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Preferences for alternative fuel vehicles by Dutch local governments

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ABSTRACT

Using a choice model, we estimate the preferences for alternative fuel vehicles by Dutch local governments. The analysis shows that local governments are willing to pay between 25% and 50% extra for an alternative fuel vehicle without a serious loss of utility. Further, local emissions are an important criterion on which to base a decision, especially for municipalities and provinces. We also calculate the utility for a number of prominent alternative fuel vehicles. We find that show that local governments value the battery electric vehicle and biogas internal combustion engine equally. It is important, however, that the time to refuel for electric vehicles is reduced to about 30 min.

1. Introduction

Local and global environmental problems have stimulated the search alternatives to the traditional internal combustion engine (ICE), including battery electric (BEVs) and fuel cell vehicles (FCVs) fueled by hydrogen, and biogas internal combustion vehicles (BICVs). There are economic reasons for suspecting that for alternative fuel vehicles (AFVs) to have an impact they need to compete with the ICE vehicles. This involves confronting problems of a lack of separate fuel infrastructure, high initial purchase costs, long refueling times, and limited driving ranges.

One possible policy instrument to stimulate market demand for AFVs is public procurement (Edler and Georghiou, 2007) involving governments purchasing them for their own use. This may help to enhance user competence, further technological development, develop economies of scale, and familiarizes the broader public with AFVs.

Like many countries, the Dutch national government is dependent on cooperation from local governments for the success of public procurement. Local governments are responsible for managing their own car fleets and face different problems than national governments. For a public procurement strategy to be successful, it is important to understand how local governments value local emissions in comparison to other attributes when purchasing new vehicles. Here, this issue is studied, along with the AFVs types preferred by DLGs, using data from a stated choice experiment among Dutch local governments (DLGs).

2. Methods

In June 2012, NL Agency (the executive office of the Dutch government for sustainable innovation) contacted all 450 DLGs to participate in an online survey about sustainable vehicles. At the time, the DLGs consisted of 412 municipalities (the

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lowest level of government in the Netherlands and are responsible for such things as local development, local traffic and transportation, local environment, and wellbeing), 12 provinces, and 26 water boards. The provinces, that are between the national government and municipalities, are responsible for spatial planning, provincial traffic and transportation, provincial environment, nature and landscape, wellbeing, and recreation. Water boards are the oldest form of government in the Netherlands, and have spatial overlap with municipalities and provinces. Their primary responsibility is to manage water in the country, notably water levels, water quality, dykes, dunes, quays, and waterways.

Invitations were sent to those local public servants responsible for traffic, transport, and the environment policies. Public servants were targeted because they are most knowledgeable about the policy and practices of their DLG with regard and able to speak on its behalf. Contact details were primarily obtained from the existing database of the NL Agency and augmented with data obtained from the local government. Some 657 people were contacted, because of multiple contacts for some DLGs, and 128 responded, of which 82 filled in usable questionnaires; two DLGs responded more than once, for which we corrected statistically. The final sample thus consisted of 55 municipalities, five provinces, and six water boards; however, 16 respondents did not indicate which type of DLG they were from, and were removed from the sample. Although this response is rather low, the sample contained a diverse set of DLGs. The municipalities that responded house 18.8% of the Dutch population, although large municipalities were somewhat underrepresented.

2.1. Stated choice experiment

Respondents were asked to fill in the questionnaire on behalf of their DLGs. Each received a series of unlabeled choice tasks with four hypothetical vehicles that systematically varied on six attributes. Respondents were asked which vehicles their DLGs would be "most likely" and "least likely" to purchase. Attributes important to DLGs when purchasing new vehicles and attribute levels were identified through expert interviews with policy makers at national and local governments, policy documents, and scientific studies. Attribute levels were chosen to be in accordance with values for AFVs that are competing for the market: ICEs, BEVs, FCVs, and BICVs. For the choice experiment itself, the exact values do not need to be in accordance with the actual technologies; only if one wishes to calculate utility for the alternatives do these values matter. All attributes and levels were explained to respondents prior to the series of choice tasks, and the following attributes were included in experiment:[1]

- Initial purchase price measured as a percentage of the purchase price of the ICE. This was done because real monetary values are difficult to understand owing to the considerable differences in car prices. Using percentages instead is common practice in stated choice experiments. Setting ICE vehicles as 100%, based on Whyatt (2010) and Kragha (2010), the average price of green gas vehicles is estimated to be between 110% and 134%. Using Thiel et al. (2010) and Lee and Lovellette (2011), we estimate the price of a BEV to be around 150% of an ICE. Van Vliet et al. (2010) and others have shown FCV prices starting at 450%. Overall, the uncertainties around prices, however, are quite large. We choose levels that were felt to be comprehendible and logical to respondents and that do justice to the technology. Therefore, 100% is used for ICEs as the reference value, 125% for BICVs, 150% for BEVs, and 200% for FCVs.
- Fuel price was measured in € per 100 km (Bunch et al., 1993). For ICE vehicles, we uses an average fuel price of €1.80 per liter (the price of normal fuel in the Netherlands around the time of the study) with an average efficiency of 15 km per liter giving a price of €12 per 100 km. For BEVs, Van Vliet et al. calculated an average price of €0.049 per kilometer, but they did not take account taxes. For both FCVs and BICVs, it has been estimated that the average price per kilometer is between €0.067 (Groengasmobiel, 2012) and €0.080 per kilometer (Kragha, 2010). Again, possible taxes are not included. To make this comprehensible to those questioned, we rounded up and choose €12 for ICE vehicles, €8 for BICVs and FCVs, and €5 for BEVs.
- The riving range is the maximum distance in kilometers that the car can drive between two fuel stops. As the benchmark, an ICE with a fuel tank of 40 l is used. Assuming an average fuel efficiency of 15 l per kilometer, this gives an average range of 600 km. For BEVs, the range lies between 100 and 200 km (ING Economic Bureau, 2011; Lee and Lovellette, 2011). Studies of BICVs and FCVs indicate a range of about 350–400 km for both types (Kragha, 2010; U.S. Department of Energy, 2012a). Therefore, we use 600 km for ICEs, 400 km for BICVs and FCVs, and 100 km for BEVs.
- Time to refuel is the time it takes to fully refuel or recharge a vehicle and is measured in hours and minutes. The average time to refuel an ICE vehicle is about 5 min, about the same as green gas fueled vehicles Refueling an FCV takes about 2 min extra (Lebutsch and Weeda, 2011), but this difference is negligible compared with the time to recharge a BEV. There is a distinction between fast charging and slow charging for a BEV. By using a high power fast charging battery, a BEV can be recharged within 20–30 min to 80% of capacity. Slow charging takes about 6–8 h to recharge completely (U.S. Department of Energy, 2012b). Therefore, for ICEs, BICVs, and FCVs, 5 min is used as the pertinent value, and for BEVs we use both 30 min and 8 h.

[1] Greenhouse gas emissions were considered in the design of the experiment, but not included. For most AFVs, greenhouse gas emissions depend on the source of the energy used to produce the fuel. For example, if the electricity needed to charge a BEV is produced in a coal-fired power plant, it still emits greenhouse gases. Further, it was assumed that greenhouse gas emissions, as opposed to local emissions, are a problem that concerns the national government more than local governments.

- Availability of fuel relates to the infrastructure that has to be built to supply the vehicles with fuel (Van der Vooren et al., 2012). It is measured as a percentage of the availability of fuel for the ICE, which is set at 100%. At the time of the study, there were over 80 green gas stations in the Netherlands (Groengasmobiel, 2012) and 3000 charging stations of which 28 were fast chargers (Oplaadpalen.nl, 2012). Hydrogen is not yet available in the Netherlands. Since this attribute is likely the most difficult for respondents to assess, we chose a four-level scale with intuitive values. We set ICEs at 100%, BEVs at 50%, BICVs at 25%, and FCVs at 'none'. For the latter it was explained that the DLG has to build its own fuel infrastructure.
- Local emissions were measured as a percentage of the emissions of the ICE. Both BEVs and FCVs have no local emissions. BICVs do have some local emissions, but these values are about 50% lower than those for ICEs (Patterson et al., 2008). Therefore, the value for ICEs is set at 100%, BICVs at 50%, and BEVs and FCV at 0% ('no emissions').

The number of attribute levels resulted in 1296 possible choice tasks. Since was considered too large for the expected responses, a fractional factorial design with orthogonal main effects was generated using NGENE software. The design consisted of 72 choice tasks with four alternatives divided over eight questionnaire versions. Each respondent thus received nine unlabelled choice tasks. A translated example choice task is seen in Fig. 1.

As a control question, all DLGs received an additional 10th best-worst choice task with the actual attribute levels of the four competing vehicles and a label stating the name of the technology. This task was analyzed separately from the other tasks. Unfortunately, owing to a coding error, the attribute pollution in the final choice task was replaced with an earlier considered attribute about CO_2 emissions. The levels of this attribute paralleled local emissions in terms of ranking among AFVs. Although this error renders the question useless for drawing independent conclusions, it can still be used as supporting evidence for the findings of the choice experiment. Finally, the two levels of the attribute of 'Time to Refuel' for BEVs were merged to 30 min and 8 h.

2.2. Analysis

Utility for an alternative was modeled as a function of the attribute values in the choice task. Since utility was measured with best-worst rankings, an ordinal logit model was fitted to the data. For each choice task, the preferred alternative was coded as one and the least preferred as minus one. The remaining alternatives were coded as zero.

The model was fitted for all DLGs and contained the main effects of the six categorical attributes as independent variables. As the reference category for the attributes, we always took the level associated with the ICE; basically the current situation. The model contained categorical control variables for choice task sequence (1–9) and position of alternatives within the task (1–4). Further, we added respondent ID as a scale parameter to the model to correct for differences in variance across respondent choices. This means that the model controls for inconsistencies over the choice tasks made by respondents (Sælensminde, 2001). This also corrects for the two DLGs with two respondents. Pretests showed that including the scale parameter significantly improved model fit.

Since the attribute levels in the choice experiment are based on actual AFV characteristics, it is possible to calculate which vehicle types would be preferred by DLGs. We thus simulated for each attribute level a normally distributed random variable involving 10,000 cases. The estimators from the main effects model served as the variable mean and the standard error of the estimator as standard deviation. The random variable represented a theoretical sample of estimator values for each attribute level. By adding the random variables together we obtained, for all, but the ICE benchmark, the utility of an alternative and a theoretical confidence interval. For the BICV and FCV, time to refuel was the same as it was for the ICE; therefore, this level also lacked a standard error. To better compare the utility of the BICV and FCV with the BEV, we excluded time to refuel in

Of the four alternatives below, choose which vehicle your local government **is most likely** to purchase and which vehicle your local government is **least likely** to purchase.

	Vehicle 1	Vehicle 2	Vehicle 3	Vehicle 4
Initial purchase price	100%	100%	125%	200%
Fuel price per 100 km	€8	€5	€8	€5
Driving range on one tank	400 km	400 km	600 km	100 km
Time required to refuel	5 minutes	5 minutes	8 hours	30 minutes
Availability of fuel	none	100%	none	25%
Local emissions	none	50% reduction	none	normal

	Vehicle 1	Vehicle 2	Vehicle 3	Vehicle 4
Most likely	O	O	O	O
Least likely	O	O	O	O

Fig. 1. A translated example choice task.

the confidence interval calculation of the BEV. Further, since time to refuel can take two attribute levels for the BEV, we calculated separate utilities for each. The utility of the BEV is thus a range between options rather than a value.

To verify the outcomes of the utility calculations we analyzed the labeled control choice task using an ordinal logit model. The independent variable was a variable with the name of the alternative, while the dependent variable was the ranking by respondents.

3. Results

Table 1 presents the results of the main effects models, with the estimators of the control variables and the scale parameter omitted. The model performs well, with the control variables showing that respondents were inclined to choose alternatives 1, 2, and 3 over 4 in a given choice task. The sizes of the estimators show that the most important attributes in determining vehicle choice are the initial purchase prices and local emissions. DLGs are willing to pay between 25% and 50% extra for a vehicle without any significant loss of utility, but a doubling in purchase price increase reduces utility significantly.

Pollution is linearly related to utility. Vehicles with no local emissions gain twice the amount of utility than do vehicles that only emit 50% of an ICE. Fuel price and driving range are the second most important attributes; with fuel prices of €8 per 100 km having no significant impact on utility, but a price of €12 seriously reducing it. Utility falls for by vehicles with a range of only 100 km, but there is no difference between 400 and 600 km. Time to refuel is the least important attribute, probably because the refueling for service vehicles can be planned in advance. There is no difference between 5 and 30 min, but 8 h of refueling time significantly reduces utility.

The fuel availability attribute behaves slightly perversely. There is no difference between 100% and 25%, but respondents derive most utility from 50% availability. A possible explanation is that DLGs consider the current density of refueling stations for the ICE to be excessive, because of the environmental and traffic problems associated with normal fuel stations. Another possible explanation is that DLGs have difficulty estimating the value of the associated infrastructure given the abstract nature of the attribute. Further, it is difficult to assess to what extent DLGs took into account that they, as governments can influence the development of a fuel infrastructure; if they have to build refueling stations themselves, utility is likely reduced significantly.

If we add an interaction effect between the attributes and DLG type, it shows that water boards lose significant less utility from an initial purchase price premium of up to 50% than do provinces and municipalities. Further, municipalities place more emphasis on low fuel prices than do water boards, and have fewer problems with a 100 km driving range. This may be explained by municipalities often having tighter budgets and covering smaller areas. Water boards place less emphasis on local

Table 1
Estimates and 95% confidence intervals for the attributes.

Attribute	Level (%)	Estimate	Sig.
Initial purchase price	200	−2.02	***
	150	−0.58	***
	125	−0.10	
	100	Ref.	
Fuel price	€5, –	1.18	***
	€8, –	0.99	
	€12, –	Ref.	
Driving range	100 km	−1.12	***
	400 km	−0.19	
	600 km	Ref.	
Time to refuel	8 hours	−0.74	***
	30 min	−0.08	
	5 min	Ref.	
Availability of fuel	None	−1.08	***
	25%	−0.08	
	50%	0.43	***
	100%	Ref.	
Local emissions	0%	1.93	***
	50%	1.10	***
	100%	Ref.	
No. Obs.		2328	
Model Chi-square		4047.13	
Nagelkerke R^2		0.32	

*: p<0.05, **: p<0.01, ***: p<0.001. Ref.: reference category. No. obs.: Number of Observations.

Table 2
(top) Utilities with simulated confidence intervals for AFVs, (bottom) Ordinal logit model predicting AFV utilities based on the labeled control task.

	All DLGs	
	Mean	Standard deviation
2a: Simulation		
ICE	0	n.a.
BEV (30 min time to refuel)	1.77	0.63
BEV (8 h time to refuel)	1.10	0.63
FCV	−0.37	0.73
BICV	1.70	0.59
No. Obs.	10,000	
	Estimate	Standard error
2b: Ordinal logit control task		
ICE	Ref.	n.a.
BEV (30 min or 8 h time to refuel)	1.37	0.38
FCV	−1.86	0.37
BICV	2.03	0.39
No. Obs.	264	
Model Chi-square	36.44	
Nagelkerke R^2	0.41	

*: $p<0.05$, **: $p<0.01$, ***: $p<0.001$. Ref.: reference category. No. obs.: Number of Observations.

emissions than provinces and municipalities, probably because they have no responsibility for clean air or local development.

The top section of Table 2 shows the utility associated with all alternatives based only on the main effects model. The BEV with 30 min time to refuel and the BICV are highest ranked option with highly overlapping confidence intervals. The BEV with 8 h refueling is ranked third, but the mean is well within the 95% interval of the other BEV and the BICV. The range of the BEV thus heavily depends on the uncertainty around the time to refuel. Only if the time to refuel were always 30 min would the utility of the BEV be equal to that of the BICV. The ICE and FCV are seen as less favored.

The lower part of Table 2 shows that this result is supported by the labeled control task. The ranking of alternatives is identical to the simulation, the mean BEV utility in the simulation is 1.435, although the FCV scores are lower than in the simulation and the BICV scores higher. A strong overlap in confidence intervals between the BEV and BICV, however, remains, indicating that there is little difference in their utilities.

Given the similarities in outcomes, we interpret the outcome of the labeled control task as a validation of our utility calculation.

4. Conclusions

This paper estimated preferences for several alternative vehicles among DLGs using a stated choice experiment based on Dutch data. We show that for DLGs, the initial purchase price and local emissions are the most important attributes in determining the choice of a vehicle. Although in general DLGs are willing to pay up to 50% more for a vehicle without any serious loss of utility, there are differences among them in how this attribute is valued. Local emissions are almost linearly related to utility, but are also sensitive to differences between DLGs. Based on these outcomes, we find that the preferred AFVs are BEVs and BICVs.

One source of uncertainty for the BEV is the time it takes to refuel; any time over 30 min reduces its ability to compete with BICVs. For water boards and provinces, the limited driving range seems to be an additional problem. The BICV can be seen as a compromise solution to the environment problem in that that it scores favorably on many attributes with scores often lying in between the BEV and ICE, but it is rarely optimal. Although the BICV reduces local emissions only half that of others, its other characteristics compensate for this. Another improvement would be to increase fuel availability to about 50%. The BICV seems to fit well with water boards, who are most willing to pay a 125% purchase price and who are least concerned with local emissions. No likely scenario exists in which the FCV is attractive to DLGs.

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