Transportation Research Part A 85 (2016) 135–156

Contents lists available at ScienceDirect

Transportation Research Part A

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

Substitution between cars within the household

Bruno De Borger [a], Ismir Mulalic [b], Jan Rouwendal [c,*]

[a] Department of Economics, University of Antwerp, Belgium
[b] Department of Transport, Technical University of Denmark, Denmark
[c] VU University, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands

ARTICLE INFO

Article history:
Received 15 December 2014
Received in revised form 20 October 2015
Accepted 5 January 2016
Available online 2 February 2016

Keywords:
Fuel efficiency
Car use
Multiple car ownership
Substitution effects
Fuel consumption

ABSTRACT

In this paper we study the demand for car kilometres in two-car households, focusing on the substitution between cars of different fuel efficiency in response to fuel price changes. We use a large sample of detailed Danish data on two-car households to estimate – for each car owned by the household – own and cross-price effects of increases in fuel costs per kilometre. The empirical results show that failure to capture substitution between cars within the household can result in substantial misspecification biases. Ignoring substitution, the basic model yielded fuel price elasticities of −0.98 and −1.41 for the primary and secondary cars, respectively. Accounting for substitution effects, these figures reduce to, respectively, −0.32 and −0.45. Consistent with substitution behaviour, we find that the fuel price elasticity of fuel demand exceeds the elasticity of kilometre demands with respect to the fuel price; the difference strongly increases at the highest deciles of the distribution of kilometre demand. Extending the model to account for driver heterogeneity and the role of car characteristics confirmed the relevance of substitution between cars within the household. We found strong evidence of substitution from the secondary to the primary car, especially if the latter is a more recent car with more horsepower. In general, the results of this paper emphasise the importance of behavioural differences related to the position of the most fuel efficient car in the household, suggesting that households' fuel efficiency choices are related to their price sensitivity.

1. Introduction

Increasing environmental awareness in transport policy-making, concerns of energy security and increasing fuel prices have generated a recent revival of interest in the economic implications of fuel prices on car use (see, among many others, West (2004), Gillingham (2012) and Linn (2013)). In this paper, we focus on a very specific behavioural implication of changes in fuel prices: the fact that higher fuel prices may induce households that own multiple cars to substitute between cars of different fuel efficiency. This phenomenon is well known, and it has been studied several decades ago (see, among others, Mannering (1983) and Greene and Hu (2005)). Moreover, although they were not the main focus of these studies, substitution possibilities have been allowed for in several recent papers dealing with car ownership, vehicle choice and the demand for mileage (see, e.g., Feng et al. (2005), Bento et al. (2009) and Spiller (2011)).

The purpose of this paper is to reconsider the question of how households owning several cars of different fuel efficiency respond to changes in fuel prices. These price changes affect the relative per-kilometre cost of using the different cars and,

* Corresponding author.
E-mail addresses: bruno.deborger@ua.ac.be (B. De Borger), imu@transport.dtu.dk (I. Mulalic), jrouwendal@feweb.vu.nl (J. Rouwendal).

http://dx.doi.org/10.1016/j.tra.2016.01.007
0965-8564/

hence, they may induce substitution towards the more fuel efficient car in the household. Based on a simple theoretical framework that imposes very few restrictions on substitution possibilities, we develop and estimate an econometric model in first differences and investigate whether, and to what extent, such substitution takes place. Note that our focus is on the issue of substitution within households, not on estimating the overall price elasticity of the demand for vehicle kilometres.

The analysis is based on a unique Danish data set that allows us to observe, based on exact odometer readings, the number of kilometres driven by the different cars in different periods of time. In Denmark cars and car fuels are relatively expensive, which implies a relatively small share of two-car households (see the data section below). However, since we have access to all register data, we are still able to use a large sample of almost 23,000 of such households to estimate own and cross-price effects of increases in fuel prices. The empirical results point at important substitution effects, so that models that estimate responses to fuel prices on the implicit or explicit assumption of one car per household, or multiple cars that are treated independently, may imply biased results for the individual vehicle elasticities.

To see how this paper relates to the existing literature, first note that there is a large theoretical and empirical discrete choice literature that deals with households' choice of the number and type of cars to own, and the associated demand for car kilometres. Among many others, Mannering and Winston (1985), Train (1986), Berkowitz et al. (1990), De Jong (1990, 1991), Goldberg (1998) and West (2004) developed detailed empirical analyses of car ownership and car use in both single and multiple vehicle households. More recently, Fullerton and Gan (2005) and Feng et al. (2005) analyse empirical models that allow simultaneous estimation of decisions related to car ownership, car type and kilometre demand, and they use the models to study the relative efficiency of different emission reduction policies (an emission tax, a fuel tax, annual registration fees, etc.). Fang (2008) and Brownstone and Fang (2014) study the impact of the residential location on car ownership and utilisation. Although several of the studies mentioned implicitly allowed for some substitution within the household, analysing such substitution was not their main focus.[1]

Second, a substantial literature specifically focuses on the economic effects of changes in gasoline prices, but few of these papers account for possible substitution within the household. Some studies have focused on the implications of gasoline prices for the car market itself, others emphasised the impact on car use. For example, with respect to the former, Busse et al. (2013) study the equilibrium market adjustments in response to changes in fuel prices and other usage cost. They find that in the new car market, the adjustment is primarily in market shares, while in the used car market the adjustment is primarily in prices. Klier and Linn (2010) also find large demand responses of higher gas prices on the car market, arguing that nearly half of the decline in market share of U.S. manufacturers from 2002 to 2007 was due to the increase in the price of gasoline. Increases in the gasoline tax were found to have remarkably modest effects on average fuel economy of new cars.

A few recent studies have focused on the implications of fuel price changes on the demand for car use. Gillingham (2012) argues that household choices of vehicle and utilisation of the vehicle are closely linked: vehicle choice is affected by how much consumers anticipate using it, and the characteristics of the good such as fuel efficiency in turn influences subsequent usage. He estimates an empirical model based on these premises and explores the implications of ignoring the "selection on anticipated usage". Using a dataset of new personal vehicle registrations and odometer readings in California, he estimates a medium-run gasoline price elasticity of driving of −0.15 and of fuel economy of 0.09. He emphasises that ignoring the selection issue leads to an over-estimate of the gasoline price responsiveness. He further finds (see Gillingham (2014)) considerable heterogeneity in elasticities across buyer types, demographics, and geography. Vehicle-level responsiveness is found to increase with income. Interestingly (given the topic of the current paper), the author argues that this finding may be due to within-household switching of vehicles.

In the literature discussed so far, substitution possibilities between cars within a household are not the main focus, and they play no major role. Of course, as mentioned above, such substitution has been studied before. In an early study, Mannering (1983) developed an econometric analysis of car use in households with multiple vehicles, and he found important substitution effects. Greene and Hu (2005) estimated a bundle model to capture multiple household cars, specifically focusing on the effect of the gasoline price on the use of the different cars. However, as they only distinguished between small cars, large cars and trucks, they find that price elasticities are not strongly affected by substitution between vehicles. Later models developed by Golob and McNally (1997) and Golob et al. (1996) have also emphasised the importance of travel interactions within households. Most recently, Spiller (2011) develops a model of households simultaneously choosing car types and vehicle miles, allowing miles to be the result of optimal allocation of total mileage over the bundle of cars owned. By doing so she allows for substitution in response to changes in gasoline prices. Taking into account a very wide range of car types in households' choice sets, she finds larger substitution possibilities than earlier studies.

While some of the papers mentioned above have implicitly – and a few quite explicitly – allowed for car substitution within the household, their primary purpose was to develop comprehensive models of car ownership, choice of car type and car use. Our purpose in this paper is at the same time more modest but also more specific. We do not model car ownership decisions but explicitly focus on car use, conditional on households owning different cars of given fuel efficiency.[2] We

[1] A small literature focusing on issues of optimal taxation of different types of cars (e.g., diesel versus gasoline) has also limited the analysis to single car owners (see, e.g., Chia et al. (2001), De Borger and Mayeres (2007)).

[2] Our model also ignores distributional considerations. A small but growing literature has emphasised that the distributive effects of changes in gasoline prices can be large. Early studies include, for example, Hausman and Newey (1995), West (2004) and West and Williams (2005). More recent papers by Bento et al. (2009) and Jacobsen (2013) incorporate the supply side of the car market into the analysis, confirming that fuel prices and fuel efficiency standards have substantial distributional effects.