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Welfare effects of distortionary tax incentives under preference heterogeneity: an application to employer-provided electric cars*

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Abstract

This paper presents an approach for the estimation of welfare effects of tax policy changes under heterogeneity in consumer preferences. The approach is applied to evaluate the welfare effects of current tax advantages for electric vehicles supplied as fringe benefits by employers. Drawing on stated preferences of Dutch company car drivers, we assess the short-run welfare effects of changes in the taxation of the private use of these vehicles. We find that the welfare gain of a marginal increase in the taxation of electric company cars is substantial and even outweighs the marginal tax revenue raised.

Keywords: Social welfare; Latent class; Stated preference; Company car; Electric vehicle; Plug-in hybrid.

JEL Classification codes: D12, H23, H24, H31, O33, Q58, R41.

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1. Introduction

Governments often seek to stimulate the diffusion of environmentally benign technologies by providing tax incentives for their adoption. As the magnitude of these incentives frequently surpasses the expected environmental cost savings induced by these technologies, the latter are offered at implicit prices lower than their optimal ones. Policy makers usually justify these tax policies by arguing that the provided incentives are not only meant to reflect these technologies' environmental and energy security benefits, but also to serve as workhorses for the stimulation of their diffusion (see also Beresteanu and Li, 2011). The quantification of these benefits is a challenging process and strongly depends on country- and industry-specific characteristics. This paper develops an approach to quantify the welfare implications of changes in such tax incentives, assuming that the benefits stemming from the facilitation of market penetration of these technologies are *negligible*. If this assumption is relaxed, our estimates can still serve as a basis against which the additional benefits suggested by policy makers can be weighed.

Preference heterogeneity has a central role in the developed approach. We draw on stated preference data and use an adapted version of the latent class model popularised by Kamakura and Russell (1989). The model enables the identification of groups of potential early adopters of these technologies and pinpoints the socio-demographic factors contributing to the likelihood that individuals belong to this group. The model further accommodates lexicographic choices, i.e. the behaviour of individuals choosing the same alternative in all choice scenarios (Sælensminde, 2006). The usefulness of the proposed approach is highlighted in the context of tax incentives provided for the adoption of plug-in electric vehicles (PEVs) in the Dutch company car market.

In Europe, around half of new vehicle registrations concern company cars, defined as passenger cars offered as fringe benefits in kind by employers to employees and serving mainly employees' private travel needs (Copenhagen Economics, 2010). Company cars are usually leased by firms and are offered to employees under contracts of a predetermined duration (usually 3 to 4 years). These contracts usually cover all operating costs of the car, including fuel costs (Gutiérrez-i-Puigarnau and Van Ommeren, 2011). Even though company car taxation rules vary widely among countries, employee's private use of the car, which is a fringe benefit, is generally taxed on the basis of a tax base rate applied to the car's purchase or list price (Copenhagen Economics, 2010).[1]

The company car market is the driving force of changes in the car fleet of many Western European countries, such as Belgium, Germany, the Netherlands, Sweden and the UK (cf. Copenhagen Economics, 2010). It also serves as the main diffusion channel for alternative fuel

[1] For example, given a 20% tax base rate for a car with a list price of €35,000, and a marginal income tax rate of 42% (which is commonly applicable in the Netherlands), the annual tax that the driver has to pay for this fringe benefit is 42% × 20% × €35,000 = €2940.

vehicles (AFVs), for two main reasons. First, company car drivers do not have to incur (the usually high) upfront costs for the use of the AFV. Second, in the company car market the uncertainty about vehicle's resale price and operating costs is shifted from the car user to the employer or the car leasing firm. In view of the potential contribution of AFVs to the pursuit of environmental and energy security goals, European governments have attempted to stimulate their diffusion in the company car market by providing generous tax incentives for drivers, firms and car leasing companies. Even though these incentives are often particularly effective in achieving the intended policy objectives, they are also likely to yield important unintended welfare effects.

We hereby focus on PEVs and policies aiming to stimulate their adoption through reduced company car tax base rates.[2] First, a stated choice experiment is used to elicit Dutch company car driver preferences for three different types of PEVs. The initial step of the developed approach lies in the analysis of drivers' sensitivity to changes in the applicable tax base rates and other vehicle characteristics. We then proceed by estimating the changes in consumer welfare caused by marginal adjustments in PEV tax base rates and comparing them with the changes in drivers' tax expenses implied by these adjustments. Preference heterogeneity is taken under consideration throughout this procedure.

The rest of the paper is organised as follows. Section 2 provides background information about company car taxation and the incentives provided for the adoption of company PEVs. Section 3 describes the stated choice experiment and illustrates summary statistics for the sample. Section 4 presents the methodology used to elicit company car driver preferences and estimate the welfare effects of changes in the taxation of company PEVs. Section 5 discusses heterogeneity in company car drivers' preferences for PEVs, while Section 6 evaluates the welfare effects of marginal changes in PEV tax base rates. Section 7 concludes.

2. Background

Company cars constitute a common fringe benefit offered by European employers to their employees. One of the most important reasons for their widespread use is their beneficial tax treatment. From employers' perspective, the provision of company cars does not increase social security contributions, as other forms of employees' remuneration do. On employees' side, the

[2] The term plug-in electric vehicle (PEV) is used here to denote both *full electric vehicles* (FEVs), i.e. vehicles powered exclusively by electric motors, and plug-in hybrid and extended-range electric cars, i.e. vehicles propelled by both electric motors and internal combustion engines whose batteries can be recharged by plugging them into an electricity outlet. The technological differences between plug-in hybrid EVs and extended-range EVs (EREVs) are not of primary interest in this study and we denote both with the encompassing term *plug-in hybrids* (PHEVs). Vehicles with electric motors which cannot be plugged into an electricity outlet, such as hybrid electric vehicles (HEVs), are not considered as PEVs.

applicable tax base rates for the private use of the company car are usually set at lower than optimal levels (see e.g. Gutiérrez-i-Puigarnau and van Ommeren, 2011), which entails that their taxable income due to the private use of the car increases much less than the company car costs incurred by employers. This implicit subsidy for employees is further reinforced in taxation systems where the fuel costs of the private use of the car are also covered by employers, but are not taken into account in the calculation of employees' taxable income (Copenhagen Economics, 2010).[3]

Company car taxation has recently gained attention in economic and transportation literature. Most empirical studies have focussed on the quantification of the welfare effects stemming from the beneficial tax treatment of the *private travel* of company car drivers (e.g. Gutiérrez-i-Puigarnau and van Ommeren, 2011; Shiftan et al., 2012). These studies conclude that the current taxation of company cars is distortionary, resulting in employees opting for more expensive cars (Gutiérrez-i-Puigarnau and van Ommeren, 2011), driving more kilometres (Shiftan et al., 2012), and expanding their household fleet (van Ommeren and Gutiérrez-i-Puigarnau, 2013). However, empirical research on the effects of the favourable treatment of PEVs and other low emission vehicles (LEVs) in the company car market has so far been missing.[4]

The European Union has set ambitious environmental targets for 2020, which include the reduction of CO2 emissions to levels 20% lower than the ones of 1990 (European Commission, 2010). In this framework, environmental performance has recently been established as a main criterion in the specification of the levels of applicable car taxes in the majority of European countries (Adamou et al., 2013). The company car market is affected in various ways by these developments in tax systems. First, since car registration taxes increase in many cases with vehicle's worse environmental performance (e.g. higher CO2 or particulates' emissions), less polluting company cars have become cheaper for both employers and employees. The first are benefitted from lower purchase or lease prices of LEVs, whereas the latter from lower values of the benefit-in-kind they receive and thus from lower increases in their taxable income.

Second, in some cases, LEVs are eligible for partial or full exemptions from road taxes (e.g. in Germany, the Netherlands and the UK). This entails that LEVs have lower operating costs or lease prices than their higher emission counterparts, which can be further reduced by their lower fuel costs. On the other hand, in countries where the fuel costs of the private use of the car are not considered in the calculation of employee's taxable income, the decreases of tax revenue caused by exemptions from road taxes will be partially offset by reductions in the levels of the fuel subsidy

[3] Examples of such taxation systems can be found in the Netherlands and Spain, and under conditions, France and Germany. Car fuel expenses are in most countries fully tax-deductible for firms.

[4] Throughout the text, the term "low emission vehicles" is used to denote vehicles with zero or low tailpipe emissions. The assessment of the emissions produced during the production of the vehicle and its components, as well as in the course of fuel production, is not in the scope of this study.

provided for low emission company cars. Third, some tax authorities provide additional incentives for firms' purchase of LEVs, either in the form of more flexibility with regard to the timing of depreciation of the company car or in the form of deductibility of a proportion of the expenses related to it from corporate taxable profit.

Last, several European countries have designated special rules for the taxation of the benefit in kind arising from the private use of company LEVs, either by adjusting the considered value of LEVs or by tailoring the tax base rates applied to them. For example, tax authorities in Germany and Sweden consider list prices of company PEVs that are substantially lower than their market prices when calculating employees' addition to taxable income. In *Germany*, the list price of a PEV depends on the capacity of its battery. In 2013, a PEV's list price was lower than its market price by €500 per kWh of battery capacity, up to a maximum of €10,000.[5] In *Sweden*, the considered taxable value of a company PEV can be as much as 40% lower than the value of a comparable petrol or diesel car. The decrease of the taxable value is restricted to a maximum of SEK16,000, i.e. ca. €1850, per year (ACEA, 2013).

In other countries, such as Belgium, France, the Netherlands, and the UK, the tax base rate used for the taxation of the private use of the car is itself a function of the car's CO2 emissions. In *the UK*, for example, full electric vehicles (FEVs) enjoy zero tax base rates until April 2015, envisaged to increase to 9% in the 2015-2016 tax year. At the same time, all vehicles with emissions between 1 and 75 gCO2/km (according to the New European Driving Cycle official measurements) are eligible for very low tax base rates, equal to 5% for petrol-fuelled vehicles and 8% for diesel-fuelled ones. All plug-in hybrids (PHEVs) currently available in the European market fall within these CO2 emission thresholds. The special rates for these vehicles are planned to be abolished in the 2015-2016 tax year (HM Revenue and Customs, 2014).

In *the Netherlands*, the country we focus on, cars with emissions less than 50 gCO_2/km qualified for zero tax base rates in 2013. In other words, the private use of FEVs and most PHEVs was not taxed until the end of that year. The tax base rates increased for purchases made from the beginning of 2014 onwards to 4% for FEVs and 7% for vehicles whose emissions were between 1 and 50 gCO_2/km. To facilitate comparison, the median tax base rate for company cars in the Netherlands was 20% in 2012 (VNA, 2013).[6]

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[5] For example, the 24kWh battery pack of the 2013 Nissan Leaf renders it eligible for the maximum reduction of €10,000. Therefore, the calculation of employee's addition to taxable income will not be based on Leaf's €30,000 minimum list price, but instead on an amount around €20,000. In this case, employee's annual taxable income is reduced by €1200.

[6] Building on the example provided in the first footnote, a zero company car tax rate entails annual tax savings for the driver equivalent to €2940. As demand elasticities can be high in the car market (see e.g.

3. Data

The welfare implications of changes in the tax treatment of PEVs in the company car market can be evaluated through the analysis of revealed and stated preference data. Appropriate revealed preference data are, however, unavailable for this purpose for two main reasons (cf. Klier and Linn, 2013). First, while car registration data are widely available, registrations of company cars are usually made under the name of firms or car leasing companies. This has several shortcomings, the most important of which being that it does not allow the identification of the driver of the vehicle. Another important shortcoming is that it does not enable a distinction between company and fleet cars, i.e. cars serving solely business trips. Second, the number of PEV registrations in the past years in the Netherlands – at the end of 2012 amounting to around 1900 FEVs and 4300 PHEVs – is insufficient to allow a sound econometric analysis of driver preferences.

Therefore, we build our empirical approach around a new dataset of stated vehicle choices of Dutch company car drivers in an experimental setting. The data stem from drivers' responses to an online questionnaire inviting them to make 8 hypothetical choices between cars propelled by internal combustion engines (ICE), PHEVs, and two types of FEVs, in the context of their next company car acquisition. The two following subsections provide details about the design of the questionnaire, the online survey, and the choice experiment, while the third subsection presents sample descriptive statistics.

3.1. Survey design

We use data from a survey carried out between November 2012 and January 2013. The survey was addressed by a sample drawn from a panel of motorists of a Dutch market research company (TNS-NIPO). This panel has around 45,000 Dutch vehicle owners with experience in filling out car-related questionnaires. Among these panel members, there are around 4,000 households owning at least one company car. The sample was stratified by the number of cars owned, cars' ownership status (private or company) and fuel type. TNS-NIPO was requested to draw a sample evenly distributed between single-car and multi-car households, as well as between households having at least one company car and ones owning only private cars. Within these four categories, we asked for an adequate representation of households having at least one hybrid-electric vehicle, as we were interested in examining possible differences in preferences between HEV drivers and drivers of cars propelled solely by internal combustion engines.

The survey was carried out with an extensive online questionnaire developed in Sawtooth SSIWeb. Respondents driving less than once a week, having a minor role in their household's

Bento et al., 2009; Gutiérrez-i-Puigarnau and van Ommeren, 2011; Train and Winston, 2007), we expect that these subsidies can cause strong demand reactions.

vehicle choice making, and not intending to purchase a car in the next 5 years, were excluded from the sample. The present study draws only on the responses of individuals reporting that their *current car* is a *company car* and that their *next car* will be a *leased car*. Following an elaborate presentation of the alternative types of propulsion systems and the vehicle attributes used in the study, respondents were given the opportunity to familiarise themselves with the choice experiment by means of an example choice question. Thereafter, they were invited to choose their preferred alternative in 8 hypothetical choice scenarios. They were later asked to report how they made their choices, i.e. whether they considered all attributes or just a subset of them or whether they chose an option at random. The time that respondents spent to handle different parts of the questionnaire was closely monitored, in order to provide us with a measure of how seriously they addressed the questionnaire. Demographic characteristics of respondents were provided by TNS-NIPO.

Following focus group discussions, a small-scale pretesting of the questionnaire and a pilot survey with 206 respondents from TNS-NIPO's panel, 3900 invitations were sent to panel members. We collected 2921 complete responses (response rate of 75%; similar to comparable studies, e.g. Koetse and Hoen, 2014). Another 134 respondents (3.5%) were disqualified from the rest of the questionnaire after reporting that they made random choices in the choice scenarios. About 15% of the complete responses were excluded from the rest of our analysis, due to respondents' extremely fast handling of choice scenarios. All questionnaires with a median duration of response to the choice scenarios of less than 10 seconds were not further processed, as it would be hard to argue that these respondents actually attempted to make trade-offs between vehicle attributes. Of the remaining 2473 valid responses, 847 concern drivers who reported that they currently mostly drive in a company car and that their next vehicle transaction is foreseen to concern a company car. After some additional data cleaning, 845 complete responses are used for the remainder of the analysis.

3.2. Choice experiment

Respondents were initially instructed to think about their next company car and treat the choice scenarios presented to them as real choice tasks. They addressed 8 choice scenarios inviting them to choose their preferred option among 4 versions of the same car: a plug-in hybrid (PHEV), a full electric with fixed battery (FBEV), a full electric with swappable battery (SBEV) and a version driving on respondents' preferred propulsion system and fuel (e.g. petrol, diesel, LPG, HEV, biofuels, etc.). When respondents reported that their next car would be an FEV or a PHEV, the fourth alternative was automatically set to a petrol-fuelled car. They were further instructed to assume that the four options were different only in the 8 attributes presented to them and that fuel costs would be paid by their employer.[7] Table A.1 in Appendix A presents an overview of the attributes and attribute levels used in the choice experiment. These were determined on the basis of a comprehensive literature review (see also Dimitropoulos et al., 2013) and deliberations with colleagues. The selection of attribute levels aimed at the presentation of realistic scenarios, on the one hand, and at the elicitation of driver preferences across a wide range of possible attribute values, on the other.

Apart from the propulsion system, the four options differed with respect to the following seven attributes: list price, tax base rate, employee's annual net contribution, driving range, refuel time at the station, charging time at home, and detour time required to reach the nearest fast-charging or battery-swapping station on top of the time needed to access the nearest petrol station. The *list price* of FEVs and PHEVs included the costs of a charging cable and a standard home-charging unit. The list price of the ICE car was customised on respondent's selected price range.[8] The price of the three other options varied around the price of the ICE car in accordance with the coefficients shown in Table A.1. We also considered cases where FEVs and PHEVs were priced lower than the ICE, in order to be able to examine trade-offs for a wider range of attribute levels.

Dutch regulation requires company car drivers to be taxed for their private use of the car when it exceeds 500 kilometres per year.[9] The addition to driver's taxable income due to the private use of the company car is calculated as the product of the purchase price of the car and a *company car tax base rate* which currently depends on vehicle's CO2 emissions (cf. Chorus et al., 2013). Until the end of 2013, all employees who acquired company cars with tailpipe CO2 emissions of less than 50 g/km directly qualified for a 5-year exemption from taxation on the private use of the car. At the same time, rates of 14%, 20%, and 25% apply to vehicles with higher tailpipe emissions of CO2. These values provide the basis for the levels considered in the design of our study, where company car tax rates vary between 14% and 25% for conventional cars (including HEVs), while between 0 and 14% for FEVs and PHEVs.

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[7] Only 3% of our sample reports that the fuel costs associated with the private use of the car are (partially) paid by themselves.

[8] Before engaging in the choice scenarios, respondents were asked to select the anticipated price range of their next company car from a list of possible ranges. For each choice scenario, a random number was drawn from a uniform distribution defined in the interval between 1/100th of the minimum value of that price range and 80% of 1/100th of the maximum one. The resulting integer was then multiplied by 100 to present the respondent with a price rounded to hundreds of Euros. For example, if the respondent reported that their next car would fall in the price range €15,000-€20,000, a random number was drawn in the interval [150,190]. The integer was then multiplied by 100 to provide a price between €15,000 and €19,000.

[9] This condition holds for around 97% of the company car drivers who completed the questionnaire. To ensure that the *tax base rate* attribute is consistently considered across respondents, drivers who were not taxed for the use of the company car at the time of the survey were excluded from the rest of the analysis.

We further presented respondents with the actual annual tax payment they would have to incur under the considered purchase price and company car tax rate to facilitate their comparison of different alternatives. In the Netherlands, two income tax rates are mostly applicable for this purpose depending on driver's income, 42% and 52%.[10] As information about the income tax rate category within which respondents fall was unavailable, they were presented with annual tax figures for both categories. These figures are calculated as the product of purchase price, company car tax rate and income tax rate.

Employees usually make substantial private use of the company car and are often asked to contribute to the monthly expenses made by the employer for this purpose. The magnitude of this contribution usually depends on the price of the car. Chorus et al. (2013) report that employees' monthly contribution usually varies between €0 and €400. We adopt a narrower range and consider values of €0, €100, €300 (annualised to €0, €1200 and €3600, respectively) for *employee's annual net contribution*, independent of the fuel technology in context.

Driving range varied for all alternatives. For PHEVs, we considered values spanning from the current situation for extended-range electric cars to the current situation for plug-in hybrids. For FEVs, we employed driving range levels from as low as 100 km, slightly lower than the level advertised for most commercially available FEVs, to 500 km, somewhat higher than the one estimated for the 85-kWh battery-pack of Tesla Model S.[11] *Refuel time at the station* denoted the time required to refuel the tank of the ICE car or the PHEV, to fast-charge the battery of the FBEV, or to swap the batteries of the SBEV at specialised stations. It varied only for the FBEV, from 15 to 45 minutes for a full charge. Standard *charging time at home or work* was substantially shorter for PHEVs than FEVs, due to their usually smaller battery-packs. It varied from 1½ to 5 hours for the PHEVs and from 4 to 10 hours for the FEVs. *Extra detour time* to reach the nearest fast-charging or battery-swapping station was essentially a measure of the availability of refuelling infrastructure, as it informed respondents about the extra time they would have to spend in searching for a quick alternative to standard home-charging, if they adopted an FEV (cf. Chorus et al., 2013; Train, 2008). As the investment required for the building of a battery-swapping station is currently about 20 times higher than the installation of an AC fast-charging unit, we considered slightly higher levels of this attribute for SBEVs than for FBEVs.

Regarding the design of the study, we used SSIWeb's *Complete Enumeration* method to generate a close to orthogonal design with 300 choice experiment versions (Sawtooth Software, 2008). To accommodate the attribute differences among the four propulsion systems presented to

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[10] Lower income tax rates are applicable to individuals with low income, but the latter are a very small minority of company car drivers.

[11] http://www.teslamotors.com/models/options.

respondents, we used an alternative-specific design. The sequence of the four alternatives was randomised, whereas the attribute sequence was fixed to reduce the complexity of the task. Perl and HTML scripting was extensively used to accommodate the alternative-specific nature of the attribute levels and to customise them in accordance with respondents' stated values for their next transaction. Figure 1 presents an example of a choice scenario.

Choice Question 1

The four options presented below are different versions of the same model. They differ only in the presented attributes.
The annual costs of the company car are equal to the sum of annual tax payment and your annual net contribution.

	Option 1	Option 2	Option 3	Option 4
Fuel type	Diesel	Electric car with fixed battery	Electric car with swappable battery	Plug-in Hybrid
List price	€ 22,000	€ 30,800	€ 24,200	€ 44,000
Tax base rate	25%	0%	14%	7%
- *Annual tax payment: 42% tariff*	*€ 2310 per year*	*€ 0 per year*	*€ 1420 per year*	*€ 1290 per year*
- *Annual tax payment: 52% tariff*	*€ 2860 per year*	*€ 0 per year*	*€ 1760 per year*	*€ 1600 per year*
Employee's contribution	€ 0 per year	€ 3600 per year	€ 1200 per year	€ 1200 per year
Driving range	750 kilometres	300 kilometres	100 kilometres	500 kilometres
Refuel time at the station	5 minutes	30 minutes	5 minutes	5 minutes
Charging time at home or work	Not applicable	8 hours	10 hours	3 hours
Extra detour time	No extra detour time	10 minutes	15 minutes	No extra detour time

Please indicate below which option you would choose:

	Option 1	Option 2	Option 3	Option 4
Your choice →	○	○	○	○

Figure 1: Example of a vehicle choice scenario

Note: In the example above, the respondent stated that his next purchase would be a new, medium-sized, diesel-fuelled car, costing €20,000–€25,000. The example is translated from Dutch.

3.3. Descriptive statistics

Table 1 provides the main descriptive statistics of the sample. It mainly consists of males (ca. 83%) and highly educated drivers (60%). An important share (38%) of the sampled drivers belongs to high-income households with gross annual earnings greater than €77,500. The mean and median age of respondents is 44 years. These results are in general agreement with earlier studies of the Dutch company car market (Ecorys, 2011). Furthermore, the distribution of our sample's sex, age, and education level is similar to the one reported by Koetse and Hoen (2014) for their sample of Dutch company car drivers. Relevant statistics for the population of company car drivers are not available, as there is no relevant census or regular survey.

Table 1: Sample descriptives

Variable	Percentage	Variable	Percentage
Demographic Characteristics		Characteristics of respondent's current car (cont.)	
Sex		*Fuel type*	
Male	0.83	Petrol	0.36
Female	0.17	Diesel	0.54
Age		Hybrid	0.09
18-24	0.01	LPG	0.00
25-34	0.18		
35-44	0.35	Next company car characteristics	
45-54	0.31	*Fuel type*	
55-64	0.16	Petrol	0.26
65 +	0.00	Diesel	0.54
Education (completed)		Hybrid	0.13
Primary and lower secondary	0.08	LPG	0.00
Higher secondary vocational	0.20	Plug-in Hybrid	0.03
Higher secondary professional	0.12	Electric	0.02
Bachelor	0.41	CNG / Biofuels	0.01
Masters / PhD	0.20	Unknown	0.01
Unreported	0.00	*Segment*	
2011 Gross household income (€)		Small	0.07
Less than 32,500	0.02	Medium-sized	0.45
32,500 - 51,300	0.18	Large / Estate	0.34
51,300 - 77,500	0.36	MPV	0.09
77,500 - 103,800	0.22	SUV	0.04
103,800 - 155,100	0.12	Van	0.01
155,100 or above	0.03	Sports / Luxury	0.01
Unreported	0.06	*Annual distance travelled (km)*	
		< 20,000	0.10
Characteristics of respondent's current car		20,000 - 30,000	0.24
Applicable tax base rate (%)		30,000 - 40,000	0.32
14	0.29	40,000 - 50,000	0.22
20	0.37	> 50,000	0.13
25	0.34		

Table 1 also provides summary statistics about variables that are used in the class membership model, described in the next sections. The majority of respondents currently drive in diesel-fuelled cars (54%), while a minority drives in HEVs, such as the Toyota Prius (9%). Compared to the population of leased cars in 2012 (VNA, 2013), diesel cars are slightly overrepresented (by around 4 percentage points), while petrol-fuelled cars are underrepresented by around 8 percentage points. As already noted, we aimed for an overrepresentation of HEVs (around 4 percentage points) to enable us to study the preferences of these drivers in more detail. Turning to the company car tax base rate, the most common category is the *20%* tax rate, followed by *25%* and

14%. This distribution is in close agreement with national statistics for company cars registered in the period 2010-2012 (RAI Vereniging and BOVAG, 2013).

Diesel-fuelled cars also have the lion's share in respondents' preferences for the fuel type of their next company car. The characteristics of this fuel technology (e.g. long range and low fuel costs) render it especially suitable for the needs of company car drivers. Slightly less than 5% of respondents state that their next company car will be a PEV. Two-thirds of them will opt for a PHEV and one-third for an FEV. This already indicates that even though PEVs have not yet passed the early-adoption stage, there is a non-trivial interest in electric vehicles. Due to their long range and important similarities to ICE-propelled cars, plug-in hybrids currently appear as the most attractive PEV technology for company car drivers.

Respondents' choices for the segment of their next company car and the annual distance expected to be travelled confirm that they are heavy car users who place emphasis on comfort and good performance. The average expected annual distance travelled in our sample is around 35,000 km. For comparison purposes, a private car travels, on average, around 12,000 km per year in the Netherlands, whereas a company car around 25,000 km. There are also important differences in the annual distance travelled between fuel technologies. Company cars running on diesel travel, on average, around 31,500 km per year while the ones running on petrol travel slightly more than 18,000 km (RAI Vereniging and BOVAG, 2013). The need for long range and increased comfort are relatively high for company car drivers, rendering larger cars more suitable for their needs. Sample statistics confirm this expectation, as medium-sized cars are the most popular segment in drivers' choice for their next company car, followed by large/estate cars and multi-purpose vehicles.

4. Methodology

This section discusses the methodological approach developed to elicit company car driver preferences for PEVs and estimate the welfare effects of changes in their beneficial tax treatment. Consumer heterogeneity has a central role in our modelling framework.

4.1. Modelling preference heterogeneity

We investigate consumer preference heterogeneity by using a panel latent class model (Kamakura and Russel, 1989) which accommodates the seemingly lexicographic behaviour of some consumers. Class membership is modelled as a stochastic function of consumer socio-demographic and behavioural characteristics. Before proceeding with the formulation of the model, we motivate the use of stated preference techniques which appropriately treat lexicographic choices.

In stated preference studies, it is common that a small proportion of respondents do not appear to make trade-offs among attributes. This non-trading practice is hereby expressed by respondents choosing the same technology in all choice scenarios.[12] This behaviour can be either interpreted as consonant with random utility theory (RUT) or as inconsistent with the RUT framework. The former interpretation boils down to the possibility that the differences in attribute levels between the technology always chosen by the respondent and the other alternatives were simply not adequately large to make the respondent opt for another alternative (see e.g. the experimental work by Cairns and van der Pol, 2004). This is essentially an indication of very strong preferences towards a specific technology. On the contrary, the analysed behaviour can be an expression of decision heuristics used by the respondent, arising, for instance, due to the complexity of the choice task (Sælensminde, 2006). This interpretation renders respondent's choices inconsistent with the assumptions underlying the use of compensatory models.

The appropriate treatment of such lexicographic choices of respondents in the discrete choice analysis depends on the interpretation assigned to them (see also Hess et al., 2012; Lancsar and Louviere, 2006). Our modelling approach attempts to address possible biases stemming from the inclusion of these respondents' choices in the data as such or their complete neglect, by treating respondents with lexicographic choices differently from individuals who make trade-offs among attributes. To this end, we use the general framework provided in Hess et al. (2012), where individuals with lexicographic choices are deterministically assigned to special classes. We define the probability that individual *n* belongs to the non-trading class, H_n^{NT}, as follows:

$$H_n^{NT} = \sum_{r=1}^{R} \prod_{s=1}^{S} I_{rns} , \tag{1}$$

where I_{rns} is an indicator taking a value of 1, if respondent *n* chooses technology *r* in choice scenario *s*, and the value of zero otherwise. Individuals are allocated to the non-trading class, only if they have selected the same technology in all choice scenarios, i.e. iff $H_n^{NT} = 1$.

For the remainder of our sample, we assume that, conditional on membership in class *g*, company car driver *n* behaves according to a random utility model when choosing alternative *i* in choice scenario *s*. Utility is modelled in willingness to pay (WTP) space (see, e.g. Scarpa and Willis, 2010; Train and Weeks, 2005) and is of the form:

$$U_{nis}^{g} = \beta^{g} (M_{nis} - \boldsymbol{\omega}^{g\prime} \mathbf{X}_{nis}) + \varepsilon_{nis}^{g} , \tag{2}$$

where *U* stands for random utility, *M* is the monetary attribute used for the calculation of the WTP, **X** is a vector of the (levels of the) other attributes used in the experiment, *β* and **ω** represent class-specific parameters and vectors of WTPs to be estimated, and *ε* is an idiosyncratic, unobserved by the researcher, component of utility, which is assumed to be i.i.d. Gumbel across individuals.

[12] In our data, 77 individuals (9.1%) chose the ICE car and 12 respondents (1.4%) the PHEV in all scenarios.

Conditional on her membership in class *g*, the logit probability that individual *n* chooses alternative *i* among *J* alternatives in scenario *s*, can then be expressed as:

$$P_{nis}^{g} = \frac{e^{\beta^{g}(M_{nis} - \boldsymbol{\omega}^{g\prime}\mathbf{X}_{nis})}}{\sum_{j=1}^{J} e^{\beta^{g}(M_{njs} - \boldsymbol{\omega}^{g\prime}\mathbf{X}_{njs})}}, \tag{3}$$

while the probability that she makes the sequence of choices that she is observed to make can be calculated as (Greene and Hensher, 2003):

$$P_{n}^{g} = \prod_{s=1}^{S} P_{nis}^{g} \ . \tag{4}$$

Individuals who make trade-offs among attributes are probabilistically assigned to different classes according to a class membership model (CMM). Assuming that the random component of the membership likelihood function is also i.i.d. Gumbel, the logit probability that individual *n* is a member of class *g* among *G* classes is (Boxall and Adamowicz, 2002):

$$p_{\mathrm{n}}^{g} = \frac{e^{\alpha^{g} + \boldsymbol{\zeta}^{g\prime}\mathbf{Z}_{\mathrm{n}}}}{\sum_{g=1}^{G} e^{\alpha^{g} + \boldsymbol{\zeta}^{g\prime}\mathbf{Z}_{\mathrm{n}}}} \ , \tag{5}$$

where the normalisations $\alpha^{G} = 0$ and $\boldsymbol{\zeta}^{G} = 0$ are required to ensure identification (Greene and Hensher, 2003). In Equation (5), $\mathbf{Z}_{\mathrm{n}}$ is a vector of socio-demographic and behavioural characteristics of individual *n*, while class-specific constants α and vectors of parameters $\boldsymbol{\zeta}$ are to be estimated.

The likelihood that individual *n* makes the observed sequence of choices is then:

$$L_{\mathrm{n}} = H_{\mathrm{n}}^{NT} + (1 - H_{\mathrm{n}}^{NT}) \sum_{g=1}^{G} p_{\mathrm{n}}^{g} P_{\mathrm{n}}^{g} \ , \tag{6}$$

and the log-likelihood for the sample will be:

$$LL = \sum_{n=1}^{N} \ln(L_{\mathrm{n}}) \ . \tag{7}$$

The parameters of interest are estimated by maximising this log-likelihood function. This procedure results in identical parameter estimates and the same maximum value as the ones derived from the estimation of a PLCM solely on the group of traders. As will be shown later, however, the magnitude of welfare effects of tax policy changes also depends on the interpretation assigned to the behaviour of non-traders. We, therefore, believe that it is important that this group of respondents is not ignored in the analysis. Regarding the desirable number of latent classes, it is determined by estimating models with different numbers of classes and comparing them on the basis of the meaningfulness of the yielded estimates and their performance with respect to the Schwarz Information Criterion (SIC, see Gupta and Chintagunta, 1994).

4.2. Estimation of welfare effects

The PLCM can serve as a basis for the evaluation of the short-run welfare effects of changes in the policy framework governing the adoption of environmentally benign technologies. We hereby show how it can be used for the assessment of the welfare implications of marginal increases in the tax base rates applicable to PEVs in 2013 in the Netherlands. In light of the increase of PEV rates by the Dutch government in the beginning of 2014, this application is of high policy relevance.

We assume that the number of company cars in the market is exogenously determined and focus on the demand for alternative fuel technologies. The car market is perfectly competitive and the supply of PEVs and ICE-propelled cars is fully elastic.[13] This assumption is plausible in the context of the Dutch car market, as its size is relatively small. The external cost savings caused by PEVs (e.g. in terms of lower tailpipe emissions of CO2, air pollutants and lower noise levels) are *fully compensated* by the exemption of these cars from registration and road taxes. Support for this assumption is found in tax policies applied in the Dutch *private* car market to encourage the purchase of PEVs, whereby the principal tool used at the national level is their exemption from these taxes.

We further postulate that the *income tax rate* is set at the optimal level. Economic theory then suggests that the addition to employee's income due to the private use of the company car should fully reflect the difference between car's operating costs and the increase in employee's productivity stemming from its use (see Clotfelter, 1983; Katz and Mankiw, 1985).[14] Accordingly, the optimal tax base rate is the one whose product with the list price of the car yields exactly this difference (Gutiérrez-i-Puigarnau and van Ommeren, 2011). We hereby assume that the optimal tax base rate is the one most commonly applied to company cars in the Netherlands, i.e. 20%.[15] If income effects of price changes are assumed to be negligible, this framework entails that the subsidisation of company PEVs through lower tax rates is distortionary and leads to welfare losses.

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[13] See Berry et al. (1995) and Verboven (2002) for discussions of alternative market structures.

[14] The operating costs of the company car encompass all costs incurred by the employer for the provision of the company car and comprise fuel costs and leasing costs, whereby the latter reflect car depreciation, maintenance costs, insurance costs and road taxes.

[15] Other studies (see e.g. Gutiérrez-i-Puigarnau and van Ommeren, 2011) argue that the tax rates should be much higher than 20% to reflect the expenditure actually incurred by employers for the use of these cars. As tax rates were varied in the experiment between 0 and 25%, we perform a welfare analysis within these boundaries. If the optimal level of tax base rate is higher than the one taken into account here, the welfare gains induced by marginal increases of tax base rates for PEVs are hereby underestimated.

Provided that demand for company PEVs is not completely inelastic, changes in their taxation entail changes in social welfare. This holds for the drivers assigned to the three latent classes of our sample. The fourth class encompasses drivers who always choose either the ICE vehicle or the PHEV, implying that their demand for all alternatives is fully inelastic within the range of attribute levels examined or that their treatment of the choice scenarios is not consistent with RUT. In the first case, changes in PEV taxation yield no welfare effects for about 10.5% of our sample. In the second case, the choices made by these drivers can be neglected and social welfare effects induced by tax rate changes can be extrapolated to the whole sample.[16]

We are interested in the net welfare effects of a marginal increase of the tax rate for a PEV from its 2013 levels, i.e. from zero percent, and focus on the *average* company car driver. Net welfare, W, is defined as the difference between social benefits and costs. In this case, the former are hereby captured by consumer surplus, CS, whereas the latter by implicit subsidy D, being equal to the difference between the actual operating costs of a PEV (hereby assumed to be equal to 20% of their acquisition price) and the consumer price implied by the applicable tax base rate for this PEV in 2013, i.e. zero. That is, $W = CS - D$. A marginal increase of the PEV tax rate will yield two effects. First, it will result in a reduction in consumer surplus. Second, it will lead to a decline in the implicit subsidy provided for the use of the PEV. We now look closer into these two effects.

When utility is linear in income, the expected consumer surplus is equal to the monetary equivalent of the logsum, plus an unknown constant (see e.g. De Jong et al., 2007; Small and Rosen, 1981). Latent class models offer a key advantage over continuous logit mixtures in regard to the computation of the expected consumer surplus, as there is a closed-form expression for it. In particular, CS can be computed as the class membership probability weighted average of the consumer surpluses of the three latent classes, i.e.:

$$CS = \sum_{g=1}^{G} p^g [-\frac{1}{\beta^g} \ln(\sum_{j=1}^{J} e^{\beta^g (M_j - \omega'^g \mathrm{x}_j)})] + \psi \, , \tag{8}$$

where ψ is a constant. Thus, a marginal increase in the tax rate of a PEV alternative of type q (with $q \in \mathbf{K}$={PHEV, FBEV, SBEV}) will yield a reduction in consumer surplus equal to:

$$\frac{\partial CS}{\partial t_q} = \sum_{g=1}^{G} p^g \omega_t^g P_q^g \, , \tag{9}$$

[16] It is also possible that only a fraction of the drivers with lexicographic choices behaved consistently with RUT when engaging in the experiment, whereas the rest of them did not. In the absence of information about the decision rule employed by drivers, we hereby analyse the two extreme cases.

where p^g is the probability of membership in class g, t_q is the tax rate for PEV alternative q, ω_t^g is the WTP of class g for tax rate changes, and P_q^g is the probability of choice of q conditional on membership in latent class g. [17]

For each latent class g and PEV technology k, the implicit subsidy per company car is equal to the product of the probability that k is chosen, with the difference between the optimal tax base rate and the one currently applied to k, and the acquisition price of k. When lower than optimal tax base rates are applied to all PEV alternatives (as was the case in 2013 in the Netherlands), the total subsidised amount per class will be captured by the sum of the relevant amounts per alternative. The class membership probability weighted average of the subsidised amounts per class yields the total amount of subsidy implied by the applicable tax base rates, i.e.:

$$D = \sum_{g=1}^{G} p^g \sum_{k=1}^{3} P_k^g (t_{\text{ICE}} - t_k) LP_k \,, \tag{10}$$

where P_k^g is the probability that k is chosen conditional on membership in class g; t_{ICE} is the (optimal) tax rate applicable to ICE-propelled cars; and LP_k denotes the list price of alternative k. A marginal increase in the tax rate of a specific alternative q will result in a reduction in the subsidised amount equal to:

$$\frac{\partial D}{\partial t_q} = -\sum_{g=1}^{G} p^g P_q^g \left\{ LP_q + \beta^g \omega_t^g \sum_{k=1}^{3} [(t_{\text{ICE}} - t_k) LP_k (1 - P_k^g)^y (-P_k^g)^{(1-y)}] \right\}, \tag{11}$$

where y is a binary variable taking the value of 1 if k=q, and 0 otherwise.[18] The change in net welfare implied by a marginal change in the tax rate of alternative q will be equal to the change in consumer surplus (Equation 9) net of the change in the subsidy (Equation 11), i.e.:

$$\frac{\partial W}{\partial t_q} = \sum_{g=1}^{G} p^g P_q^g \left\{ LP_q + \omega_t^g \left\{ 1 + \beta^g \sum_{k=1}^{3} [(t_{\text{ICE}} - t_k) LP_k (1 - P_k^g)^y (-P_k^g)^{(1-y)}] \right\} \right\}. \tag{12}$$

5. Empirical results

Table 2 presents the estimation results of the panel latent class model (PLCM). For comparison purposes, we also illustrate the results of a specification which allocates respondents to two deterministic classes, a non-trading and a trading one, and where a multinomial logit (MNL) model

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[17] We note here that: $\partial[\ln(\sum_{j=1}^{J} e^{\beta^g (M_j - \omega'^g \mathrm{x}_j)})] / \partial t_q = -\beta^g \omega_t^g e^{\beta^g (M_q - \omega'^g \mathrm{x}_q)} / \sum_{j=1}^{J} e^{\beta^g (M_j - \omega'^g \mathrm{x}_j)} = -\beta^g \omega_t^g P_q^g$.

[18] Note that for k=q: $\partial[P_k^g (t_{\text{ICE}} - t_k) LP_k] / \partial t_q = (t_q - t_{\text{ICE}}) LP_q \beta^g \omega_t^g P_q^g (1 - P_q^g) - LP_q P_q^g$,

and for $k \neq q$: $\partial[P_k^g (t_{\text{ICE}} - t_k) LP_k] / \partial t_q = (t_{\text{ICE}} - t_k) LP_k \beta^g \omega_t^g P_k^g P_q^g$.

is used to estimate the parameters of the trading class. This specification is equivalent to an MNL estimated on a sample excluding respondents belonging to the non-trading class. All models were coded and estimated using PythonBiogeme 2.3 (Bierlaire, 2003, 2009). We tested PLCMs with 2, 3, 4 and 5 latent classes. The model with 3 latent classes resulted in the lowest value of SIC and in intuitively appealing estimates and is, hence, our preferred specification. PLCM clearly outperforms MNL in terms of statistical fit. Its principal merit, however, is that it provides insights into preference heterogeneity and links it to heterogeneity in individual characteristics.

Table 2: Estimation results of the MNL and Latent Class model

	Multinomial Logit		Latent Class Model					
			Potential early adopters		Conventionalists		Mainstream	
Random Utility Model								
Attribute	estimate	std. error	estimate	std. error	estimate	std. error	estimate	std. error
Employee's annual net contribution (1000 €)	-0.433***	0.012	-0.502***	0.048	-0.283***	0.041	-0.718***	0.045
	WTP estimate	std. error	WTP estimate	std. error	WTP estimate	std. error	WTP estimate	std. error
Components of addition to taxable income								
Tax base rate (%)	-0.181***	0.008	-0.150***	0.017	-0.202***	0.038	-0.195***	0.016
Purchase price (1000 €)	-0.062***	0.004	-0.057***	0.010	-0.168***	0.028	-0.032***	0.007
Alternative specific constants								
Plug-in hybrid [PHEV]	-0.755***	0.249	0.861	0.587	-3.030***	0.942	-0.537*	0.312
Electric: fixed battery [FBEV]	-7.960***	0.521	-3.430***	0.745	-16.600***	3.560	-10.100***	2.790
Electric: swappable battery [SBEV]	-7.970***	0.430	-2.840***	0.693	-15.300***	2.650	-10.700***	2.890
Driving range (km)								
ICE 600 → 750	0.566***	0.168	0.417	0.343	0.925*	0.546	0.383*	0.211
ICE 600 → 900	0.872***	0.175	0.085	0.453	1.890***	0.637	0.664***	0.250
PHEV 500 → 700	0.701***	0.175	-0.089	0.364	3.430***	0.846	0.222	0.273
PHEV 500 → 900	0.983***	0.179	0.014	0.372	3.910***	0.874	0.354	0.286
FEVs 100 → 300	2.490***	0.265	2.250***	0.343	-0.265	1.500	5.240**	2.640
FEVs 100 → 500	4.460***	0.264	3.440***	0.469	4.140***	1.130	7.390***	2.740
Detour time (min/refuelling action)								
FBEV 20 → 10	0.616*	0.333	0.537	0.491	1.830	2.500	0.596	0.575
FBEV 20 → 0	1.410***	0.319	1.440***	0.419	1.780	2.350	1.310***	0.477
SBEV 30 → 15	0.948***	0.262	0.057	0.377	2.250*	1.340	1.620***	0.456
SBEV 30 → 0	1.590***	0.256	0.728*	0.431	3.800***	1.380	2.160***	0.470
Charging time at home/work (100 min/charging action)								
PHEV	-0.145*	0.081	-0.069	0.161	-0.662**	0.257	0.054	0.106
FEVs	-0.099*	0.052	-0.026	0.066	-0.051	0.341	-0.236***	0.088
Charging time at station (10 min/refuelling action) [a]	-0.279***	0.108	-0.200***	0.096	-0.200***	0.096	-0.200***	0.096
Class Membership Model								
			estimate	std. error	estimate	std. error		
Constant	-	-	-1.100***	0.425	-0.279	0.291		
Individual characteristic								
Age < 35 years	-	-	-0.362	0.323	-0.592*	0.305		
Annual gross household income ≥ €77,500	-	-	-0.474*	0.278	-0.024	0.236		
Current car is hybrid	-	-	-0.067	0.361	-1.310**	0.559		
Business kilometres (10%)	-	-	0.043	0.049	0.069*	0.041	*Reference Class*	
Annual distance with next car < 20,000 km	-	-	1.030**	0.414	0.505	0.460		
Next car: small / medium-sized	-	-	0.767***	0.275	0.062	0.247		
At least 1 acquaintance drives a PHEV	-	-	0.524*	0.282	-0.578*	0.323		
Class size [b]	-		*0.227*		*0.293*		*0.375*	
Parameters	19		71					
Observations (Individuals)	6760		6760 (845)					
Log-likelihood at convergence	-5605.0		-5099.0					
McFadden's rho-squared	0.331		0.392					
Adjusted McFadden's rho-squared	0.329		0.383					

Note: WTP estimates are annual amounts in €1,000. Standard errors are heteroskedasticity-robust. ***, ** and * indicate statistical significance at the 1%, 5% and 10% level respectively.

[a] The WTP for charging time at the station is constrained to be equal between latent classes.

[b] The shares of the three latent classes add up to approximately 89.5% of the sample. The remainder 10.5% of respondents comprise the deterministically defined class of non-traders.

5.1. Random Utility model results

The random utility model is estimated in WTP space. The monetary attribute used to derive WTP estimates (*M*) is *employee's annual net contribution* to company car's costs. This attribute was selected because it reflects a payment that has to be fully incurred by the company car driver, in contrast to the purchase price of the car and the addition to driver's taxable income where the final costs incurred depend on driver's annual income. Table 2 shows that ICE technologies are generally preferred to PEV alternatives, closely followed by their closest alternative in terms of performance and refuelling behaviour, PHEVs. In sharp contrast, full electric vehicles fall far behind PHEVs. A closer look at the WTP estimates, however, manifests substantial heterogeneity in preferences among classes and reveals where the class labels stem from.

The first class draws on the preferences of 23% of the sample and comprises a group of *potential early adopters* of PEV technologies. Membership in this group reveals one's indifference between ICE cars and plug-in hybrids, despite the latter's shorter driving range and long charging time at home and workplace, and relatively low utility losses suffered from the adoption of full-electric vehicles. The second class corresponds to almost 29% of the sample and encompasses a group of *conventionalists*. These are drivers who have a strong preference for conventional technologies and attach high values to the driving range of the car. The third class has the highest membership probability in the sample (around 37.5%) and reflects the preferences of *mainstream* company car drivers. This class has only a marginal preference for ICE cars over PHEVs, but derives considerable disutility from FEVs. In contrast to the other 2 classes, *mainstream* drivers marginally prefer FBEVs to SBEVs. Later in this subsection, we elaborate on the preferences of *potential early adopters* as they are the most interesting group for the welfare analysis that follows. WTP estimates of the other two classes can be interpreted analogously.

Valuation of monetary attributes

Drivers appear very sensitive to changes in tax base rates, thereby confirming that tax incentives are a powerful tool for the stimulation of the demand for PEVs in the hands of policy makers. Differences in the sensitivity to changes in tax base rates among classes are generally rather small. It seems that only *potential early adopters* exhibit a slightly lower sensitivity, equivalent to around 75% of the sensitivity of the other two classes. On the contrary, the three classes show great heterogeneity in their sensitivity to company car's acquisition price. The sensitivity of the first class is on average around 80% higher than the sensitivity of the third one, while the second class shows by far the highest sensitivity, being more than fivefold the one of the third class. *Conventionalists* are consistently the most responsive class to changes in tax rates and acquisition prices. This might be a reflection of differences in the *personal* income between members of this class and members of other classes. However, we cannot test the validity of this hypothesis as data on respondents' income is only available at the *household* level.

Valuation for driving range and refuelling time attributes

Previous research on drivers of private cars has shown that their utility is non-linear in driving range (Dimitropoulos et al., 2013). We allow for this non-linearity in two ways. First, we allow the WTP for this attribute to differ across fuel technologies. Differences in the valuation of driving range are likely to exist, for instance, due to the employment of different attribute levels for different technologies in the experimental setting. Second, the utility function of each alternative contains a set of dummy variables accounting for the various driving range levels employed in the study design, directly thus considering non-linearities in driver preferences. The same approach is employed to allow for non-linearities in the WTP for extra detour time. Reference levels for driving range and extra detour time are set to the least attractive levels used in the study design to resemble the alternatives available in the market at the time of the survey.

For refuelling time at home and workplace, utility specifications with dummy variables did not perform as well as linear specifications. However, we allow for differences in preferences for this attribute between PHEVs and FEVs, as the levels employed for the two technologies span different ranges. Station refuelling time is the only attribute whose WTP is restricted to be fixed among classes.[19] The WTP estimate for this attribute amounts to €20/min.

A closer look at the WTP estimates of the three time attributes reveals that a rather consistent ranking of their importance is made by drivers. The WTP for a 1-minute reduction in extra detour time is higher than the WTP for an equal decrease of station fast-charging time, which in turn considerably exceeds the WTP for the same reduction in home/workplace charging time. This is an intuitive finding, reflecting the fact that the opportunity costs of detouring, refuelling at the station and charging at home/workplace differ substantially from each other, as the range of other activities that drivers can perform while engaging in these refuelling-related actions varies widely. While detouring, the main activity that can be performed is driving, whereas while charging at the station, other activities like working, enjoying a meal or engaging in some form of entertainment can be undertaken. The opportunity costs of charging at home or workplace approach zero as drivers can carry out the activities they would anyway do while the car is getting charged.

Potential early adopters

Potential early adopters consider PHEVs equivalent to ICE-propelled cars and incur moderate losses from the adoption of FEVs. They attach no value to increases in the range of plug-

[19] The use of separate WTPs for each class resulted in all three estimates being insignificantly different from zero. As the station refuelling time attribute varied only for the FBEV, the large standard errors of these estimates might be attributed to the small number of choices of FBEVs in the experiment (ca. 6%).

in hybrids and ICE cars, but have important gains from increases in the driving range of FEVs. Their WTP for FEV range is non-linear and decreases from around €11/km in the 100-300 km interval to €6/km in the 300-500 km one. Apparently, an increase of FEV range to 500 km would render these vehicles almost equally competitive to their ICE and PHEV counterparts for this class.

Potential early adopters derive no utility change from increases in home-charging time, neither for plug-in hybrids nor for FEVs. This group of company car drivers is, however, sensitive to changes in the extra detour time required to reach a fast-charging facility or a battery-swapping station, particularly when marginal reductions concern low levels of extra detour time. Reductions of detour time to reach the nearest fast-charging station are much more highly valued than reductions of the time needed to access the nearest battery-swapping station. A 20-min reduction per refuelling action in the former has a value almost double that of a 30-min decrease in the latter. These findings highlight that policies directed to the expansion of the network of fast-charging facilities can be an effective stimulus for the early adoption of FBEVs, which can *partially* substitute tax reductions aimed at triggering their demand. Such policies might further lead to savings of public spending for the stimulation of PEV adoption, as the financing of this expansion might be delivered via public–private partnerships or private initiatives.

5.2. Class membership model results

The class membership model (CMM) explains individuals' class membership by their socio-demographic background and car ownership and use patterns. The presented model is the outcome of extensive search of different model specifications exploring the influence of drivers' socio-demographic characteristics and car ownership and use patterns on class membership probabilities.[20] In regard with socio-demographic characteristics, only income and age are found to have an effect on these probabilities. In particular, drivers with relatively high gross annual household income, which is defined as income above €77,500, are around 38% less likely to belong to the group of *potential early adopters* than drivers with lower income. This is in contrast with studies on the private car market suggesting that high-income households are more likely to become early adopters of innovative environmentally benign technologies (e.g. Qian and Soopramanien, 2012), but concurs with previous empirical findings rejecting this hypothesis (e.g. Bunch et al., 1993; Hidrue et al., 2011). As a higher marginal income tax rate is applicable to higher incomes

[20] For example, we tested the performance of other socio-demographic variables, such as sex, education and household size, car ownership characteristics (number of cars owned by the household), and car use patterns (e.g. availability of a fixed working location, commuting distance, availability of parking spot at home or workplace, frequency of travelling abroad, frequency of using a tow-hitch) in the estimation of the CMM. However, none of these variables led to significant improvements in model fit or had a statistically meaningful effect on the class membership probabilities.

(52% vs. 42% for lower-income ones), our findings suggest that potential early adopters are slightly more likely to belong to the 42% income tax rate category. At the very least, this implies that efficient tax policies for the stimulation of the early adoption of PEVs should not provide additional benefits to higher income households than to lower income ones, as the current policy does.

Similar to other studies in the field (e.g. Ewing and Sarigöllü, 1998; Hidrue et al., 2011), our estimates show that younger drivers have a significantly lower probability to be *conventionalists*. In particular, we find that drivers younger than 35 years old are 45% less likely to belong to this group than older individuals. We do not find significant differences in the probabilities to belong to one of the classes between the remainder age categories.

A relatively underexplored issue in SP studies on alternative fuel vehicle choice is the impact of current car ownership and use on choices made. As already noted, we sampled an adequate number of individuals currently driving in a company HEV, in order to be able to explore differences in preferences between them and drivers of ICE cars. Our findings show that these drivers are indeed 73% less likely to be *conventionalists*. Even though this result refers to people *currently driving* in an HEV and not individuals who report that their *next purchase* will probably be an HEV, this finding is in line with other studies revealing that drivers interested in HEVs are unlikely to fall within classes oriented to ICE vehicles (e.g. Hidrue et al., 2011).

Ceteris paribus, it is expected that drivers who travel relatively short distances would be more likely to adopt electric vehicles, as they can more easily address driving range limitations. Our findings support this hypothesis, as individuals planning to drive less than 20,000 kilometres per year in their next company car are 2.8 times more likely to belong to the group of *potential early adopters* than drivers who plan to drive more than this. This finding is in agreement with Koetse and Hoen (2014), who show in the framework of an MNL model with interaction effects that preferences of Dutch company car drivers for driving range, net annual contribution and different propulsion technologies depend on their annual mileage. On the other hand, our estimates reveal that drivers with a higher share of business kilometres (excluding commuting) are more likely to be *conventionalists*. In particular, a 10-percentage-point increase in the share of business kilometres to the total number of kilometres travelled in the company car leads to a 7% increase in the likelihood to belong to this group. The average share of business kilometres reported by respondents is 39%.

In agreement with Hidrue et al. (2011), we find that individuals who indicate that their next purchase will most likely be a small or medium passenger car have a significantly higher probability to belong to the class of *potential early adopters*. This probability is ca. 2.2 times higher than the one of drivers intending to adopt a larger company car. Several reasons could be masking behind this finding. First, it might be a reflection of consumer perceptions of PEVs as smaller cars. This would have been the signal that well-informed consumers would have got from the Dutch car market, as almost all PEV models available at the time of the survey belonged to these two categories. Another reason could be that there is some correlation between the desired body type of the car and the driving range needs of the driver. Even though we control for the effect of small annual distances driven by the company car on the class membership probabilities, that variable might not be comprehensively capturing the impact of driving range needs on those probabilities.

There is a growing literature investigating the influence of social networks and word of mouth on the adoption of PEVs (e.g. Axsen and Kurani, 2012; Axsen et al., 2013). Our analysis provides support to the findings of this literature and reveals a positive social influence for PHEVs. In particular, we find that individuals who have at least one acquaintance who drives in a PHEV have around 69% higher probability to be *potential early adopters* and 44% lower probability to be *conventionalists* than people who are not aware of anyone driving in a PHEV in their close social environment.[21] This is an encouraging finding for the future demand for PHEVs, as it shows that the experiences of first adopters are rather positive, inducing their colleagues and acquaintances to also take a more positive stand towards this technology. In our sample, around 81% does not have any acquaintances driving in PHEVs, whereas 14% report that they know only one person driving in a PHEV and 5% declare knowing more PHEV drivers. We also investigated the impact of social influence in the case of FEVs, but probably due to the small number of people who had an acquaintance driving in an FEV (7.7% of the sample) we did not find any significant effect of this variable on class membership probabilities.

6. Welfare effects of taxation of electric company cars

Our PLCM estimates confirm that drivers are highly sensitive to adjustments in PEV tax base rates and, therefore, the latter can be very effective in triggering demand for PEVs. However, this high sensitivity also implies that these adjustments may have substantial social welfare effects. We are hereby interested in estimating the welfare effects of marginal changes in PEV tax base rates from zero percent and, hence, we use the formula provided in Equation (12). Estimates of ω_t^g and β^g are extracted from Table 2, and t_{ICE} and t_k take the values 20% and 0% respectively. LP_k is computed as the weighted average of the list prices of representative PEV models for each car segment. The weights used are equal to the shares of the segments in respondents' statements about the likely body type of their next company car.[22] A summary of the PEV models available in the Dutch car

[21] It could be argued that a driver's awareness of acquaintances driving in PEVs also captures some implicit prior interest to PEV technologies. Unfortunately, there is no way that we can differentiate between the effect of such prior interest and the one of social influence in our data.

[22] Note that these are not the same with the ones presented in Table 1, as those include also respondents with lexicographic choices. The shares (weights) used in this analysis are as follows: Small: 6.5%; Medium-sized: 46.0%, Large: 32.8%; MPV: 9.3%; SUV: 3.3%; Van: 1.3%; Sports/Luxury: 0.8%.

market in 2013 and their list prices, as well as a short description of the approach developed to estimate list price values for segments where PEVs were unavailable in the market, can be found in Section B.1 of Appendix B.

We consider two cases. In the first case, all respondents with lexicographic choices behave consistently with RUT. The estimates of p^g are, therefore, equal to the class sizes presented in Table 2 and welfare effects are equal to zero for the non-trading class. In the second case, we consider that none of the respondents with lexicographic choices behaves according to RUT. Estimates of p^g are in this case equal to the class sizes of Table 2 divided by their sum (ca. 89.5%). For each PEV technology k, $\sum_{g=1}^{G} P_k^g$ approximately equals its *observed* (company car) market share in 2013. The choice probabilities of PEVs conditional on class membership, P_k^g, are, however, unknown. To estimate them, we work as follows. We first develop a baseline scenario using the attribute values best resembling the characteristics of the car models available in the market (see Section B.2 of Appendix B for details). On the basis of this scenario, we simulate the PLCM using the point estimates of the parameters and WTPs presented in Table 2. We then compute each class's average share on the probability that an alternative is chosen ($P_i^{\,g}/P_i$). The company car market shares of PEV technologies in 2013 are allocated to the three latent classes according to this ratio (see also Section B.3 of Appendix B). Table 3 presents the simulated class-probability-weighted company car market shares of ICE-propelled cars, PHEVs and FEVs derived from this exercise, considering the two extreme cases for the behaviour of the non-trading class.

Table 3: Simulated class-probability-weighted company car market shares of alternative fuel types.

Latent class	ICE-propelled cars	PHEVs	FEVs
NT class consistent with RUT			
Potential early adopters	0.18	0.02	0.01
Conventionalists	0.42	0.02	0.00
Mainstream	0.20	0.04	0.00
Non-trading class	0.09	0.01	0.00
All classes	0.90	0.09	0.01
NT class inconsistent with RUT			
Potential early adopters	0.20	0.02	0.01
Conventionalists	0.47	0.02	0.00
Mainstream	0.23	0.05	0.00
All classes	0.90	0.09	0.01

Note: NT class refers to non-trading class.

Table 4 presents the estimates of welfare changes arising from marginal increases in the tax rate for PHEVs and FEVs under alternative assumptions for the behaviour of the non-trading class. A one percentage point increase in the tax rate for PHEVs results in annual welfare gains of around €23-28 per company car in the market. In sharp contrast, a marginal increase in the tax rate for FEVs causes welfare gains of around €1.6 per company car. In both cases, the achieved welfare gains comprise a substantial portion of the reduction in subsidies, amounting to around 50-60%. These gains even outweigh the marginal tax revenue raised by the policy change, which correspond to 42-52% (income tax rates for the majority of drivers) of the reduction in subsidies. Estimates by latent class reveal that welfare changes from increases in the PHEV tax rate are mainly driven by the classes of potential early adopters and mainstream drivers, whereas welfare changes from increases in the FEV tax rate are almost solely driven by potential early adopters. The estimated average welfare effects of increases in the PHEV tax rate depend on the assumption made for the behaviour of non-traders, as around 1.4% of the sample opted for PHEVs in all choice scenarios. Lexicographic choices were not manifested for the two types of FEVs and thus the average welfare effects of increases in the FEV tax rate do not vary with the assumption made about the behaviour of the non-trading class.

Table 4: Estimates of annual welfare effects of marginal changes of PHEV and FEV tax rates per company car

Latent class	Marginal change in the tax rate for PHEVs			Marginal change in the tax rate for FEVs		
	Change in CS	Change in Subsidy	Change in Welfare	Change in CS	Change in Subsidy	Change in Welfare
NT class consistent with RUT						
Potential early adopters	-€ 13.45	-€ 44.03	€ 30.58	-€ 5.92	-€ 12.62	€ 6.70
Conventionalists	-€ 10.93	-€ 26.50	€ 15.57	-€ 0.70	-€ 1.11	€ 0.41
Mainstream	-€ 20.60	-€ 52.47	€ 31.87	-€ 0.02	-€ 0.04	€ 0.01
Class-size weighted average	-€ 13.98	-€ 37.42	€ 23.44	-€ 1.55	-€ 3.20	€ 1.64
NT class inconsistent with RUT						
Potential early adopters	-€ 14.32	-€ 46.88	€ 32.56	-€ 5.30	-€ 11.30	€ 6.00
Conventionalists	-€ 11.62	-€ 28.18	€ 16.56	-€ 0.62	-€ 0.99	€ 0.36
Mainstream	-€ 21.85	-€ 55.64	€ 33.79	-€ 0.02	-€ 0.03	€ 0.01
Class-size weighted average	-€ 16.59	-€ 44.43	€ 27.83	-€ 1.55	-€ 3.20	€ 1.64

Note: The weights used for the calculation of the class-weighted averages are the class size estimates presented in Table 2, when the non-trading class is assumed to behave consistently with RUT, and the class size estimates divided by their sum (≈ 0.895), when the opposite assumption is made.

Considering that there are about 600,000 company cars in the Netherlands which also serve drivers' private travel needs (RAI Vereniging and BOVAG, 2013), the aforementioned amounts imply that annual welfare gains of around €14-17 million can be achieved by a marginal increase in the tax rate for PHEVs, whereas gains of around €1 million by a marginal increase in the rate for FEVs. These estimates do not take into account possible dynamic effects of PEV subsidisation. They should be thus interpreted as benchmarks against which the monetary equivalents of such effects can be weighed.

7. Conclusions

This paper develops an approach to quantify the social welfare effects of tax policy changes when consumer preferences are heterogeneous. Stated preference data and an advanced panel latent class model are used to this end. We show the usefulness of this approach by applying it to elicit company car driver preferences for different fuel technologies and estimate the welfare effects of changes in taxation of plug-in electric vehicles (PEVs). In light of the potential contribution of alternative fuel vehicles to the pursuit of environmental and energy security goals and the cardinal role played by the company car market in the diffusion of these vehicles in Europe, this application is of high policy relevance.

We find that potential early adopters of company PEVs, comprising almost one quarter of our sample, will primarily opt for plug-in hybrid and extended-range EVs. They are more likely to be found among company car drivers travelling relatively short annual distances but less likely to be part of high-income households. At the early stage of adoption, governmental intervention through reductions in company car tax base rates emerges as a very effective strategy for the stimulation of PEV demand. However, it is also likely to be yielding important welfare implications, often overlooked by policy makers. Using the 2013 levels of tax base rates applied to PEVs in the Netherlands, i.e. zero, as reference values and assuming that the environmental cost savings and energy security benefits induced by PEVs are fully offset by other tax advantages, we estimate that the welfare gain of a 1-percentage-point increase in these tax rates is substantial and even outweighs the resulting marginal tax revenue. Our results support the use of different tax base rates for PHEVs and FEVs, as substantially higher welfare gains can be achieved by increases in the former than by increases in the latter. As the policy rationale behind the provision of reduced tax base rates for company PEVs is usually the facilitation of their diffusion process, our estimates can be weighed against the benefits brought by lower rates to this process.

At the stage of early adoption of new technologies, the scarcity of market data highlights the importance of using alternative data sources to assess the welfare implications coming with the implementation of policy changes. In this paper, we show how stated preference data can be effectively used to evaluate the social welfare effects of marginal changes in the taxation of innovative and environmentally benign technologies. We acknowledge, however, that our analysis is susceptible to biases associated with the hypothetical nature of the experimental setting faced by consumers and that it would have benefitted from the joint use of stated and revealed preference data. As the availability of relevant revealed preference data is expected to increase in the near future, we would encourage the dedication of more research efforts towards this direction.

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Appendix A: Supplementary material for the description of the choice experiment[†]

Table A.1: Attributes and attribute levels used in the choice experiment

Attributes	Attribute levels			
Propulsion system and fuel type	ICE or Hybrid	Plug-in hybrid	Electric with fixed battery	Electric with swappable battery
List price (€)	Customised on reported price range for next car	0.8 * List price ICE 1.4 * List price ICE 2.0 * List price ICE	0.8 * List price ICE 1.4 * List price ICE 2.0 * List price ICE	0.8 * List price ICE 1.1 * List price ICE 1.4 * List price ICE
Tax base rate (%)	14 20 25	0 7 14	0 7 14	0 7 14
Employee's annual net contribution (€)	0 1200 3600	0 1200 3600	0 1200 3600	0 1200 3600
Driving range (kilometres)	600 750 900	500 700 900	100 300 500	100 300 500
Refuel time at station (minutes)	5	5	15 30 45	5
Extra detour time (minutes)	N.A.	N.A.	0 10 20	0 15 30
Charging time at home/work (hours)	N.A.	1.5 3 5	4 8 10	4 8 10

Note: ICE encompasses vehicles propelled solely by an internal combustion engine.

[†] To be considered for publication online.

Appendix B: Supplementary material for the welfare analysis[†]

B.1. Description of the PEV models in the 2013 company car market

Table B.1 presents the PEV models available in 2013 in the Dutch market, alongside with their body type and list price. The last column of the table indicates the car segment for which the (price of the) model is used in our welfare analysis. For the segments where more than one model was available per PEV type, the most popular one is selected. In contrast, for the segments where no model was available for a PEV type, it is assumed that consumers would pick a model from the segment with the closest characteristics. In the case of PHEVs, models of MPVs, vans and luxury cars were unavailable in the market. We, thus, consider that consumers who would otherwise choose an MPV or van would eventually pick the Mitsubishi Outlander PHEV, whereas consumers with a preference towards luxury cars would in the end select the Volvo V60 PHEV, which has many characteristics resembling them. In the case of FEVs, only SUV models were not offered in the market. We hereby assume that SUV supporters would have to compromise with an MPV.

Table B.1: Overview of the PEV models available in 2013 in the Netherlands

	Body type	List price (1000 €)	Segment for which it is used in the welfare analysis
Plug-in hybrids and EREVs			
Mitsubishi Outlander PHEV	SUV	44.0	SUV, MPV, Van
Volvo V60 PHEV	Station wagon	64.0	Large, Luxury
Toyota Prius PHEV	Compact car	39.5	Medium-sized
Chevrolet Volt EREV	Compact car	38.5	-
Opel Ampera EREV	Compact car	48.5	-
BMW i3 EREV	Subcompact car	40.0	Small
Full electric cars			
Renault Kangoo Z.E. [a]	Small van	24.5	Van
Renault Kangoo Maxi Z.E. 5 [a]	MPV	28.0	MPV, SUV
Tesla Model S [b]	Full-size luxury car	69.0	Luxury
Renault Fluence [a]	Full-size car	26.5	Large
Ford Focus EV	Compact car	40.0	-
Nissan Leaf	Compact car	30.0	Medium-sized
Renault Zoe [a]	Subcompact car	21.0	Small
Mitsubishi i-MiEV	Subcompact car	28.5	-
Citroen C-Zero	Subcompact car	30.0	-
Peugeot iOn	Subcompact car	30.0	-
Smart 4-2 Coupe EV	Subcompact car	24.0	-

Note: EREV refers to extended range electric vehicle. The table shows only the models which sold at least 10 cars in 2013. Prices were accessed in January 2014, concern the most economical version of the model, and are rounded to the nearest €500. They were extracted from www.directlease.nl and from car manufacturers' original websites. Even though Fisker Karma also sold 48 cars in 2013, it is not included in our analysis, as Fisker Automotive filed for bankruptcy at the end of that year.
[a] Prices do not include battery costs. Extra costs for battery leasing apply.
[b] The cited price concerns the version equipped with a 60 kWh battery.

[†] To be considered for publication online.

B.2. Attribute levels used in the baseline scenario

Table B.2 shows the attribute levels used in the baseline scenario for the PLCM simulation. The selected attribute levels closely resemble the situation of the company car market in 2013. Even though the table is mostly self-explaining, we provide further details with respect to two monetary attributes. First, we note that the list price of ICE-propelled cars is individual-specific and is customised on drivers' anticipated price range of their next company car. Second, it is assumed that the net contribution of employees is zero in the case of ICE-propelled vehicles. Their gross contribution for PEVs is computed as the difference between the annual lease price of a PEV and the one of its ICE-propelled counterpart.[‡] The expected net contribution of the employee for the company car is then calculated by subtracting the applicable tax from gross contribution. To this end, we use the income tax rate level usually applicable in the Netherlands, i.e. 42%.

Table B.2: Attribute levels used in the baseline scenario of the simulation of the PLCM.

Attributes	Attribute levels			
Propulsion system and fuel type	ICE or Hybrid	Plug-in hybrid	Electric with fixed battery	Electric with swappable battery
List Price (€)	Mean value of reported price range for next car	Price of most popular model per segment [a]	Price of most popular model per segment [a]	Price of most popular model per segment [a b]
Tax base rate (%)	20	0	0	0
Employee's annual net contribution (€)	0	(Lease price of PHEV - Lease price of ICE car) × (1-Income tax rate) [c]	(Lease price of FBEV - Lease price of ICE car) × (1-Income tax rate) [c]	(Lease price of SBEV - Lease price of ICE car) × (1-Income tax rate) [c]
Driving range (kilometres)	750	700	100	100
Refuel time at station (minutes)	5	5	30	5
Extra detour time (minutes)	0	0	10	30
Charging time at home or work (hours)	N.A.	5	8	8

Note: ICE encompasses vehicles propelled solely by an internal combustion engine.
[a] List prices of the most popular models per segment are provided in Table B.1.
[b] Where prices of electric cars excluding battery costs were publicly available (e.g. Renault models and Nissan Leaf), they were used as proxies for the prices of SBEVs. For the segments that such information was unavailable, we presumed (based on the comparison of models for which we had information about the price of the model with and without the battery) that list prices of SBEVs are equal to 80% of the prices of the corresponding FBEVs.
[c] Lease prices concern contracts of 4-year duration, for maximum annual distance of 35,000 km, and inclusive of fuel costs. Lease prices were obtained from www.directlease.nl, except for the prices of Renault Zoe and Fluence Z.E. which were extracted from http://www.leaseprijsonline.nl. Lease prices for the two versions of Kangoo Z.E. were imputed by multiplying the ratios of List Price (Renault Kangoo Z.E.)/List Price (Renault Fluence Z.E.) by the lease price of Fluence Z.E.

[‡] When the lease price of a PEV is lower than the one of its ICE-propelled counterpart, this difference is set equal to zero. The underlying assumption made here is that the driver is required to contribute to company car's operating costs only if these exceed the ones of the representative ICE-propelled alternative of the segment.

B.3. Approximation of PEV shares in the 2013 company car market

The actual market shares of different PEV types in the company car market are not known at the time of this study. We use information from various official sources to approximate them. RVO (2014) suggests that there were 2251 FEVs and 20,164 PHEVs registered in the Dutch market in 2013, out of a total of slightly less than 420,000 new car registrations. Data from RAI Vereniging and BOVAG (2013) for years 2007-2012 reveal that on average around 1/3 of the new car registrations per year concern company cars to which tax base rates are applicable. Around 63% of the PEVs registered in the market in 2012 fall under this category. Assuming that the 2013 proportions will not be very different from previous periods, we infer that PEVs amount to around 14,000 company car registrations, i.e. 10% of the 140,000 registrations for which tax base rates are applicable. We further assume that the share of company PHEVs in the total number of company PEVs is approximately the same with their share in the total PEV registrations, i.e. ca. 90%. Thus, PHEVs are estimated to account for ca. 9% and FEVs to around 1% of the 2013 company car registrations.