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Toward more general hedonic estimation: Clarifying the roles of alternative experimental designs with an application to a housing attribute☆

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ABSTRACT

Traditional hedonic estimation approaches are known to be biased when exogenous shocks affect multiple product attributes, the market for the product's complements and substitutes, and aggregate quantity produced. Our research develops a more general hedonic model to recover the marginal willingness to pay for an attribute in the presence of such known hazards to identification based on randomized experiments. Three experimental approaches are introduced on how to estimate attribute demand that address known biases, have transparent identification assumptions, and are feasible to implement. We apply one of the estimators developed to measure the marginal value placed by householders on subsidized carbon monoxide detectors.

1. Introduction

Hedonic estimation and the measurement of marginal willingness to pay (MWTP) for product attributes are vital tools for quantifying the benefits of public policies that improve safety, environmental, school, or health care quality (Black 1999; Chay and Greenstone 2005; Cutler, Rosen, and Vijan 2006; Viscusi 1993, 1996). Hedonic methods are used to understand the demand for heterogeneous goods such as automobiles, computers, food, housing, and jobs (Bajari and Benkard, 2005; Hamermesh 1999; Kiesel and Villas-Boas 2007; Raff and Trajtenberg 1995; Sheppard 1999). They are also used to calculate the Consumer Price Index and one fifth of expenditures in the Gross Domestic Product (Landefeld and Grimm 2000; Moulton 2001). For the purposes of measurement and policy evaluation it is desirable to have robust hedonic estimators whose empirical results are correct generally. Our research demonstrates the identifiability of MWTP without the strong econometric restrictions often applied in earlier applications and presents straightforward estimators of MWTP and related measures for use in experimental empirical settings.

A cursory reading of the hedonics literature might yield the impression that MWTP cannot be identified without imposing highly restrictive assumptions about the equilibrium price function, even when a natural experiment is available. Models adopted often assume that

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unobserved product attributes either are uncorrelated with observed ones, or do not exist (Berry et al. (1995); Epple 1987; Rosen 1974). In addition, the adopted models generally assume that the product of interest has no complements or substitutes, so that a location-specific attribute, like weather, cannot affect the labor market and housing market simultaneously. Finally, adopted models also typically specify aggregate quantity consumed as exogenous and unresponsive to price changes.[1]

There is a widespread belief in the literature that the above restrictions are appropriate and necessary to estimate MWTP. Earlier applied studies of heterogeneous goods generally employ slight modifications of the hedonic frameworks, or measure reduced-form price effects without estimating MWTP directly. More recent empirical work in hedonic estimation focuses on quasi-experiments, and some innovative studies have incorporated quasi-experimental variation into existing hedonic models (Bayer, Ferreira, and McMillan 2007; Berry and Haile 2010; Boes and Nüesch 2011; Chay and Greenstone 2005; Klaiber and Smith 2009; Kuminoff and Pope 2012, 2014; Lewbel 2000; Parmeter and Pope 2013; Pope 2008a, 2008b).[2] To our knowledge, no previous hedonic frameworks simultaneously allow for unobserved product attributes that are affected by exogenous shocks, complementarity with the good of interest, and aggregate quantities that vary.[3]

Randomized experiments have become common in the economics literature to address possible biases when estimating important economic parameters (e.g., Bertrand and Mullainathan, 2004; Hanson and Hawley, 2011; Kling, Ludwig, and Katz, 2005; Landry, et al., 2006; Manning, et al., 1987). Such experimental approaches have not been widely adopted within the urban economics and hedonic literatures. In this study we describe the potential benefits of using randomized experiments to correct for biases that may arise when using traditional hedonic estimation strategies. We provide a theoretical framework and discuss the practical approaches of how researchers may utilize randomized experiments to more clearly identify MWTP, with particular attention to the urban economics field of study.

In what follows we first provide an intuitive discussion of the types of biases that endogenous omitted attributes, complement and substitute goods, and aggregate quantity effects generate in traditional hedonic approaches. Next, we present experimental estimators to address the biases. Of the estimators presented, we start with estimators with the least restrictive modeling assumptions, but have the most demanding data requirements. The modeling assumptions become more restrictive and the data requirements less demanding with successive estimators. We then focus on developing nonparametric experimental estimators that identify the entire distribution across consumers of the demand for a given product attribute. In particular, we present experimental estimators of the aggregate demand for a product attribute among a population of consumers. The experimental estimators we develop avoid the effects of endogenous omitted attributes and complement and substitute goods by offering products and subsidies to consumers.

It is important to emphasize that the estimators we develop here rely upon straightforward, transparent identification conditions that are feasible to implement in future research. Variations on the estimators have been previously applied in recent studies to estimate the value of freedom from jail, the demand for avoiding the Vietnam draft, the value of a statistical life, and the demand for class size reductions in elementary school (Abrams and Rohlfs 2011; Rohlfs 2012; Rohlfs, Sullivan, and Kniesner 2015; Rohlfs and Zilora 2013). The new class of experimental hedonic estimators, however, has not been widely applied within a housing context, where researchers often adopt hedonic estimators with the strongest econometric restrictions. As a final exercise, we illustrate how one of the proposed estimators could be used to estimate the marginal willingness to pay for a housing attribute. More specifically, we conducted a small-scale field experiment that randomly subsidized the price of carbon monoxide detectors offered to participants.

2. Discussion of possible bias in hedonic models

Previous hedonic and discrete choice research by Rosen (1974); Epple (1987); and Berry et al. (1995) discuss concerns with the types of bias which appear in the framework described here. Those models assume that a consumer purchases a single unit of a heterogeneous good represented by a vector $\mathbf{z}$ of characteristics z_k and spends remaining income or wealth on a homogenous consumption good. Traditional Rosen (1974) style hedonic models can effectively be decomposed into three primary steps:

(i) Estimate the price function and gradient for attribute z_k, $P(z_k)$.
(ii) Assuming the market is thick and that agents are optimizing, the gradient and a first order condition can be used to recover marginal willingness to pay (MWTP) at the point of consumption, $p'(z_k^*) = mwtp(z_k^*)$.
(iii) Estimate the full MWTP function, $mwtp(z_k)$.

Typically, the literature refers to the combination of (a) and (b) as Rosen's first stage and (c) as Rosen's second stage. Our paper primary focuses on feasible methods to estimate the marginal willingness to pay at the point of consumption or Rosen's first stage. In addition, we offer some secondary information on how researchers might use these methods to estimate the entire MWTP function under certain conditions.[4] Given the sources of biases that may arise in traditional hedonic estimation strategies, it is important for researchers to understand how to correct these deficiencies using transparent estimation methods that are feasible to implement.

To illustrate the sources of biases that our research seeks to addresses, let P_{ht} be the average price of house h in year t. Let z_{1ht} be an observable attribute about house h, such as local school quality. Next, let the value of z_{1ht} be determined by a quasi-experiment so that it varies exogenously across locations and over time. Let z_{2ht} be an attribute about house h that is difficult to measure, such as the pleasantness of neighbors in the area. Finally, let P_{ht} be a linear function of the two attributes and an error term denoting unobserved attributes:

$$P_{ht} = \beta_0 + \beta_1 z_{1ht} + \beta_2 z_{2ht} + \varepsilon_{ht} \quad (1)$$

The aim of a hedonic price regression in this case is to identify β_1, the effect of attribute z_{1ht} on housing prices, holding all other attributes constant. Once identified, the hedonic price effect is used in a second-stage procedure to estimate MWTP for z_{1ht} (Epple, 1987; Rosen, 1974).[5] For the second stage to produce accurate estimates, the estimates from the first-stage hedonic regression (1) must be consistent.

[1] Rosen (1974) and Epple (1987) additionally require that markets are sufficiently thick so that every conceivable product is available and that supply is competitive. Berry et al. (2005) additionally requires specific functional forms for utility and firm costs, plus a specific distribution for heterogeneity in preferences.

[2] Some recent theoretical studies relax the functional form assumptions from earlier models but leave the frameworks largely intact elsewhere (Athey and Imbens 2007; Ekeland, Heckman, and Nesheim 2004; Heckman, Matzkin, and Nesheim 2010).

[3] Roback (1982) allows for one type of complementarity (housing and jobs), and Sieg et al. (2002) include area-specific dummy variables to proxy for the areas' job quality and public goods. Berry et al. (2005) allow for market shares (but not aggregate quantity produced) to vary. No single framework has addressed more than one of the biases simultaneously.

[4] In order to conduct non-marginal analyses it is desirable to recover the entire MWTP function and not just the value of that function at the point of consumption which is why provide some additional information on this topic. This is perhaps the area of most discussion about identification and estimation with many claims and counter claims made in papers such as Mendelsohn (1982), Bartik (1987), Epple (1987), and Ekeland, Heckman and Nesheim (2004).

[5] The procedure proposed by Berry et al. (2005) is different from that described here, but BLP require consistent estimation of the effect of the attribute on the decision to purchase the product.