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Essays in Applied Microeconometric Analysis

A Dissertation
Presented to the Faculty of the Graduate School
of
Yale University
in Candidacy for the Degree of
Doctor of Philosophy

Phillip J. Leslie*

Yale University
Department of Economics

Committee: Ariel Pakes, Steven T. Berry, Moshe Buchinsky

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Abstract

This dissertation is based on two applications of structural microeconometric analysis. Chapter 1 is a general discussion of structural microeconometrics, together with specific background and motivation for the studies undertaken in Chapters 2 and 3.

In Chapter 2 a model of price discrimination is described which includes *both* second-degree and third-degree price discrimination. The model is designed to analyze ticket sales for a Broadway play. Heterogeneous consumers choose between tickets for various seat qualities, tickets sold at a discount booth, and tickets requiring a coupon available to a subset of the potential consumers. Using data from a Broadway play, the structural model is estimated and various experiments are conducted to investigate the implications of alternative pricing policies. Among the findings, price discrimination may improve the firm's profit by approximately 5%, relative to uniform pricing. The difference for aggregate consumer welfare is negligible. The presence of capacity constraints implies rationing, which leads to unusual substitution patterns between ticket categories.

Chapter 3 is an analysis of individuals' schooling decisions and is joint work with Moshe Buchinsky. We combine contemporaneous decision making with the forecasting of future distributions into the unified framework of a dynamic optimization model. The insights from our approach are in the form of analyses of the effects from: (a) actual changes in conditional wage distributions over the years 1980 to 1994; (b) the use of alternative forecasting behaviors; (c) altering the individual's aversion to risk; and (d) changing various constraints such as tuition costs and the individual's initial level of wealth. These issues are studied in a variety of simulations using the *March Current Population Survey*. By modeling the individual's optimal choice of education based upon empirical wage distributions, we offer an evaluation of the effects of changes in the U.S. labor market on individuals' investments in their educational human capital.

Contents

1 INTRODUCTION

The goal of this dissertation is to undertake empirical analysis in which there is a direct connection between a theoretical model of economic behavior and the econometric model that is fitted to the data. The methodology falls under the broad category of *structural microeconometrics* and can be contrasted with reduced-form econometrics in which empirical analysis may be informed by a behavioral theory, but is otherwise independent of such behavioral theory.

Technical differences aside, the main distinction between structural and reduced-form approaches is interpretation. The estimated coefficients in a structural model have a specific interpretation within the context of a behavioral framework. The estimated coefficients in reduced-form models have less formal interpretation and may only be controlled measures of correlation between variables. Depending on the question to be investigated and the available data, either approach may be an appropriate framework for analysis.

The studies I present in this dissertation are highly structural in nature and this first chapter is devoted to providing background and motivation for doing so. Two particular applications are considered, and I will argue that each yields results that could not have been obtained without structural formulations. The first application is to price discrimination. The second is to individuals' choices of educational investments.

The remainder of this chapter is as follows. In Section 1.1 I elaborate on some ad-

vantages and disadvantages of structural microeconometric modeling, paying particular attention to examples in the industrial organization literature. I then provide background and motivation in Section 1.2 for the analysis of price discrimination which is presented in Chapter 2. Similarly, in Section 1.3 I discuss the application to educational attainment which constitutes Chapter 3 of my dissertation.

1.1 Structural Microeconometric Modeling

Structural microeconometrics refers to econometric models that directly incorporate elements from the economic theory that is the basis of analysis. Furthermore, in a fully structural model there exists no unexplained component, including error terms. Thus, in principle and sometimes in practice, the econometric model is a perfect fit to the data. Every aspect of the econometric model has a specific interpretation within the context of a behavioral theory. Residual errors have a formal interpretation as a particular kind of unobservable heterogeneity that is consistent with the behavioral model. There are a few generalizations about structural approaches which are important to understanding the applications.

First, structural models introduce additional assumptions to the econometrics, relative to reduced-form (or less structural models.) By adding structure, or assumptions, it is possible to identify features of the data which would otherwise not be possible. But this also suggests the major potential weakness of structural econometrics—if the assumptions are wrong, the model is misspecified and the resulting empirical conclu-

sions may be fundamentally incorrect. The structure, however, is that which comes from economic theory. Hence, at issue is whether an appropriate behavioral model has been adopted as the framework for empirical analysis. For this reason, structural econometrics is invariably accompanied by a deeper understanding by the researcher of the environment that the data comes from. For example, the researcher should seek to learn a great deal about an industry he or she is analyzing in order to best inform the model choice of firm behavior that is used. It is also to be remarked that reduced-form estimation is not assumption-free and is therefore also subject to the possibility of misspecification; though fewer assumptions reduce the chances of this happening.[1]

Second, while a major strength of structural formulations is the potential to identify aspects of a model which could not otherwise be recovered from the data, of equal importance is the ability to undertake experiments once the model has been estimated. The estimated model may give rise to a fully specified economic model of endogenous behavior. We can then alter the value of certain variables, introduce or remove constraints, and so forth, each time evaluating the effect on the model's endogenous variables. Indeed, experiments may even be relatively radical in nature, so long as we believe the basic model is well specified and the parameters are correctly estimated. As an approach to understanding observed behavior and to predicting the implications of policy interventions, this is a very appealing aspect.

A third generalization is that, in practice, structural econometric models tend to

[1]There is actually a potential downside to using fewer assumptions in reduced-form models. Without formal assumptions and a suitable explanation about the error term, there is increased concern for the presence of endogenous right hand side variables.

be computationally burdensome to estimate. These models are usually nonlinear and do not have analytic solutions. And it is common that multivariate integration is required for the estimation, which is a prime source of computational burden. Indeed, this is a reason for the relatively recent increase in the use of structural models, as increases in computing power and lowering costs have made the approach more feasible to implement.

There are a multitude of ways a behavioral theory may directly enter into the econometrics, and it is helpful to briefly mention a couple of examples.[2]

The empirical auction literature has grown rapidly in the last ten years.[3] One set of papers in this area focuses on recovering the underlying distribution of bidders' unobservable valuations. Consider parametric estimation of a first-price sealed-bid auction.[4] The approach is to postulate a parameterized distribution of private valuations and then estimate the true parameterization. For a given parameterization, and in accordance with auction theory, there exists a monotonic optimal bid function that relates individuals' optimal bid to their private value and the distribution of private values. The optimal bid function is inverted so that for any observed bid, the associated private valuation is computed. Using a likelihood function, an optimization algorithm is used to determine the parameterization for the distribution of private values that maximizes

[2]The examples I discuss here are from the empirical industrial organization literature where structural approaches have been widely used. Indeed, the tendency towards using structural models in this field has led some researchers to adopt the label: the new empirical industrial organization. This is not to say that other fields of economics have no use for structural econometrics.

[3]For a detailed summary of the initial empirical auction literature see Hendricks and Paarsch (1995), which I draw on for this discussion.

[4]This is the simplest example and suffices for the current purposes. Extensions exist to nonparametric estimation, and to others kinds of auctions.

the likelihood of obtaining the imputed valuations.

The auction example is of interest because it is then possible to examine how different auction mechanisms compare, given the estimated distribution of valuations; or how bidders' valuations change with the nature of the good being auctioned. These are issues it would not be possible to address without a structural econometric model.

A second example is the estimation of structural models of demand, and in particular in cases utilizing a predicted differentiated products price equilibrium in the estimation procedure. A prominent example of this approach is Berry, Levinsohn and Pakes (1995) analysis of automobile demand. In that study, a utility function is specified which incorporates the individual consumer's characteristics (tastes and income) and the bundle of characteristics describing a given automobile; these characteristics include observable and unobservable aspects with formal structural interpretations. Each consumers' behavior is modeled as a discrete choice problem. However, while the decision-maker in the analysis is an individual consumer, the available data is aggregate quantities, prices and observable product characteristics. Hence, predicted individuals' choices are explicitly aggregated to yield a prediction for aggregate quantities which is then fitted to the data.

To enhance the accuracy of the estimated parameters in their study, Berry *et al* employ a nonlinear restriction that the observed prices equal predicted prices according to their model. To obtain these predicted prices, the authors compute a Nash equilibrium in prices for the multiproduct firms. In this way, a formal model of firm behavior, indeed

of market equilibrium, is tied to the econometric model, allowing for the estimation of parameters which would otherwise not be possible.

1.2 Application to Price Discrimination

Price discrimination refers to a situation when two or more similar goods sold by a single firm are sold at prices that are in different ratios to marginal costs.[5] The theory literature is relatively well developed and Varian (1989) is a comprehensive review of that. The empirical literature is much less developed and Chapter 2 of my dissertation is aimed at improving on this, using the example of ticket pricing in Broadway theatre.

The theoretical framework is a utility-based model of consumer behavior that incorporates characteristics suggested by the data and institutional details of the Broadway theatre industry. The demand model is designed to be consistent with the observed behavior of the firm and includes both second-degree and third-degree price discrimination. In the model, heterogeneous consumers are sequentially presented with a menu of discrete ticket choices for seeing a play, or not. The possible choices include tickets for various seat qualities and tickets with various discounts. Due to capacity constraints and variation in seat quality among equally priced seats, different individuals can be presented with different ticket options. Motivated by behavior in the industry, the model contains a rich variety of different forms of price discrimination.[6] Setting

[5]This is the definition put forward by Stigler (1987).

[6]Tirole (1988) gives a thorough explanation of the different kinds of price discrimination. For a discussion on the difficulties of defining price discrimination in general, see Phlips (1983).

different prices for different seat qualities is an example of second-degree price discrimination, or nonlinear pricing.[7] Discount mail coupons are targeted to consumers with lower willingness to pay, which provides an example of third-degree price discrimination, or market segmentation.[8] The sale of day-of-performance half-price tickets sold at a discount booth is modeled as a damaged good which further discriminates among self-selecting consumers.[9]

The econometric specification of the behavioral model is a random-utility discrete choice model with endogenously random choice sets. This presents a non-standard and computationally intensive estimation, which is often a feature of structural models that incorporate peculiarities of the market in question. The data detail all aspects of the production and marketing for *Seven Guitars*, a play that ran on Broadway in 1996. For each performance there are up to 15 different ticket prices. The producer of the play designs the price schedule with the objective of maximizing revenue. A virtue of using a structural econometric framework in this case is that a range of experiments can be performed using the estimated demand system. The experiments include uniform pricing, non-sticky prices over time, and abolishing the discount booth. In each case, comparisons are drawn with the benchmark scenario of the actual behavior of the firm and consumers.

There have been several prior empirical studies regarding price discrimination in

[7]Wilson (1993) provides a detailed account of the theory of nonlinear pricing. In this study, the terms nonlinear pricing and second-degree price discrimination are used interchangeably.

[8]See Narasimhan (1984) for a study of coupons as a method of price discrimination.

[9]A damaged good, in this context, refers to the practice of a firm deliberately damaging its product, to create a lower quality version of the product. See Deneckere and McAfee (1996).

specific markets. Borenstein (1991) examines price differences between leaded and unleaded retail gas sales; Shepard (1991) investigates price differences between full-service and self-service retail gas sales; and Borenstein and Rose (1994) study price dispersion in the airline industry. All of these studies involve multi-firm settings and consequently focus on the question of, to what extent can firms price discriminate in the presence of competition? The approach is always to consider whether the observed price dispersion is due to some cost-based explanation. On the basis of reduced-form regressions, these studies have found strong support for the presence of price discrimination.

Two previous studies of price discrimination involve structural econometric modeling, similar in spirit to the approach used here. Ivaldi and Martimort (1994) analyze second-degree price discrimination in energy sales to farmers using a fully specified empirical model. In that paper, a model of firm interaction and consumer behavior is described, which is then fitted to the data, which enables them to draw conclusions about the form of competition between energy suppliers. In a second study, Bousquet and Ivaldi (1997) describe a model of demand for telephone services which is fitted to data, and then allows for the computation of the optimal nonlinear price schedule for the monopolist firm. The paper by Bousquet and Ivaldi (1997) is the closest in nature to this study, and also emphasizes the need for a utility specification that is tailored to the specific market in question. My study differs from both of these papers in two fundamental ways. First, nonlinear pricing, in my model, is over qualities rather than quantities. This presents a problem since quality is not observable. Second, I incorporate other types of price discrimination in addition to nonlinear pricing.

This research is also a study of theatre ticket pricing. Since Baumol and Bowen (1966) and Moore (1966) first began applying principles of economics to understanding behavior in the performing arts, several researchers have analyzed pricing and the demand for theatre tickets. Two of these studies, in particular, focus on the issue of multiple ticket prices. Huntington (1993) asks the question, is there a significant difference in revenue for theatres charging a range of ticket prices, over theatres that charge a single price for all tickets? Using data from a sample of theatres in England, which includes a binary variable for whether a theatre uses a single price policy or not, it is found that theatres which use a single price obtain significantly less revenue than theatres which do not.[10] In this study, the uniform pricing experiment also addresses this issue in a manner that controls for all other factors. And I consider several other possible pricing regimes. In a theoretical study, Rosen and Rosenfield (1997) describe a model of ticket pricing that involves second-degree price discrimination. Their analysis indicates the joint distribution of peoples' reservation prices for different quality categories is an important determinant of the optimal price schedule. The behavioral model used here differs in several ways which include the use of an explicit utility-based demand specification and the addition of third-degree price discrimination.

There is also an on-going debate in the cultural economics literature regarding price and income demand elasticities for the performing arts, which has been fueled by competing results from various empirical studies. For example, Moore (1966) finds the price elasticity of demand for Broadway theatre to be in the range -.33 to -.63, and an income

[10]The other explanatory variables are limited to the number of performances and theatre capacity.

elasticity of roughly .4; Felton (1992) finds price elasticities in the range -.13 to -.95 for various orchestra, ballet and opera companies in the U.S.; Lévy-Garboua and Montmarquette (1996) find price elasticities in the range of -1 to -1.47 for consumers with varying tastes for theatre in France. An advantage of this study is the use of data which details every ticket sale for every performance of a particular show. Not only does this give rise to a large data set by the standards of previous studies, but also overcomes the need for a simplifying assumption that all tickets are sold at the average price, and hence allows for the determination of demand elasticities for several different ticket types. A limitation, however, is that the data used here is for a single show, whereas previous studies use data from many different shows.[11]

1.3 Application to Educational Attainment

A key feature to any analysis of individuals' choices of educational investments is individuals' expectations of the future returns to education versus additional work experience. In Chapter 3 of my dissertation, which is joint work with Moshe Buchinsky, we investigate how different types of forecasting behavior affect schooling decisions, in particular during the 1980s which was a period of dramatic change in the returns to education.

We develop a finite horizon dynamic optimization model in which a risk averse individual decides in each period his current consumption level and whether to attend school or to gain a year of work experience. This latter choice affects the stream of

[11]Though almost all of these studies use data which is aggregated over the shows, treating the data as if it were for a single product.

stochastic future earnings. As is standard in such models, the valuation of alternative choices is obtained by integrating over the uncertain future outcomes, namely wages. A unique feature of our model is the inclusion of evolving perceptions about future wage distributions. That is, future conditional wage distributions are unknown to the individual in our model, necessitating the use of a forecast, which is updated as the individual moves forward in time and obtains more information upon which to base his forecast.[12]

We combine contemporaneous decision making with the forecasting of future distributions into the unified framework of a dynamic optimization model.[13] The insights from our approach are in the form of analyses of the effects from: (a) actual changes in conditional wage distributions over the years 1980 to 1994; (b) the use of alternative forecasting behaviors; (c) altering the individual's aversion to risk; and (d) changing various constraints such as tuition costs and the individual's initial level of wealth. These issues are studied in a variety of simulations using the *March Current Population Survey*. By modeling the individual's optimal choice of education based upon empirical wage distributions, we offer an evaluation of the effects of changes in the U.S. labor market on individuals' investments in their educational human capital.

Modern empirical studies on human capital investment and the return to education begin with the seminal work by Becker (1964). In subsequent work, Ben-Porath (1967),

[12]Note that we generically refer to our individual throughout our study as a male simply because the data extract we use contains only males.

[13]There are dynamic discrete choice models in the literature and there are studies on educational choices, but the two are rarely integrated into a single model.

Blinder and Weiss (1976), Griliches (1977), Rosen (1976), and Willis and Rosen (1979) expanded on the original work by Becker in various ways.[14] Common to several of these papers are attempts to capture individuals' anticipation of their future income, and account for the subsequent consequences of sample-selection. Other studies sought to view education as a process providing the individual with an option value.[15] None of this research explicitly includes any manner in which people update their beliefs about future distributions over time and accordingly modify their behavior.

Since changes in the wage structure during the period of our study were sharp and irregular, the consequences resulting from these changes cannot be satisfactorily captured by a traditional parametric static model. Such non-stationary changes in the wage distribution have undoubtedly altered people's perceptions about future distributions. Since these are the distributions from which they will obtain the rewards for their current investments in human capital, these changes are likely to affect individuals' decisions regarding further schooling in a way which cannot be well represented by a static stationary distribution.

In a sequence of papers, Manski (1989, 1993a, 1993b) and Dominitz and Manski (1994) focus their attention on individual's perceptions of the rewards from education and rationalize the process by which people form expectations and make their decisions. The current project draws on the ideas expounded in these papers, while

[14]These are only a few of the outstanding studies in the literature on human capital in general, and the returns to schooling in particular. For a variety of interpretations on the theory of human capital see the survey by Willis (1986).

[15]For example, Comay, Melnik and Pollatschek (1973, 1976, 1977), Dothan and Williams (1981).

further extending the approach to a fully dynamic context.

In our model the individual's perception of future wage distributions is a forecast derived from the observed past distributions at the time the individual makes his decisions. For this purpose we employ the semiparametric technique of quantile regression to estimate historical conditional wage distributions. A problem inherent to any forecasting procedure stems from the fact that the individual possesses only estimates of the true parameters for the underlying distributions. This introduces an additional source of uncertainty for the individual agent, indistinguishable from the uncertainty induced by the stochastic nature of future wages. As the individual moves forward in time, he obtains more information upon which he bases his forecast. In general, this implies learning behavior that must be anticipated, since current behavior depends upon predicted future behavior. While our study does not include estimation of the parameters of the behavioral model, it helps in characterizing the effects of the changing wage structure over the last few decades on the educational choices of recent generations.[16]

A particularly important issue in the literature on human capital are the direct and indirect costs of education.[17] The structural nature of our model is well suited to studying this issue, so we also provide an analysis of the impact of tuition costs. In addition, we investigate the effects of liquidity constraints on individuals' educational choices by varying the initial wealth they have at the initial period after high school graduation.

[16]The particular method in which the future wage distributions are formed will be the basis for estimating a structural model, but this is beyond the scope of the current study.

[17]e.g. Flyer and Rosen (1994), Fuller, Manski and Wise (1982) and Kane (1995).

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