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German Car Buyers' Willingness to Pay to Reduce CO_2 Emissions

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Non-technical Summary

Motorised individual transport strongly contributes to global CO_2 emissions, due to its intensive usage of fossil fuels. Current political efforts addressing this issue (i.e. emission performance standards in the EU) are directed towards car manufacturers. Concretely, the whole car industry has to comply with an average of 120 grams of CO_2 per kilometre between 2012 and 2015, with interim targets. The long-term target for 2020 is an average of 95 grams of CO_2 per kilometre (by way of comparison, passenger cars currently emit 160 grams of CO_2 per kilometre on average). Manufacturers who exceed the specified standard will have to pay fines.

From an economic point of view this measure has to be regarded critically. But given the present EU regulation the question arises as to what the optimal strategy for car manufacturers is. Exceeding the emission standard generates costs (through the payment of fines) – but so does complying with the emission standard (through costly abatement measures). Depending on the amount consumers are willing to pay for a specific reduction in CO_2 emissions it could well be optimal for manufacturers to exceed the mandatory standard.

This paper focuses on the demand side. It examines whether CO_2 emissions per kilometre is a relevant attribute in car choices. Based on a stated preference experiment among potential car buyers from Germany, different mixed logit specifications are estimated. In addition, distributions of willingness to pay measures for an abatement of CO_2 emissions are obtained. The results suggest that the emissions performance of a car matters substantially, but its consideration varies heavily across the sampled population. In particular, some evidence on gender, age and education effects on climate concerns is provided. So, we find that women are willing to pay more for an abatement of CO_2 than men, people under 45 years more than people 45 and older, and people who possess a higher education entrance qualification more than those who do not.

Das Wichtigste in Kürze

Der motorisierte Individualverkehr stellt eine der bedeutendsten globalen CO_2-Quellen dar. Grund dafür ist vor allem der starke Einsatz fossiler Brennstoffe als Antrieb für Automobile. Um die klimaschädlichen Auswirkungen des motorisierten Individualverkehrs zu reduzieren, setzte die EU kürzlich verbindliche Emissionsstandards für Neuwagen fest. Demnach gilt für die gesamte Automobilindustrie ein durchschnittlicher Emissionsgrenzwert von 120 Gramm CO_2 pro Kilometer. Dieser soll zwischen 2012 und 2015 schrittweise erreicht werden. Das langfristige Ziel bis 2020 ist ein durchschnittlicher Grenzwert von 95 Gramm CO_2 pro Kilometer (zum Vergleich: der derzeitige Durchschnitt liegt bei 160 Gramm). Autohersteller, die diese Grenzwerte verfehlen, müssen Bußgelder zahlen.

Aus ökonomischer Sicht stellen Emissionsstandards kein sinnvolles Politikinstrument zur Bekämpfung des Klimawandels dar. Es stellt sich allerdings die Frage, wie Autohersteller angesichts der bestehenden EU-Regulierung am besten vorgehen sollten. Für die Hersteller verursacht sowohl das Überschreiten der Emissionsgrenzwerte Kosten (durch zu leistende Bußgelder), als auch deren Einhaltung (durch teure technologische Vermeidungsmaßnahmen). Die optimale Strategie wird letztlich auch von der Zahlungsbereitschaft der Konsumenten für vermiedene Emissionen abhängen.

In diesem Papier wird untersucht, inwieweit die CO_2-Menge, die ein Pkw pro Kilometer emittiert, für Autokäufer entscheidungsrelevant ist. Basierend auf Daten eines deutschlandweit durchgeführten *Stated-Preference*-Experiments werden dazu verschiedene *Mixed-Logit*-Spezifikationen ökonometrisch geschätzt. Darüber hinaus werden Verteilungen der Zahlungsbereitschaften für CO_2-Vermeidung abgeleitet. Die Ergebnisse zeigen, dass die CO_2-Emissionen eines Pkw tatsächlich einen signifikanten Einfluss auf die Kaufentscheidung haben. Abhängig von soziodemographischen Faktoren ist dieser Einfluss allerdings unterschiedlich stark ausgeprägt. Beispielsweise achten Frauen in unserer Stichprobe stärker auf die Emissionen eines Pkw als Männer, und sind dementsprechend auch bereit mehr für Vermeidungsmaßnahmen zu zahlen. Ähnliche Effekte ergeben sich auch in Abhängigkeit vom Alter und der formellen Bildung der befragten Personen.

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Abstract

Motorised individual transport strongly contributes to global CO_2 emissions, due to its intensive usage of fossil fuels. Current political efforts addressing this issue (i.e. emission performance standards in the EU) are directed towards car manufacturers. This paper focuses on the demand side. It examines whether CO_2 emissions per kilometre is a relevant attribute in car choices. Based on a stated preference experiment among potential car buyers from Germany, different mixed logit specifications are estimated. In addition, distributions of willingness to pay measures for an abatement of CO_2 emissions are obtained. The results suggest that the emissions performance of a car matters substantially, but its consideration varies heavily across the sampled population. In particular, some evidence on gender, age and education effects on climate concerns is provided.

JEL classification: C25, D12, Q51.

Keywords: CO_2 emissions; Willingness to pay; Passenger cars; Stated preferences; Mixed logit.

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1 Introduction

Climate change and its anthropogenic character are widely taken as demonstrated within the scientific community. Recent studies (e.g. Stern 2006, IPCC 2007) provide overwhelming evidence in this regard. The main driver of global warming is the greenhouse gas (GHG) carbon dioxide (CO_2). It is produced mainly by burning fossil fuels, and causes 60 percent of the anthropogenic greenhouse effect.

Due to its intensive use of fossil fuels the transport sector is one of the main emitters of CO_2. In 2006, transport contributed approximately 23 percent of total CO_2 emissions (in absolute terms 857,583 gigagrams) within the EU-15. Most of the emissions in this sector are caused by road transport. Passenger cars, in particular, account for approximately 12 percent of total CO_2 emissions. Moreover, a growing demand for road transport was the main reason for the increase in EU-15 CO_2 emissions between 1990 and 2006 (EEA 2008).

Consequently, motorised individual transport plays a major role in the political debate on climate change. The European Commission has set the goal of reducing GHG emissions by 20 percent by 2020, compared to 1990 (EU 2008). To ensure that the EU will achieve its climate targets, the European Parliament approved the EU's energy and climate package. Part of this package is a regulation which sets emission performance standards for new passenger cars registered in the EU. More concretely, the whole car industry has to comply with an average of 120 grams of CO_2 per kilometre between 2012 and 2015, with interim targets. The long-term target for 2020 is an average of 95 grams of CO_2 per kilometre (by way of comparison, passenger cars currently emit 160 grams of CO_2 per kilometre on average). Manufacturers who exceed the specified standard will have to pay fines. For each gram exceeding the target, 95 euros will have to be paid from 2019 onwards. In the transitional period between 2012 and 2018 the fine for the first three exceeding grams is considerably lower (i.e. 5 euros for the first gram, 15 euros for the second gram, and 25 euros for the third gram).

From an economic point of view this measure has to be regarded critically. Generally, standards are not cost-efficient. Unlike market-based instruments (i.e. taxes and tradable permits), CO_2 emission standards will not equal the marginal abatement costs of different manufacturers (e.g. Kolstad 2000). Moreover, market-based instruments perform better than standards in providing incentives for firms to adopt advanced abatement technology and to develop such new technology (Requate 2005). As a consequence the EU environmental targets will be achieved – if at all[1] – at unnecessarily high costs.

But given the present EU regulation the question arises as to what the optimal strategy for car manufacturers is. Exceeding the emission standard generates costs (through the payment of fines) – but so does complying with the emission standard (through costly abatement measures). Depending on the amount consumers are willing to pay for a specific reduction in CO_2 emissions it could well be optimal for manufacturers to exceed the mandatory standard.

This paper focuses on the following questions: Do car buyers care about the environment? Or, more precisely: Do CO_2 emissions have a negative impact on car purchase decisions? And, if yes: How much are car buyers willing to pay for emission reductions? Based on a stated preference experiment we answer these questions for German car buyers.

In addition, we study the impact of specific demographic characteristics on the interviewees' stated choice decision. Scientific literature discusses whether age, education, gender and income influence consumers' perceptions of environmental issues and their related willingness to pay. The existing results are ambiguous. For example, Hersch and Viscusi (2006) find that older people have a significantly lower willingness to pay higher gasoline prices in order to protect the environment. The authors further provide evidence that the level of support for this environmental policy measure increases with the respondents' education and, to a lesser extent, income levels. Gender is not influential in this study. However, the results of Torgler et al. (2008) indicate that women have stronger preferences towards the environment. On average, for example, women are more likely than men to state a high willingness to pay for environmental protection. In their recent study Hsu et al. (2008) identify income as a strong determinant of the willingness to support gasoline tax increases.[2] They also find some effects of educational level and gender

[1]Improving the emission performance (i.e. fuel efficiency) of cars that run on fossil fuels reduces car travel costs. Consumers' likely response to this cost reduction is an increase in car travel demand (implying the so-called "rebound effect"). Frondel and Vance (2009) investigate the determinants of car travel for German households and quantify the effect of fuel prices. Their results suggest that "the logic of introducing fuel efficiency standards to reduce emissions is dubious".

[2]It is important to note that Hsu et al. (2008) coupled the question of gasoline tax increase with income tax reductions.

(i.e. women are more likely to support gasoline tax increases), but not of age. To contribute to this discussion we derive the willingness to pay for CO_2 abatement, depending on the interviewees' gender, age, and educational level.[3]

For this purpose we estimate different mixed logit models. Mixed logit (or random parameter logit) is more flexible than standard logit and helps to obviate its limitations (Train 2003): the coefficients are allowed to vary in the population rather than being fixed, the restrictive *independence of irrelevant alternatives* (IIA) assumption may be dropped, and repeated choices by an interviewee may be modelled as correlated. Brownstone and Train (1999) suggest that the "extra difficulty of estimating a mixed logit" would not be necessary if "the ratios of coefficients are adequately captured by a standard logit model" and when "the goal is simply estimation of willingness to pay". However, Algers et al. (1998) find significant differences in estimated willingness to pay measures, depending on whether model coefficients are allowed to vary or not. We use mixed logit specifications since they fit our data better than standard logit, and through further improvements in computer speed the additional expenditure of time is reasonable.

The rest of the paper is organised as follows: The data and the methods used are described in detail in section 2. In section 3 the results of our econometric analysis are presented. The final section summarises and concludes.

2 Data and methods

2.1 Description of the survey

The data analysed in this paper comes from a Germany-wide survey among potential car buyers.[4] The survey was designed to study people's preferences regarding cars with alternative propulsion technologies and fuel types. It was conducted via computer-assisted personal interviewing (CAPI), from August 2007 to March 2008.[5] The interviews took place in showrooms of car dealers of different brands

[3]Since about 20 percent of survey interviewees did not indicate their household income we do not consider income in our analysis.

[4]The survey was conducted in the framework of the research project ECO-CARS. Further details about the project ECO-CARS may be found here: http://kooperationen.zew.de/en/eco-cars/home.html

[5]In January 2009, the German government introduced government-financed trade-in incentives in order to stimulate demand for new cars and thereby to modernise the existing car fleet.

and in selected offices of the technical inspection authority. The interviewers were requested to ask consumers of all population groups. Only two restrictions were made. Firstly, interviewees should be of age and have a valid driving licence. And secondly, they should intend to replace an existing car or to buy a new car in the near future (or at least be able to imagine doing it). We interviewed approximately 600 people living in different regions in Germany (Eastern vs. Western Germany, urban vs. rural areas). Although the drawn sample pictures a broad cross-section, it is not representative. While people with a higher education entrance qualification are overrepresented, women are underrepresented (for details on the demographic profile of our survey sample, see Table 2).

The core of the questionnaire was a stated preference (SP) choice experiment concerning a car purchase decision. Each interviewee faced six choice sets. Each choice set consisted of seven hypothetical vehicles, each characterised by the six following attributes: purchase price, fuel costs per 100 kilometres, engine power, CO_2 emissions per kilometre, fuel availability (given by the size of the service station network), and fuel type.[6] Note that all fuel types considered in this experiment were covered exactly once in each choice set, and behave therefore like a label of the alternatives. Hence, the (by design unlabelled) SP experiment is quasi-labelled.

Table 1 gives the attribute levels used in the SP experiment, according to the fuel type. To create realistic choice situations each interviewee was asked beforehand to characterise the vehicle he or she could imagine to buy. This characterisation referred to the car classification (full-size, compact, mid-size, van, sports car, ...) as well as to upper and lower bounds for purchase price and engine power. The individualised values of purchase price and engine power in the SP experiment were equal to 75, 100 and 125 percent of the average of indicated bounds. Although this determination causes some correlation between purchase price and

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Drivers who scrap their at least nine years old cars receive 2500 euros for a new car (regardless of its fuel efficiency). Since our data was collected roughly one year earlier, it is not biased by this context.

[6]Purchase price, fuel costs and engine power are standard explanatory variables in vehicle choice models (Horne et al. 2005, Ewing and Sarigollu 2000, Brownstone et al. 2000, McCarthy and Tay 1998, McCarthy 1996, Bunch et al. 1993 as well as Manski and Sherman 1980). CO_2 emissions and fuel availability are used in only a few surveys (Horne et al. 2005, Brownstone et al. 2000 and Bunch et al. 1993).

engine power it avoids unreasonable values for the interviewee.[7]

The set of possible CO_2 values differs with respect to the underlying fuel type. Since, in the long term, there is no end-of-pipe technology that may address vehicle CO_2 emissions, we allow solely strictly positive emissions for fossil fuels (i.e. diesel, gasoline, CNG or LPG). Only for non-fossil fuels (i.e. biofuel, hydrogen, electric) do we include the attribute level "no emissions" – since their in-use emissions are effectively zero.[8] However, emissions emerge in the course of the process of fuel production. Therefore, we also allow positive CO_2 emissions for non-fossil fuels.

For fossil fuels there is indeed a constant correlation between fuel consumption and CO_2 emissions. By burning one litre of gasoline, for example, 2.32 kilograms of CO_2 are emitted.[9] In other words, decreasing the CO_2 emissions of a fossil-fuel-based vehicle automatically means a decrease in fuel consumption – and therefore in fuel costs. There is no such unambiguous correlation for the other propulsion technologies and fuel types. Power generation by burning coal, for example, is cheaper than power generation by using renewable energies – but emits substantially more CO_2. In trying to capture the pure effect of CO_2 emissions on choice decisions we considered both fuel costs and emission performance as independent car attributes in our experimental design. However, it is still possible that interviewees associate low emissions with low fuel consumption, or generally with high quality.

2.2 Model specification

To analyse the stated choices of interviewees we use mixed logit models. Mixed logit models can be derived from utility-maximising behaviour. Meeting the requirements of repeated choices in our survey, the utility U_{njt} that person $n \in$

[7]In reality, purchase price and engine price are correlated. More expensive cars usually have a higher engine performance than inexpensive cars. Such correlations are typical for revealed purchase decisions (Fowkes and Wardman 1988).

[8]Biofuels may be considered CO_2 neutral if they are the product of an entirely natural process of growth.

[9]Because of this correlation between fuel consumption and CO_2 emissions, fuel taxes are indeed working like a carbon tax. In Germany, fuel taxes are relatively high. For one litre of gasoline, for example, car drivers have to pay 65.45 eurocents fuel tax. Moreover, the value added tax (19 percent) is added to the sum of the net fuel price and the fuel tax. Hence, the existing incentives for car manufacturers to develop low-emission (i.e. fuel-efficient) cars for the German market are high.

$\{1, \ldots, N\}$ obtains from alternative $j \in \{1, \ldots, J\}$ in choice situation $t \in \{1, \ldots, T\}$ is modelled as a random variable

$$U_{njt} = \beta_n' x_{njt} + \varepsilon_{njt} \tag{1}$$

with attributes of the alternative and demographics of the person x_{njt}, a related vector of coefficients β_n, and iid extreme value random term ε_{njt}. Unlike in standard logit, here β_n is allowed to vary over individuals with a specified density f.[10] This specification represents random taste variation in the population.

However, also unlike standard logit, the probability that person n chooses a sequence of alternatives $\mathbf{i} = (i_1, \ldots, i_T)$, given by

$$P_{n\mathbf{i}} = \int \prod_{t=1}^{T} \frac{e^{\beta' x_{ni_t t}}}{\sum_{j=1}^{J} e^{\beta' x_{njt}}} \; f(\beta) \; \mathrm{d}\beta, \tag{2}$$

cannot be solved analytically (Train 2003). It has to be simulated. We use Halton draws with 500 replications for the maximum simulated likelihood estimation with Stata's `mixlogit` command, as suggested by Hole (2007).

The independent variables that enter our models (and the way in which they enter them) are briefly discussed in the following. We try to keep the models simple, focussing basically on the car attributes that specified the alternatives in the choice sets. The different propulsion technologies and fuel types are included by alternative-specific constants, where diesel serves as baseline alternative. Since different people might prefer different fuels, we assume normal distributions for the related coefficients. Engine power also enters with normally distributed coefficient, while the coefficients of service station availability and CO_2 emissions are assumed to be log-normally distributed. Unlike normal distribution, the log-normal one induces the same coefficient sign for the whole population. It is possible that some people dislike too much horsepower. It is, however, not explainable why people should dislike a denser service station network or fewer emissions. Therefore, we did not allow for both directions of preferences for these variables.[11] Fuel costs per

[10]Note that we assume β_n to be constant over time for a given person n and, therefore, allow for correlation over time. This is reasonable since the repeated choices were all made within one interview.

[11]McFadden and Train (2000), for example, specify service station availability as normally distributed. During the model specification search we have also experimented with normal dis-

100 kilometre enter our models with log-normally distributed coefficient. Since the negative impact of fuel costs is unambiguous, we thereby restrict the coefficient to be non-positive for all individuals.[12] Purchase Price is the only attribute we consider as fixed parameter. Evidently, it may be expected that price sensitivity varies among individuals (depending on income, for example). Nonetheless, we follow Revelt and Train (1998) and (2000) with this specification, since it simplifies the derivation of the distribution of the willingness to pay.

Based on this model we develop three extensions to capture demographic differences in assessing CO_2 emissions. Therefore, we generate disjoint interaction terms between dummies covering information about gender, age or educational level, and the CO_2 emissions variable. In model 2 we differentiate between women and men, in model 3 between people under 45[13] years and people 45 and older, and in model 4 between individuals who possess, at least, a higher education entrance qualification (HEEQ) and those who do not. Table 2 describes how these demographics are distributed among our sample. There are only slight correlations between them (below $|0.15|$). Our hypotheses are that women, younger, and more educated people are more concerned about the environment and, therefore, evaluate the CO_2 emissions of a car more negatively. Since approximately 20 percent of survey interviewees did not indicate their household income we do not consider income in our analysis.[14]

There are two reasons for not including all three demographics in the same model. First, the distribution of the sum of log-normally distributed variables is unknown so far. Therefore, if we would include one interaction term per demographic variable, it would be difficult to make comparisons between different

tributions for service station availability and CO_2 emissions. The resulting portion of sampled population with unexpected coefficient sign was approximately 15 percent for both. Hence, it is reasonable to assume that the unlike signs occurred purely by specification.

[12]Note that fuel costs and CO_2 emissions each multiplied by minus one actually enter our models. This is due to the fact that a log-normally distributed coefficient has to be positive for all individuals. This conversion is undone after the estimation. See Hole (2007) for more details.

[13]We choose this value since it is the sample mean and, in addition, almost the sample median.

[14]Interviewees could indicate ranges for the household's monthly net income (up to 1000, between 1000 and 2000, between 2000 and 4000, or more than 4000 euros). Note that gender (below $|0.10|$), age (below $|0.15|$), and education (below $|0.20|$) variables are only slightly correlated with the different income ranges – at least for those who did indicate their income level. Hence, there is no evidence that gender, age, or educational effects possibly identified might be some sort of income effect.

population groups. Second, our sample does not provide sufficient observations for all possible subgroups[15], and so we also avoid the inclusion of one interaction term per subgroup. We are aware, nonetheless, that this procedure possibly bias the results.

3 Empirical results and discussion

The estimation results are given in Table 3. Note that for log-normally distributed variables (i.e. fuel costs, service station availability and CO_2 emissions) the estimated mean (b) and standard deviation (s) of the natural logarithm of the coefficients are presented. The median, mean and standard deviation of the coefficient itself can be computed by $\exp(b)$, $\exp(b+s^2/2)$ and $\exp(b+s^2/2) \times \sqrt{\exp(s^2)-1}$, respectively (Shimizu and Crow 1988).[16] For easier interpretation we give these values for all CO_2 terms in Table 4.

We first briefly discuss model 1. A likelihood ratio test rejects the standard logit specification (log-likelihood of -6115.6)[17] relative to our mixed logit specification, chosen in model 1. That is, allowing for random parameters and correlation over time leads to a significant improvement of model fit in our case. The significant standard deviations also indicate that there are taste variations across the sampled population.

We find that the fuel type of the passenger car is a relevant attribute. On average, diesel is preferred by car buyers.[18] As expected, lower prices, denser service station networks and lower fuel costs per 100 kilometres increase choice probabilities. Furthermore, approximately 74 percent of individuals in our sample prefer more horsepower.[19] This holds analogously for the extended models 2 – 4.

[15]For example, there are only 22 women who are 45 or older and possess an HEEQ in our sample.

[16]For fuel costs and CO_2 emissions, actually, the median and the mean formulas have to be additionally multiplied by minus one. This is due to the sign change introduced in the estimation process (Hole 2007).

[17]The standard logit estimation details are not presented in this paper but are available from the author upon request.

[18]Note that, in Germany, the vehicle tax for diesel-driven cars is higher than for gasoline-driven cars, while the tax on diesel fuel is lower than the tax on gasoline.

[19]Note that if $\beta \sim \mathrm{N}(b,s)$, then $(\beta-b)/s \sim \mathrm{N}(0,1)$. Thus, $\mathrm{P}(\beta<0)=\Phi(-b/s)$, where Φ is the cumulative standard normal distribution.

Most notably, we find that the emissions performance of a car influences choice decisions. The CO_2 variable enters our model significantly, negatively signed (see Table 4). This might reasonably be expected. According to a recent study commissioned by the German Federal Ministry for the Environment and the Federal Environment Agency (BMU 2008), environmental awareness of Germans is high. In this study, 91 percent of the population rate environmental protection as important. Moreover, 75 percent blame the car industry for contributing strongly to pollution by not developing environmentally friendly cars. However, this does not automatically mean that people are willing to act on their own account in this regard. Our results suggest that people's environmental and climate concerns are indeed motivating them to consider CO_2 emissions as a relevant attribute in car choices. But the impact of this attribute varies in the sampled population, as indicated by the related standard deviation.

With the help of models 2 – 4 we try to better understand what this variation depends on, at least to some extent. The estimation results show that there are differences in assessing the CO_2 emissions of a car, depending on gender, age and educational level. We can confirm our hypotheses that women assess the emission variable more negatively than men do (model 2), people under 45 more than older (model 3), and people with an HEEQ more than people without (model 4). This follows from a simple comparison of the estimated CO_2 coefficients in models 2, 3 and 4, respectively (see Table 4).

However, the insights that can be directly drawn from parameters in a nonlinear model are very limited. A useful way to quantify the impact of CO_2 and the observed differences depending on gender, age and educational level is to derive the related willingness to pay (WTP). That is, for model 1, for example, the amount a person is willing to pay in addition to the baseline price p for a decrease $\eta \leq 0$ of the baseline emissions e, without a change in utility. This is simply the negative ratio $-\beta_e/\beta_p$ of the emission (β_e) and the price coefficients (β_p), multiplied by η. As the price coefficient is fixed, this ratio follows the same distribution as the negative emission coefficient. In our case this implies that the WTP is log-normally distributed. More precisely, it holds $\ln(-\beta_e/\beta_p \times \eta) \sim \mathrm{N}(\ln(\eta/\beta_p) + b_e, s_e)$, where b_e and s_e are the mean and standard deviation of the natural logarithm of $-\beta_e$ (given in Table 3), respectively. The WTPs of the single groups specified in models 2 – 4 are derived accordingly. Table 4 gives the median, mean and standard deviation of all relevant WTPs for a one gram decrease in CO_2 emissions per kilometre (i.e. $\eta = -1$).

In the following discussion we will refer to the median WTP which divides the cumulative distribution function in half. Note that in a (right-skewed) lognormal distribution the standard deviation has a significant positive effect on the mean. Since in our models the estimated standard deviations for the WTP measures are relatively high (indicating very heterogeneous preferences and resulting in a high skewness of distributions), the much less outlier-sensitive median seems to be the appropriate measure of central tendency here. Beyond this more technical reason, we assume that the median WTP is more meaningful also from a practical perspective. Note that in model 1, for example, approximately 70 percent are actually not willing to pay the 114 euros given by the mean value.[20] But politicians and car manufacturers might be interested in the average person's WTP value. This is rather given by the median WTP.

According to model 2, women are willing to pay 87 euros for an emission reduction of one gram CO_2 per kilometre. This is 27 euros more than men are willing to pay. In the literature, differences in gender socialisation are discussed as a possible explanation for observed differences between women and men regarding environmental awareness and behaviour. For example, it is often argued that the traditional role of women as caregivers and nurturers implies higher environmental concern and stronger willingness to contribute (Hunter et al. 2004 and Zelezny et al. 2000 give overviews). Our empirical findings support the existence of gender differences, but cannot provide a further explanation for this phenomenon.

The obtained differences in median WTP between people aged under 45 and people 45 and older are even higher (model 3). In our sample, younger people's WTP for an emission reduction of one gram CO_2 per kilometre is 91 euros, compared to older people's 36 euros. This observed age effect is in line with findings by Hersch and Viscusi (2006) who examined intergenerational differences in support for climate change policies. Their results suggest that "younger age groups may believe that they will personally benefit more from climate change policies" and are therefore more likely to be willing to pay higher gasoline prices to protect the climate. It is reasonable to assume that people's self interest is determining the

[20] If $X \sim \Lambda(b, s)$, then $P(X < x) = \Phi((\ln(x) - b)/s)$, where $x > 0$ and Φ is the cumulative standard normal distribution (Shimizu and Crow 1988).

age-related differences in this paper as well.

According to model 4, people with an HEEQ are willing to pay 21 euros more for the considered emission reduction than people without. The usual rationale for the effect of education on environmental attitudes and behaviour is as follows: well-educated people are better informed about potential environmental risks and damages, and therefore have a stronger willingness to contribute to the protection of the environment (e.g. Torgler and García-Valiñas 2007). Findings of Viscusi and Zeckhauser (2006) support this argument. In 2004, they surveyed over 250 Harvard students, thus a group of relatively well-educated individuals. On average, the students estimate the climate-change-induced temperature increase in Boston consistently with the Intergovernmental Panel on Climate Change (IPCC) estimate.[21] However, Torgler and García-Valiñas (2007) point out that not only formal education (specified by levels, degrees or number of years), but also informal education can be influential. Maybe this explains the relatively small gap between WTP of people with an HEEQ and of those without, compared to the gender or age effect on WTP.

Based on the actual average emissions of 160 grams of CO_2 per kilometre and assuming a steady car fleet composition, an abatement amount of 40 grams would be necessary on average to meet the EU target of 120 grams. To obtain the sample's median WTP for such an abatement (i.e. $\eta = -40$) we just have to multiply the derived median WTP for an emissions reduction of one gram of CO_2 (68 euros) by 40. The resulting 2720 euros mean that a car costing approximately 2720 euros more and at the same time emitting 40 grams of CO_2 per kilometre less compared to a reference car, yields the same level of utility in model 1 and would therefore be chosen with the same probability as the reference car (given that all other car attributes are unchanged).

Overall, it is striking how much car prices could be raised in connection with an emissions reduction of 40g, based on our estimation results. However, real-world price differences between cars with different emission performances (but apart from that broadly similar car attributes) are even higher. The full hybrid LS600h of Lexus emits 219 grams of CO_2 per kilometre and costs approximately

[21] In their paper, Viscusi and Zeckhauser provide a rough calculation that converts the students' willingness to pay higher gasoline taxes to curb climate change into an amount of 1500 dollars per year.

101,000 euros. Thus, this car model emits roughly the same 40 grams of CO_2 per kilometre less and costs approximately 17,000 euros more than the almost equivalent non-hybrid LS460 of Lexus (emission performance: 261 grams of CO_2 per kilometre, purchase price: 83,900 euros).[22] Another real-world example is given by the conversion of a gasoline driven car to a CNG car. The retrofit costs roughly 1500 to 4000 euros[23] and leads to as much as a 25 percent reduction in CO_2 emissions.[24] Of course, these price differences should not be seen as revealed WTP for CO_2 abatement. Since in the given examples better emission performance automatically means lower fuel costs – through lower fuel consumption (hybrid) or cheaper fuel (CNG) – there are also financial reasons for people to choose the low-emission car. Nonetheless, it illustrates the dimension of what people are currently paying additionally for "greener" cars.

Unfortunately, it is not straightforward to translate the derived WTP value into a WTP per tonne of CO_2 (tCO_2), and therefore to compare our results with existing literature.[25] This is due to the fact that different people travel a different total mileage with their cars which results in a different total emission reduction. However, by using average values of annual mileage (approximately 14,300 kilometres[26]) and age of a car at the time of its abandonment (approximately ten years[27]), we may obtain at least an idea of what the WTP per tCO_2 might be. Over the course of ten years, given an annual mileage of 14,300 kilometres, a reduction of 40 grams of CO_2 per kilometre yields a total reduction of 5.72 tons of CO_2. Dividing the WTP value by this 5.72 tons results in an approximation of the average WTP per tCO_2. Accordingly, the derived WTP could be translated into 476 euros per tCO_2.

Note that it might be that this value overestimates the true WTP per tCO_2. During the interview, interviewees were asked to indicate the annual mileage they intend to drive with their new car. In our sample the intended annual mileage is

[22]See: http://www.lexus.de/ (accessed on: 8 June 2009).

[23]DIW (2008).

[24]See: http://de.wikipedia.org/wiki/Erdgasfahrzeug.

[25]Brouwer et al. (2008) give an overview of the still very limited literature on WTP estimates for climate policy based on stated preference methods. It should be noted that most studies cited therein survey the WTP for the use of a tonne of CO_2 equivalent rather than for its abatement.

[26]DIW (2008).

[27]KBA (2008). Note that the reason for abandonment is not identified and that in 2007 some 20 percent of abandoned cars were licensed again abroad.

19,500 kilometres, on average. Therefore, it is likely that the 14,300 kilometres, used in the calculation above, underestimate the total emissions reduction. By comparison, the sample average of 19,500 kilometres would result in a total reduction of 7.8 tons of CO_2, which could be translated analogously into 349 euros per tCO_2. Nonetheless, both values are extremely high compared to what people would have to pay for a CO_2 certificate on the market for emission certificates. However, we expect that most people do not yet know of this way to offset emissions they account for.

A possible explanation for the high WTP value might be the ongoing media presence of global warming and climate change issues and its strong impact on public awareness. Results of Sampei and Aoyagi–Usui (2009) support this assumption. In their recent study, they find evidence for a positive correlation between Japanese newspaper coverage of global warming and public concern for the issue. Though we do not have concrete figures regarding German media, an increase in coverage of climate change was definitely observable in recent years. Hence, people are aware that their demand for motorised mobility accounts for a substantial share of anthropogenic climate change. Our results seem to suggest that Germans are willing to pay for low-emission cars to fulfil their responsibility in this regard, and simultaneously to maintain their mobility.

Besides, the used survey method may also influence the results. Since stated choices by interviewees lack the monetary commitment, an overestimation of the true willingness to pay is possible. This phenomenon is referred to as hypothetical bias. For example Murphy et al. (2005) assess the magnitude of the hypothetical bias using a meta-analysis. The median ratio of hypothetical to actual value reported in this study is only 1.35. Murphy et al. (2005) further provide some evidence that choice-based methods are associated with less hypothetical bias. However, their results also suggest that the bias is an increasing function of the hypothetical value. In a car choice experiment like ours, the hypothetical values are car prices – which are naturally high. Additionally, though we tried to capture the pure effect of CO_2 emissions on car choices through our experimental design, it still could be that interviewees regarded good emission performance of a car as an indication of high quality and use of efficient technologies.

4 Summary and conclusion

Motorised individual transport strongly contributes to global CO_2 emissions, due to its intensive usage of fossil fuels. Current political efforts addressing this issue (i.e. emission performance standards in the EU) are directed towards car manufacturers. This paper focuses on the demand side. We examine whether CO_2 emissions per kilometre is a relevant attribute in car choices. Based on a stated preference experiment among potential car buyers from Germany, different mixed logit specifications are estimated. In addition, distributions of willingness to pay measures for an abatement of CO_2 emissions are obtained. Our results suggest that the emissions performance of a car matters substantially, but its consideration varies heavily across the sampled population. In particular, some evidence on gender, age and education effects on climate concerns is provided.

What do we gain from these empirical findings? The gain is twofold. On the one hand, given the emissions performance standards in the EU, the obtained WTP values may help car manufacturers to adopt an appropriate strategy. In a very simplified setting, the sum of possible fines for exceeding the EU standard and WTPs for cars with lower emissions defines the limit for reasonable costs for further abatement measures. On the other hand, knowing people's preferences with respect to public goods (such as climate protection) generally helps to design effective and economically efficient policy instruments. The results seem to suggest that Germans are aware of climate change and its anthropogenic character, and that – on average – they are willing to pay substantial amounts of money to fulfil their responsibility in this regard. However, in view of demographic changes in Germany, the observed effect of age indicates that the public's willingness to contribute to climate protection might change again in future.

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Table 1: Within the SP experiment used attribute levels (according to the fuel type).

Fuel Type	Diesel	Gasoline	LPG/CNG	Hybrid	Electric	Biofuel	Hydrogen
Purchase Price	125	125	125	125	125	125	125
(% of given value)	100	100	100	100	100	100	100
	75	75	75	75	75	75	75
Fuel Costs	20	20	20	20	20	20	20
(€/100km)	10	10	10	10	10	10	10
	5	5	5	5	5	5	5
Engine Power	125	125	125	125	125	125	125
(% of given value)	100	100	100	100	100	100	100
	75	75	75	75	75	75	75
CO_2 Emissions	-	-	-	-	no emissions	no emissions	no emissions
(gCO_2/km)	90	90	90	90	90	90	90
	170	170	170	170	170	170	170
	250	250	250	250	250	250	250
Service Station Network	100	100	100	100	100	100	100
(%)	60	60	60	60	60	60	60
	-	-	20	20	20	20	20

Table 2: Sample demographics (proportions in parentheses).

		45 and older	under 45	no HEEQ	HEEQ
male	446 (0.75)	220 (0.49)	226 (0.51)	254 (0.57)	192 (0.43)
female	152 (0.25)	60 (0.39)	92 (0.61)	84 (0.55)	68 (0.45)
Total	598 (1.00)	280 (0.47)	318 (0.53)	338 (0.57)	260 (0.43)

Table 3: Coefficients of the estimated mixed logit models.

	Model 1	Model 2	Model 3	Model 4
Mean				
Purchase Price	$-6.2e-05$	$-6.1e-05$	$-6.3e-05$	$-6.2e-05$
Gasoline	−0.841	−0.790	−0.789	−0.802
Hybrid	−0.777	−0.766	−0.747	−0.762
LPG/CNG	−1.071	−1.043	−1.037	−1.055
Biofuels	−1.280	−1.258	−1.283	−1.245
Hydrogen	−1.137	−1.144	−1.143	−1.144
Electric	−1.752	−1.736	−1.734	−1.727
Engine Power	0.009	0.009	0.010	0.009
Fuel Costs	−2.569	−2.568	−2.550	−2.555
Network	−4.388	−4.398	−4.350	−4.383
CO2	−5.463			
CO2Xfemale		−5.230		
CO2Xmale		−5.592		
CO2Xunder45			−5.156	
CO2X45older			−6.076	
CO2Xheeq				−5.334
CO2Xnoheeq				−5.653
SD				
Gasoline	2.218	2.224	2.141	2.208
Hybrid	1.641	1.609	1.645	1.615
LPG/CNG	1.811	1.764	1.856	1.769
Biofuels	1.148	1.184	1.236	1.132
Hydrogen	1.766	1.759	1.789	1.768
Electric	1.254	1.240	1.173	1.222
Engine Power	0.014	0.014	0.016	0.014
Fuel Costs	1.423	1.352	1.355	1.329
Network	1.116	1.117	1.150	1.133
CO2	1.016			
CO2Xfemale		0.944		
CO2Xmale		1.066		
CO2Xunder45			0.738	
CO2X45older			1.491	
CO2Xheeq				0.952
CO2Xnoheeq				1.114
Log likelihood	−5315.9	−5321.0	−5299.6	−5322.8
McFadden's adj. R2	0.236	0.235	0.238	0.234

Note: all estimated coefficients are significant on the $p < 0.01$ level.

Table 4: Coefficients of CO_2 variables and related WTP for an emission reduction of one gram CO_2 per kilometre (Standard Errors in parentheses).

	Model 1	Model 2		Model 3		Model 4	
	CO2	CO2Xfemale	CO2Xmale	CO2Xunder45	CO2X45older	CO2Xheeq	CO2Xnoheeq
Median	−0.0042	−0.0054	−0.0037	−0.0058	−0.0023	−0.0048	−0.0035
	(0.0005)	(0.0010)	(0.0006)	(0.0007)	(0.0006)	(0.0008)	(0.0006)
Mean	−0.0071	−0.0084	−0.0066	−0.0076	−0.0070	−0.0076	−0.0065
	(0.0005)	(0.0010)	(0.0006)	(0.0006)	(0.0009)	(0.0007)	(0.0007)
SD	0.0095	0.0100	0.0096	0.0064	0.0200	0.0092	0.0102
	(0.0016)	(0.0027)	(0.0020)	(0.0012)	(0.0067)	(0.0021)	(0.0022)
Median WTP	68.08	87.25	60.70	91.30	36.41	78.05	56.76
	(9.48)	(17.06)	(10.31)	(13.01)	(9.49)	(13.71)	(11.12)
Mean WTP	114.01	136.17	107.10	119.92	110.62	122.81	105.51
	(12.54)	(19.26)	(13.14)	(13.78)	(17.07)	(15.46)	(13.70)
SD WTP	153.16	163.18	155.66	102.12	317.42	149.19	165.33
	(28.78)	(46.09)	(35.08)	(21.23)	(108.93)	(36.84)	(38.40)

Note: all estimated coefficients are significant on the $p < 0.01$ *level.*