Simulating the take up of electric vehicles based on the financial benefit of the vehicle

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Abstract

The introduction of electric vehicles and their many variants is an important step in the effort to reduce greenhouse emissions and dependence on fossil fuels. Nevertheless, the take up rate of electric vehicles is still low. Although many people agree that electric vehicles provide an environmental benefit, the main purchasing factor for vehicles is based significantly on financial benefits and practicality. This study aims to estimate the number of electric vehicles that could replace conventional vehicles based only on financial benefit and the distribution of households that financially benefit from taking up an electric vehicle.

1 Introduction

Concern about the environmental impact of petrol-based vehicles on everyday life has encouraged many countries to invest in and promote the use of electric vehicles (EV), which have less or no greenhouse gas emissions (de Haan et al. 2009; Caulfield et al. 2010; Plötz et al. 2014). In addition, the continuous reduction of oil as the main source of fuel around the world has increased the importance of this type of vehicle (Ozaki and Sevastyanova 2011; Carley et al. 2013; Smith et al 2017). However, the proportion of EVs on the road is still very small. For example, in Denmark, where the proportion of battery powered EVs is the highest in Europe, EVs only accounted for 0.3% of vehicles sales in 2012. Similarly, in Germany in 2013, fully electric vehicles only accounted for 0.02% of all vehicles on the road while hybrid cars accounted for 0.15% (Plötz et al. 2014). There are some success stories emerging as Norway and the Netherlands have seen their EV market share of new car sales rise since 2013 but this has not been seen in markets like Australia (Smith et al 2017). The number of EVs on the road is very small in Australia with an EV market share of 0.04% as of 2014. In 2018, there were around 8130 combined pure electric vehicles and hybrid vehicles in Australia which is equivalent to around only 0.1% of all vehicles in Australia.

Several important works have investigated the reasons/factors for households to choose an EV. Financial benefit is one of the main reasons for purchasing a hybrid car (Ozaki and Sevastyanova 2011). Ozaki and Sevastyanova (2011) found that reduction in fuel costs is one of the perceived financial benefits which strongly affect the decision to purchase a hybrid car. Their findings follow other works that show consumers are considering the substitution of their vehicles for efficiencies in fuel use and petrol costs (de Haan et al., 2006; Heffner et al., 2007; Klein, 2007). Carley et al. (2013) found that people consider fuel economy as the main advantage of buying electric vehicles but the intent to purchase is hampered by cost premium, range limitations, and recharging time. Caulfield et al. (2010) also found that fuel costs and the vehicle price are the crucial factors in deciding to purchase an electric vehicle, in addition to reliability and safety. In Western Australia, Smith et al (2017) also confirm that people take price and running cost into account when considering purchasing an electric vehicle. However, there are other contributing factors such as individual environmental concerns and subjective norms (Smith et al 2017).

Ozaki and Sevastyanova (2011) look at this further by determining two groups motivated by other factors – those who are concerned about preserving the environment and eager to reduce its ecological footprint, and those who are concerned about complying with community norms. Carley et al. (2013) found age, gender and education play an important role in viewing the importance of electric vehicles as well as determining stronger environmentally-minded attitudes. Hidrue et al (2011) also list age and education as big factors and found that attitudes such as lifestyle, the willingness to buy a new product, fuel price expectation and length of driving also contribute to vehicle purchasing decisions. Interestingly, income level has been found to have an insignificant impact (Carley et al. 2013, Hidrue et al 2011).

The literature discussed above shows that financial benefits are still the main factors in deciding to purchase an electric vehicle. Other factors were considered in the literature but they are not as influential as economic factors. Therefore, it is important that further research should look more closely at the financial aspects, such as who benefits from the incentives associated with hybrid vehicles and how much costs and energy consumption can be reduced by their adoption. This study aims to develop a simulation model considering the financial benefit to analyse the demand function of the vehicle. The model also aims to understand the distribution of this demand among different household types and locations.

2 Methodology

There are two main steps in the simulation – producing the database and simulating the choice of electronic vehicle.

2.1 Synthetic data of households and their vehicles

The simulation will cover the passenger vehicles and motorcycles owned by households in Australia. This is made possible by the synthetic data of households and their vehicles created by Vidyattama et al (forthcoming). Their model allocates households from surveys into the statistical areas using spatial microsimulation (Tanton et al. 2011) and then uses an imputation technique to assign a vehicle to the household. The modelling was conducted at the ABS Statistical Area 2 (SA2) level. The SA2 is a term that is part of the ABS Australian Statistical Geography Standard (ASGS) (ABS 2016), and in most capital cities SA2s are suburbs.

The spatial microsimulation model distributes a survey unit record dataset such as persons or households to the small areas based on the small area population census benchmarks. The survey dataset used in this model was the Confidentialised Unit Record File (CURF) from the ABS 2015-16 Household Expenditure Survey (HES), as it had the necessary fuel expenditure, value of vehicles and data on income and household characteristics. This modelling used the ABS 2016 Census to provide the necessary benchmarks at SA2 level. Nevertheless, there are two stages in the benchmarking process as the database is first distributed at a bigger area level called

Statistical Area 4 (SA4) that usually represents a labour market region in an Australian city. The main benchmark of this stage of the spatial microsimulation process uses the small area estimate of fuel expenditure from the Bureau of Infrastructure, Transport and Regional Economics (BITRE).

The ABS Motor Vehicle Census is used to impute different types of motor vehicles to households. This imputation is based on the probability that a household with various characteristics owns a certain type of vehicle. This probability is estimated using a regression model. The imputation is implemented after the household is distributed to the small area by a spatial microsimulation process. This is because the motor vehicle census from the ABS provides information about the postcode where a vehicle is garaged and can be translated to an SA2 area. Therefore, the allocation of vehicles to households can be done based on the vehicles and households that are located in the same SA2 to increase accuracy. After the vehicles are distributed to households, the spatial data from BITRE on fuel prices across Australia and the ABS Survey of Motor Vehicle Use (SMVU) 2016 that contains the various vehicles' fuel consumption per hundred kilometres, translates into the fuel expenditure of Households in HES to the vehicle kilometres driven. A further and more complete description of this model can be found in Vidyattama et al (forthcoming).

By using the census of population and housing and motor vehicle census as a benchmark, the modelled dataset tries to capture all of the households living in the occupied private dwelling and the passenger motor vehicle they own in Australia at SA2 area level. Vidyattama et al (forthcoming) validates the result of this distribution by comparing the results with aggregated known data from another source. The first comparison is the kilometres travelled modelled with some estimates of kilometres travelled from BITRE at the SA4 level. The estimate of the standard error is at 0.9512. the second comparison is the aggregated Household Expenditure Survey data on fuel expenditure by different household types, state/territory and capital city/rest of state. The estimates from the model are close to the estimates from the Household Expenditure Survey, with a standard error of 0.8189. The important validation for this simulation is not being done by Vidyattama et al (forthcoming) which is comparing the number of motor vehicles. It can be shown that the number of motor vehicles in the model is very close to the estimates from the population census and the motor vehicle census, which means that the model is allocating the correct number of motor vehicles to households.

2.2 Electric vehicles take up simulation

As stated in the introduction, the simulation assumes that households would purchase electric vehicles based on financial considerations alone. This means we ignore the preference of reducing emissions, the reduction of noise and more importantly, the ability to include newer vehicles in the simulation. In addition, household attitudes to environmental concerns are not represented. This is because although there are other important considerations such as preference, practicability and reliability, financial benefit is still the main consideration especially with regard to petrol prices and fuel consumption (Gallagher and Muehlegger, 2008; Ozaki and Sevastyanova 2011, Carley et al. 2013).

While there are a few studies looking at who and what factors lie behind the purchase of electric vehicles, as seen from the discussion in the introduction, the work to simulate and see the impact of these decisions is still limited. The two notable works are Mueller and de Haan (2009) and Plötz et al. (2014). Mueller and de Haan (2009) based their model on activity in the car market. In this model, a choice set of vehicles in the market is first set up based on make-model-engine combinations and then a discreet choice model is applied to predict consumer choice of vehicle. In particular, Mueller and de Haan (2009) look at the changes in the consumer choice due to partial and full feebate systems such as fuel taxes or excise. On the other hand, Plötz et al. (2014) look at the total cost of ownership (TCO) of a vehicle. Investment based on purchase price and the operating costs based on the kilometres driven are the two components of TCO.

The simulation in this article follows the TCO concept used by Plötz et al. (2014). The spatial microsimulation database done by Vidyattama et al (forthcoming) described above is suitable for this simulation as it has been designed to estimate the kilometres travelled by different household in different locations. Following Plötz et al. (2014), there are two main considerations in terms of financial benefit that become the basis of this simulation. The first one is that the household will only replace their vehicle if its value (to be sold) is higher than the price of buying an electric vehicle, resulting in a financial benefit for the household. The variable value of vehicles is available in the Household Expenditure Survey, however, it is the total value for all vehicles. Therefore, we need to try to split the value of the vehicle by age and number of cylinders so we grouped the vehicles according to those criteria. Given the many types of vehicles in each group, we decided to use the trading price of the five most popular vehicles from each year range and cylinder number in 2016 in determining the value of individual vehicles per household.

The second consideration in terms of financial benefit is fuel consumption. The simulation is based on the assumption that, in selling a vehicle to buy a more expensive one, one of the options is to borrow to finance the purchase. The decision to buy a new vehicle can be based on whether the expenditure for fuel is higher than the repayment. To arrive at this calculation we need additional assumptions about the most common length of time and interest rate on vehicle financing, which is represented by a 5-year repayment period and a 6.5% comparison rate, respectively. The cost of electricity for the same number of kilometres travelled is estimated based on the average price for electricity per kilowatt hour (kWh). In Australia, it costs about $0.25 and takes around 18 kWh to travel 100km in an average EV, which equates to approximately $4.50 in electricity charges.

3 Result

The result is not encouraging for households that are considering replacing their car with an EV. Current prices are around $100,000 for a large EV and $50,000 for a small EV, which would only result in 0.7% and 4.4% of current vehicles, respectively, being replaced by EVs by household. Hybrid vehicles can be purchased for around $50,000. While there is an indication of overestimation in the estimation result, this can arise from the issues of reliability and preference which are not addressed in this simulation.

More households could be expected to replace their vehicles if the price was lowered to $25,000, with the simulation showing 20.2% of vehicles could be replaced by EVs. However, this simulation could be unrealistic since such a price may only enable the purchase of small EVs which would not be acceptable to many households which prefer a larger vehicle. Therefore, a further scenario is to replace the 6- and 8-cylinder engine vehicles with a more expensive EV than the smaller vehicles. The results show that at a price of $100,000 for a large vehicle and $50,000 for a small vehicle, around

3.5% of current vehicles would be replaced by EVs (Table 2). While the price may be pushed down to $50,000 for a large vehicle and $25,000 for a small vehicle in the near future, our simulation indicates that this will only result in the replacement of 16% of vehicles.

Another capability of this kind of simulation is to analyse the distribution of the type or location of households that are replacing their vehicles. The simulation below analyses the effect when the price of an EV is simulated to be $50,000 for a large vehicle and $25,000 for a small vehicle. Table 3 indicates that in terms of income decile, the higher income decile is more likely to be able to adopt an EV and the estimated probability of the highest decile is much greater than the rest (26%). However, surprisingly, the lowest decile also has a relatively high proportion and further examination is required into the kind of household that may obtain this EV (although we know that the number of vehicles itself is low in this household type). The current simulation seems to suggest that this could be due to students living in group households.

In terms of household type, couple households are more likely to obtain an electric vehicle than single households (Table 4). There is a special note that needs to be added that the estimated probability of replacing the current vehicle with an EV for those with children is increased sharply when fuel is being considered. This shows that the higher distance that needs to be travelled due to the number of family members and their activities could make buying an EV more beneficial.

Based on the remoteness of the area, major cities are the lowest adopters (15.4%). Table 5 indicates that the adoption of electric vehicles in inner regional areas (17.7%) is expected to be higher than in outer regional areas (16.6%). Most surprisingly, the simulation estimates that people in remote areas are more likely to change their vehicles based on financial benefit only (19.6%). This indicates that the areas where EVs may have the largest financial benefit do not have the infrastructure to make EVs a reliable form of transport.

Given that the distribution of households and their vehicles was done at SA2 level, it is possible to map the area to further analyse the distribution of possible electric vehicle take-up in different areas in Australia. The map in Figure 2 shows that the differences between cities are stark. Sydneysiders are more likely to adopt EVs based on financial benefit alone. The inner-city area as well as the tip of the outskirts have a higher probability of households replacing their vehicles. Remote area adoption also varies where more people in mining areas could obtain a financial benefit by purchasing an EV.

4 Concluding remarks

This project aims to simulate the number of electric vehicles that could replace the conventional vehicles based only on financial benefit and the distribution of households that would financially benefit from taking up EVs. The model is able to produce the estimate using a simple scenario and several assumptions. A high potential of this model is also confirmed – it enables a more realistic simulation by putting more conditions, especially with regard to reliability of the vehicle as well as preference and utility of different households, towards having a new electric vehicle compared to their current vehicle.

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