Energy Policy 62 (2013) 686–696

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Simulating demand for electric vehicles using revealed preference data

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HIGHLIGHTS

- Market values placed on a range of observable car characteristics are quantified.
- We simulate market shares of electrical vehicles from values of car characteristics.
- We assume electric vehicles will benefit from an "environmental" premium.
- Large premium not enough to reach government targets for market penetration.
- Very high subsidies required to reach government targets for market penetration.

ARTICLE INFO

Article history:
Received 28 May 2012
Accepted 17 July 2013
Available online 7 August 2013

Keywords:
Structural market model
Private car demand
Electric vehicles

ABSTRACT

We have modelled the market for new cars in Ireland with the aim of quantifying the values placed on a range of observable car characteristics. Mid-sized petrol cars with a manual transmission sell best. Price and perhaps fuel cost are negatively associated with sales, and acceleration and perhaps range are positively associated. Hybrid cars are popular. The values of car characteristics are then used to simulate the likely market shares of three new electric vehicles. Electric vehicles tend to be more expensive even after tax breaks and subsidies are applied, but we assume their market shares would benefit from an "environmental" premium similar to those of hybrid cars. The "environmental" premium and the level of subsidies would need to be raised to incredible levels to reach the government target of 10% market penetration of all-electric vehicles.

1. Introduction

The Irish government provides incentives for purchase of electric vehicles in pursuit of climate and energy targets, following the directions set out in the EU Climate and Energy Package and the Renewable Energy Directive (2009/28/EC). Ireland has set as own target that 10% of all vehicles will be electric by 2020.[1]

Electric vehicles reached the Irish market in 2008. In that first year just five electric cars were sold, and by 2011 that number was only up to 44 units. Considering the ambitious plans for the electrification of Irish motoring through government policy such as grants and favourable taxation since 2008, these sales are disappointing. Leaving aside the question of whether national targets for electric vehicles are a good or bad idea, we attempt to cast light on whether electric vehicles will succeed in gaining the level of market share specified in government objectives without further intervention. By using automobile differentiated product-level characteristics (with price one of them) and unit sales, this article estimates a demand system for the Irish new automobile market. The estimated demand coefficients are used to simulate the demand from the introduction of new electric vehicles in the economy.

Using a Lancastrian model of demand (Lancaster (1971, 1991)), the vehicle is considered as a bundle of differentiated attributes rather than a homogeneous single product. Using a random utility framework, market shares of new electric vehicles can be

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[1] These EU targets are the 20-20-20 targets and include a 20% reduction in EU greenhouse gas levels on 1990 levels, 20% of energy from renewable resources and 20% improvement of energy efficiency, all by 2020.

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http://dx.doi.org/10.1016/j.enpol.2013.07.061

simulated by multiplying each of their characteristics (e.g. price, range, etc.) by the marginal valuation of the same or similar attributes in existing cars. One difficulty in simulating the introduction of a new model in the characteristics space is that some of its observable attributes may not have existed before. This possible limitation in the dimensions of the characteristics space makes any evaluation of the product introduction harder, for no marginal valuation is available for the innovative attributes of the innovative model. Thanks to the availability of hybrid automobiles we do not have to worry much about this issue. 240 hybrid automobiles were sold in Ireland in 2008 (0.3% of the total market) and that number rose to 1022 (0.9% of the market) in 2011.

Public policy may affect the uptake of electric vehicles. The effects of different pricing scenarios on electric vehicles' market shares are presented. The current policy whereby electric vehicles benefit from a grant and do not incur a Vehicle Registration Tax (VRT) is taken as the baseline scenario. Two other scenarios are shown: one that removes the grant and a second that both removes the grant and imposes VRT. A further possible avenue for public policy intervention is through informational advertising; that is, to raise ecological awareness through an energy efficiency campaign and thus to stimulate demand for electric vehicles indirectly. The dissemination of the charging stations in the country will also contribute to raise ecological awareness. The effect of varying levels of ecological awareness on the base results is illustrated.

The paper continues as follows. Section 2 examines the existing literature in the areas of consumer vehicle choice and electric vehicles. The methodology and data used are detailed in Sections 3 and 4. The results are presented in Section 5. Section 6 provides a discussion and conclusion.

2. Previous research on the car market

There has been much written on the environmental impact of the car market and consumer choice but there is little literature specific to electric cars.

Emissions have been the focus of a number of Irish papers relating to the car market. O′Gallachoir et al. (2009) utilise new car data from 2000 to 2006 and show how purchasing trends over this period counter the efficiency benefits of improved engine performance. The paper, and a subsequent follow-up study in Rogan et al. (2011), also examines the 2008 vehicle registration and motor tax reforms that were put in place to change these trends; it is discovered that the resultant drop in emissions is not from a shift to smaller cars but to diesel cars. Hennessy and Tol (2011) confirm these results using data over a longer time period. Analysing the impact of Irish government policy on car ownership, following the 2008 tax reforms, they note the shift from petrol to diesel cars led to a decrease in carbon emissions but an increase in car usage, due to cheaper operating costs of diesel. They conclude that car-related CO_2 emissions are likely to continue to increase despite improving fuel efficiency, mainly due to growth in the stock of cars and a preference for larger cars.

Also looking forward, Daly and O′Gallachóir (2011) forecast car demand and related energy use using a bottom-up model, and their baseline prediction implies modest growth of 0.2% per annum in energy use by private cars in Ireland from 2008 to 2025. The same authors have also simulated the effects of electric vehicle adoption in Ireland on carbon emissions, showing that the level of abatement depends heavily on what sorts of vehicles are displaced. If future adoption of electric vehicles in Ireland displaces mainly relatively efficient cars – as predicted by Hennessy and Tol (2011) – or city cars that are used relatively little, Daly and O′Gallachóir (2012) show that it will have a much more limited effect on emissions than if it displaces a broader range of car types.

A number of studies focus on assessing governmental policies or aims in relation to electrification of the car fleet. Mandell (2009) describes different policy instruments used to incentivise the purchase of low emission cars and draws attention to Sweden where a subsidy was offered. The programme, due to run to 2010, was replaced by a 5 year exemption from motor tax in 2009 owing to the surprisingly large number of sales qualifying for the subsidy. California and France both pursued policies promoting electric vehicles in the 90s; two very different approaches were followed, compared by Calef and Goble (2007), but neither resulted in substantial number of electric vehicles on the roads. Carlsson and Johansson-Stenman (2003), in a cost benefit analysis for Sweden using American data, find that while electric cars are privately profitable they are not socially profitable. This result arises from the heavy subsidies and, often overlooked, lost tax revenues. Excluded from the result are the external costs of electricity production as well as the social costs associated with publically provided rapid charging, both of which would further widen the gap between private and social benefits. It is also emphasised that, while privately financially profitable, this does not mean electric cars are more attractive than other cars as characteristics such as acceleration, engine power, range, and battery power matter.

Another approach by Brandon et al. (2011) involves behaviour analysis in examining the adoption of electric, hydrogen fuel cells and hybrid vehicles in the UK. Car type, car size and distance driven can be regarded as behavioural variables, depending on car user choices. Policy, such as fuel and car taxation, alters car users' choices but evidence on these influences is often incomplete. Unintended responses and rebound effects can complicate analysis and make forecasting future policy difficult.

Our paper takes into account the effect of consumers' ecological awareness on their demand for electric vehicles. Energy efficiency campaigns as a form of advertising have been studied and can be classified as Demand Side Management (DSM) or Market Transformation (MT) (Birner and Martinot, 2005, Blumstein et al., 2000). Birner and Martinot (2005) find that increased awareness of energy savings potential can impact markets on the supply side even before formal project implementation. Blumstein et al. (2000) point to the more technical meaning of MT that has developed, a policy objective of promoting social, technology and economic change towards greater energy efficiency. Gillingham et al. (2006) review DSM programmes in the United States and conclude that the most effective policies are the ones that offer incentives to buy energy-efficient durable goods.

Energy efficiency campaigns can take the form of generic advertising. Its impact is studied by Chakravarti and Janiszewski (2004), revealing that, while the goal is to increase primary demand of a product without influencing market share of any producer, often brand-level demand is affected. Brand differentiation can be strengthened or weakened by generic advertising through decreasing access to non-advertised product attributes and as such increasing price responsiveness. It is concluded that generic advertising should be used to suggest product appropriateness such as awareness advertising in immature commodity markets while concentrating on usage situation in more mature markets.

Many studies refer to the importance of substitution patterns in understanding car choice. The car ownership decision, because of its discrete nature, is often examined using discrete choice models. Brownstone and Train (1999) demonstrate the importance of mixed logit and probit models for new product forecasting in allowing for realistic substitution patterns. Applying standard logit models to Californian survey data on households' choices among fuel types, they find that the new electric car in the model will