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A policy-based weighted averaging model to predict green vehicle market shares

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This paper investigates the effect of single and combined pricing measures on the potential shift from intended purchase of conventionally fuelled vehicles to environmentally friendly ones. First, a factorial judgment task was designed to elicit the combinatory rule that governs the integration of different pricing policies into judgments of probability of switching to an environmentally friendly vehicle. Our results show that individuals convey these judgments mainly according to an equal weights averaging rule. Next, contingent valuation methodology was applied in a large-scale vignette study to estimate market shares of environmentally friendly vehicles given different single pricing policies. Total potential market shares for environmentally friendly vehicles for combined pricing policies were subsequently modeled according to a weighted average of "market scale values" based on the best-fitted functions of willingness-to-pay cumulative frequencies and "policy weight values" elicited through a direct rating procedure. The resulting model enables policy makers to calculate the switch to environmentally friendly vehicles at any hypothetical price level for different pricing policy packages.

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Reducing the use of fossil fuels by road transport is currently one of the most important sustainability issues in the European Union (European Commission, 2009). As most consumers are not inclined to give up the car as primary means of transportation, stimulating the purchase of vehicles with alternative fuels (liquefied petroleum gas , compressed natural gas, biofuels etc.) or drive trains (hybrid and battery electric vehicles) is the single most important intervention to reduce pollutant emissions from the vehicle fleet (Hickman et al. 2010). Fiscal measures in particular are seen as a strong incentive to steer consumers' behavior towards more fuel-efficient vehicles (European Commission, 2007). Besides the availability of a now wider range of "green" vehicles on the supply side, this mainly requires for the consumer purchase patterns to change. Recent views suggest that one single policy is unlikely to change behavior and that adopting a simultaneous top-down and bottom-up policy making approach is necessary (Gordon, 2005; Hickman et al. 2010). The bottom-up component entails developing fiscal policies based on sound principles i.e. aligning prices with marginal social costs such as establishing variable prices for fuels, vehicles, and roads that are related to energy consumption, pollution, congestion, and other socially harmful impacts. A top-down effort involves examining different fiscal policies as a complete package. Unfortunately, this component often gets less attention. Any individual fiscal policy is only one part of the total set of prices faced by consumers. Consequently, it can be assumed that the total shift to environmentally friendlier vehicles would be much higher when applying a multi-faceted price strategy.

In order to support policy makers in choosing adequate policy packages, we propose a model to predict the potential share of the green vehicle market when applying combined pricing strategies. To do so, a number of key questions need to be answered.

Question 1: How do evaluations of single pricing policies combine when consumers express green car purchase intentions based on judgments of pricing policy packages?

Question 2: For any given pricing policy, at which pricing level will consumers switch from conventionally fueled vehicles (CFVs) to a greener alternative (low CO_2 emitting vehicles or alternatively fueled vehicles)? Or, with respect to market shares, what percentage of consumers will switch from CFVs to a greener alternative at a set pricing level?

Question 3: What is the relative importance of each separate pricing policy?

Conceptually, Anderson's information integration theory (IIT) and its methodological counterpart Functional Measurement (FM; Anderson, 1981, 1982, 1996, 2001, 2009) provide both a theory and a method to address most of these questions. The study of the integration operation is central to FM and directly addresses the question how subjective representations of stimuli combine into a single overt response (question 1). Typically, integration functions are exposed by presenting participants with a set of different stimulus-combinations in a factorial judgment task. Extended empirical research over the last four decades (for an overview, see Anderson (1996, 2009)) showed that three algebraic integration rules approximate the internal integration functions for most judgment tasks: an addition rule, a multiplication rule and an averaging rule. In each of these integration models, the integrated response is a function of weight and scale values. Each piece of information is considered to have its own importance (weight) and its own location (scale value) on a latent variable. Referring to our original problem, integration rules describe the cognitive algebraic combination rule of single policy measures within a policy package. Computing scale values allows to determine at which pricing level consumers will switch from conventionally fueled vehicles to a greener alternative (question 2) and weight values (question 3) indicate the relative importance of each policy measure.

However, for eliciting meaningful monetary scale values and deriving a valid integration rule, a traditional factorial judgment task using pricing levels expressed in monetary values may not be entirely appropriate. The stimulus material itself may reduce the integration task to a simple addition/subtraction exercise rather than being the result of a true integration process. To determine the integration rule (question 1) and capture the qualitative differences in the perception of pricing policies, we first conducted a factorial judgment task where attribute levels were manipulated without explicitly mentioning numerical price levels (STUDY I). In order to obtain meaningful pricing levels expressed in monetary values, in STUDY II we applied the Contingent Valuation method (CV; Mitchell & Carson, 1989). In contingent valuation, value elicitation is whole-product based by asking respondents to express their maximum willingness to pay (WTP) for public aspects of a marketed good (Hanly et al. 2001; Veisten, 2007). CV is the most frequently used method for environmentally friendly policy evaluation. It has been used for setting eco-taxes in the UK to justify the tax and for determining its level (Hanly et al. 2001). Past CV research has also investigated consumers' WTP for air quality improvement (Wang et al. 2006; Brouwer et al. 2008; MacKerron et al. 2009), market potential for alternative fuels and drive trains (Sperling et al. 1995; Mourato et al. 2004; Solomon and Johnson, 2009) and eco-labeled goods (Ozanne & Vlosky, 1997; Veisten, 2007). From WTP values, potential market shares can be estimated using cumulative frequencies of WTP values of pooled sample data.

In this paper, we propose to apply CV methodology within the framework of information integration theory to construct a predictive model for green vehicle purchase allowing for the estimation of the population distribution willing to switch to an environmentally friendlier alternative based on different pricing levels of combined policy measures.

STUDY I: FACTORIAL JUDGMENT TASK

METHOD

Participants. Seventy-one unpaid subjects (39 males and 32 females, M_{age} = 34.6 years; SD_{age} = 10.3) participated in a factorial judgment task on car purchase intention and pricing policies. Inclusion criteria for the study were being in the possession of a driver's license and having purchased a car for private use. Four subjects did not complete the experiment and were excluded for further analyses.

Stimuli and design. Stimuli were selected based on pricing policies currently in place in the Belgian legislation and a potential policy pathway of road pricing which has been proposed by a consortium of regional governments. Four quantifiable main attributes were selected for the judgment task: (a) vehicle registration tax, (b) kilometer charging, (c) fuel prices and (d) parking tariffs. Tax-levels for conventionally fueled vehicles were symbolized by a black polluting car on top of a colored visual analogue scale representing a price continuum going from green (inexpensive) to red (expensive). Tax-levels for alternatively fueled vehicles were represented by a green non-polluting car below the colored visual analogue scale (Figure 1). Main attributes such as operating costs and environmental performance were manipulated visually along 2 attribute-intensity levels: high price (the black polluting car near the end of the pricing continuum) and low price (black polluting car near the beginning of the pricing continuum). All 36 car mixes were presented once in random order according to a 2×2×2×2 full-factorial design and all three- and two-way sub designs as qualitative tests for averaging integration and to allow for subsequent parameter estimation.

Procedure. The experiment was designed using FM BUILDER, a JAVA-based software program developed to conduct judgment experiments using text and image stimuli (Mairesse, Hofmans & Theuns, 2008). Participants were instructed to evaluate the probability on purchasing a car based on randomly presented combinations of levels of vehicle registration taxes, kilometer charging, fuel prices and parking tariffs. When presented with stimuli from reduced designs, participants were requested to convey their judgment based only on the stimuli appearing on screen, thus ignoring the influence of the other attribute(s). Subjective probabilities were obtained by means of a 100-point slider displayed in the center of the screen, taking 80% of the screen width, with "not a chance" and "very high purchase probability" serving as end labels. In order to minimize non-compliance to the experiment (i.e. by skipping through the trials) a 1-second delay before the appearance of the next-button was built in. Participants were also required to express on a 10-point rating scale to what extent they believed each single pricing measure would have on their purchase intention for green cars.

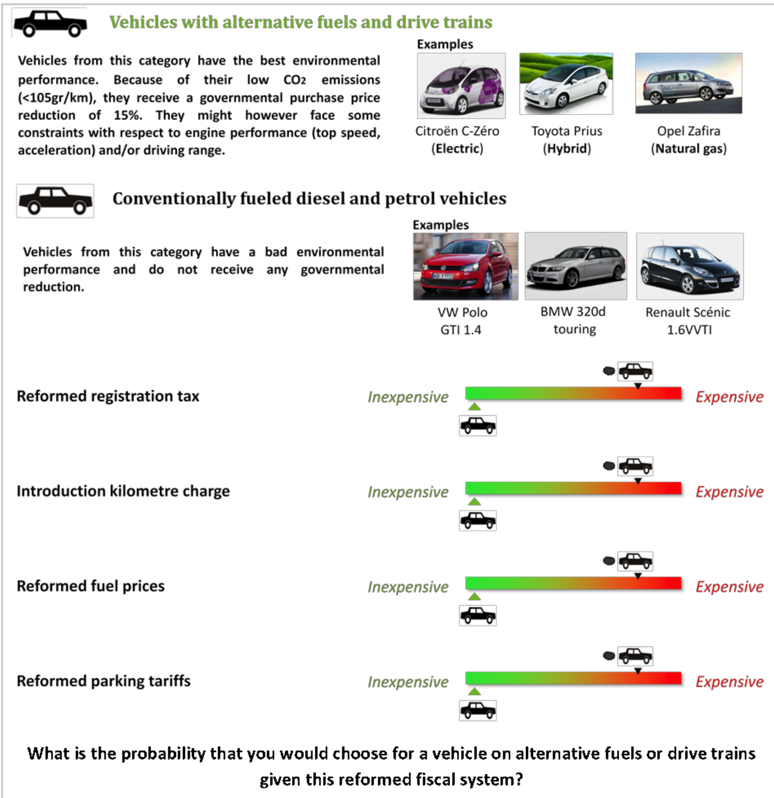

Figure 1: Example of an experimental trial

RESULTS

Statistically, we observe main effects of reforming vehicle registration taxes ($F(2,132)= 22.79$, $p<.001$), introducing kilometer charging ($F(2,132)= 54.93$, $p<.001$), reforming fuel prices ($F(1,66)= 59.52$, $p<.001$) and parking tariffs ($F(1,66)= 7.04$, $p<.05$). We found significant interactions between reforming vehicle registration taxes and introducing kilometer charging ($F(4,264)= 5.58$, $p<.001$), between vehicle registration taxes and reforming fuel prices ($F(2,132)= 9.10$, $p<.001$), between introducing kilometer charging and reforming fuel prices ($F(2,132)= 18.19$, $p<.001$) and between introducing kilometer charging and reforming parking tariffs ($F(2,132)= 5.55$, $p<.005$). Visual inspection of factorial interaction plots at group level corroborates these results (Figure 2) and suggest that at group level, an averaging rule best describes the integration of different non-monetary pricing measures for green purchase probability judgments.

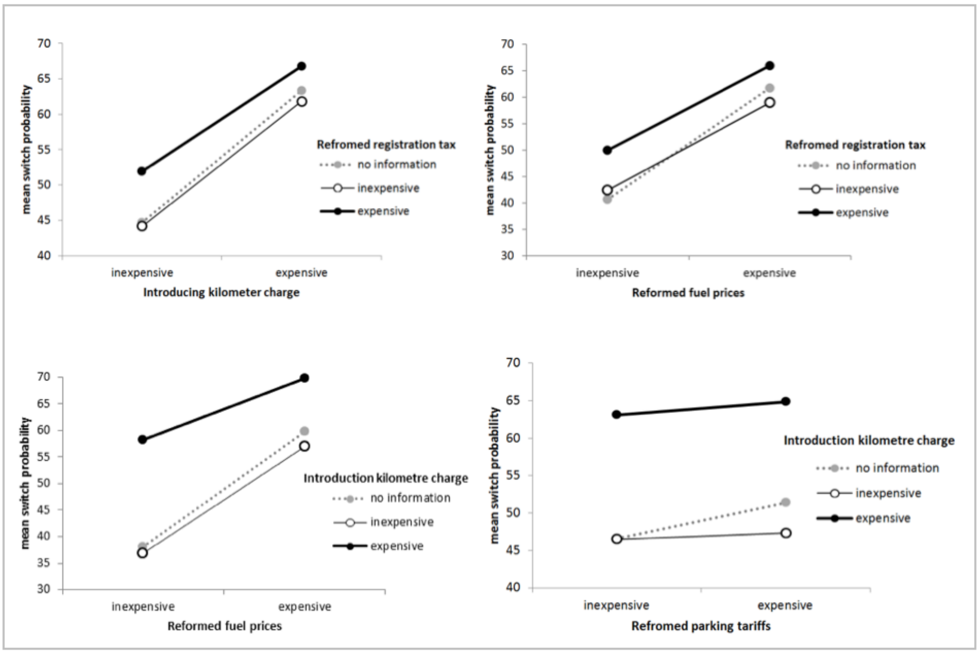

Figure 2. Probability of switching to a vehicle on alternative fuels or drive trains given fiscal reforms.

Establishing the averaging model of integration allows for the separation and calculation of weights and scales by means of R-average (Vidotto & Vincentini, 2007), an optimization routine in R using the L-BFGS-B algorithm. Individual analyses revealed that 52 out of 67 subjects follow an equal averaging rule rather than an averaging rule with differential weights. Group results of the parameter estimation procedure are displayed in Table 1. Table 1 also lists empirical weights compared to weights obtained by means of the direct rating procedure previously described. Pairwise comparisons yielded no statistically significant differences between empirical weights and estimated weights.

Table 1. Model parameters and comparison of estimated and empirically derived weight values.

	$s_{inexpensive}$	$s_{expensive}$	$w_{empirical}$	$w_{direct\ rating}$	t	p
Reformed registration tax	34.2	82.3	19%	17%	1.319	0.192
Introduction kilometer charge	28.7	86.6	35%	34%	0.496	0.621
Reformed fuel prices	22.3	76.8	33%	35%	-0.946	0.348
Reformed parking tariffs	33.2	78.6	13%	14%	-0.555	0.581

DISCUSSION

This experiment addressed the first question in our larger study: *"How do evaluations of single pricing policies combine when consumers express green car purchase intentions based on judgments of pricing policy packages?"* Our results support an equal weight averaging model as the main integration rule for judgments of probability of switching from a conventionally fueled vehicle towards a vehicle on alternative fuel, given different fiscal policy packages. This finding corroborates previous empirical research that consumers do not add information on attributes, but rather apply an averaging rule (Troutman & Shanteau, 1976; Gaeth et al. 1990; Adaval, 2003). However, these studies often focus on non-monetary attributes (e.g. availability, compatibility, processor speed (see Johar et al. (1997)), driving experience, environmental aspects and vehicle quality (Mairesse, Macharis, Lebeau & Turcksin, 2012). For monetary attributes such as pricing and cost-benefit calculations, it is highly conceivable that participants will follow addition-subtraction rules (Anderson, 2009). However, in real market situations, this seems not to be always the case. Individuals react differently to the introduction of diverse price measures, even when the total financial burden is similar. Tax compliance is dependent on different psychological mechanisms such as framing (the manner in which acts, stimuli or situations are presented), heuristics, cultural cognitions, social norms, personal values, etc. (Kornhauser, 2007). With respect to IIT, this translates in an averaging process where adding a positively valued monetary attribute can actually decrease the value of the whole good, because of extra-financial aspects associated with the attribute.

Estimation of weight parameters shows that introducing kilometer charging and reforming fuel prices have the largest impact on green car purchase intentions followed by a reform of vehicle registration taxes and a reform of parking tariffs. Fuel prices and vehicle taxation mainly impact vehicle ownership by raising the cost of owning a particular vehicle type. On the other hand, pricing measures such as reformed parking tariffs mainly affect vehicle use and not ownership and is targeted on commuters and urban citizens. We explain the relative higher weight of kilometer charging because of its wider scope as it also addresses consumers from rural areas as shown previously by Litman (2010).

Finally, we showed that, using empirical weights as benchmark, estimated weights derived from a direct rating procedure are not significantly different. This finding is in line with previous research of Zhu & Anderson (1991) and Wang & Yang (1998) showing that, using the EAM as a benchmark, theoretically valid weights can be approximated by using either direct rating, SMART or AHP.

STUDY 2: VIGNETTE SURVEY

Rationale

In the next study, we build on the results of the previous experiment by applying principles of IIT in a vignette survey using contingent valuation (CV) methodology.

First, CV is used to elicit the policy pricing level at which someone is willing to switch from a conventionally fueled vehicle to a greener alternative to obtain *willingness-to-pay* (WTP) values.

Second, *single-policy market shares* are defined as the percentage of consumers willing to switch to an environmentally friendly vehicle resulting from a reform of a single policy measure. Single-policy market shares are then calculated from the cumulative frequency distribution of WTP values of all respondents for the policy measure of interest. Each policy measure is to be considered with all other fiscal instruments remaining unchanged.

Third, we assume that the *total potential market share* resulting from a policy package is a function of single-policy market shares (*market scale values*) and the importance of each policy measure (*policy weights*). Based on the results of the previous experiment, we assume that single-policy market shares combine by means of an equal weights averaging rule and that weights can be estimated by means of direct rating. Consequently, the total potential market share of green vehicles as a result from combined pricing policies can be formalized as the following equal weights averaging model:

$$r_{hijkln} = \left[\frac{w_{RT}s_{RT_h} + w_{ACT}s_{ACT_i} + w_{UCC}s_{UCC_j} + w_{KC}s_{KC_k} + w_{PT}s_{PT_l} + w_{FP}s_{FP_n}}{w_{RT} + w_{ACT} + w_{UCC} + w_{KC} + w_{PT} + w_{FP}}\right]^{*}$$

with *r* as the total potential market share of environmentally friendly vehicles, *w* as the policy weight values elicited through direct rating and *s* as the market scale values expressed as cumulative frequency distributions of the respondents' WTPs.

METHOD

Participants. Respondents were recruited from a panel provided by a Belgian marketing research institute (iVOX). 1186 respondents completed the survey, for which they received an incentive. Table 1 compares the socio-economic characteristics of the respondents with those from the Belgian population from which they were drawn (NIS, 2008). It is shown that a representative sample has been obtained for region ($\chi^2(2)=1.47$, p= .480) and gender ($\chi^2(1)=.03$, p= .863), but not for age ($\chi^2(1)=6.66$, p< .01).

Procedure. The vignette study was designed as part of a larger survey. In part 1, participants were required to provide information on transportation choices and motives, travel and purchase profiles and information on currently owned vehicles. Participants also had to select which vehicle they planned to purchase to replace the primary vehicle in their household. This information was used as basis for the willingness-to-pay items in the third part of the survey.

* RT= registration tax; ACT=annual circulation tax; UCC= urban congestion charge; KC= kilometer charge; PT=parking tariffs; FP=fuel price

Table 2. Socio-economic characteristics of the sample and Belgian population (NIS, 2008a).

Characteristic	Level	% Sample	% Population
Region	Brussels	9.0	9.8
	Flanders	65.6	57.7
	Wallonia	25.3	32.4
Gender	Men	52.0	49.9
	Women	48.9	51.0
Age	Middle-aged (18-65)	92.3	78.6
	Retired (> 65)	7.6	21.4

In part 2, general background information was provided on climate change and on the prospect of the implementation of policy measures to encourage sustainable transportation. Meanwhile, it was emphasized that each policy measure should be considered separately in the survey question, all other fiscal instruments remaining unchanged.

Part 3 showed separate pages with customized taxation levels for existing vehicle registration taxes, annual circulation taxes, parking tariffs, fuel prices and hypothetical pricing measures (urban congestion charge, kilometer charge) based on the characteristics of the vehicle that respondents indicated in part 1 to be the future replacement of their main household car. Taxation levels for existing pricing measures were based on the same information of this preferred vehicle. When a taxation system was not yet installed, a price on reference values from neighboring countries was presented. For example, in the case of road pricing, a yearly charge is approximated by using proposed reference values from the Netherlands (0.11 euro/km in peak traffic and 0.03 euro/km otherwise) and the respondents self-reported travel profiles. Respondents were then informed that a new level of taxation would be based upon the vehicle's environmental performance. For this purpose, 4 environmental categories were identified and shown to the respondents (Figure 3). Additionally, an environmental label (A, B, C or D) was given to the respondent's preferred car. Under each governmental action, C and D-labeled vehicles would be discouraged with a higher financial burden, whereas B-labeled vehicles (low CO_2 emitting vehicles) would receive a more advantageous tariff and A-labeled vehicles (alternative fuels and drive trains) would enjoy minimum tariffs or in some cases even exemptions. Given this scenario (vignette), the respondents could indicate whether and at which taxation level they would find their initial vehicle choice so expensive that they would consider a switch to a B-labeled or an A-labeled vehicle.

In part 4, demographic information was gathered (gender, age, education and income) and the possibility to provide comments was given.

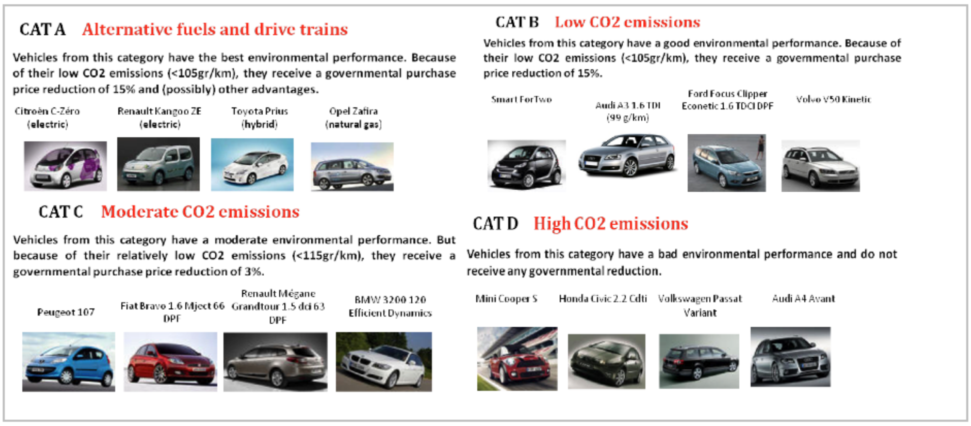

Figure 3. Vehicle categories.

To elicit the contingent values, open-ended questions with discrete choice questions were combined (Figure 4). For the open-ended question, the payment card method was used, in which individuals could indicate the pricing level at which they would find their preferred car so expensive that they would consider a switch to an environmentally friendlier car (A or B-labeled vehicle). In order to identify protest bids and social desirable bids producing zero WTPs, two additional discrete choice options were added (protest bids: "I will not change to an environmentally friendlier car, despite the higher price for the conventional car" and social desirable bids: "I will immediately change to an environmentally friendlier car"). Protest voters were further determined by means of additionally provided comments. Potential social desirable respondents were identified as people who indicated the environment is the sole crucial aspect in their decision to buy a car (part 1 of the survey). Responses from protest voters and social desirable respondents were excluded for model building purposes (Carson, 2000; Nunes & Schokkaert, 2003). Hypothetical biases - a potential divergence between the real and hypothetical WTP due to the absence of a real economic commitment (Brownstone et al. 1994; MacKerron et al. 2009) have been limited by considering only owners of private passenger cars, as these people have already made economic commitments with respect to the purchase and use of their privately owned car.

Reformed annual circulation tax

The annual circulation tax will be based on the environmental performance of the vehicle. All other fiscal measures will remain unchanged. Vehicle with high or moderate CO2 emissions (category C or D) will be faced with heavier taxes, whereas vehicles with low CO2 emissions (category B) will enjoy a more advantageous tariff, and vehicles on alternative fuels or drive trains (category A) will enjoy a minimum tariff (69.7€/year).

You chose the following vehicle: BMW 3 SERIES, a vehicle of category D
In the current fiscal system, the annual circulation tax is 365.11 €/year.

1) At which amount would you find the reformed circulation tax of a BMW 3 SERIES so expensive that you would switch to a car with low CO2 emissions (category B, more advantageous tariff?

- I'd only switch to a low CO2 emitting vehicle if the reformed circulation tax for a BMW 3 SERIES would be more than
- I couldn't or wouldn't switch to a vehicle with low CO2 emissions, no matter how expensive the circulation tax for a BMW 3 SERIES would be
- I would immediately switch to a low CO2 emitting vehicle.

2) At which amount would you find the reformed circulation tax of a BMW 3 SERIES so expensive that you would switch to a vehicle on alternative fuels/drive trains (e.g. electric, hybrid) (category A, max. 69.7€/year)?

- I'd only switch to a vehicle on alternative fuels/drive trains (e.g. electric, hybrid) if the reformed circulation tax for a BMW 3 SERIES would be more than
- I couldn't or wouldn't switch to a vehicle on alternative fuels/drive trains (e.g. electric, hybrid), no matter how expensive the circulation tax for a BMW 3 SERIES would be.
- I would immediately switch to a vehicle on alternative fuels/drive trains (e.g. electric, hybrid).

Figure 4. Vignette and elicitation format.

In analogy to the first study, weight values were elicited by means of direct rating (Figure 5).

RESULTS

Willingness-to-pay values

The WTP values of each individual pricing measure are estimated from the frequency distributions of the actual bids from the respondent's maximum WTP . In Table 3, the mean WTP represents the amount induced by the pricing measure at which the average consumer would find its preferred conventionally fueled car so expensive that he or she would consider a switch to respectively a low CO_2 emitting vehicle or a vehicle on alternative fuels or drive trains.

"Which governmental measure would have the largest influence on your purchase behavior?"											
	No influence at all										**Extreme influence**
Reformed registration tax	○	○	○	○	○	○	○	○	○	○	○
Reformed annual circulation tax	○	○	○	○	○	○	○	○	○	○	○
Introducing an urban congestion tax	○	○	○	○	○	○	○	○	○	○	○
Introducing a kilometer charge	○	○	○	○	○	○	○	○	○	○	○
Reformed parking tariffs	○	○	○	○	○	○	○	○	○	○	○
Reformed fuel prices	○	○	○	○	○	○	○	○	○	○	○

Figure 5. Direct rating of the importance of pricing measures on purchase behavior.

Policy measure	**Switch to**	***n***	**Mean WTP (SD)**	**Current mean tax**	***t***	***p***
Registration tax (€)	Low CO_2 car	184	**€ 968 (1379)**	**€ 123**	8.314	<.001
	Alternatively fuelled vehicle	194	**€ 1153 (1870)**	**€ 123**	7.672	<.001
Annual circulation tax (€/year)	Low CO_2 car	205	**€ 835 (1248)**	**€ 243**	6.788	<.001
	Alternatively fuelled vehicle	191	**€ 932 (1462)**	**€ 243**	6.514	<.001
Urban congestion charge (€/entrance)	Low CO_2 car	164	**€ 5.15 (5.73)**	***n/a***		
	Alternatively fueled vehicle	165	**€ 5.98 (6.64)**	***n/a***		
Kilometer charge (€/year)	Low CO_2 car	169	**€ 731 (825)**	***n/a***		
	Alternatively fuelled vehicle	167	**€ 742 (812)**	***n/a***		
Parking tariff (€/hour)	Low CO_2 car	152	**€ 3.31(2.94)**	**€ 2.5**	3.379	<.001
	Alternatively fuelled vehicle	160	**€ 3.40 (3.10)**	**€ 2.5**	3.657	<.001
Fuel prices (€/l)	Low CO_2 car	178	**€ 2.03 (0.73)**	**€ 1.2**	15.225	<.001
	Alternatively fuelled vehicle	202	**€ 2.11 (0.83)**	**€ 1.2**	14.884	<.001

Table 3. Mean WTP estimates and differences between mean WTPs and current mean tax levels.

In order to compare the WTP values to current legislation, reference price levels are based on existing mean figures: registration tax and annual circulation tax levels are based on the average engine size (1658 cc) and the average engine power (71 kW) of the Belgian private car fleet in 2009; the parking tariff level (2,5 Euro/hour) is the average parking tariff in Brussels, the capital city of Belgium and the fuel price level (1,2 Euro/L) is the average maximum price of diesel in 2010 knowing that diesel is the dominant fuel type of the Belgian vehicle fleet (75% of all new purchases in 2009) (VITO, 2010; City of Brussels, 2010; Petrolfed, 2010; Febiac, 2010). All mean WTP values are significantly higher than the current tax levels.

Market scale values

To policy makers, the entire WTP distribution is of bigger interest than mean WTP values to forecast market shares (Carson, 2000; Carson et al. 2001). Therefore, single-policy market shares (=market scale values) are calculated based on the best-fitted functions of the WTP's cumulative frequencies to allow for predictions at any hypothetical policy price level (see Table 4a).

Table 4a. Single-policy market shares.

Low CO_2 car	R^2	Alternatively fuelled vehicle	R^2
$S_{RT} = 5.8561 ln(RT) - 1.442$	.95	$S_{RT} = 5.4359 ln(RT) - 3.7079$	.95
$S_{ACT} = 6.7902 ln(ACT) - 7.971$	.87	$S_{ACT} = 5.7461 ln(ACT) - 6.0224$	.91
$S_{UCC} = 7.0007 ln(UCC) + 21.548$	.92	$S_{UCC} = 6.9239 ln(UCC) + 17.774$	.95
$S_{KC} = 7.4044 ln(KC) - 15.782$	.87	$S_{KC} = 6.5821 ln(KC) - 13.373$	.90
$S_{PARK} = 7.563 ln(PT) + 21.814$	.95	$S_{PARK} = 7.4213 ln(PT) + 19.64$	.95
$S_{FP} = 17.933 ln(FP) + 20.074$	.87	$S_{FP} = 17.432 ln(FP) + 17.124$	.89

Legend: RT= registration tax; ACT=annual circulation tax; UCC= urban congestion charge; KC= kilometer charge; PT=parking tariffs; FP=fuel prices

Policy weight values

In the survey, weight values were elicited through direct rating on a 10-point categorical scale from "no influence at all" to "extreme influence" (Figure 5). The weight statistics are based on the private vehicle owners sample, filtered for protest and social desirable bids. Table 5 shows the descriptive statistics of the attributed weight values to the different pricing measures on the 0-10 scale. Our data show that fuel prices have the greatest absolute weight in the car purchase decision, followed by the annual circulation tax, kilometer charge, registration tax, urban congestion charge and parking tariffs.

Table 4b. Policy weight values.

Policy measure	n	$w_{direct\ rating}$	SD	proportional $w_{direct\ rating}$
Registration tax (RT)	580	5.40	2.75	16%
Annual circulation tax (ACT)	580	5.91	2.67	17%
Urban congestion charge (UCC)	579	5.09	3.03	15%
Kilometer charge (KC)	578	5.81	2.99	17%
Parking tariff (PT)	580	4.76	3.00	14%
Fuel prices (FP)	579	6.98	2.61	21%

Policy-based green vehicle demand model

By integrating the abovementioned results, a policy-based green vehicle demand model can be constructed with the aim of estimating the distribution of respondents willing to switch to either a lower CO_2 emitting car or an alternatively fuelled vehicle resulting from combined pricing policy scenarios. Hereunder, a case is worked out to illustrate the applicability of the model for assisting in complex decision making problems.

Introducing green vehicle taxation. In 2005, the European Commission (EC) presented a proposal for a Council Directive that requires member states to restructure their car passenger taxation systems, linked to the CO_2 emissions of the vehicle (European Commission, 2005). So far, 15 European countries have already applied taxation systems, correlated with the CO_2 emissions and fuel consumption of the car (ACEA, 2009). To be in line with European Union policy, the Belgian government could introduce a budgetary-neutral reform of the vehicle taxation system, based on the vehicle's environmental profile. Tables 5 and 6 show the switch to respectively low CO_2 emitting vehicles and AFVs, given a budgetary-neutral reform of the vehicle taxation system (registration tax, annual circulation tax), all other existing pricing measures (parking tariffs and fuel prices) and incentives (see the CO_2 incentives, displayed in Figure 1) remaining unchanged. In order to enable a comparison with actual market transactions, pricing policy levels are based on existing mean figures as described previously. Please note that a budgetary-neutral reform implies similar mean taxation levels in the current as well as in the reformed taxation scheme.

Table 5. Case 1: Low CO_2 emitting vehicles.

Low CO2 Car	Price level	Market scale value	Policy weight	Total potential market share
Refistration tax (€)	123	26.74%	5.40	**26.79%**
Annual circulation tax (€/year)	243	29.33%	5.91	
Urban congestion charge (€/entrance)	0	0.00%	0	
Kilometer charge (€/year)	0	0.00%	0	
Parking tariffs (€/hour)	2.5	28.74%	4.76	
Fuel prices (€/l)	1.2	23.34%	6.98	

Table 6. Case 1: Alternative fuels and drive trains.

Low CO2 Car	Price level	Market scale value	Policy weight	Total potential market share
Refistration tax (€)	123	22.45%	5.40	**23.42%**
Annual circulation tax (€/year)	243	25.54%	5.91	
Urban congestion charge (€/entrance)	0	0.00%	0	
Kilometer charge (€/year)	0	0.00%	0	
Parking tariffs (€/hour)	2.5	26.44%	4.76	
Fuel prices (€/l)	1.2	20.30%	6.98	

To test the validity of the model, we can compare these total market potential figures (27% and 23%) with revealed preference data since in the existing fiscal system at the time of conducting this study. Low CO_2 emitting vehicles benefitted from reduced purchase prices in Belgium. More specifically, vehicles with CO_2 emissions lower than 105 g/km received a 15% reduction, whereas vehicles with CO_2 emissions lower than 115 g/km received a 3% reduction of the purchase price (FPS Finance, 2010). The combination of this fiscal legislation with an CO_2 incentive has led to an increased market share of low CO_2 emitting vehicles. In the first 10 months of 2010, vehicles with CO_2 levels below 115 g/km reached 30% of total vehicle sales, among which vehicles with CO_2 levels below 105 g/km represented a 18 share (Mobimix, 2010). A budgetary-neutral reform of the taxation system is found to produce vehicle shifts in the same order of magnitude as in the fiscal system applicable in the same year.

DISCUSSION

In Study II, we addressed question 2 and 3 of our larger study, namely how many consumers will switch from CFVs to a greener alternative at a set pricing level and what is the relative importance of each separate policy? To do so, contingent valuation methodology has been extended with the principles of IIT in an attempt to inoculate conventional willingness-to-pay assessments with psychological theory. This combination results in a policy-based model to predict green vehicle market shares and as such enables decision makers to estimate the population distribution willing to switch to an environmentally friendlier car based on different pricing levels of combined policy measures. The following section discusses the parameters of the model and the results of the case studies estimated from the model.

Market scale values

Market scale values were obtained by means of WTP functions estimated from CV. For a better understanding of the model outcomes, WTP dynamics are first investigated. Concerning single pricing measures, mean reported WTP values are found to be significantly higher than the average taxation levels in the current Belgian legislation (e.g. registration taxes, annual circulation taxes). Consumers are thus willing to pay additional money to keep the conventionally fuelled vehicle of their choice despite a higher imposed financial load. This illustrates that besides financial aspects, other attributes considerably affect the adoption of green vehicles. Previous research has repeatedly shown that qualitative aspects (e.g. reliability and safety), practical aspects (e.g. car volume and car type) and hedonistic aspects (e.g. design) also play a significant role in the car purchase decision (Mairesse et al. 2008, Mairesse et al. 2012; Cao & Mokhtarian, 2003; Borgsteede & van Tatenhove, 2004). However when, due to a tax reform or other pricing measure, the financial outcome reaches an individual critical level, taxes will become more significant in the trade-off between other vehicle attributes and may encourage consumers to switch to a cleaner (less penalized) vehicle (van Bree et al. 2010; Goerlich & Wirl, 2012; Knight et al. 2000). Here again, financial aspects will not primarily determine the consumers' choice. Our data show that respondents are more likely to switch to low CO_2 emitting vehicles in comparison to alternatively fuelled vehicles, even though they often benefit from payment exemptions whereas the others can only enjoy from a reduced tariff under the proposed pricing measure. Nowadays, most large car manufacturers offer a range of low CO_2 emitting variants of existing conventionally fuelled vehicles for which there is virtually no trade-off for other important purchase attributes besides reduced performance. On the other hand, the current offer of alternatively fuelled vehicles is less extended, meaning that consumers still have to give up other important car attributes that determine the car purchase decision (e.g. in case of electric vehicles: range, recharging time). The transition to low CO_2 emitting vehicles requires less “effort” from the consumer and is therefore more likely to happen when a tax reform or new pricing measure is installed.

Whether positive environmental attitudes will actually translate into green car purchase still remains arguable. Recently, we used FM-methodology to examine this so-called “attitude-action” gap (Mairesse et al. 2012). It was shown that although positive attitudes towards the environment exist (high scale values), environmental performance (15%) is outweighed mostly by vehicle quality (39%), purchase costs (24%) and operating costs (22%) in the car purchase decision. This phenomenon of other attributes outweighing the environmental one has been repeatedly reported in the literature (Lane & Potter, 2007; Olmos & Gateman, 2002; Blake, 1999). Consequently, in order to increase sales volumes of environmentally friendlier vehicles, environmental attributes should be associated with attributes that carry a greater weight like quality (reliability, safety, comfort, design), purchase costs (purchase price, registration tax) and operating costs (fuel costs, maintenance costs). According to these results, acting on financial aspects by rewarding environmentally friendlier vehicles and penalizing polluting vehicles makes not only sense at an economical level, but also at the level of psychological information processing.

Policy weight values

The relative importance of pricing measures in the purchase decision was measured by means of weight elicitation on a 0-10 rating scale. According to Zhu & Anderson (1991), this technique provides empirically sound weight estimates with respect to the FM benchmark, as was confirmed in STUDY I. In line with literature (EPA, 1998; Mairesse et al. 2008; Lehman et al. 2003), fuel prices will mainly affect the car purchase decision (6.98), followed by annual circulation taxes (5.91), kilometer charging (5.81), registration taxes (5.40), urban congestion charging (5.09) and PT (4.76). On average, these weights illustrate that pricing policies do have impact on the purchase decision (> 0), but that this impact is limited to a certain level.

Model simulations

The results on the individual WTP values and weight values have been used to construct a policy-based green vehicle demand model. The purpose of this model is to estimate the potential market share of environmentally friendlier cars based on different weighted pricing levels of combined policy measures. For illustration purposes, a case study showed that combined pricing measures do enhance the adoption rate of green vehicles, but to a limited extent. Indeed, by comparing the stated preference with revealed preference data, a budgetary-neutral reform of the vehicle taxation system is found to produce vehicle shifts in the same order of magnitude as in the existing fiscal system. This result illustrates that reformed vehicle taxation might potentially have a limited behavioral impact, but when combined with measures that directly affect the purchase price (e.g. CO_2 incentive), it might more effectively target the purchase decision.

CONCLUSION

As an effort to support top-down policy making, we propose a model to predict the potential share of the green vehicle market when applying combined pricing strategies. For this purpose, we aimed at answering a number of main questions, namely: (1) how do different pricing policies combine in eliciting purchase intentions, (2) what is the market share of green vehicles at a set pricing level for a single policy measure and (3) what is the relative importance of each separate policy?

The first question was addressed in Study I by means of a factorial judgment task. In this task, we chose to use non-monetary attributes. In pricing calculations, individuals are suspected to follow addition-subtraction rules (Anderson, 2009), but since individuals seem to react differently to price measures even with similar financial burden, we hypothesized that monetary judgments may be governed by another integration process. Our results showed indeed that consumers mainly use an equal weight averaging rule for judgments of probability of switching from a conventionally fueled vehicle towards a vehicle on alternative fuel, given different fiscal policy packages. This implies that extra-financial aspects associated with pricing attributes also play a role in judgment formation with respect to green car purchase intentions. Additionally, our results also show that using the equal wieghts averaging model (Anderson, 1981) as theoretical benchmark, valid weights can be achieved by a direct rating procedure, as previously showed by Wang and Yang (1998).

In the second study, we addressed the second question by using contingent valuation methodology to elicit willingness-to-pay values for single pricing policies and estimated market shares for environmentally friendly vehicles by calculating best-fitting WTP cumulative frequency functions for each policy measure separately (=market scale values). The third question was addressed by estimating policy weight values by means of a direct rating procedure. We finally combined both market scale values and policy weights into a weighted averaging model to predict green vehicle total potential market shares. Results from our calculations show to be similar to revealed preference data.

To conclude on a more applied note, we believe that the greatest shifts in environmentally vehicle ownership might occur when combining reductions of purchase costs with a mix of pricing measures that promote the beneficial effects of operating environmentally friendly vehicles. Further adoption on green vehicles will not only depend on additional governmental incentives that act on the other important aspects that determine the purchase decision (such as regulations to ensure the quality of environmentally friendly vehicles, information campaigns to contribute to a better knowledge and understanding, etc.), but also on the participation of a network of stakeholders in the overall value chain (Eggers & Eggers, 2010). In this respect, the adoption of environmentally friendly vehicles might be facilitated by the availability of a recharging/refuelling infrastructure, or by large-scale vehicle demonstrations in private and public fleets (e.g., public transport fleets, vehicle fleets of national or local authorities) that illustrate the compatibility and user friendliness and hence eliminate potential barriers related to the purchase and use of environmentally friendly vehicles.

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