first and then the energy performance, the opposite result is found. The cross-price elasticities AO are, in general, also higher than OA, with the exception of sedans. This gives information with respect to the degree of substitutability between efficient and non-efficient cars, that is, how sensitive the demand of efficient (non-efficient) cars is to price changes of non-efficient (efficient) cars. This is an important piece of information to undertake a full welfare analysis of any policy.

The information provided by this paper should help to improve the design of energy-efficiency policies in Spain and elsewhere, as it enables policy-makers to conduct a preliminary comparison of the effects of different policy instruments such as taxes, rebates or combinations of the two in so-called bonus-malus schemes. However, one should note that undertaking a more in-depth welfare analysis is highly recommended to fully understand efficiency and effectiveness issues of the policies.

Additionally, one could look at different examples from countries where absolute and relative labelling have been used and try to determine whether there have been any changes in purchasing behaviour after the introduction of the labelling. This approach would further improve our understanding of the effectiveness of each type of labelling scheme.

Finally, future research should determine how consumers actually make their purchasing decisions. This information would ultimately help to identify the most appropriate labelling and incentive schemes.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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