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The impact of fixed and variable cost on automobile demand: Evidence from Denmark

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ABSTRACT

Many car characteristics, for instance cabin space and engine power, have a positive impact on fixed and variable costs. We extend the hedonic model, that considers only one type of cost, to the situation in which fixed as well as variable costs depend on the characteristics of the durable and derive an expression for the full willingness to pay for characteristics that takes into account the impact on fixed as well as variable costs. We apply the model to the demand for automobiles using rich Danish register data. Estimation reveals considerable heterogeneity and a non-negligible contribution of the variable costs in total willingness to pay. Next we show that under suitable assumptions a structural interpretation of our estimates is possible. We show that the willingness to pay per kilometer driven can be interpreted as a parameter of the utility function and study how it is related to household characteristics. Finally, we illustrate the model by computing how consumers change car quality in response to an increase in the fuel price.

1. Introduction

For many durable goods fixed and variable costs are both important. For instance, car owners have to pay for fuel and wear and tear, but the value of an automobile also decreases over time independent of its use. In general, both costs depend on the characteristics of the durable. More engine power means a higher car price as well as higher fuel use per kilometer. Making a car safer – for those inside it – makes it more expensive and it often also means that its weight increases, which implies (all else equal) that fuel costs will be higher. More cabin space implies that the car will be more voluminous and (again, all else equal) this will increase fuel costs per km. Somewhat surprisingly, the hedonic literature has usually ignored variable costs when studying the demand for durables. The aim of this paper is to fill this gap by developing and estimating a model that analyzes demand for a heterogeneous durable good when fixed and variable costs both depend on car characteristics.

The trade-off between fixed and variable costs of energy using durables has been studied by Hausman (1979) and Dubin and McFadden (1984). Hausman (1979) computed the discount rate implied by the choices of the consumers, and Dubin and McFadden (1984) showed that, in reaction to increasing fuel prices, consumers switch to more fuel efficient varieties and decrease the use made of the durable to some extent. The focus of the present paper is different: we concentrate on the trade-off between the additional utility provided by characteristics of the durable, such as more cabin space or engine power for cars, and the higher variable and fixed costs associated with them. We document the empirical importance of this issue by showing that for car makes there is a strong *positive* correlation between fixed and variable costs, not a trade-off.

Our model is close to Rosen's (1974) setup in that we regard the durable good as a bundle of characteristics, but we distinguish between fixed and variable costs and allow both to depend positively on the car characteristics. We assume that consumers derive utility from car characteristics like engine power and cabin space in a direct way, whereas fuel efficiency does not appear as an argument of the utility function, but is only valued through its impact on the cost per kilometer driven. We derive a simple relationship between the marginal willingness to pay for characteristics and the fixed and variable costs. More specifically, we show that the marginal willingness to pay for a quality characteristic has to be equal to the full marginal cost, which is the sum of the marginal fixed cost and the product of the marginal variable costs and the number of kilometers driven. The conventional approach in hedonic analysis of durable goods corresponds to the special case in which the characteristic has no impact on variable cost. The situation studied by Hausman (1979) and Dubin and McFadden (1984) corresponds to another special case

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in which the characteristic under study does not affect preferences directly. We show that in this case the characteristic must have opposite impacts on fixed and variable costs.

The model is applied to Danish data on car ownership and use. We analyze an unusually rich dataset that informs us about car prices, car costs and car use. This allows us to estimate hedonic price functions for fixed as well as variable costs.[1] We implement our model and compare the full marginal willingness to pay with that implied by analyzing the fixed cost only and find important differences. Moreover, we show later in the paper, in Section 5, that additional assumptions motivate a structural interpretation of the full marginal willingness to pay per kilometer driven as a parameter of the consumer's utility function[2] and we investigate how it varies with household characteristics.

If a car characteristic is positively related to variable as well as fixed cost, a higher fuel tax implies a shift towards lower quality and lower fixed cost. This contrasts with the Hausman (1979) and Dubin and McFadden (1984) models, in which a higher fuel tax implies a shift toward higher fixed cost. The two approaches will therefore have different implications for the incidence of tax measures, see for instance West (2004), or for the effect of fuel prices on automobile prices and sales, see e.g. Goldberg (1998), Busse et al. (2013), Klier and Linn (2010), Allcott and Wozny (2010). In Section 6 we apply the results of estimating our model by investigating the impact of an increase in the fuel price on the demand for car characteristics.

To sum up, the contribution of this paper is the construction and estimation of a model in which the choice of product characteristics depends on their impact on fixed as well as variable costs and to explore the possibility of a structural interpretation.

The paper proceeds as follows. The next section introduces the theoretical model of consumer choice behavior for durables. Section 3 provides information on the data employed; Section 4 presents the estimation strategy and the empirical results; Section 5 reports on a further investigation of preferences and the impact of fuel price changes; Section 6 studies the consequences of our model estimates for the impact of fuel prices on the demand for car characteristic; Section 7 concludes.

2. The model

This section discusses the model that underlies the empirical work that follows. We introduce quality in the standard (two good) microeconomic model of consumer behavior in a very general way: one of the two goods, the car, is quality differentiated and the consumer has preferences over quality.[3] Car kilometers have a constant unit price, referred to as variable cost. Fixed and variable costs depend both on the quality level chosen by the consumer.[4] In subsection 2.1 the model is introduced, 2.2 analyzes quality choice.

2.1 Preliminaries

We consider a household that derives utility u from car kilometers,[5] denoted as k, the quality of the car, q, and other goods x (which are treated as a single composite):

$$u = u(x, k, q). \tag{2.1}$$

In what follows we treat q as a scalar for expositional simplicity. Specification (2.1) is very general. For instance, it is consistent with consumers who prefer to have a high quality car although they don't drive a large number of kilometers.[6] The utility function is increasing in its three arguments and its indifference curves are convex. Car kilometers k and other goods x are conventional goods in the sense that they are available in continuous amounts at fixed unit prices. The price of car kilometers equals variable car costs p while the price of the composite good is normalized to 1.[7] Car quality is different from the other goods: it is an intrinsic property of the car owned by the household and as such it affects fixed as well as variable costs. The budget constraint is:

$$x + p(q)k = y - f(q), \tag{2.2}$$

where p denotes the variable cost (per kilometer) of car use, and f the (annual) fixed cost and y is the income.[8] Both depend on quality. The fixed cost should be interpreted as user cost, that is as the sum of fixed maintenance costs, taxes, and the difference between the value of the car at the beginning of the year and the present value of its expected price at the end of that year (i.e. depreciation).

Conditional upon the choice of q, the maximization of (2.1) subject to (2.2) is the textbook utility maximization problem that under standard conditions can be solved to derive the demand equations for k and x. The former can be expressed as

$$k = k(y - f(q), p(q), q). \tag{2.3}$$

Assumption 1.. Demand for car kilometers is normal, that is, the demand function $k(y - f(q), p(q), q)$ is increasing in $y - f(q)$.

Economic theory (the Slutsky equation) now implies that the demand for car kilometers will be decreasing in the variable car cost p.

The sign of the effect of quality on the demand for car kilometers can be derived from a second assumption that refers to the relationship between a change in quality, Δq, and a change in the amount of the composite consumption, Δx, that compensates the consumer for the change in q, while keeping k constant. This Δx is implicitly defined by the following equation:

$$u(x - \Delta x(u, k, q, \Delta q), k, q + \Delta q) = u(x, k, q), \tag{2.4}$$

and we assume

Assumption 2.. For any given $\Delta q > 0$, $\Delta x(u, k, q, \Delta q)$ is an increasing function of k.

This assumption states that a consumer who drives more kilometers is willing to give up more of the composite good in exchange for a given increase in the quality of the car.[9] The assumption is illustrated in Fig. 1. This figure shows two indifference curves in k,x-space. Both indifference curves refer to the same level of utility, u^*, but to different levels of car quality. Since car quality is valued positively by the consumer, the lower indifference curve in k,x-space refers to the higher level of car quality. For

[1] Bajari and Benkard (2005) have shown that hedonic price analysis does not need the assumption of perfect competition made by Rosen (1974) but is compatible with many other market structures, including the oligopolistic one that is often supposed in analyses of the car market.

[2] The analysis in Section 5 is analogous to that in Bajari and Benkard (2005).

[3] The model thus refers to a static, one-period setting.

[4] The model is similar to that of De Borger and Rouwendal (2014). They distinguish two types of characteristics. The empirical work presented in these papers shows that empirically only one of these is relevant.

[5] Although we realize that travel demand is in many cases derived from the demand for other goods, we follow the bulk of literature by treating car kilometers as a conventional good.

[6] We assume here that consumers do not have 'green preferences' that make them happier because they drive a more fuel efficient car. That is, we assume that fuel efficiency itself is not an argument of the utility function.

[7] The value of $p(q)$ reflects the expectations of the consumer with respect to fuel prices. A similar remark applies to $f(q)$ and car prices.

[8] Note here that the variable cost (per kilometer) of car use are unaffected by the car kilometers k.

[9] Note that this assumption is consistent with the possibility that consumers who drive a small number of kilometers (or even zero) attach positive value to quality aspects.