

Pricing and Market Concentration in Oligopoly Markets

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This paper investigates the relationship between prices and market concentration in the auto rental industry. We assemble an original database that includes the number of auto rental operators and other exogenous demand and cost conditions at every commercial airport in the country. The data are interesting because we observe a large variation in market structure, ranging from more than 100 monopoly and duopoly markets to several competitive airports with more than eight firms. In addition, we collect daily rental prices in each market that are regressed against the number of operating firms and other control factors. Due to potential biases in treating market participants as exogenously assigned, we employ a two-stage estimation procedure in which an equilibrium model of endogenous market structure provides correction terms for the second-stage price regression. Results show that ignoring the endogeneity of market structure severely underestimates the impact of additional competitors on prices, with the competitive interaction parameters doubling in magnitude after the correction procedure. The downward bias in the competitive parameter can have important implications for horizontal mergers, which may incorrectly appear innocuous when using a model that ignores the endogeneity of market structure. More generally, our results serve as a warning on the potential biases to a large number of applications in marketing and economics that attempt to relate outcome variables such as prices, markups, or profits to the observed market structure.

Key words: pricing; market structure; entry; horizontal mergers; endogeneity

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1. Introduction

A long stream of literature in economics and marketing strategy examines the relationship between competitive characteristics of market and profitability. In the structure-conduct-performance paradigm of industrial organization, this literature relies on cross-sectional data across industries to document the impact of market concentration on profitability. A general finding in this literature is that higher market shares and seller concentration are associated with higher profitability (see, e.g., Buzzell and Gale 1987, Schmalensee 1989). However, the profit concentration studies have been criticized on several grounds. First, these studies are plagued by measurement problems because, in general, accounting profits are poor indicators of economic profits. Second, the cross-sectional data from different industries used in these studies are problematic because of large differences in demand and supply conditions across industries. Finally, these studies are subject to the “efficiency” critique offered by Demsetz (1973), who argued that positive correlation between profits and

market concentration could be due to the competitive superiority of a few firms.

Over the past several decades, the profit concentration studies have been replaced by a stream of research that examines the relationship between market structure and prices rather than profits. An advantage of using prices as opposed to profits is that they are easier to obtain and are not subject to accounting conventions. Weiss (1989) provides a large number of price concentration studies and argues that because prices are determined in the market, they are not subject to superiority criticism, as is the case with profits. Furthermore, the majority of the price concentration studies use data across local markets within an industry rather than across industries and incorporate more industry- and firm-specific details. These studies include a wide range of industries such as grocery (Cotterill 1986), banking (Calem and Carlino 1991), airlines (Borenstein and Rose 1994), hospitals (Keeler et al. 1999), driving lessons (Asplund and Sandin 1999), cable television (Emmons and Prager 1997), and movie theaters (Davis 2005).

A general finding in this literature is that high concentration is associated with significantly higher prices (Weiss 1989; see also various studies cited in a recent survey by Newmark 2004). However, as both Bresnahan (1989) and Schmalensee (1989) point out in their chapters in the *Handbook of Industrial Organization*, price concentration regressions, such as those used in the literature, suffer from serious endogeneity issues. The fundamental problem arises because market structures are not randomly assigned, a necessary condition for a standard regression model to yield consistent estimates. Instead, the observed market structures are the outcome of strategic decisions by firms that evaluate demand and cost conditions as well as potential competitors in the market in making their entry decisions. As such, there are likely to be unobserved demand and cost shocks in a market that influence not only prices but also the underlying market structure. For example, markets with unobserved high costs are likely to have higher prices, but these markets are also likely to attract fewer entrants. In this case, a regression of prices on the number of firms may lead to the inference that high prices are associated with a low number of firms, but this finding may partially be driven by the unobserved costs. Similarly, unobserved positive demand shocks may result in higher prices and an unusually large number of firms in a market, in which case the impact of competition on prices may be understated. Evans et al. (1993) formally address this issue and propose a combination of fixed effects and instrumental variable procedures that are applicable when panel data are accessible. They study the price concentration in the airline industry and find that the impact of concentration on price is severely biased using ordinary least-squares (OLS) procedures.

Recent structural work in marketing (see Chintagunta et al. 2006 and the accompanying comments) has pointed out the endogeneity problems associated with short-term marketing activities, such as pricing and promotions in both aggregate (e.g., Besanko et al. 1998) and individual panel data (e.g., Villas-Boas and Winer 1999). This literature uses variants of the methods proposed by Berry et al. (1995) to examine issues such as brand value creation and competitive advantage (Besanko et al. 1998), product line competition (Kadiyali et al. 1999), channel power (Kadiyali et al. 2000), retailer pricing (Sudhir 2001, Villas-Boas and Zhao 2005, Villas-Boas 2007, Manuszak 2005), and price discrimination (Chintagunta et al. 2003, Khan and Jain 2004). However, given the nature of the industry (mostly packaged goods) and relatively short time periods, these studies take the existing market structure (e.g., the number of firms in a market) as exogenously determined.

In this paper, we study the relationship between prices and the number of firms in the auto rental industry. We develop an original data set that includes the number of car rental firms at every commercial airport in the United States. The data are unique in that we observe a wide cross-section of market structures, ranging from several monopoly and duopoly markets to many airports with more than eight firms. For each of these markets, we collect an extensive set of variables that captures the demand and cost conditions. These variables include both airport-specific factors (e.g., airline passenger traffic) and local demographics in the city in which the airport is located (e.g., income, retail wages). In addition, we collect data on daily rental prices from every firm and for each car type (economy, full-size, etc.). Thus our data set consists of approximately 450 markets (airports) for which we observe the number of firms that serve each market and the prices they charge.

Our primary objective is to test how the prices change with the number of competitors in the market. However, in doing so, we account for the endogeneity of market structure. Because we observe only a cross-section of markets, we cannot use the Evans et al. (1993) approach, which requires a panel data structure with sufficient variation in the number of players over time. Such data, with substantial entry and exit over time, are rarely available. In addition, even with a panel data structure, it is still necessary to worry whether the changes in the error term for the price regressions are correlated with the changes in market structure. As Manuszak and Moul (2007, p. 98) point out, “the panel data approach shifts the concern about correlation between unobservables and market structure to differences in those two items over time.”

In this paper we use a two-stage estimation procedure to address the endogeneity of market structure. In the first stage, we estimate an equilibrium model of entry that predicts the number of competing firms in a market. In particular, we follow the literature advanced by Bresnahan and Reiss (1987, 1990, 1991) and Berry (1992) that endogenizes competitive structure characteristics such as the number of firms and the degree of concentration in the market. The key insight underlying this stream of research is that we can infer features of a firm’s latent profit functions by observing its entry decisions because it will enter if it expects positive profits, but it will not otherwise. Because market entry decisions are discrete, the model suggests using a discrete-choice framework to draw inferences about the factors that affect firms’ actions. The approach parallels the standard single-agent discrete-choice models in which the researcher makes inferences about unobserved latent utility on the basis of the inequality restrictions. However, in

the case of entry games, payoffs and resultant behavior reflect the interaction of decisions of multiple individual agents. Thus, the estimation is based on an oligopolistic equilibrium concept rather than on an individual utility maximization.

In the empirical application, the parameter estimates from this first-stage entry model are used to derive correction terms that are inserted in the price equation to correct for the correlation between the price errors and the market structure variables. The procedure is similar to the two-step estimation used widely in labor econometrics (Heckman 1976). Mazzeo (2002a) uses this procedure in a similar context as this paper to study the relationship between prices and market structure for motels. To check the sensitivity of the correction procedure to the first-stage model specification, we estimate three models of endogenous market structure: (1) a model without firm heterogeneity, (2) a model with only unobserved heterogeneity, and (3) a model with both observed and unobserved firm heterogeneity. As discussed below, the results are robust directionally and in relative magnitude across all model specifications.

We apply this procedure to the auto rental industry, which offers several advantages over previous applications in this stream of research. As we discuss in the data section, we observe a wide range of market structures, ranging from 68 monopoly markets and 66 duopoly markets to more than 50 very competitive markets with more than eight firms. Such large variation in market structure provides a unique setting to study the relationship between prices and the number of firms. In addition, most previous price concentration applications suffer from problems related to market and product definition as well as price measurement, which is much less of a concern in the current application. For example, consider the retailing sector, such as grocery or office supply stores as studied in Cotterill (1986) and Manuszak and Moul (2007), respectively. In these industries, the market definition and trading areas are difficult to define. The problem is magnified because product assortments tend to overlap across a wide range of retail formats. For example, supermarkets, discount stores, dollar stores, price clubs, and supercenters all tend to have significant overlap in product assortment, which makes the industry and the resultant competition difficult to define. In addition, retailers are multiproduct firms that carry thousands of products, which makes the collection and comparison of prices for all products difficult, if not impossible. The common approach to deal with the problem is to create some aggregate price indexes or to rely on the prices from a handful of products. For example, Cotterill (1986) uses an aggregate price index for grocery products, and Manuszak and Moul (2007) use data from three products (paper,

writing pads, and envelopes). The extent to which an aggregate price index or prices from a handful of products capture competition in these industries is subject to debate.

The auto rental industry that we analyze herein overcomes the problems associated with market definition and price measurement to a large extent. First, our data are complete in that we have collected information on the number of firms and prices for every commercial airport in the country. Second, the market in this industry is reasonably well defined because the primary clientele for auto rentals at the airport locations is the passengers flying into the airport (according to various firms' annual reports). Although airport locations might compete with the outlets in downtowns or other city locations that we do not consider, the problem is less severe than market definitions in the previous studies. Third, the price information is reasonably easy to collect and compare across firms and markets because, at least at the outlet level, these are single-product firms and car rental is the primary business. Finally, the product is fairly homogenous in that the quality of a particular car type tends to be similar across firms, although these firms may differ in terms of service quality.

The results from the first-stage model show that many demand and cost factors, such as airport traffic, wages, and local demographics, are important determinants in firms' entry decisions. In addition, parameters of the latent payoff functions show that profits are higher in holiday markets and markets with headquarters for large firms, whereas markets with better public transportation infrastructure are less profitable. Entry of additional competitors in the market is found to reduce profits significantly. For the pricing equation, several demand and cost control variables, service quality (in-terminal counters), and product quality (car size) are found to be significant. In terms of the primary focus of the paper, we find that concentrated markets (those with fewer than three firms) have prices that are approximately 30% higher than competitive markets (with more than eight firms). More important, we find that ignoring the endogeneity of market structure in the price regressions severely underestimates the competition parameters. In particular, the competitive interaction parameters are doubled in magnitude when we insert the correction terms in the price equation. Thus, the impact of market concentration on prices appears less severe if the endogeneity of market structure is ignored. In the empirical analysis, we test the sensitivity of the results to various first-stage model specifications. The direction and magnitude of bias is consistent across model specifications and similar to those in Evans et al. (1993), who find that OLS parameters are biased in the magnitude of 150%.

The bias in the parameters capturing the competitive interactions underscores the fundamental problem in the vast literature that uses regression technique to understand the relationships between variables such as prices, markups, revenues, or profits and market structure. In addition, it has important policy implications because price concentration approaches are commonly used econometric techniques employed by the Federal Trade Commission (FTC) to analyze horizontal mergers (Whinston 2003). As Baker and Rubinfeld (1999, p. 405) note, “[R]educed form price equations are the workhorse empirical methods for antitrust litigation.” For example, such price regressions were used in the highly litigated case on the merger between Staples and Office Depot, which was eventually declined by the FTC. Using a similar two-stage approach as in this paper, Manuszak and Moul (2007) revisit this case and point out the bias in price regressions employed by the FTC. In the current application, the negative ramifications of market concentration are underestimated, implying that horizontal mergers in this industry may incorrectly appear innocuous using a model that ignores the endogeneity of market structure.

The rest of the paper is structured as follows: In the next section we describe the price regression, the first-stage entry model, and the correction procedure. In §3, we discuss the data from the auto rental market. Section 4 presents the results; the implications of the main findings of the paper, along with directions for future research, are discussed in §5.

2. Model

2.1. Price and Market Concentration

Consider a typical price concentration regression model in which the relationship among the prices, exogenous market characteristics, and the market structure variables can be specified as follows:

$$\ln p_{mk} = Z_{mk}\theta + f(N_m, \delta_p) + \varepsilon_{mk}^p, \quad (1)$$

where p_{mk} are the observed prices in market m for firm k , and Z_{mk} are all observed firm and market characteristics except the market structure variables that affect prices. The function $f(N_m, \delta_p)$ represents the impact of the underlying market structure on prices. In empirical applications, the market structure variables are typically captured using measures such as concentration ratio or the Herfindahl index. Finally, ε_{mk}^p are firm-market-specific unobservables that influence prices.

In the current context, our dependent variable, p_{mk} , would be the price of a particular car type (e.g., economy) at each airport location, and the exogenous variables Z_{mk} would include demand and cost conditions

at the airports, such as the number of passengers flying into the airport, local demographics, and other controls, e.g., firm and car size fixed effects. Because we do not observe market shares in our data, we cannot use concentration ratio or the Herfindahl index. Instead, we capture the competitive structure in our application by including the total number of car rental firms that offer services at the airport. In the empirical application, we also run models using a flexible dummy specification for monopoly markets, duopoly markets, and so forth.

The price equation in (1) represents a typical model used in the price concentration literature (see, e.g., various studies in Weiss 1989). As is well known, the OLS estimator applied to such a model is biased and inconsistent if the unobservable ε_{mk}^p are correlated with explanatory variables in the regression. Of particular concern in (1) are the variables that capture the competitive structure, N_m , because there are likely to be unobserved demand and cost conditions in a market that influence not only prices but also the number of firms that operate in the market. For example, markets with unusually high costs are likely to have higher prices, but these markets are also likely to attract fewer entrants. Similarly, unobserved positive or negative demand shocks can influence a firm’s pricing and its decision to operate in the market. For instance, suppose that $f(N_m, \delta_p) = \delta_p N_m$ and that N_m and Z_{mk} are not perfectly correlated; then, the OLS estimator of δ_p is $\hat{\delta}_p = \text{cov}(N_m, \ln p_{mk}) / \text{var}(N_m) = \delta_p + \text{cov}(N_m, \varepsilon_{mk}^p) / \text{var}(N_m)$. If there are unobserved demand shocks that influence prices and the number of firms in the same manner such that $\text{cov}(N_m, \varepsilon_{mk}^p) > 0$, the parameter estimate $\hat{\delta}_p$ will be biased downward (i.e., $\hat{\delta}_p > \delta_p$, or $|\hat{\delta}_p| < |\delta_p|$ because we would expect δ_p to be negative).¹

A possible solution to this econometric problem is to use instrumental variable techniques. For example, there could be variables that affect firms’ long-term

¹ The atheoretical nature of the typical price regression makes it difficult to infer the nature of biases that may occur. For instance, consider a simple cournot model with linear cost and demand:

$$P(Q) = a - Q \quad \text{and} \quad C_i(q_i) = cq_i + F, \quad \text{for all } i.$$

If there are n firms in the market, the equilibrium price is $p^* = a - nq^* = (a + nc)/(n + 1)$. With free entry, the number of firms is determined by $\Pi^* = 0$, and we obtain $n^* = (a - c)/\sqrt{F} - 1$. Note that if the variation in the number of firms is determined by some unobserved factors in a , then in the price regression, the endogeneity effect would be in the direction of greater n being associated with higher price, whereas the opposite is true if the variation in n is determined by some unobserved factors in c . If the variation in n is determined by variation in only F , then there would not be any endogeneity effect. The empirical results in this paper seem to show that in the particular industry considered, the endogeneity effect due to the demand shocks (a) seems to be most important. We thank the associate editor for this insight.

entry decisions but do not affect the short-term prices. In our study, we use a variation of instrumental variable approach by first estimating a model that directly describes the determinants of market structure. Formally, this model considers the observed market structure as the outcome of a strategic game between potential entrants. Estimates from the first-stage model are then used to derive correction terms that are inserted in the price equation to alleviate the correlation between the price errors and the market structure variables. The procedure is similar to the two-step estimation used widely in labor econometrics (Heckman 1976). Mazzeo (2002a) and Manuszak and Moul (2007) use this procedure in a similar context as ours to study the relationship between prices and market structure for motels, and office supply stores, respectively.

2.2. Model of Endogenous Market Structure

To model the number of car rental companies operating at an airport, we follow the literature on multi-agent discrete games, which provides an empirical approach to analyze game-theoretic models in which agents make discrete choices, such as entry and exit (for a survey, see Reiss 1996). The approach is advanced by Bresnahan and Reiss (BR) (1987, 1990, 1991) and Berry (1992). The authors develop econometric models to investigate how the number of firms varies across markets as a result of various demand and cost factors. The approach endogenizes the competitive structure in the market by implicitly analyzing the first stage of a two-stage game in which firms first decide whether to enter and then determine price or quantity competition. The key insight underlying the research is that features of latent profits can be inferred by observing firms' entry decisions because they will enter if they expect positive profits, but they will not enter otherwise.

Unlike the structural models of supply and demand that provide marginal conditions, the discrete decisions imply threshold conditions for players' unobserved profits. Econometrically, this feature of the model suggests using a discrete-choice framework to make inferences about the factors that affect firms' actions. However, unlike the single-agent discrete-choice models that have been used extensively in the marketing literature to model consumer choice, in the case of a discrete game, payoffs and resultant behavior reflect the interaction of multiple agents' decisions. Thus, estimation is based on an oligopolistic equilibrium concept rather than on an individual utility maximization. In what follows, we build on the existing literature to develop a model that describes firms' entry decisions. The model is general and includes simpler setups of no firm heterogeneity as special cases.

Assume that firm k 's latent profits in market m with N entrants (including itself) can be specified as follows:

$$\begin{aligned}\pi_{mk}^N &= \bar{\pi}_{mk}^N(X_{mk}, \beta, \delta) + \varepsilon_{mk} \\ &= X_{mk}\beta + \delta(N-1) + \varepsilon_{mk},\end{aligned}\quad (2)$$

where

$$\varepsilon_{mk} = \eta u_{m0} + \sigma u_{mk}.\quad (3)$$

In the profit function (2), $\bar{\pi}_{mk}^N(X_{mk}, \beta, \delta)$ captures the expected payoffs as a function of exogenous demand and cost shifters as well as the number of competitors in the market. The term $\delta(N-1)$ captures how a firm's profit decreases as more competitors enter the market.² The vector X_{mk} represents the observed component of the profit function and includes market characteristics that are common across players as well as firm-specific observed components. Note that several variables in X_{mk} describing firms' entry behavior can be the same as those that affect the prices; that is, Z_{mk} in (1). When all exogenous variables in (1) and (2) are identical (i.e., $X_{mk} = X_m = Z_{mk}$), identification of the correction procedure we describe subsequently is through a nonlinear functional form of the entry model alone. However, our empirical application includes several variables in the entry model that are not included in the price regression. For example, variables such as annual population growth, real estate value, traffic in past years, and distances to firms' headquarters are likely to affect market structure, but not short-term pricing, and serve as exclusion restrictions.

The second component in (2), ε_{mk} , summarizes the unobserved characteristics. In (3) we decompose these unobservables into two terms, where u_{m0} represents unobserved market characteristics that are common across all players, and u_{mk} is firm-specific unobservables. Thus, this model allows for heterogeneity across firms due to firm-specific observed components in X_{mk} and unobserved heterogeneity across firms. The terms u_{mk} and u_{m0} are assumed to be independently distributed with standard normal distribution across firms and markets. For identification, we impose the traditional constraint that the variance of ε_{mk} equals one, via the restriction $\sigma = \sqrt{1 - \eta^2}$, where η is the correlation of the unobservables ε_{mk} in a given market.

²Note that there is a structural relationship between δ in the entry model and δ_p in price regression that we do not model. For example, if demand is linear and firms compete in quantities (as in the example presented in Footnote 1), $(\partial\Pi^*/\partial n)/(\partial p^*/\partial n) = 2(a-c)/(n+1)$, where n is the number of firms in a market. It would be nice to know the conditions under which there would be a structural model that would be consistent with both the price and profit equations used in the paper. We would like to thank the associate editor for pointing this out.

To identify the parameters of the model, we impose an equilibrium assumption that all active firms expect nonnegative profits and that an additional entrant would find entry into the market unprofitable.³ In the empirical application, we estimate three models with different specifications on firms' payoff functions: (1) no firm-specific heterogeneity, (2) unobserved firm heterogeneity, and (3) observed and unobserved firm heterogeneity.

2.2.1. Symmetric Firms ($\varepsilon_{mk} = u_{m0}$; $X_{mk} = X_m$; $\pi_{mk}^N = \pi_m^N$ for All k). Bresnahan and Reiss (1990) describe a special case of the model (2) that assumes symmetric firms. In this framework, the equilibrium assumption implies that the probability of observing n active firms in a market is

$$\begin{aligned} P(N_m = n) &= \Pr(\pi_m^n \geq 0 \text{ and } \pi_m^{n+1} < 0) \\ &= \Pr(-\bar{\pi}_m^n \leq u_{m0} < -\bar{\pi}_m^{n+1}) \\ &= F(-\bar{\pi}_m^{n+1}) - F(-\bar{\pi}_m^n), \end{aligned} \quad (4)$$

where $F(\cdot)$ is the cumulative distribution function of u_{m0} . If a firm does not enter a market, its payoff in that market is normalized to zero. Therefore,

$$\begin{aligned} P(N_m = 0) &= \Pr(\pi_m^1 < 0) \\ &= F(-\bar{\pi}_m^1). \end{aligned}$$

Although restrictive, the model generates closed-form solutions for the probability of each market configuration and is straightforward to estimate.

2.2.2. Unobserved Firm Heterogeneity ($\varepsilon_{mk} \neq \varepsilon_{mk'}$ if $k \neq k'$; $X_{mk} = X_m$ for All k). In this specification, each firm is allowed to be different but only because of unobserved factors. Similar to the previous model, no firm-specific observed information is incorporated in the model. This model is able to predict only the number of entrants in the market (but not their identities):

$$N_m = \max_n \{n : \#\{k : \pi_{mk}(n, \varepsilon_{mk})\} \geq 0\}. \quad (5)$$

Because the number of entrants is uniquely determined, we can base an estimation strategy on this unique number of firms. However, even with this simple form of firm heterogeneity, we no longer have

³ The literature on entry games focuses on pure strategy Nash equilibria for simplicity. However, it may be important to allow for mixed-strategy equilibria when making inferences about the payoff structure of a game in certain applications. For instance, suppose there are two potential entrants in a market. If we observe that both firms choose to enter, we may infer that the competition effect is small or the market conditions are good. However, with mixed-strategy equilibria, the entry by both may merely be the result of a randomization by firms. Therefore, ruling out the mixed-strategy equilibria may underestimate the competition intensity.

a closed-form solution. Berry (1992) proposes a simulation method to solve this problem, which involves defining a prediction error as the difference between the observed number of firms and the expected number of firms $E(N | X_m; \beta, \delta, \eta)$ from the model:

$$v_m \doteq N_m - E(N | X_m; \beta, \delta, \eta). \quad (6)$$

By construction, v_m is mean independent of the exogenous data when it is evaluated at the true parameter values:

$$E[v_m | X_m; \beta = \beta^*, \delta = \delta^*, \eta = \eta^*] = 0. \quad (7)$$

Given the condition, either nonlinear regression or generalized method of moments (GMM) can be used to estimate the model, where $E(N | X_m; \beta, \delta)$ is obtained using simulation. In particular, given S draws for the underlying random variables and guesses of β , δ , and η , we can construct the equilibrium number of firms $\hat{N}(X_m, \delta, \beta, u_0^s, u_1^s, \dots, u_{\bar{N}}^s)$, where u_0^s is the unobserved market characteristics, $u_1^s, \dots, u_{\bar{N}}^s$ represents the firm-specific unobservables, and \bar{N} is the number of potential entrants in the market. The estimate of $E(N | X_m; \beta, \delta)$ is

$$E(N | X_m; \beta, \delta) = \frac{1}{S} \sum_{s=1}^S \hat{N}(X_m, \delta, \beta, \eta, u_0^s, u_1^s, \dots, u_{\bar{N}}^s). \quad (8)$$

In our application, we use this “frequency estimator” to construct the predicted number of entrants for each market and use nonlinear regressions to estimate the parameters that minimize the distance between the predicted and the observed number of firms in the data.

2.2.3. Observed and Unobserved Firm Heterogeneity ($\varepsilon_{mk} \neq \varepsilon_{mk'}$; $X_{mk} \neq X_{mk'}$ for $k \neq k'$). This final specification allows for firm-specific observed characteristics to enter the payoff functions. For example, we may expect firms to enter markets that are closer to their headquarters with a higher probability. Similarly, firms targeting a specific segment—say, leisure travelers—may be more likely to enter holiday markets. Besides complication in estimation, the cost of allowing such firm heterogeneity is that there might be multiple equilibria in a simultaneous-move game. We follow Berry (1992) and assume that firms make decisions sequentially and that the order of moves is determined by firms' profitability (i.e., the firm with the highest profit moves first). Given the sequential-move assumption, we can construct moment conditions on the basis of the identities of entrants in the market:

$$\begin{aligned} E[v_{mk} | X_{mk}, \beta = \beta^*, \delta = \delta^*, \eta = \eta^*] &= 0, \quad \text{where} \\ v_{mk} &= y_{mk} - E(y_{mk} | X_{mk}; \beta = \beta^*, \delta = \delta^*, \eta = \eta^*). \end{aligned} \quad (9)$$

Note that the observed market structure y_m is now an $\bar{N} \times 1$ vector, where \bar{N} is the number of potential entrants in the market. Each element of y_m , y_{mk} , is an indicator variable that equals 1 if firm k enters the market m and 0 otherwise. The term $E(y_m | X_{mk}; \beta, \delta)$ is the predicted market structure. With M independent markets, a sample analog of the GMM estimation procedure based on the derived moment restriction that v_{mk} is uncorrelated with the exogenous data X_{mk} is

$$\bar{g}(\theta) = \frac{1}{M} \sum_m \begin{pmatrix} v_{m1} \\ v_{m2} \\ \vdots \\ v_{m\bar{N}} \end{pmatrix} \otimes X_{mk}, \quad (10)$$

and the estimate of $\hat{\theta} = (\hat{\beta}, \hat{\delta}, \hat{\eta})$ is chosen to minimize

$$G(\theta) = \bar{g}(\theta)' A \bar{g}(\theta), \quad (11)$$

where A is the weighting matrix.

This model discussed above is quite general, allowing for firm-specific profit functions, and can be directly applied in industries with a few firms. For example, Manuszak and Moul (2007) study office supply stores and focus on three firms: Staples, Office Depot, and OfficeMax. Similarly, Zhu et al. (2008) analyze entry decisions in the retail discount industry and explicitly model firm identities for Wal-Mart, Target, and Kmart. However, in the current application, we have a total of 17 distinct firms. Restricting attention to national players and lumping all regional firms as one still leaves us with nine firms, which makes the estimation cumbersome. Our approach to deal with the problem is to classify the eight national firms into either “business” or “leisure” on the basis of their stated primary business segment from their annual reports. In addition, all smaller regional players are classified as “other.” Thus, our empirical application involves three estimation equations for each market:

$$\begin{aligned} v_m^O &\doteq N_m^O - E(N^O | X_{mk}; \beta, \delta, \eta), \\ v_m^B &\doteq N_m^B - E(N^B | X_{mk}; \beta, \delta, \eta), \\ v_m^L &\doteq N_m^L - E(N^L | X_{mk}; \beta, \delta, \eta), \end{aligned}$$

where v_m^O is the prediction error of “other” entrants, and v_m^B and v_m^L are prediction errors of the number of entrants targeted at business travelers and leisure travelers, respectively. The GMM estimation procedure is based on the derived moment restriction that $(v_m^O, v_m^B, v_m^L)'$ are uncorrelated with the exogenous

data X_{mk} and with M independent markets; the sample analog is

$$\bar{g}(\theta) = \frac{1}{M} \sum_m \begin{pmatrix} \hat{v}_m \\ \hat{v}_m^B \\ \hat{v}_m^L \end{pmatrix} \otimes X_{mk},$$

where

$$\begin{pmatrix} \hat{v}_m^O \\ \hat{v}_m^B \\ \hat{v}_m^L \end{pmatrix}$$

is the frequency estimator of the prediction errors. An estimate of $\hat{\theta} = (\hat{\beta}, \hat{\delta}, \hat{\eta})$ is chosen to minimize

$$G(\theta) = \bar{g}(\theta)' A \bar{g}(\theta).$$

Following the traditional method of moments technique, we first set A equal to the identity matrix and then update it using the sample variance of the individual moment conditions.

2.3. Correcting for Endogenous Market Structure in the Price Equation

Having estimated the parameters from the latent payoff functions, we derive correction terms that will be inserted in the price regression to correct for the potential correlation between the price errors and the market structure variables. More formally, we specify the correlation of the error terms for the prices and the entry payoffs as follows:

$$\begin{pmatrix} u_{m0} \\ \varepsilon_{mk}^p \end{pmatrix} \sim BVN \left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho \\ \rho & \sigma^2 \end{pmatrix} \right), \quad (12)$$

where ε_{mk}^p and u_{m0} represent the error terms from the price and entry models, respectively, and ρ is the covariance between the two. With normally distributed error terms, the conditional distribution of ε_{mk}^p given u_{m0} is also normal, and the mean is equal to ρu_{m0} . Note that u_{m0} is not observable, but we are able to infer the range of u_{m0} given the observed market characteristics and the market structure at market m . We can represent the expectation of the error term in price regression by using iterated expectation as follows:

$$E[\varepsilon_{mk}^p | X_{mk}, N_m] = \rho E[u_{m0} | X_{mk}, N_m].$$

Given the observed number of firms N_m , we can specify the price regression as follows:

$$\ln p_{mk} = Z_{mk} \theta + f(N_m, \delta_p) + \rho E[u_{m0} | X_{mk}, N_m] + v_{mk}^p, \quad (13)$$

where $v_{mk}^p = \varepsilon_{mk}^p - E[\varepsilon_{mk}^p | X_{mk}, N_m]$ is now the pure idiosyncratic error term affecting prices. In the empirical application, we insert the estimates of

$E[u_{m0} | X_{mk}, N_m]$ from the first-stage entry model⁴ in the price regression such that the covariance between u_{m0} and ε_{mk}^p , ρ , becomes an additional parameter to be estimated.

With no firm heterogeneity, the expression of $E[u_{m0} | X_{mk}, N_m]$ has a closed form and can be easily obtained as follows:

$$E[u_{m0} | N_m, X_m] = \int_{-\bar{\pi}_m^{N_m}}^{-\bar{\pi}_m^{N_m+1}} \varepsilon \frac{\phi(\varepsilon)}{\Phi(\bar{\pi}_m^{N_m}) - \Phi(\bar{\pi}_m^{N_m+1})} d\varepsilon$$

$$= \frac{\phi(\bar{\pi}_m^{N_m}) - \phi(\bar{\pi}_m^{N_m+1})}{\Phi(\bar{\pi}_m^{N_m}) - \Phi(\bar{\pi}_m^{N_m+1})}. \quad (14)$$

We can derive a similar error correction term from the entry model that allows for firm heterogeneity. Note, however, that with firm heterogeneity, there is no closed form solution for $E[u_{m0} | X_{mk}, N_m]$ so that we rely on simulation techniques. In particular, given a set of parameter values $(\hat{\beta}, \hat{\delta})$ from the first-stage entry model and a set of random draws capturing the unobservables, we solve for the equilibrium market structure in market m . Let ω_m^r denote the solved equilibrium (i.e., the predicted entry decisions) for the r th draw. We repeat the procedure for R sets of random draws to obtain a consistent estimate of the conditional expectation of the market unobservables:

$$\hat{E}[u_{m0} | X_{mk}, N_m] = \frac{1}{R} \sum_{r=1}^R u_{m0}^r 1(\omega_m^r = y_m | X_{mk}; \hat{\beta}, \hat{\delta}, \hat{\eta}), \quad (15)$$

where y_m is a variable representing the observed entry decisions of the firms, and $1(\omega_m^r = y_m | X_{mk}; \hat{\beta}, \hat{\delta}, \hat{\eta})$ is an indicator function that equals 1 if the predicted entry outcomes from the r th draw are consistent with the observed outcome and 0 otherwise. This simulator yields an estimator that is consistent as the number of simulations grows large.⁵

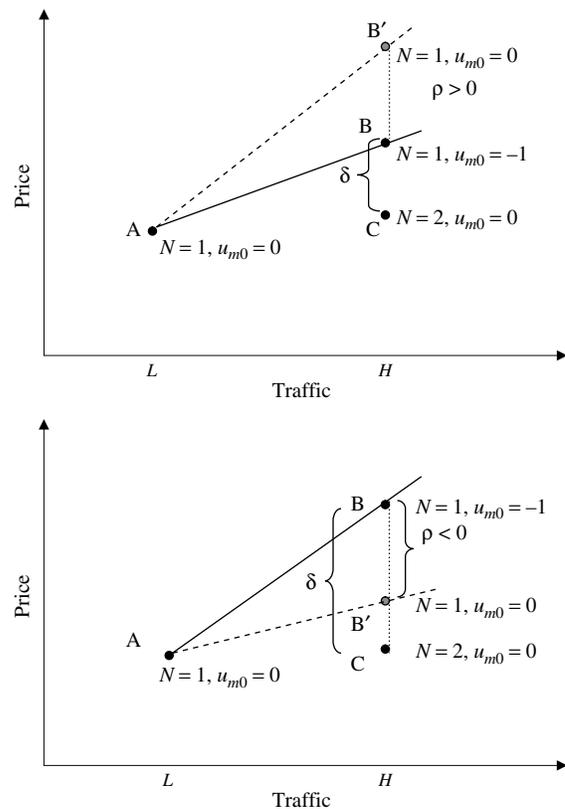
The two-stage procedure described above is relatively straightforward to account for the endogeneity of market structure in regressions attempting to study the relationship between prices or profits and market concentration. To illustrate how the competitive interaction parameters may be biased by ignoring the endogeneity of market structure, consider the following simple example: Suppose our sample consists of three airport markets for which we observe the number of car rental firms and corresponding prices. For simplicity, assume that the only observed market condition in our data is airport traffic, which is either

high (H) or low (L). In addition, there are market-specific unobservables u_{m0} that impact firms' entry decisions and are assumed to take one of two values: 0 or -1 . Suppose that the observed prices, market structure, traffic, and unobservables from the three markets are as follows:

Market	Number		Unobservable u_{m0}	Price
	Traffic	of firms		
A	L	1	0	p_A
B	H	1	-1	p_B
C	H	2	0	p_C

Here, Market B has high traffic, but only one firm enters this market due to unobserved negative shocks ($u_{m0} = -1$). These negative shocks could be related to cost factors (e.g., high wages) or to demand factors (e.g., good public transportation), both of which are likely to deter entry. At the same time, these negative shocks could influence firms' pricing decisions. However, note that the impact of these unobservables will be different on market structure and prices, depending on whether the cost or demand factors dominate. For example, negative demand shocks result in lower entry and lower prices, whereas high costs result in lower probability of firm entry but higher prices. Figure 1 illustrates the bias depending on the direction of

Figure 1 Illustration of Estimation Bias



⁴Note that if a firm's payoff is not affected by its competitors' entry decisions, i.e., $\delta = 0$ in the first-stage entry model, the model reduces to the Heckman-type single-agent framework.

⁵An additional concern when constructing the standard errors of parameter estimates in price regressions is that we need to worry about the uncertainty around our first-stage estimates, for which we rely on a bootstrap technique.

correlation, which is also summarized in the following table. The correlation between the unobserved factors influencing prices and entry is represented by ρ , and δ_{true} and θ_{true} represent the competition and traffic parameters in the price regression. When the correlation is positive, both δ_{true} and θ_{true} are underestimated, whereas the opposite is true for $\rho < 0$.

	True parameter values	Biased estimates	$\rho > 0$	$\rho < 0$
Competition effect	$\delta_{\text{true}} = p_B - p_C$	$\delta = p_B - p_C$	$\delta_{\text{true}} > \delta$	$\delta_{\text{true}} < \delta$
Sensitivity to traffic	$\theta_{\text{true}} = \frac{p'_B - p_A}{H - L}$	$\theta = \frac{p_B - p_A}{H - L}$	$\theta_{\text{true}} > \theta$	$\theta_{\text{true}} < \theta$

3. Data Description

Our application in this paper is to the auto rental industry, which began as early as 1918 with small operators providing car rentals to people in local markets. Currently, the industry is fairly consolidated, with eight major firms and a host of regional operators that conduct their operations through a combination of company-owned and licensee-operated locations. These firms serve both business and leisure travelers, although different firms may focus more on a particular segment. These firms offer services in local markets as well as commercial airports. The local city locations typically target individuals who need a vehicle for special occasions, insurance replacements, or repairs, whereas the airport locations are primarily geared toward business and leisure travelers. With the deregulation in the airline industry, the number of airport locations has grown dramatically over the years, now accounting for a significant proportion of revenues for most companies. For example, Hertz generates 90% of its revenues from its airport locations in the United States (2003 annual report). In this study, we focus on the airport car rental locations, for which we develop an original database that consists of three major pieces of information: (1) a list of all domestic commercial airports and the exogenous variables describing each airport, (2) the number and identities of all car rental companies operating at those airports, and (3) the rental prices for each car type (e.g., economy, full-size).

Given the three pieces of information, the auto rental industry seems quite suitable for the purpose of this study for several reasons. First, our data are complete in that we have been able to collect information on the number of firms and prices for every commercial airport in the country. Second, our focus on only airport locations makes the market definition reasonably clean because these locations tend to target customers who fly into the airport. Although to a certain extent the airport locations compete with the

outlets in downtowns or other city locations that we do not consider, the market definition is significantly cleaner than previous applications (e.g., in retailing or banking industries). Finally, the price information in this industry is also reasonably easy to collect and compare across firms and markets because these are single-product firms, with car rental being the primary business. However, we should point out that these firms also generate revenues by providing ancillary products and services, such as supplemental equipment (e.g., child seats, ski racks, cell phones, navigation systems), insurance, and gasoline payment options, for which we do not have any information. Nevertheless, the problem is not as severe as with multiproduct operations such as supermarkets and hospitals.

Our data collection strategy relies on various sources. First, we use the list of commercial airports provided by the Federal Aviation Administration. This list consists of the airport codes, full names, and addresses (city, state, and zip codes) for all commercial airports in the country, including Alaska and Hawaii. For each of these airports, we use the aviation data provided by the Bureau of Transportation Statistics to collect information on the air traffic variables. These include measures on the total number of passengers and information on the number of major airlines flying into the airport. Finally, we use the airport addresses to collect information on various demand and cost factors using data from the U.S. Census Bureau, the Bureau of Labor Statistics, and the COMPUSTAT.

The full list of variables describing each airport appears in Table 1. The first set includes the standard variables that capture the demand (e.g., population) and cost (e.g., wages) conditions in a market. The variable “Traffic_2004” is the total number of passengers flying into the airport in 2004. Because the primary clientele for car rentals at the airport locations tends to be passengers flying into the airport, we expect this variable to play a major role in determining the number of car rental firms that operate.

Table 1 Summary Statistics

Variables	Mean	Std. dev.
Population	412,269.97	966,758.39
Pop. growth	0.14	0.16
Poverty ratio	0.13	0.05
Retail wages	21,800.54	3,211.57
Housing value	79,350	49,777
Traffic_2004	1,267,136.46	3,633,197.91
No. of HQ	6.69	19.53
Pub_Ratio	0.02	0.05
Holiday	0.09	0.29
Hub	0.08	0.27

Table 2 Airport Traffic and Prices by Market Structure

Market structure	<i>N</i>	Traffic	Economy	Compact	Mid	Standard	Full
No firms	19	2,637	na	na	na	na	na
Monopoly	68	6,401	45	49	53	56	61
Duopoly	66	16,927	43	45	49	52	56
Oligopoly-3	49	38,656	41	43	47	51	53
Oligopoly-4	33	60,582	40	42	45	50	51
Oligopoly-5	33	146,821	37	39	44	47	49
Oligopoly-6	49	731,332	35	37	42	46	48
Oligopoly-7	37	702,145	34	36	40	44	45
Oligopoly-8	53	2,747,626	35	36	41	45	47

The variable “No. of HQ” is the number of large corporations (with annual sales over \$100 million) that have their headquarters located in the market, and the variable “Pub_Ratio” is the percentage of population in the market that uses public transportation to get to work. This variable serves as the proxy for public transportation infrastructure in a market, which can be considered as a substitute for renting cars. Finally, “Holiday” represents holiday airports, such as Miami, Las Vegas, and Atlantic City, and “Hub” is a dummy variable that indicates whether the airport is a hub of any major airlines.

Our next major piece of data includes the number and identities of all car rental companies that operate at each airport. We collected this information from Orbitz and Expedia websites as well as from individual firms. In Table 2, we report the observed market structures in this industry, along with a distribution of airport traffic for each market structure. We use a total of 407 airports in the analysis and exclude airports from Alaska and an additional nine markets with missing variables. As Table 2 shows, we observe a wide range of market structure in this industry, ranging from more than 130 airports with either a monopoly or duopoly to more than 50 very competitive markets with eight firms. We can also observe that the number of firms increases with demand, as measured by the airport traffic.

The final piece of information in our database is the daily rental prices of the cars at all the airports. The prices are for the rental period from 10 A.M. Monday, March 21, 2005, to 10 A.M. Tuesday, March 22, 2005. The price information was collected on Monday, March 14, exactly one week in advance.⁶ We collected the prices on five popular car types: economy, compact, mid-size, standard, and full-size; we excluded special vehicles, such as minivans and SUVs, because these tend to be available in only a few markets.

⁶Note that the actual prices paid might not be the same as the posted prices, particularly for corporate clients that may have special contracts with individual firms. We repeated our entire exercise using weekend rental prices (with probably few corporate travelers), and the findings are similar to those reported in the paper.

In Table 2, we display the average prices for each car type under different competitive structures. Two patterns are apparent from the distribution of prices shown in Table 2. The prices increase by car size from economy to full-size, and prices tend to fall with competition. However, in our data, there is wide dispersion in prices within market structure, suggesting the need for other control variables. We discuss these issues further in the next section.

4. Results

We now present the results from the model and data discussed above. We provide estimates from the first-stage entry model, followed by the price regressions, and then we discuss the implications of the bias when treating market structure variables as exogenous.

4.1. First-Stage Entry Estimates

We rely on the variables outlined in the data section to capture the factors that affect firms’ entry decisions. Profits and entry costs at any airport location depend on a large number of factors, including agreements between car rental firms and airport authorities through negotiations and/or bidding processes. These agreements provide for concession payments based upon a specified percentage of revenue generated at the airport, subject to a minimum annual fee, and often include fixed rent for terminal counters or other leased properties and facilities. Unfortunately, we do not observe many of these factors and rely primarily on the observed market characteristics.

We estimate three alternate models to describe the factors that affect firms’ entry decisions: (1) no firm heterogeneity, (2) only unobserved heterogeneity, and (3) observed and unobserved firm heterogeneity. The left column of Table 3 presents the parameter estimates based on the model that ignores firm heterogeneity and is similar to the model considered in BR and subsequent applications (e.g., Manuszak and Moul 2007). Most of the parameter estimates seem reasonable and in the correct direction. The profitability of a market is increasing in market size, which is captured by annual airport traffic, population in

Table 3 Parameter Estimates from Entry Model

Variable	With heterogeneity					
	Without heterogeneity		With unobserved heterogeneity only		With unobserved and observed heterogeneity	
	Parameter est.	Std. error	Parameter est.	Std. error	Parameter est.	Std. error
Intercept	2.674	0.182	3.025	0.155	0.695	0.170
No. of HQ	0.120	0.045	0.121	0.041	0.155	0.047
Holiday	0.740	0.231	0.743	0.212	0.726	0.216
Hub	0.117	0.276	0.099	0.257	0.184	0.261
Poverty ratio	0.078	0.060	−0.068	0.058	−0.008	0.070
Pub_Ratio	−0.305	0.070	−0.306	0.067	−0.284	0.044
Log(Traffic_2004)	1.757	0.097	1.647	0.082	1.577	0.090
Population growth	0.147	0.060	0.100	0.058	0.103	0.046
Log(Population)	0.406	0.096	0.417	0.093	0.343	0.069
Retail wages	−0.136	0.086	−0.143	0.082	−0.119	0.094
Housing value	−0.034	0.071	−0.038	0.068	−0.052	0.079
Midwest	−0.042	0.173	−0.069	0.170	−0.061	0.172
South	0.265	0.169	0.309	0.165	0.455	0.252
West	0.099	0.1715	0.160	0.167	0.117	0.179
Observed heterogeneity						
Business					1.087	0.123
Business × no. of HQ					0.093	0.094
Leisure					0.141	0.039
Leisure × holiday					1.786	0.811
Dummy_car HQ					0.224	0.106
Number of firms (δ)	−0.702	0.0273	−0.650	0.016	−0.346	0.024
Correlation (η)			0.399	0.027	0.506	0.014

the market in which the airport is located, and the population growth rate in that market. The local population, airport traffic, and population growth rates have a statistically significant impact on demand. To capture the costs of entry, we use retail wages, real estate prices in the market, and regional dummies that capture any systematic differences in fixed costs across airports in different parts of the country. Firms' entry profits decrease with retail wages and, given the same market characteristics, are higher in airports in the South. The estimate for number of HQ of large companies is positive, suggesting that the presence of headquarters captures attractiveness of market conditions beyond what local demographic characteristics capture. Similarly, the positive coefficient for the Holiday dummy suggests that profitability is higher in holiday markets. Finally, the estimate for Pub_Ratio, a variable we include to capture the convenience of public transportation, has a strong negative impact, which is intuitive because a good public transportation infrastructure can be considered as a substitute for renting cars. The estimate of the competition effect, δ , indicates that the number of rivals in the market is an important determinant of profitability, because entry by additional competitors reduces profits significantly.

The middle column of Table 3 shows the results of the entry model that only allows for unobserved

heterogeneity. The results are more or less consistent with those we discussed previously. However, we estimate one more parameter, η , that captures how the unobserved component in firms' profitability is correlated with each other and is found to be highly significant. The right column of Table 3 shows the results of the entry model with both observed and unobserved heterogeneity discussed in §2. Unlike the other two models, this specification allows for firm-specific observed variables to enter the latent profit function. In particular, using the firms' annual reports, we create dummy variables for "Business" or "Leisure" depending on whether a particular firm primarily serves business or leisure clientele. These two variables also interact with "No. of HQ" and "Holiday" variables discussed above. Finally, we create a dummy variable for all airports that are located in the state or in surrounding states in which the firm's headquarters is located.

Comparing the estimates from the middle column with the results from the full model, we find that most of the parameters are more or less comparable in both direction and magnitude. On average, the business-type firms earn higher profits because the parameter estimate for the business dummy is positive and larger than the estimate for the leisure dummy. Examining the interactions between market conditions and firm types, we find that leisure-type firms benefit more if they are present in holiday markets, which is

Table 4 Pooled Estimation Results from Price Regression

Variable	Estimates without correction				Estimates with correction			
	Model 1		Model 2		Model 3		Model 4	
	Parameter	Std. error	Parameter	Std. error	Parameter	Std. error	Parameter	Std. error
Intercept	3.651	0.017	3.475	0.025	3.562	0.022	3.188	0.044
Log(March traffic)	0.019	0.002	0.022	0.002	0.040	0.004	0.043	0.003
PopulationD	1.154	0.262	1.124	0.263	1.585	0.270	1.509	0.266
Retail wages	0.010	0.004	0.011	0.004	0.013	0.004	0.014	0.004
Pub_Ratio	0.007	0.005	0.005	0.005	-0.009	0.005	-0.010	0.005
No. of HQ	-0.006	0.003	-0.006	0.003	0.002	0.003	0.003	0.003
Poverty ratio	-0.001	0.003	-0.001	0.003	0.000	0.003	-0.001	0.003
Holiday	-0.081	0.008	-0.076	0.009	-0.052	0.010	-0.046	0.009
In-terminal	0.059	0.007	0.056	0.007	0.060	0.007	0.057	0.007
Economy	-0.148	0.007	-0.148	0.007	-0.147	0.007	-0.147	0.007
Compact	-0.103	0.007	-0.103	0.007	-0.103	0.007	-0.103	0.006
Standard	0.092	0.007	0.092	0.007	0.092	0.007	0.092	0.007
Full-size	0.115	0.006	0.115	0.006	0.115	0.006	0.115	0.006
Midwest	-0.020	0.007	-0.025	0.007	-0.026	0.007	-0.033	0.007
South	0.024	0.007	0.024	0.007	0.038	0.007	0.040	0.007
West	0.004	0.007	0.003	0.007	0.006	0.007	0.003	0.007
No. of firms	-0.018	0.002	na	na	-0.041	0.004	na	na
Monopoly	na	na	0.136	0.017	na	na	0.311	0.028
Duopoly	na	na	0.105	0.014	na	na	0.254	0.023
Oligopoly-3	na	na	0.123	0.011	na	na	0.247	0.019
Oligopoly-4	na	na	0.110	0.011	na	na	0.214	0.017
Oligopoly-5	na	na	0.111	0.010	na	na	0.196	0.015
Oligopoly-6	na	na	0.050	0.008	na	na	0.112	0.011
Oligopoly-7	na	na	0.005	0.007	na	na	0.041	0.009
Error correction	na	na	na	na	0.036	0.006	0.038	0.005

Notes. All regressions include firm fixed effects that are suppressed for brevity. We use mid-size car prices as base. na, not available.

intuitive. Finally, we find that firms are more likely to enter the markets that are closer to their headquarters. The competition effect estimate from the third model is smaller than the estimates from the other two models. Note that the magnitude of the competition parameter is not directly comparable across models because of different normalization. However, we can compare the relative importance by calculating the ratio of the competition parameter to some estimate of demand, e.g., annual traffic, and the competition effect estimate from the third model is smaller than the other two models. A potential explanation for this is that the full model explicitly accounts for the “superiority” of the early entrants in the market. Recall that the full model allows for the more profitable firm to enter first due to the sequential move assumption. The competition parameter in these models is inferred from the difference between the market characteristics in concentrated (e.g., monopoly) markets and those in the more competitive markets. If firms’ payoffs are the same, i.e., there is no heterogeneity across potential entrants, firms’ profits are lower in the competitive markets only due to the competition. However, if we allow for heterogeneity across firms and assume that the most profitable firm moves first, the difference between a firm’s payoff in

a competitive market and, say, a monopolist’s payoff is driven not only by the intensity of competition but also the superiority of the monopolist. Therefore, we may expect a lower competition parameter estimate after we control for such superiority in the full-entry model.

4.2. Price Regressions

The first-stage entry estimates, although interesting on their own, serve mainly as a tool for correcting potential endogeneity in the price regression. Our primary objective in the paper is to study the relationship between prices and market structure. Our data include the prices from every firm serving the market for five car types: economy, compact, mid-size, standard, and full-size. In what follows, we pool the data across firms and car types and regress the log of prices against firm and car type fixed effects, other market-specific covariates, and a market structure variable, which is captured using two specifications: (1) total number of firms⁷ and (2) an indicator variable for monopoly, duopoly, and so on. We

⁷ Using log (number of firms) produces similar results.

subsequently present the results for each car type separately to determine whether the competition differs across product types.

The results from the regression appear in Table 4. The unit of analysis in these regressions is the log of price for each firm and car type. We use seven market-specific covariates: Log(March traffic), PopulationD (population density in the market), Retail wages, Pub_Ratio (percentage of population that uses public transportation to get to work), No. of HQ (the number of headquarters for major firms in the market), Poverty ratio (measure of income), and Holiday (an indicator variable for holiday destinations). Note that the airport traffic in the price regression is the total number of passengers flying into the airport in March 2005, the month in which our price data are collected, but not the annual airport traffic in 2004, as used in the first-stage model. Finally, note that all regressions include 16 firm fixed effects that are suppressed for brevity.

The left panel in Table 4 shows the results from the models that ignore the endogeneity of market structure variables. The first specification uses the total number of firms in the market to capture the competitive structure, and the second uses a more flexible indicator variable specification to capture the nonlinearities in the relationship between prices and the number of firms in the market. In general, the control variables have the expected sign. Prices tend to be higher in markets with greater traffic, population density, and higher retail wages, whereas markets that are holiday destinations tend to have lower prices. The variable “In-terminal” is an indicator variable that takes a value of 1 if the car is offered inside the airport terminal and 0 otherwise. The parameter estimate shows that the prices are significantly higher for such convenience. In terms of car type, the parameters are of the expected sign. Economy cars are approximately 15% cheaper and full-size cars are 12% more expensive compared with mid-size cars. Finally, the regional indicator variables suggest that prices are highest in airports in the South and lowest in the Midwest. With respect to the more interesting parameters capturing the competitive structure, the results from the first column indicate that adding an equivalent of one additional firm at the airport reduces the price by approximately 2%. Column 2 uses a more flexible specification and shows that monopoly markets have prices that are approximately 14% higher than highly competitive markets with eight firms.

The right panel in Table 4 shows the regression results after we insert the term that corrects for the endogeneity of market structure. Note that this correction term is derived from the first-stage model that incorporates observed and unobserved firm heterogeneity in entry decisions (i.e., the full model

in Table 3). The last row in columns 3 and 4 shows the estimated parameter that represents the correlation between the unobservables that affect the prices and the payoff functions underlying firms’ entry decisions. The parameter is similar in magnitude in both columns and is precisely estimated. The estimate is positive, suggesting that the unobserved factors affect both observed prices and probability of firm entry in the same way. Recall from our discussion in §2.3 that a positive coefficient results in an underestimation of the competition parameters. Comparing the control variables across the models that correct for this endogeneity and the models in columns 1 and 2, we find that the parameters for some of the market-specific variables change somewhat, but there is little change in the In-terminal or car-type fixed effects. The greatest change, however, is in the parameters of primary interest—those that capture the competitive interactions. In particular, examining the No. of firms parameter in Model 3, we find that the impact of an additional entrant in the market is almost twice that suggested by Model 1. A similar picture appears when we use a dummy variable specification. For example, the monopoly prices are approximately 30% higher than the base of the eight-firm oligopoly versus 14%, as suggested by Model 2. As we discussed in §2, this finding is consistent with the notion that unusually attractive demand conditions encourage entry while also supporting higher prices.

We next explore how competition effects vary by car types. For this we run separate regressions for the five car types in our data: economy, compact, mid-size, standard, and full-size. These regressions include the same set of explanatory variables as those in Table 4, including firm fixed effects, and we run them separately for each car type. Since the results were similar for “Large” (mid-size, standard, and full-size) and “Small” (economy and compact) cars, we pool the data for these products for brevity. The results are presented in Table 5. We present the results from regressions without correction for endogeneity of market structure, and for comparison we report the estimates using correction terms derived from the first-stage model that ignores firm heterogeneity and the full model as in Table 4.⁸ Looking at the parameter estimates, a few patterns are apparent. First, in terms of control variables, the coefficients are in the same direction and in similar magnitude for both car types. In terms of the variables capturing the market structure, it appears that the competition is more intense for the smaller (economy and compact) cars, which is probably driven by higher price sensitivity for these customers. Comparing the correction results from the

⁸ Results from model with only unobserved heterogeneity are similar to the full model.

Table 5 Estimation Results from Price Regression for Different Car Types

Variable	Estimates with correction															
	Estimates without correction				Symmetric firms											
	Small cars		Large cars		Small cars				Large cars				Full model			
	Est.	Std. error	Est.	Std. error	Est.	Std. error	Est.	Std. error	Est.	Std. error	Est.	Std. error	Est.	Std. error		
Intercept	3.292	0.042	3.580	0.031	2.915	0.073	3.263	0.054	2.983	0.074	3.309	0.055				
Log(March Traffic)	0.025	0.003	0.021	0.003	0.052	0.006	0.044	0.004	0.047	0.005	0.040	0.004				
PopulationD	1.068	0.444	1.157	0.329	1.028	0.442	1.128	0.328	1.482	0.450	1.522	0.334				
Retail wages	0.006	0.007	0.014	0.005	0.002	0.007	0.010	0.005	0.010	0.007	0.017	0.005				
Pub_Ratio	0.004	0.008	0.006	0.006	-0.006	0.008	-0.003	0.006	-0.012	0.009	-0.009	0.007				
No. of HQ	-0.008	0.005	-0.004	0.004	0.003	0.005	0.005	0.004	0.001	0.005	0.004	0.004				
Poverty ratio	-0.001	0.004	-0.001	0.003	0.002	0.004	0.001	0.003	-0.001	0.004	-0.001	0.003				
Holiday	-0.061	0.014	-0.085	0.011	-0.061	0.014	-0.084	0.011	-0.030	0.016	-0.057	0.012				
In-terminal	0.058	0.012	0.056	0.009	0.061	0.012	0.059	0.009	0.058	0.012	0.056	0.009				
Midwest	-0.019	0.012	-0.028	0.009	-0.033	0.013	-0.041	0.009	-0.028	0.013	-0.036	0.009				
South	0.023	0.012	0.026	0.009	0.024	0.012	0.028	0.009	0.039	0.012	0.041	0.009				
West	0.005	0.012	0.001	0.009	-0.001	0.012	-0.003	0.009	0.005	0.012	0.002	0.009				
Monopoly	0.175	0.030	0.115	0.021	0.420	0.049	0.321	0.036	0.362	0.047	0.280	0.034				
Duopoly	0.135	0.024	0.086	0.017	0.335	0.040	0.255	0.029	0.296	0.039	0.227	0.029				
Oligopoly-3	0.164	0.020	0.096	0.014	0.319	0.032	0.227	0.023	0.297	0.033	0.214	0.024				
Oligopoly-4	0.137	0.019	0.092	0.014	0.271	0.029	0.205	0.021	0.249	0.029	0.191	0.022				
Oligopoly-5	0.124	0.017	0.101	0.013	0.248	0.026	0.206	0.019	0.216	0.025	0.182	0.018				
Oligopoly-6	0.074	0.013	0.034	0.010	0.164	0.019	0.109	0.014	0.140	0.018	0.092	0.014				
Oligopoly-7	0.028	0.012	-0.012	0.009	0.081	0.015	0.033	0.011	0.068	0.015	0.023	0.011				
Error correction	na	na	na	na	0.046	0.007	0.039	0.005	0.041	0.008	0.036	0.006				

Notes. “Large” refers to mid, standard, and full-size cars; “Small” refers to economy and compact cars. na, not available.

model with homogenous firms and the full model, we find that directionally they are consistent in that the competitive parameters increase in magnitude after the correction term is inserted. All estimates for the parameter representing the correlation between the unobservables that affect the prices and the payoff functions are positive, suggesting that the unobserved factors affect both observed prices and probability of firm entry in the same way. While the magnitude of change is slightly greater for the homogenous model, there are large changes in the competitive parameters under all model specifications and for both car types. Thus the specification of the first-stage entry model does not seem to impact the correction procedure in our application. Nevertheless, it may be important in other industries and applications to test the robustness of results to the first-stage model specification.

5. Discussion

We investigate the relationship between prices and the number of firms in the auto rental industry. Our work follows the long stream of literature in economics and marketing that has examined relationships between market structure measures and prices, markups, revenues, or profits (e.g., Weiss 1989, Buzzel and Gale 1987). Typically, this type of application involves a regression of the outcome variable of interest on a market structure variable such as concentration ratios or the number of firms. However,

regressions of this type are problematic because market structures are not randomly assigned, a necessary condition for a standard regression model to yield consistent estimates of the relationship between market structure and an outcome variable. The results presented above show that the resulting bias in the competitive interaction parameters can be severe and can bring into question the conclusions drawn from the previous studies using such regression techniques. Furthermore, the magnitude of bias in the OLS regressions can have important policy implications. As discussed in §1, such price regressions are often used by the FTC to predict price and welfare effects of mergers. Because the negative ramifications of market concentration on prices are underestimated, our results suggest that horizontal mergers in this industry may incorrectly appear innocuous when using a model that ignores the endogeneity of market structure.

The two-stage estimation procedure outlined in the paper can also be useful in making predictions due to the changes in exogenous variables. For example, consider the change in prices due to an exogenous change in airport traffic. According to the price regressions reported above, the coefficient of traffic is positive, indicating that an increase in demand results in higher prices. However, it is important to understand the source of the increase in traffic—that is, whether it is a short-term demand shock or a long-term change of market condition. If it is a short-term event, e.g.,

a sports competition that attracts a lot of travelers to the airport, we expect prices to go up because of the higher demand. However, if the higher traffic is driven by a long-term factor, e.g., a new resort, the answer becomes subtle. In particular, according to the parameter estimates from the entry model, a permanent increase in traffic (which is an important determinant of the number of firms) may induce additional competitors to enter the market, leading to lower prices.

From a methodological point of view, our approach provides an alternative to the methods used by Evans et al. (1993), who study the price concentration in the airline industry. These authors observe a panel data structure and use a combination of fixed effects and instrumental variable procedures to account for the endogeneity of market structure. As noted in §1, such panel data with substantial entry and exit over time are rarely available. In light of the cross-sectional data used in majority of applications in this area, our approach, in which we explicitly model the determinants of underlying market structure, can provide a useful alternative. However, the validity of the correction procedure depends on the correct specification of the first-stage entry model. In this paper, we tried three model specifications and found similar results. Depending on the specific application, models used in Mazzeo (2002b) for discrete heterogeneity, Seim (2006) and Orhun (2006) for firm location, and Zhu and Singh (2007) and Zhu et al. (2008) that allow for firm identities can be considered. All of these papers analyze the underlying market structure variables but have limited or no information on price, quantity, and costs. In the marketing literature, researchers have looked at issues such as reactions to entry (Singh et al. 2006) or changes in the marketing strategies of competitors (Steenkamp et al. 2005), implications of brand-positioning strategies on other marketing mix elements (e.g., Hauser and Shugan 1983, Carpenter 1989), and the impact of short-term marketing activities such as price and advertisement on sales (e.g., Bass 1969). More recent structural work has tried to endogenize such marketing mix activities of firms while treating the market structure variables as exogenous. With availability of data sets with sufficient variation in the number of firms over time or across markets, an interesting area for future inquiry could involve estimating supply and demand functions with endogenous market participants to provide a more complete characterization of the long-run equilibrium in a marketplace.

Acknowledgments

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References

- Asplund, M., R. Sandin. 1999. Competition in interrelated markets: An empirical study. *Internat. J. Indust. Organ.* **17** 353–369.
- Baker, J., D. L. Rubinfeld. 1999. Empirical methods in antitrust litigation: Review and critique. *Amer. Law Econom. Rev.* **1**(1/2) 386–535.
- Bass, F. 1969. A simultaneous equation regression study of advertising and sales of cigarettes. *J. Marketing Res.* **6**(3) 291–300.
- Berry, S. T. 1992. Estimation of a model of entry in the airline industry. *Econometrica* **60**(4) 889–917.
- Berry, S. T., J. Levinsohn, A. Pakes. 1995. Automobile prices in market equilibrium. *Econometrica* **63**(4) 841–890.
- Besanko, D., S. Gupta, D. Jain. 1998. Logit demand estimation under competitive pricing behavior: An equilibrium framework. *Management Sci.* **44**(11) 1533–1547.
- Borenstein, S., N. Rose. 1994. Competition and price dispersion in the U.S. airline industry. *J. Political Econom.* **103** 653–683.
- Bresnahan, T. F. 1989. Empirical studies in industries with market power. R. Schmalensee, R. D. Willig, eds. *Handbook of Industrial Organization*, Vol. II. Elsevier Science Publishing, Amsterdam, 1011–1057.
- Bresnahan, T. F., P. C. Reiss. 1987. Do entry conditions vary across markets? *Brookings Papers Econom. Activity* (3) 833–881.
- Bresnahan, T. F., P. C. Reiss. 1990. Entry in monopoly markets. *Rev. Econom. Stud.* **57**(4) 531–553.
- Bresnahan, T. F., P. C. Reiss. 1991. Entry and competition in concentrated markets. *J. Political Econom.* **99**(5) 977–1009.
- Buzzell, R. D., B. T. Gale. 1987. *The PIMS Principles—Linking Strategy to Performance*. The Free Press, New York.
- Calem, P. S., G. A. Carlino. 1991. The concentration/conduct relationship in bank deposit markets. *Rev. Econom. Statist.* **73**(2) 268–276.
- Carpenter, G. S. 1989. Perceptual position and competitive brand strategy in a two-dimensional, two-brand market. *Management Sci.* **35**(9) 1029–1044.
- Chintagunta, P., J. P. Dube, V. Singh. 2003. Balancing profitability and customer welfare in a supermarket chain. *Quant. Marketing Econom.* **1**(1) 111–147.
- Chintagunta, P., T. Erdem, P. Rossi, M. Wedel. 2006. Structural modeling in marketing: Review and assessment. *Marketing Sci.* **25**(6) 604–616.
- Cotterill, R. 1986. Market power in the retail food industry: Evidence from Vermont. *Rev. Econom. Statist.* **68**(3) 379–386.
- Davis, P. 2005. The effect of local competition on retail prices in the U.S. motion picture exhibition market. *J. Law Econom.* **48**(2) 677–707.
- Demsetz, H. 1973. Industry structure, market rivalry, and public policy. *J. Law Econom.* **16**(April) 1–9.
- Emmons, W. R., R. A. Prager. 1997. The effects of market structure and ownership on prices and service offerings in the U.S. cable television industry. *RAND J. Econom.* **28** 732–750.
- Evans, W. N., L. M. Froeb, G. J. Werden. 1993. Endogeneity in the concentration-price relationship: Causes, consequences, and cures. *J. Indust. Econom.* **61**(4) 431–438.
- Hauser, J., S. Shugan. 1983. Defensive marketing strategies. *Marketing Sci.* **2**(4) 319–360.
- Heckman, J. J. 1976. Common structure of statistical-models of truncation, sample selection and limited dependent variables and a simple estimator for such models. *Ann. Econom. Soc. Measurement* **5**(4) 475–492.
- Kadiyali, V., P. Chintagunta, N. Vilcassim. 2000. Manufacturer-retailer channel interactions and implications for channel power: An empirical investigation of pricing in a local market. *Marketing Sci.* **19**(2) 127–148.

- Kadiyali, V., N. Vilcassim, P. Chintagunta. 1999. Product line extensions and competitive market interactions: An empirical analysis. *J. Econometrics* **89**(1–2) 339–363.
- Khan, R., D. Jain. 2005. An empirical analysis of price discrimination mechanisms and retailer profitability. *J. Marketing Res.* **42**(4) 516–524.
- Keeler, E. B., G. Melnick, J. Zwanziger. 1999. The changing effects of competition on non-profit and for-profit hospital pricing behavior. *J. Health Econom.* **18**(1) 69–86.
- Manuszak, M. D. 2005. Firm conduct in the Hawaiian retail gasoline industry. Working paper, Carnegie Mellon University, Pittsburgh.
- Manuszak, M. D., C. C. Moul. 2007. Prices and endogenous market structure in supply superstores. *J. Indust. Econom.* **56**(1) 94–112.
- Mazzeo, M. J. 2002a. Competitive outcomes in product-differentiated oligopoly. *Rev. Econom. Statist.* **84**(4) 716–728.
- Mazzeo, M. J. 2002b. Product choice and oligopoly market structure. *RAND J. Econom.* **33**(2) 221–242.
- Newmark, C. 2004. Price concentration studies: There you go again. Manuscript prepared for the DOJ/FTC Merger Workshop, “Concentration and Market Shares” panel.
- Orhun, Y. 2006. Spatial differentiation in the supermarket industry. Working paper, Graduate School of Business, The University of Chicago, Chicago.
- Reiss, P. C. 1996. Empirical models of discrete strategic choices. *Amer. Econom. Rev.* **86**(2) 421–426.
- Schmalensee, R. 1989. Inter-industry studies of structure and performance. R. Schmalensee, R. D. Willig, eds. *Handbook of Industrial Organization*, Vol. 2. North-Holland, Amsterdam, 951–1009.
- Seim, K. 2006. An empirical model of firm entry with endogenous product-type choices. *RAND J. Econom.* **37**(3) 619–640.
- Singh, V. P., K. T. Hansen, R. C. Blattberg. 2006. Market entry and consumer behavior: An investigation of a Wal-Mart supercenter. *Marketing Sci.* **25**(5) 457–476.
- Steenkamp, J. E. M., V. R. Nijs, D. M. Hanssens. 2005. Competitive reactions to advertising and promotion attacks. *Marketing Sci.* **24**(1) 35–54.
- Sudhir, K. 2001. Structural analysis of manufacturer pricing in the presence of a strategic retailer. *Marketing Sci.* **20**(3) 244–264.
- Villas-Boas, S. B. 2007. Vertical relationships between manufacturers and retailers: Inference with limited data. *Rev. Econom. Stud.* **74**(2) 625–652.
- Villas-Boas, J. M., R. Winer. 1999. Endogeneity in brand choice models. *Management Sci.* **45** 1324–1338.
- Villas-Boas, J. M., Y. Zhao. 2005. Retailer, manufacturers, and individual consumers: Modeling the supply side in the ketchup marketplace. *J. Marketing Res.* **42**(1) 83–95.
- Weiss, L. 1989. *Concentration and Price*. MIT Press, Cambridge, MA.
- Whinston, M. D. 2003. *Lectures on Antitrust Economics, Chapter 3: Horizontal Mergers*. Working Paper 0041, The Center for the Study of Industrial Organization, Northwestern University, Evanston, IL.
- Zhu, T., V. Singh. 2007. Spatial competition with endogenous location choices: An application to discount retailing. Working paper, Carnegie Mellon University, Pittsburgh.
- Zhu, T., V. Singh, M. Manuszak. 2008. Market structure and competition in the retail discount industry. *J. Marketing Res.* Forthcoming.