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THE CENTER FOR THE STUDY
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AT NORTHWESTERN UNIVERSITY

Working Paper #0003

Product Choice and
Oligopoly Market Structure

By

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Abstract

This paper proposes an empirical model to analyze the effects of product differentiation on oligopoly market structure. Building on prior studies of entry, the model endogenizes firms' product-type decisions and measures how the effects of competitors differ depending on their product types. The model can also accommodate alternative specifications for how the product choice game among oligopolists is played. This permits evaluation of competing explanations for market differentiation outcomes. I estimate the model using data from a cross-section of oligopoly motel markets located along U.S. interstate highways. The motel industry is well-suited for analysis of product choice; firms are characterized by their choice of product quality, which is an important business strategy for motel establishments. The results demonstrate a strong incentive for firms to differentiate their products. The effects of demand characteristics on product choice are also significant. Game specification, however, is of minor importance, even though differences in how entry and product-type decisions are made affect equilibrium market structure predictions in some cases.

I. Introduction

Understanding the causes and consequences of concentrated industry structure continues to pose a formidable challenge for industrial organization economists. Markets in which firms can differentiate their products are especially complex, as each individual firm's product choice affects its own profitability and the extent of product differentiation influences the intensity of competition for all market participants. This paper address one particularly difficult question: what drives the product-type decisions of firms in oligopoly markets? The empirical model estimated in this paper endogenizes firm product choice and can be used to evaluate competing explanations for the resulting product differentiation observed in equilibrium.

Numerous game-theoretic models have been designed to analyze how firms choose their product type and to make equilibrium predictions about the extent of product differentiation in markets. The framework introduced in Hotelling's (1929) classic paper sets up the underlying tradeoff firms face: competition among firms may be less intense if they offer products that are less substitutable, but firms may have an opposing incentive to select an undifferentiated product for which demand is strong. Subsequent models have experimented with various factors that can influence this tradeoff and the resulting array of product types offered by firms in equilibrium. For example, players may choose their product types simultaneously or in some sequence. They may be committed to their choice or have the option to change in response to the decisions of other firms. Price competition may be Bertrand or Cournot, or firms may be somehow able to collude. In each case, product choice and market structure predictions depend critically on the assumptions and specifications of the particular model in question.

Critics of this literature have noted that while theory models could describe the conditions and assumptions under which almost any market structure could be supported, they explained almost nothing about which assumptions were most appropriate.¹ In an effort to bring evidence to bear on the relative usefulness of these theoretical results, interest has been sparked in applying new empirical methods to analyze the structure of product differentiated markets. Several recent papers, including Berry, Levinsohn and Pakes (1995), Goldberg (1995), and Bresnahan, Stern and Trajtenberg (1997) have begun by addressing the consequences of concentration and product differentiation. These models, however, take market structure as given and do not incorporate the supply decisions of firms — whether to enter the oligopoly and each firm's optimal product choice.

¹ See, for example, Fisher (1989), Peltzman (1991) and Sutton (1990, 1997a). Fisher (1991) went on to say that “the principal result of theory is to show that nearly anything can happen.” Sutton (1997) agreed: “The central lesson that has emerged from the game-theoretic literature in Industrial Organization is that most results depend in a delicate way on various details of the model that are hard to measure, identify or proxy.”

This paper focuses on the structure of differentiated product markets, using an equilibrium model that predicts the number of firms operating in a market and the product types each firm has chosen. An equilibrium model is necessary in this context because of the hypothesized endogenous relationship between concentration, differentiation and profits: firms enter the market if their margins are high enough to cover fixed costs, but margins fall with the entry of additional firms and may depend on the relative product space location of competitors. As such, the model extends the equilibrium entry models estimated by Bresnahan and Reiss (1991b) and Berry (1992) by allowing firms' product choices to affect competitors' profits as well as their own. The model can also be used to evaluate competing explanations for the extent of equilibrium product differentiation: parameters of the model measure the benefits firms earn by offering different products, as well as the effects of market characteristics on optimal product choice. No other study has estimated an empirical equilibrium model that includes the product types of competing firms.²

I estimate this endogenous product choice equilibrium model using a new dataset consisting of firm and market information for 492 small motel markets located along U.S. interstate highways. The structure of these local markets can be readily approximated by categorizing each operating motel firm according to the quality of services that it offers. The empirical results indicate that motel firms earn substantially higher payoffs by choosing differentiated products. However, the effects of demand characteristics, represented by demographic variables, are also significant. These effects can be large enough to outweigh the incentive to differentiate in some cases, generating a market outcome with little or no differentiation. The results of this paper also demonstrate that game specification is of minor importance; instead, the incentives to reduce competition through differentiation and to choose a product type with strong demand are critical.

The remainder of the paper starts with section II, which presents the endogenous product choice equilibrium model in detail. Section III contains information about the motel industry and the dataset that I have constructed, describing why they are particularly appropriate for pursuing the agenda proposed above. Parameter estimates appear in Section IV, and the model is extended in section V to allow three rather than two product-type choices for firms. Section VI offers some conclusions.

² Reiss and Spiller (1989) attempted this on a smaller scale by estimating the relative competitive effects of perfect and imperfect substitutes in the context of predicting whether the imperfect substitute enters the market. Stavins (1995) empirically examined the product-type decisions of firms by regressing the relative product space location of newly established products on market and firm characteristics. Her analysis does not model competitive effects or account for the endogeneity problem explicitly. Berry and Waldfogel (1997) also look at heterogeneous product markets, but again do not allow the competitive effects to vary by product type.

II. Model

This section presents the empirical model designed to analyze equilibrium market structure in differentiated product oligopolies. The model endogenizes firms' decisions regarding entry and product choice. When making these decisions, firms anticipate the effects on payoffs of their own product choice, as well as the decisions of their competitors. The model posits a profit function that firms consider, containing parameters that measure both the benefits of product differentiation and the effects of demand characteristics. Alternative specifications of how firms make their entry and product choices can also be accommodated within this framework. This section discusses the intuition behind the endogenous product choice equilibrium model and describes the profit functions and game specifications estimated.

II.A. Endogenous Product Choice Equilibrium Model

Two related mechanisms determine equilibrium market structure in a differentiated product oligopoly: each firm's entry and product-type decision and how these choices affect the other firms in the market. Firms make their product choice by comparing payoffs to operating under each product type alternative. Meanwhile, the number of competing firms and their product types will affect the toughness of price competition and, ultimately, the payoffs for firms under each possible product choice. As a result, every firm's behavior affects the product choice of all its competitors. The entry and product-type decisions of all market participants must be estimated simultaneously because of this endogeneity. The endogenous product choice equilibrium model accomplishes this by treating the observed product-type configuration — the number of firms operating in each quality category — as the dependent variable. A game theory solution concept determines the equilibrium product-type configuration outcome, based on firm payoffs under the various potential market structures.

This proposed framework fits into the growing series of multiple-agent qualitative-response models.³ These models describe the preferences and choices of interacting agents and are particularly useful for incorporating a game-theoretic behavioral model to analyze equilibrium market structure outcomes. Bresnahan and Reiss (1991b) and Berry (1992) have applied the multiple-agent qualitative-response setup to analyze entry in oligopoly markets. The observed number of market participants is the dependent variable; it is the equilibrium outcome of a multi-stage game in which firms choose whether to enter the market. In both papers, a reduced-form profit function describes the resulting payoffs in terms of market conditions and the (fixed) number of operating firms. They enforce a Nash equilibrium solution concept, so no profitable deviations from the observed equilibrium outcome are permitted. Operating firms make positive profits, but firms not operating — which would face one more competitor

³ Reiss (1996) provides an outline of the modeling strategy in his review of this literature.

than the extant firms if they were to enter the market — would make negative profits if they did operate. Additional competitors negatively affect firms' profits in the post-entry stage of the game; this particular additional competitor reduces profits to below zero for firms in that market.⁴ Along with a market-specific error (representing unobserved payoffs to operating in the market), a probability is assigned to each outcome (number of operating firms) based on this solution concept. Maximum likelihood selects parameters of the payoff function that maximize the probability of the observed outcomes.

My model extends this framework in three ways. First, it modifies the game to explicitly include each firm's product choice as well as its entry decision. The dependent variable is the number of market participants in each defined product type, not just the total number of extant firms. This equilibrium outcome represents the combination of each market participant's decision concerning both whether to operate and which of the possible product types to choose. Second, the model posits a separate payoff function for each product type, including the number and types of competitors as arguments. This setup recognizes that same-type competitors may affect payoffs more than different-type competitors.⁵ Third, I analyze alternative behavioral specifications for the entry and product choice game, which change how the model translates relative values of the payoffs (for each type) into equilibrium outcomes. Estimates of the underlying payoff functions measure how product differentiation may increase payoffs through competition avoidance, how demand characteristics influence payoffs and, thus, product selection, and how alternative assumptions about how entry and product choice are modeled might change these measured effects.

II.B. Payoff Functions

Once all the market participants have made entry and product-type decisions, firms compete in prices and quantities and payoffs are realized. The intensity of the second-stage competition may depend on the number and types of competing firms; therefore, these will be the crucial arguments in the reduced-form payoff function. Market conditions, both observed and unobserved by the econometrician, also affect payoffs. In order to make the appropriate entry and product-type decisions, firms must anticipate what their payoffs will be under different market structure scenarios, as well as the optimal actions of the other market participants. As described in the following subsection, an equilibrium product-type

⁴ "Positive" and "negative" profits should be interpreted somewhat loosely here. Profits must be higher than entry costs to join the market; firms may remain in the market if their variable costs are being met, even if profits are negative. Firms must have identical entry costs to attribute profit differences exclusively to competition. Profits for firms not operating are normalized to zero.

⁵ The model does not, however, explicitly examine the mechanics of price and quantity determination. In related work (Mazzeo, 1998), I investigate these outcomes and measure the extent to which product differentiation softens price competition in these markets.

configuration will follow from the specification of entry and product choice behavior and the payoff matrix — payoffs to operating as each product type with all potential combinations of competitors — which is assumed to be known by all firms.

The econometrician does not observe payoffs; instead, the equilibrium product-type configuration observed at the markets in the dataset imply that particular payoff threshold inequalities hold. I parameterize payoffs for any firm operating as quality type T in market m using the following reduced-form profit function:⁶

$$\mathbf{p}_{Tm} = X_m \mathbf{b}_T + g(\mathbf{q}_T; \bar{N}) + \mathbf{e}_{Tm}$$

The first term represents market demand characteristics that affect firm payoffs (note that the effect of X_m varies by type). The $g(\mathbf{q}_T; \bar{N})$ portion of the payoff function captures the effects of competitors, with the vector \bar{N} representing the number of competing firms of each type that the firm faces. The parameter vector θ also varies across T , so that the competitive effects may differ by type. The unobserved part of payoffs, \mathbf{e}_{Tm} is assumed to be different for each product type at a given market.

Parameters in the $g(\mathbf{q}_T; \bar{N})$ function distinguish between the effects of same-type and different-type firms on payoffs, and capture the incremental effects of additional firms of each type.⁷ The framework permits definition of a particular number of discrete product-type choices. Here, I consider at most three distinct types — representing low, medium, and high quality products. I assume a linear form for $g(\mathbf{q}_T; \bar{N})$; each individual term is a dummy variable representing the incremental effect of a particular competitor on payoffs. The θ -parameters can be summarized with the following notation:

$$\mathbf{q}_{TSCN}$$

- where T is the product type whose payoffs are under consideration.
- S is the number of type T firms competing in the market (only present if $C \neq T$).
- C is the product type of the competitor whose effect this parameter captures.
- N is the number of the type C parameter whose effect is being considered.

⁶ This specification of the profit function was chosen primarily to make the estimation tractable. Following Berry (1992) and Bresnahan and Reiss (1991b), it can be interpreted as the log of a demand (market size) term multiplied by a variable profits term that depends on the number (and product types, in this case) of market competitors. There are no firm-specific factors in the profit function. The error term represents unobserved payoffs from operating as a particular type in a given market. It is assumed to be additively separable, independent of the observables (including the number of market competitors), and identical for each firm of the same type in a given market.

⁷ Note that this specification measures the same competitive effect for all values of the X-variables. While this does not allow the competitive effects to vary according to values of the demand regressors, it keeps the number of parameters to estimate manageable. Recall, in addition, that the payoff function is expressed in logarithmic terms.

For example, θ_{L1H2} is the effect of the second high competitor on low-type payoffs, when there is one low firm in the market. If there are only three subscripts, the parameter measures the effect of a same-type firm: θ_{LL1} is the effect of the first low competitor on low-type payoffs.

The dummy variables “turned on” in any particular payoff function depend on \bar{N} , the number of competing firms of each type in the market. Suppose the observed configuration of firms in market m is (2,1,1), where the first number in the triple is the number of low-type firms operating, the second is the number of medium-type firms, and the third is the number of high-type firms. \bar{N} represents only the competing firms, so $\bar{N} = (1,1,1)$ for each of the low-type firms. With $g(\mathbf{q}_T; \bar{N})$ as described above, payoffs to operating as a low-type are:⁸

$$\mathbf{p}_{Lm} = X_m \mathbf{b}_L + \mathbf{q}_{LL1} + \mathbf{q}_{L1M1} + \mathbf{q}_{L1H1} + \mathbf{e}_{Lm}$$

To facilitate estimation, some competitive effects have been collapsed in versions of the model I have estimated. The S subscript may be dropped, for example, indicating that the incremental effect of a particular different-type firm is equal no matter how many same-type firms are in the market. It is also possible to make the specification of $g(\mathbf{q}_T; \bar{N})$ leaner by collapsing some of the θ -parameters associated with the N subscript.⁹ I will clearly indicate the θ -parameters included in each estimated model.

II.C. Identification and Estimation

In order to estimate the endogenous product choice equilibrium model, a mechanism must be implemented whereby a single product-type configuration outcome is assigned for every realization of the payoff function error terms.¹⁰ The process by which error-term realizations correspond to outcomes — here, I describe the procedure when there are two product types (low and high) and the error term is (ϵ_L, ϵ_H) — follows from a game-theoretic representation of how competing firms make their entry and product

⁸ So, the firm whose payoffs are under consideration is “subtracted” from the observed configuration for the purpose of evaluating the payoff function. Similarly, payoffs for operating as a medium-type ($\bar{N} = 2,0,1$) are:

$\mathbf{p}_{Mm} = X_m \mathbf{b}_M + \mathbf{q}_{M0L1} + \mathbf{q}_{M0L2} + \mathbf{q}_{M0H1} + \mathbf{e}_{Mm}$ and as a high-type ($\bar{N} = 2,1,0$) are: $\mathbf{p}_{Hm} = X_m \mathbf{b}_H + \mathbf{q}_{H0L1} + \mathbf{q}_{H0L2} + \mathbf{q}_{H0M1} + \mathbf{e}_{Hm}$

⁹ When parameters are collapsed, the resulting estimates become the “average incremental” effect of the uncollapsed parameters. It is best to avoid collapsing parameters in cases where the individual incremental effects are very different from the average incremental effect.

¹⁰ Otherwise, a unique equilibrium does not exist and coherency conditions for the model are not satisfied (Heckman, 1978). Bresnahan and Reiss (1991a) suggest potential consequences and remedies, including methods for estimating mixed strategy equilibria.

type decisions.¹¹ The game is played by an infinite number of identical competitors; each player can be thought of as an individual who could potentially enter a given market.¹² I also assume that there is no firm-specific factor that makes a particular entrepreneur more profitable as either product type than other entrants are or more profitable in one market than another. As a result, all outcomes with the same product-type configurations are treated as the same equilibrium outcome.

Potential actions for each player include operating as a low type, a high type, or not entering the market. In order to ensure that the equilibrium is unique, I make two natural assumptions about the payoff functions described in the previous section. First, profits are nonincreasing in the number of competing firms (i.e., all the θ -parameters are nonpositive). In addition, I assume that for any given \mathbf{N} , the effect on profits is greater (or equal) for $\mathbf{T} = \mathbf{C}$ than for $\mathbf{T} \neq \mathbf{C}$. For example, profits decline more for the first same-type competitor than for the first different-type competitor. With these assumptions, an equilibrium outcome of the entry and product choice game is represented by a region in the $\{\epsilon_L, \epsilon_H\}$ space bordered by payoff functions.

The size and shape of each region depend on the value of the parameters and the specification of the entry and product choice game, as described below. To start, the following four inequalities define a rectangular region in which the (L, H) outcome could possibly obtain:¹³

$$\begin{aligned} \mathbf{p}_L(L, H) > 0 &\rightarrow \mathbf{e}_L > -r_L(L, H) & \mathbf{p}_L(L+1, H) < 0 &\rightarrow \mathbf{e}_L < -r_L(L+1, H) \\ \mathbf{p}_H(L, H) > 0 &\rightarrow \mathbf{e}_H > -r_H(L, H) & \mathbf{p}_H(L, H+1) < 0 &\rightarrow \mathbf{e}_H < -r_H(L, H+1) \end{aligned}$$

For the values of (ϵ_L, ϵ_H) defined by these four inequalities, it is profitable to operate as a low or high product-type firm in the (L,H) configuration. However further entry by either type — which would necessarily change the market structure to either (L+1, H) or (L, H+1) — is not profitable. See Figure 2.1 for a graphic representation of the payoff function inequalities.

An equilibrium defined solely by these rectangles is not unique. Since $\pi_L(L+1, H) \leq \pi_L(L, H+1)$ and $\pi_H(L, H+1) \leq \pi_H(L+1, H)$, the region described above overlaps a similar region associated with the (L-1, H+1) outcome. To resolve this nonuniqueness, such overlapping regions are partitioned by comparing the profitability of operating as a low type in the (L,H) configuration with operating as a high type in the

¹¹ The equilibrium concept and estimation procedure are considerably more complicated for the three product-type case. I describe the extension of the model, and the three product-type estimates, in section V.

¹² This contrasts with Berry (1992). For airlines, it is necessary to incorporate firm-specific factors into the payoff function to account for differences in profitability among firms in different situations. As I will discuss in the following section, these differences are unimportant for motel operators, who have less firm and market-specific capital.

¹³ The \mathbf{r} example, $r_L(L, H) = X\mathbf{b}_L + g(\mathbf{q}_L; \bar{N} = L-1, H)$.

(L-1, H+1) configuration. For (ϵ_L, ϵ_H) such that $\pi_L(L, H) > \pi_H(L-1, H+1)$, the outcome is (L, H), and (L-1, H+1) is assigned where $\pi_L(L, H) > \pi_L(L-1, H+1)$.¹⁴ In the two-dimensional $\{\epsilon_L, \epsilon_H\}$ space, therefore, horizontal and vertical entry conditions and diagonal product choice profitability comparisons border each outcome. Most importantly, this procedure divides the $\{\epsilon_L, \epsilon_H\}$ space in such a way that there is a unique product-type configuration outcome for each possible value of (ϵ_L, ϵ_H) .

The assignment procedure described above closely approximates the Nash equilibrium solution of a simultaneous-move entry/product choice game played by the (infinite) market participants. However, no pure strategy Nash equilibrium exists for the simultaneous move game, unless unacceptably restrictive assumptions are placed on payoff functions.¹⁵ As an alternative, I propose two different game specifications, each of which adds some commitment by players to their entry and product-type decisions. One is a “sunk-type” game, in which firms play sequentially, make decisions about entry and product choice together, and cannot change their actions later in the game. This is essentially a Stackleberg game — firms anticipate the actions of subsequent players, so they do not make an entry/product-type decision that will ultimately be unprofitable. The alternative “sunk-entry” game is played in two stages. Firms decide on entry in the first stage, but are not committed to either product type. Once the number of firms operating has been established, a simultaneous product choice game ensues. Because firms can switch their product type (i.e., only entry is sunk), this game involves considerably less commitment on the part of firms.

One adjustment is made to the configuration assignment mechanism described above for each version of the game. In the region of the $\{\epsilon_L, \epsilon_H\}$ space where $\pi_H(L, H+1) > 0$, $\pi_L(L, H+1) < 0$, and $\pi_L(L, H) < \pi_H(L-1, H+1)$, the two versions of the game make different equilibrium predictions.¹⁶ In the sunk-type version of the game, the L^{th} low-type firm will not enter the market, because once the $H+1^{\text{th}}$ high-type firm follows it will be unprofitable to operate as a low-type firm. Thus, the outcome (L-1, H+1) obtains. If entry is sunk, however, no additional entry will take place — since $L+H+1$ firms cannot operate profitably in the market. With the market limited to $L+H$ firms entering in the first stage, the $L+H^{\text{th}}$ firm prefers to operate as a low type, and (L, H) is the resulting configuration.

¹⁴ By symmetry, the same adjustment is made between the outcomes (L, H) and (L+1, H-1).

¹⁵ Here, we would need to assume that $g(\mathbf{q}_L; \bar{N} = (L, H)) - g(\mathbf{q}_L; \bar{N} = (L, H+1)) = g(\mathbf{q}_H; \bar{N} = (L, H)) - g(\mathbf{q}_H; \bar{N} = (L+1, H))$, which implies that the competitive effects are symmetric across product types.

¹⁶ Note that these inequalities also describe situations in which no pure-strategy equilibrium exists for the simultaneous-move entry/product choice game. Mazzeo (1998) provides further discussion and a numerical illustration.

For any realization of (ϵ_L, ϵ_H) , each equilibrium concept assigns a particular product-type configuration based on data for the market in question and values for the payoff function parameters. Assuming a distribution for the error term — here, bivariate normal — a predicted probability for each of the possible configuration outcomes is calculated by integrating $f(\epsilon_L, \epsilon_H)$ over the region of the $\{\epsilon_L, \epsilon_H\}$ space corresponding to that outcome.¹⁷ Since the equilibrium is unique, the sum of the probabilities for all market configurations always equals one. Maximum likelihood selects the profit function parameters that maximize the probability of the observed market configurations across the dataset. The likelihood function is:

$$L = \prod_{m=1}^{492} \text{Prob}[(L, H)_m^O]$$

where $(L, H)_m^O$ is the observed configuration of firms in market m — its probability is a function of the solution concept, the parameters and the data for market m . For example, if $(L, H)^O = (1, 1)$ for market m , the contribution to the likelihood function for market m is $\text{Prob}[(1, 1)]$.

Finally, note that since the two solution concepts assign the same set of payoff function values to different outcomes in some cases, the likelihood functions for the sunk-type and sunk-entry specifications are not the same. For identical parameter values, the two games contribute different probabilities of the observed configuration to the likelihood function. By incorporating the alternative versions of the solution concept directly into the estimation, I can explicitly compare the empirical implications of assumptions that theorists have exploited to construct games that alter the predicted market structure outcomes. This constitutes an initial step in measuring how important strategic considerations are in determining the equilibrium industry concentration ultimately observed in markets.

III. Industry and Dataset

To estimate the endogenous product choice equilibrium model, I have constructed a dataset specifically to investigate product choice and competition in differentiated product oligopolies. The dataset consists of information from all the motel establishments operating in 492 oligopoly markets located along interstate highways throughout the United States. This section begins with an overview of the motel industry, highlighting why it is an appropriate setting for this analysis. I then describe how the dataset was assembled and provide some summary statistics.

¹⁷ In the estimation, markets are constrained to have no fewer than zero and no more than three firms of either product type. The region corresponding to a product-type configuration with zero or three low or high quality firms operating, therefore, is unbounded on at least one side. The appropriate integration limit is (plus or minus) infinity.

III.A. Motel Industry

According to data compiled by the American Hotel and Motel Association (AHMA) and Standard and Poor's (1998), the U.S. hotel industry encompasses approximately 48,000 individual properties and 3.7 million rooms. Smith Travel Research estimated 1997 industry revenue at about \$80 billion. Motels, a segment of the industry aimed at serving automobile travelers and located along highways, represent nearly half of these properties. Motels began to prosper during the first half of this century: as Americans purchased automobiles in larger numbers, it became popular to criss-cross the country on vacations and to travel from town to town for business. The motel industry was buoyed further by the establishment of the National System of Interstate and Defense Highways, a 42,500-mile network of freeways conceived in 1956 and constructed in the years since that spans nearly all the nation's large cities. Business establishments providing services for travelers have flourished along interstate highways, even in remote areas where little demand for such services would otherwise exist.

In the early years, most motel properties were independent — often a single family designed, built, managed, and operated the motel. Over the last several decades, however, more motel owners have affiliated themselves with regional and national franchises and chains.¹⁸ This organizational form evolved in part to address a quality commitment problem between firms and consumers: since travelers often stay in a particular location only once, an establishment does not have a “repeat business” incentive to provide quality accommodations. Consumers were attracted to chain-affiliated motels, known to have a consistent and predictable level of quality.¹⁹

While all motels provide the same basic services, they differ in the level of service quality they have chosen to supply. A single-index representation of differentiation based on quality has traditionally been applied to establishments in the roadside motel class of properties.²⁰ In fact, market segmentation — a proliferation of different quality “levels” of lodging products — has become standard strategy in the motel industry. Firms attempt to create niches of market power by offering unique price/quality

¹⁸ Belasco (1979) is an excellent history of the early motel industry in the U. S. Recent trends and the current state of the industry are chronicled by Jakle et al. (1996). Today, chains actively promote franchise opportunities and often provide financial assistance to potential franchisees (see www.choicehotels.com/corp/franchise_onboard.html, for example). As a result, the pool of potential entrants at all quality levels is quite large, a key assumption for the empirical model that was perhaps not true historically.

¹⁹ Ingram (1996) lays out this argument in greater detail and presents empirical implications.

²⁰ It might be argued that certain classes of hotels differentiate themselves by the types of services they offer. Hartman (1988, 1995) has applied hedonic techniques to study demand for luxury and specialty hotels using amenities such as free parking, business/meeting services, and airport shuttles.

combinations that appeal to a particular subset of consumers.²¹ Effectively conveying quality information to their targeted niche is important for firms, and chains transmit this information through advertising, reputation and repeat business.²² Travel organizations like the American Automobile Association (AAA) have established ratings systems to provide consumers with accurate information about the quality of motel services. The measure of quality I use to classify product choice in my sample is based largely on the AAA rating for each motel.

Though franchising and chain-affiliation are widespread, independent entrepreneurs still make the product-type decisions for individual properties. This is crucially important in the empirical model, which fundamentally assumes that each characteristic of each establishment represents the choice which maximizes profits for that establishment. The individual franchisees or independent motel operators represented in my dataset almost certainly behave in this manner, although establishment-level optimization may not be ideal if franchisors make decisions for multiple outlets and the maximized franchise profit is not equal to the sum of the maximized profits for each individual establishment. The assumption that decisions are made locally is particularly appropriate for smaller rural markets, where individual franchisees choose their quality by selecting a chain to represent and independent motels remain quite common.²³

III.B. Dataset

The goal of the empirical analysis in this paper is to explain the observed product choices of firms and the equilibrium patterns of product differentiation in oligopoly markets. For this purpose, I collected information from a cross-section of 492 differentiated product oligopoly motel markets. As discussed below, these markets are all located at interstate highway exits in counties outside Census-defined Metropolitan Statistical Areas (MSAs), but they differ in several other demographic characteristics. Most importantly, there is variation in the number and product types of extant firms across the markets. The

²¹ Choice Hotel International, for example, promotes franchising opportunities in seven different motel chains, each designed to cater to a different clientele. Dahl (1993) attributes Choice's success to recognizing and exploiting market segmentation opportunities. Other companies that own multiple brand names in different quality segments include Hospitality Franchise Systems, Marriott, and Hospitality International (Standard & Poor's, 1998).

²² Jones (1995) reports that motel chains have recently redoubled their efforts to maintain consistency in quality throughout their affiliates. For example, Holiday Inn recently directed its franchisees to spend \$1 billion to renovate their properties (Harris, 1997).

²³ Although several chains do own and manage some of their franchise outlets themselves, it is well documented that the company-owned establishments are more often located in urban areas (Brickley and Dark, 1987, LaFontaine, 1992). In fact, Table 3.3 reveals that nearly 45 percent of the rural highway motels in my dataset are not affiliated with a chain or franchise. Jakle, et al (1996) also reports that individual establishments change their chain affiliation quite frequently, which provides some motivation for the sunk-entry specification of entry/product choice behavior.

empirical model exploits the variation in market conditions and outcomes to quantify the opposing forces that influence product choice behavior.

Market “size” is a key element in determining the demand for goods and services and the number of operating firms in a market. To analyze equilibrium market structure, markets must be defined in such a way that market size can be calculated as accurately as possible. Bresnahan and Reiss (1987, 1991b) accomplished this by defining markets as rural, geographically isolated towns. Geographic isolation helped ensure there would be little competition from outside firms; market size could be readily approximated by the town’s (market’s) population.

The nature of demand for highway motel services complicates market size determination and market selection in this industry. Highway motels serve both visitors of residents and businesses in the town nearby each exit, as well as long-distance travelers, resting between legs of a multi-day road trip. These mobile consumers may choose their destination market, as well as the particular motel they patronize. We observe geographically isolated clusters of motels along most interstates, however, which practically limits the extent to which motels at one exit compete with motels at other exits.²⁴ Therefore, I define a market as the cluster of motels located adjacent to an individual interstate highway exit. In so doing, I implicitly assume that competition among the motels at an exit is much stronger than between a motel at that exit and one at a nearby exit or in a town close to the exit (but away from the highway). This definition also abstracts from issues related to location strategy and whether geographic clustering provides benefits to firms. To partially account for intermarket effects, I use the distance to the closest exits with motels to help determine market size, as described below.

In an effort to avoid markets that are not oligopolies and to maintain a degree of homogeneity among the markets, I collected data from only small, rural exits. Each market in the dataset is located along one of the 30 U.S. Interstate Highways in Table 3.1.²⁵ Of all the eligible exits along these highways, 492 contained at least one motel.²⁶ I was able to assemble an exhaustive list of motel establishments at each market exit — necessary to describe the equilibrium at the market accurately — by consulting AAA’s Tourbooks, chain-affiliated motel directories, the AHMA hotel guide, and telephone listings for each town. A total of 1,817 firms were identified at the 492 markets. The top panel of Table

²⁴ Solomon (1994) and Bleakley (1995) provide interesting anecdotes regarding intermarket competition.

²⁵ Three-digit interstates and several one and two-digit interstates that do not cross a state boundary (e.g., 4 in Florida, 27 in Texas, and 97 in Maryland) or predominantly covered metropolitan areas (e.g., 84E, 91, and 93) were not included. Mileage data are from the U.S. Department of Transportation’s Interstate System Route Log and Finder List, 1978 and have been supplemented with more recent maps from AAA.

²⁶ Exits located within MSAs or in counties with more than 15 motels listed in County Business Patterns (“big market” counties) were excluded.

3.2 breaks down these markets by the number of operating motels in each. Nearly 80 percent of the markets in the sample have five or fewer properties; only 3 percent have more than ten extant firms. The bottom panel of this table displays the number of motels identified from each data source. The AAA Tourbooks were the most common source, but many establishments would not have been identified without the telephone-listing search.²⁷

I assembled detailed information about each motel, including its chain affiliation, capacity (number of rooms) and price. Table 3.3 lists the chains most often chosen by franchisees — properties affiliated with Best Western, Super 8 and Days Inn make up more than one-quarter of all the motels, and 45 percent are not affiliated with any regional or national chain. I also assigned each motel in the dataset to one of three quality “types”: low, medium, or high. For properties listed in AAA, I used their quality rating of between one and four “diamonds” to make this assignment. Motels with a one-diamond rating were put into the low category, two diamonds in medium and three or four diamonds in high. Chain-affiliated motels not listed in AAA were put into the category most populated by the members of the same chain that are in AAA. Because AAA has minimum quality standards for inclusion in its Tourbooks, independents AAA does not list were placed in the low quality category. Table 3.3 also provides a breakdown of the motels’ assigned quality levels. This quality level represents the product choice made by the firm; I examine competition among firms within and across these categories.²⁸

To complete the dataset, I appended several demographic and geographic variables describing conditions at each market to the motel information. From Census, I know the population and per capita income of both the market’s nearest town and the market’s county. The annual average daily traffic that passes each market’s exit along the interstate, which is monitored by the Federal Highway Administration (FHWA), is also included. I consulted a battery of AAA maps to determine the distance from each market to its nearest motel competition along the highway, noting whether the adjacent markets are also in the dataset or the reason why they were not included. These variables are used to help determine the demand for motels at each market, as described below.

²⁷ The data sources were searched in the order listed in the table. Subsequent sources added new properties and were used to verify the validity of previously checked sources. Phone calls were made to clear up discrepancies among the data sources.

²⁸ A discrete quality space facilitates the estimation of competitive effects within the context of an equilibrium model by limiting the number of different competitive interactions to be measured. I am interested in the effect of every type competitor on each type firm — three product types imply nine different competitive interactions. Product heterogeneity within quality types may still exist and could help explain why motels remain profitable, even when they have same-type competitors.

IV. Estimation Results

The endogenous product choice equilibrium model presented in the previous section provides a framework for analyzing the entry and product-type decisions of oligopolists. Game theory has demonstrated that firms' optimal product choices may depend on the specification of consumer demand and commitment strategies, as well as the ability to soften competition through product space isolation. This empirical model analyzes observed differentiation patterns to evaluate the importance of these factors. In this section, I present results from the two product-type version of the model, in which potential actions for firms include operating as a low quality or a high quality motel (firms previously categorized as medium quality are placed in the high quality category) and not operating.²⁹ This classification produces a total of 15 possible market configurations; the observed number of markets with each configuration is displayed in Table 4.1.³⁰ The table shows that differentiated configurations are more common (for example, there are more (1,1) markets than either (2,0) markets or (0,2) markets), but that some unbalanced configurations (the (1,3) configuration, for example) also occur frequently.

IV.A. Payoff Function Parameterization

Parameterizing the payoff function is the next critical step in the empirical analysis. The X-variables should be ones that affect demand for motel rooms at that exit (correlated with profits); parameter estimates indicate the effects of consumer demand on payoffs and product choice. The following regressors are included in the payoff function:³¹

- **PLACEPOP:** the population of the town nearest the highway exit — should be positively correlated with motel demand since a larger town has more people and businesses that highway travelers would want to visit.
- **TRAFFIC:** the FHWA's measure of the annual average daily traffic that passes by the market's exit — should also be positively correlated with motel demand since more traveled stretches of highway have more travelers looking to stay at a motel.
- **SPACING:** the distance in miles from the market exit to the closest exits along the highway with motels (the sum of the distance to the closest competitors on either side). I expect a positive

²⁹ Combining the medium and high quality categories was somewhat arbitrary, but among simple reclassification schemes, this one results in the lowest amount of within-type product heterogeneity for the two product-type case.

³⁰ I assume that the incremental competitive effects die out beyond three firms of a given type; therefore, markets with three or more firms of a type are treated the same. For example, the (1,3) group may contain some (1,4), (1,5), (1,6), etc. markets. This also reduces the number of potential market outcomes, helping to make the estimation more tractable. Note that there are no (0,0) market configurations in the dataset; in the actual likelihood function I estimate, the probability of the observed configuration is conditional on there being at least one motel in the market.

³¹ Variables representing the costs of operating motels at different markets could also qualify as X-variables, but none had a meaningful effect on the estimation.

correlation between SPACING and demand — a location is more popular if the closest alternatives are further away.

- WEST: a dummy variable indicating markets located in the west region of the United States — preferences for quality (or costs) might vary by region.

Table 4.2 provides summary statistics. Also note that, except for the dummy variable WEST, the data for the X-variables are transformed as follows for use in the estimations:

$$PLACEPOP_m^* = \ln \left[PLACEPOP_m / \frac{1}{492} \sum_{m=1}^{492} PLACEPOP_m \right]$$

Consequently, a value of PLACEPOP equal to the mean in the dataset is transformed to zero; a value above the mean becomes positive, and a value below the mean becomes negative. Analogous transformations are done on the TRAFFIC and SPACING variables. No modification is made for the WEST dummy — it equals one for WEST region markets.

As described in detail in section II.B, the $g(\mathbf{q}_T; \bar{N})$ portion of the payoff function captures the effects of competitors on product choice. The θ -parameters represent the incremental competitive effects of same-type and different-type firms. Product space isolation is a motivation for product choice to the extent that same-type competitors have a greater effect (reduce payoffs more) than different-type competitors.³² The particular competitive-effect dummy variables included for the two product-type model estimations are as follows:

$$\begin{aligned} g_{\text{Low}} = & \mathbf{q}_{LL1} * \text{presence of first low competitor} \\ & + \mathbf{q}_{LL2} * \text{presence of second low competitor} \\ & + \mathbf{q}_{L0H1} * \text{presence of first high competitor (no low competitors)} \\ & + \mathbf{q}_{L0HA} * \text{no. of additional high competitors (no low competitors)} \\ & + \mathbf{q}_{L1H} * \text{no. of high competitors (one low competitor)} \\ & + \mathbf{q}_{L2H} * \text{no. of high competitors (two low competitors)} \end{aligned}$$

³² Again, the goal is to make the specification of the competitive effects through $g(\mathbf{q}_T; \bar{N})$ as flexible as possible, while maintaining estimation feasibility. More detailed parameterizations of the different-type effects were tried, but additional estimated parameters did not yield further economic distinctions.

$$\begin{aligned}
g_{\text{HIGH}} = & \mathbf{q}_{HH1} * \text{presence of first high competitor} \\
& + \mathbf{q}_{HH2} * \text{presence of second high competitor} \\
& + \mathbf{q}_{H0L1} * \text{presence of first low competitor (no high competitors)} \\
& + \mathbf{q}_{H0LA} * \text{no. of additional low competitors (no high competitors)} \\
& + \mathbf{q}_{H1L} * \text{no. of low competitors (one high competitor)} \\
& + \mathbf{q}_{H2L} * \text{no. of low competitors (two high competitors)}
\end{aligned}$$

Table 4.3 graphically illustrates how the number and product types of market competitors determine which θ -parameters are included as part of the estimated payoff functions.

IV.B. Results

Table 4.4 displays the payoff function estimates from the two versions of the two product-type models. I will first discuss the results from the sunk-entry version of the model, which are in the left-hand columns of the table. Later in this section, I will return to the sunk-type estimates from the right-hand columns. The parameters for the payoff function of low quality firms are in the top panel of the table; the high-type payoff function estimates are in the bottom panel.

The estimated parameters can be used to evaluate the relative payoffs to operating as either a low-type or a high-type firm under different market conditions and in different product-type configurations. For example, the relative value of the constants indicates that, at markets with similar values for the X-variables and in which there are no competing firms, operating a high quality motel is on average more profitable than operating a low quality motel ($C_H = 2.5252$ vs. $C_L = 1.6254$).³³ Factoring in market conditions, however, can change this relationship. For example, suppose that in market m , PLACEPOP is one-tenth the sample mean, the other X-variables are at their sample means, and the market is outside the WEST region. In addition, ignore the competitive effects (assume no competitors) for now. Under this scenario, payoffs to operating a low quality motel are on average higher ($\pi_L = 1.6254 + (-2.303) * (0.2711) = 1.001$) than to operating a high quality motel ($\pi_H = 2.5252 + (-2.303) * (0.6768) = 0.9668$).³⁴

Next, consider the competitive effects on product choice, as captured by the θ -parameters. The large difference between the parameters representing the effects of the first same-type competitor and the first different-type competitor is striking. For low quality firms, the first low-type competitor ($\theta_{LL1} =$

³³ All the figures presented in this section represent predicted payoffs. The comparisons between payoffs to operating as each product type assume that values of the unobservable part of profits for both types are at their mean — zero. Directly evaluating the probability that one type's payoffs are greater than the other's requires the standard errors of the parameters, as well as an assumption about the variance of the low and high-type profit errors.

³⁴ Since PLACEPOP is one-tenth the sample mean, the parameter estimate for PLACEPOP is multiplied by $\ln(0.1) = (-2.303)$, to compute the predicted payoffs. The transformed value of an X-variable at its sample mean is zero; therefore, the other variables do not contribute to the predicted payoffs.

-1.7744) has more than twice the (negative) effect on payoffs as the first high-type competitor ($\theta_{LOH1} = -0.8552$). For high quality firms, the effect of the first competitor is 65 percent greater if it is also a high type ($\theta_{HH1} = -2.0270$ vs. $\theta_{HOL1} = -1.2261$). The effect of the first same-type competitor is significantly greater than that of the first different-type competitor in both cases.³⁵

The large difference in these parameters provides strong evidence that differentiation is a profitable product choice strategy for firms. To illustrate, consider a firm choosing whether to operate a low or high quality motel when there is one high-type competitor. If this market is not in the WEST region and has values of the other X-variables equal to their sample means, low payoffs are $\pi_L = 1.6254 + (-0.8552) = 0.7702$, while high payoffs are $\pi_H = 2.5252 + (-2.0270) = 0.4982$. The relative difference between the competitive effect of same and different-type firms outweighs the baseline preference for offering high quality; on average, when there is one high quality competitor the low quality option yields higher payoffs.

While the estimated θ -parameters indicate powerful incentives for firms to offer differentiated products, the demand effects are large enough to predict undifferentiated product-type configurations in some cases. For example, population has a positive and significant effect on payoffs of both product types, but the relative size of the coefficients indicates that firms in markets with population above the sample mean tend to choose high quality, while low quality is more attractive in below-average population markets. Consider once again the product choice at a non-WEST market with one high-type competitor. Let TRAFFIC and SPACING be at their sample mean, but suppose PLACEPOP is twice its sample mean at this market. In this case, the firm will, on average, earn more by choosing the high quality product choice: $\pi_H = 2.5252 + (-2.0270) + (0.6931)*(0.6768) = 0.9673$, while $\pi_L = 1.6254 + (-0.8552) + (0.6931)*(0.2711) = 0.9567$.³⁶ This empirical finding demonstrates how particular patterns of consumer preferences — the taste for high quality in markets with larger population — can cause the benefits of product space isolation to be outweighed by the benefits of offering a product type with greater demand. In such cases, an undifferentiated configuration of firms may result. Motels at markets with TRAFFIC or SPACING above the mean also tend to favor the high quality choice, since the high-type coefficients also exceed the low-type coefficients for these variables.

³⁵ For both low and high quality, the negative effect of the first same-type firm is significantly different from zero, while the first different-type effect is negative, but not significant. The correlation between the parameter estimates is fairly high; therefore, the difference between the parameter estimates is statistically significant at the five percent level for both low and high types.

³⁶ In this case, 69 markets in the dataset (14 percent) have PLACEPOP at least twice the mean.

The remaining θ -parameters represent the incremental effects of additional competing firms. These effects are smaller than the impact of the first competing firm. For example, the effect of the second high-type competitor on high-type payoffs is about one-third the effect of the first high-type competitor ($\theta_{HH1} = -2.0270$ vs. $\theta_{HH2} = -0.6841$). High-type payoffs are reduced by the sum of the two coefficients when there are two high-type competitors: $-2.0270 + -0.6841 = -2.7111$. Note that since this sum exceeds (in absolute value) the estimated high-type constant, a third high quality firm would not be profitable on average at a market with the sample mean values of the X-variables. In this case, not operating would be preferred over operating a high quality motel.

By calculating and comparing predicted payoffs of operating as either product type and not operating for each possible configuration of competitors, the estimated parameters can be converted into predicted values of the equilibrium market structures for a given set of market conditions. Figure 4.1 illustrates how the predicted equilibrium varies with different values of the PLACEPOP and TRAFFIC variables. Markets depicted in the figure are outside the WEST region and have the sample mean value of SPACING. The graph plots the equilibrium market configuration prediction generated by the estimated parameters (for the sunk-entry version of the game) as a market's values for PLACEPOP (vertical axis) and TRAFFIC (horizontal axis) vary from -2.5 to 2.5.³⁷ For the market with sample mean values for PLACEPOP and TRAFFIC, plotted at the origin of Figure 4.1, the estimated model predicts an equilibrium configuration with one low-type firm and two high-type firms operating.

More firms can operate profitably at markets with higher values of the demand variables, as the figure demonstrates. The equilibrium product-type configurations also vary depending on the values of the X-variables. For example, by holding TRAFFIC constant and increasing PLACEPOP from the origin, an additional firm becomes profitable. Interestingly, a third high-type is the next profitable firm and a (1,3) configuration is predicted. The more differentiated (2,2) configuration occurs when higher values of PLACEPOP are combined with lower values for TRAFFIC. While the incentive for firms to differentiate is strong, unbalanced configurations are also predicted for some values and combinations of the demand parameters.

Finally, we return to the right-hand columns of Table 4.4, which contain the parameter estimates from the sunk-type version of the model. Recall from section II.C that the likelihood functions used to estimate the sunk-entry and sunk-type models vary, corresponding to differences in how the two games assign equilibrium market structure outcomes under particular circumstances. Despite this, the estimated parameters are strikingly similar in the two versions of the model. Between the two sets of columns, there

³⁷ Recall that the X-variables are transformed (Table 4.2); a value of zero indicates that an X-variable is at its sample mean and a value of 2.5 is about 12 times its sample mean.

is only a small difference in the competitive effects and almost no difference in the demand effects. The equilibrium product-type configurations predicted in the two versions of the model are also quite similar. Figure 4.2 displays the predictions for the sunk-type version of the model (cf. Figure 4.1 for sunk-entry) and Figure 4.3 plots the few values of the market characteristics variables for which the two estimated games predict different market structure outcomes. The specification of the model changes the equilibrium prediction in fewer than three percent of the cases tested.³⁸

Three main conclusions follow from the estimated parameters of the endogenous product choice equilibrium models. First, the empirical evidence from oligopoly motel markets strongly supports the product choice theories that predict firms will offer products unlike their competitors'. The negative effect a competitor has on firm payoffs is up to twice as large if that competitor is the same product type. Second, the results demonstrate that demographic variables representing the influence of demand factors help predict both how many firms can operate profitably in a market and the firms' product-type decisions. The effects of demand characteristics can be large enough in some cases to outweigh the relative difference in the competitive effects, resulting in an undifferentiated market configuration. Finally, varying the degree of commitment firms make to entry and product choice has minimal effect — the sunk-type and sunk-entry versions of the model predict extremely similar values for both competitive and demand effects on payoffs and equilibrium product-type configuration outcomes. Whereas theory models demonstrate that there are scenarios under which different assumptions about entry and product choice commitment can lead to alternative equilibrium market structure predictions in some cases, the empirical results indicate that the incidence and influence of such scenarios are quite small. For this analysis, the effects of game specification are empirically negligible.

V. Three Product-Type Model

In this section, I again suppose that firms have three distinct product choices available to them: low, medium and high quality. As expected, this change complicates the specification and estimation of the empirical model substantially. The additional product type delineation is worth making, however, for at least two reasons. Motels appear to have a distinct type to select from between low and high quality. Chains like Days Inn and Super 8 are a clear step above the low quality independents but below offerings such as Holiday Inn and Ramada Inn.³⁹ Economically, it is useful to compare how competitive effects of

³⁸ The log-likelihood values for the two versions of the model are also very similar: -1143.01 for sunk-entry and -1143.12 for sunk-type. In addition, Vuong's (1989) test for evaluating non-nested models indicates no difference between the sunk-entry and sunk-type specifications.

³⁹ Other industry sources (Rompf, 1994) list as many as ten different quality level categories into which motels could possibly be placed. Estimating competitive effects at such level of detail is beyond the scope of this framework.

firms two types away (effects of high-type competitors on low profits and low effects on high) and one type away (medium effects on low and high, and vice versa) differ. Adding a third product type also surfaces some interesting modeling issues, on which I will elaborate below.

The market's product-type configuration remains the dependent variable of the model. With the medium quality product choice once again available to firms, there are 63 possible market structure outcomes to consider (again truncating at three firms of each type). Table 5.1 displays the number of motel markets in the dataset with each product-type configuration. Differentiation is more prominent when three product types are defined. For example, the (1,1,1) configuration is found at more markets than the (1,0,2) and (2,0,1) configurations combined. Overall, low quality motels are the most common (see Table 3.3); undifferentiated markets tend to have multiple low quality firms. The remainder of this section describes how the empirical model has been modified — both the equilibrium solution concept and the estimation technique — to explain the three product-type market structures, and concludes by presenting and discussing this model's estimated parameters.

V.A. Model Specification and Estimation

Just as in the two product-type case, an equilibrium concept must be formulated to convert the matrix of payoffs under all possible combinations of competitors into a predicted market structure outcome. With an additional potential action available to firms, specifying entry and product choice behavior in a way that translates into a coherent econometric model becomes more difficult. Specifically, no (pure-strategy) Nash equilibrium exists for the three product-type analogue to the sunk-entry game developed previously. With additional structure, however, a version of the model that complements the sunk-type game can be constructed for the three product-type case. The sunk-type version, in which firms make their joint entry and product-type decisions sequentially and cannot change their decisions at later stages in the game, will always have an equilibrium and define a coherent econometric model.

An equilibrium fails to exist for essentially the same reason, as illustrated in section II.C, why no (pure-strategy) equilibrium exists in the case of two product types when firms could deviate from both product choice and entry. Unless unreasonable conditions on the profit function parameters are imposed, an equilibrium will not exist when there is a stage of the game during which moves are made simultaneously and firms have more than two alternatives. To proceed in the three product-type case, a game with more commitment than the sunk-entry game analogue must be specified. The new solution concept should have the minimum amount of commitment required for an equilibrium to exist, in order to contrast with the sunk-type game.

In the specification I propose, firms play the entry/product choice stage in three separate substages. They decide on entry in the first substage; as before, the N^{th} firm enters only if there is a configuration with N firms in which all the product types make positive profits. In the second substage, firms that have entered again have two choices: they can either operate as a low quality motel or not. Finally, there is a third substage in which firms that did not choose the low product type decide between medium and high quality. The critical feature of this structure is that at each substage firms have no more than two options. Although firms cannot change their previous decisions in later substages, there is substantially less commitment than in the sunk-type version of the game. This “three-stage sunk-entry” game generates a unique equilibrium product-type configuration for all possible realizations of $(\epsilon_L, \epsilon_M, \epsilon_H)$. The intermediate substage provides enough additional commitment to guarantee the existence of an equilibrium for three product types.⁴⁰

Having defined two solution concepts for which an equilibrium exists for three product types, I estimate the parameters of each model. Conceptually, the estimation works much as before: at a given market, a probability is assigned to each possible product-type configuration based on the specification of the entry and product choice game, along with the market’s data, the parameters of the payoff function and the distribution (independent trivariate normal) of the unobserved payoffs for each type. Since both the sunk-type and three-stage sunk-entry versions of the game define a coherent econometric model, the sum of the probabilities for all the configurations always equals one. However, a frequency simulation approach is used to calculate the probabilities, as integration becomes prohibitively complex for three product types (see Appendix A for details).

V.B. Empirical Results

To facilitate the estimation, the payoff function parameterization is leaner in the three product-type case. PLACEPOP and SPACING are the only X -variables included and the θ -parameters are further collapsed, as suggested in section II.B. There is a θ -parameter representing the effect of a same-type competitor for each of the three product types. In addition, two separate parameters capture the impact of different-type competitors — θ_{CN} for the effects of competitors that are one type removed in

⁴⁰ To illustrate, consider a set of payoffs such that operating as each of the three product types is profitable in the (1,2,2), (2,1,2) and (2,2,1) configurations, and payoffs are such that $\pi_L(2,2,1) > \pi_H(1,2,2)$, $\pi_H(2,1,2) > \pi_M(2,2,1)$, and $\pi_M(1,2,2) > \pi_L(2,1,2)$. No pure strategy Nash equilibrium exists for the previously employed sunk-entry specification. However, in the intermediate stage described above, two different outcomes are possible — either one or two firms choosing to be low quality. In the latter case, the (2,1,2) configuration would be chosen over the (2,2,1) market structure, because $\pi_H(2,1,2) > \pi_M(2,2,1)$. The decision between (2,1,2) and (1,2,2) hinges on a comparison between the payoffs for low in the (2,1,2) configuration and the lower of the medium or high payoff when there are four firms selecting in the final substage. The equilibrium is (1,2,2) because $\pi_M(1,2,2) > \pi_L(2,1,2)$.

product space and θ_{CF} for the effects of competitors two types away. The following specification for the $g(\mathbf{q}_T; \bar{N})$ portion of the three payoff functions results:

$$\begin{aligned}
g_{LOW} &= \mathbf{q}_{LL} * \text{number of low competitors} \\
&\quad + \mathbf{q}_{CN} * \text{number of medium competitors} \\
&\quad + \mathbf{q}_{CF} * \text{number of high competitors} \\
g_{MED} &= \mathbf{q}_{MM} * \text{number of medium competitors} \\
&\quad + \mathbf{q}_{CN} * (\text{number of low competitors} \\
&\quad \quad + \text{number of high competitors}) \\
g_{HIGH} &= \mathbf{q}_{HH} * \text{number of high competitors} \\
&\quad + \mathbf{q}_{CF} * \text{number of low competitors} \\
&\quad + \mathbf{q}_{CN} * \text{number of medium competitors}
\end{aligned}$$

$\theta_{LL}, \theta_{MM},$

$\theta_{HH})$ and the “cross” effects (θ_{CN}, θ_{CF}), and distinguish the “near cross” effects (θ_{CN}), from the “far cross” effects (θ_{CF}).⁴¹

Table 5.2 presents estimates from the three-stage sunk-entry version of the three product-type model. Again, there is strong evidence that the (negative) effect on payoffs is greater for same-type competitors than for different-type competitors. The difference between the same and different-type effects is much larger than in the two product-type case; in fact, the relative size of the cross effects makes them almost negligible compared to the same-type effects. There is also little difference between the impact of close and far different-type competitors — both are much smaller than the same-type effects. Adding a quality category reduces firm heterogeneity within product types; the reclassification makes the average same-type competitor a closer substitute and its relative (to competitors in other product types) effects on profits greater. As a result of the more distinct quality submarkets, the benefits of product differentiation appear much stronger in the three product-type case.

The estimates of the demand effects differ for each product type, again indicating that market conditions can increase the proclivity for firms to choose a particular product type. In more extreme cases for PLACEPOP and SPACING, a product type might be selected even if its only competitor is the same type. For example, suppose there is one medium quality competitor operating at a market in which the values of PLACEPOP and SPACING are at the sample mean. Payoffs to operating as a medium-type (π_M

⁴¹ An alternative parameterization revealed no differences between the cross-effects specified separately to capture the effects of particular competitors on each product type (e.g., breaking θ_{CF} down into θ_{LH} for the effect of a high quality competitor on low-type profits and θ_{HL} for the effect of low on high). I report the version with fewer parameters here.

$= 1.4938 - 1.4939 = -0.0001$) are less on average than for operating as a low-type ($\pi_L = 1.1937 - 0.0243 = 1.1694$) or a high-type ($\pi_H = 1.0311 - 0.0243 = 1.0068$). However, if the market is larger than average, say with a transformed PLACEPOP value of two, the predicted payoff associated with choosing medium quality is highest among the three.⁴² As in the two product-type case, the effects of demand characteristics can outweigh the competitive effects and help explain some undifferentiated configurations.

Finally, the sunk-type version of the game can be used to reevaluate the role of the specification of competition for the three product-type game. I calculate and compare the equilibrium product-type configurations that the two versions of the game predict, using the estimated parameters from the sunk-type version. Where estimable models have been defined, the predicted equilibria in two alternative versions of the game differ less than one percent of the time.⁴³ Once again, the results of altering the structure of the game indicate that the importance of the specification of competition is much smaller empirically than the theoretical literature has suggested.

VI. Conclusion

This paper empirically examines the oligopoly market structure implications of endogenous product choice by firms. The theoretical literature demonstrates the difficulty of analyzing this problem, in which there are costs and benefits of all the product choice strategies available to firms. Game theory models can predict an equilibrium market structure in the presence of these opposing forces, but under some scenarios the predictions depend critically on the way the entry and product-type decisions are modeled. In this paper, empirical investigation of product choice behavior attempts to establish regularities where theory provides only stylized results.

A methodological advance is necessary to undertake a proper empirical analysis of product choice. An appropriate empirical model of oligopoly market structure must simultaneously estimate the decisions of all market participants. Previous analyses of product differentiated markets did not incorporate the fact that the product types chosen by competitors affect all firms' payoffs and, thus, their product choices. The endogenous product choice equilibrium model developed in this paper captures this simultaneity by extending the multiple-agent qualitative-response model literature to study the game

⁴² In this case, $\pi_M = 1.4938 - 1.4939 + 2*(0.7681) = 1.5361$, $\pi_L = 1.1937 - 0.0243 + 2*(0.1127) = 1.3948$, and $\pi_H = 1.0311 - 0.0243 + 2*(0.2603) = 1.5274$.

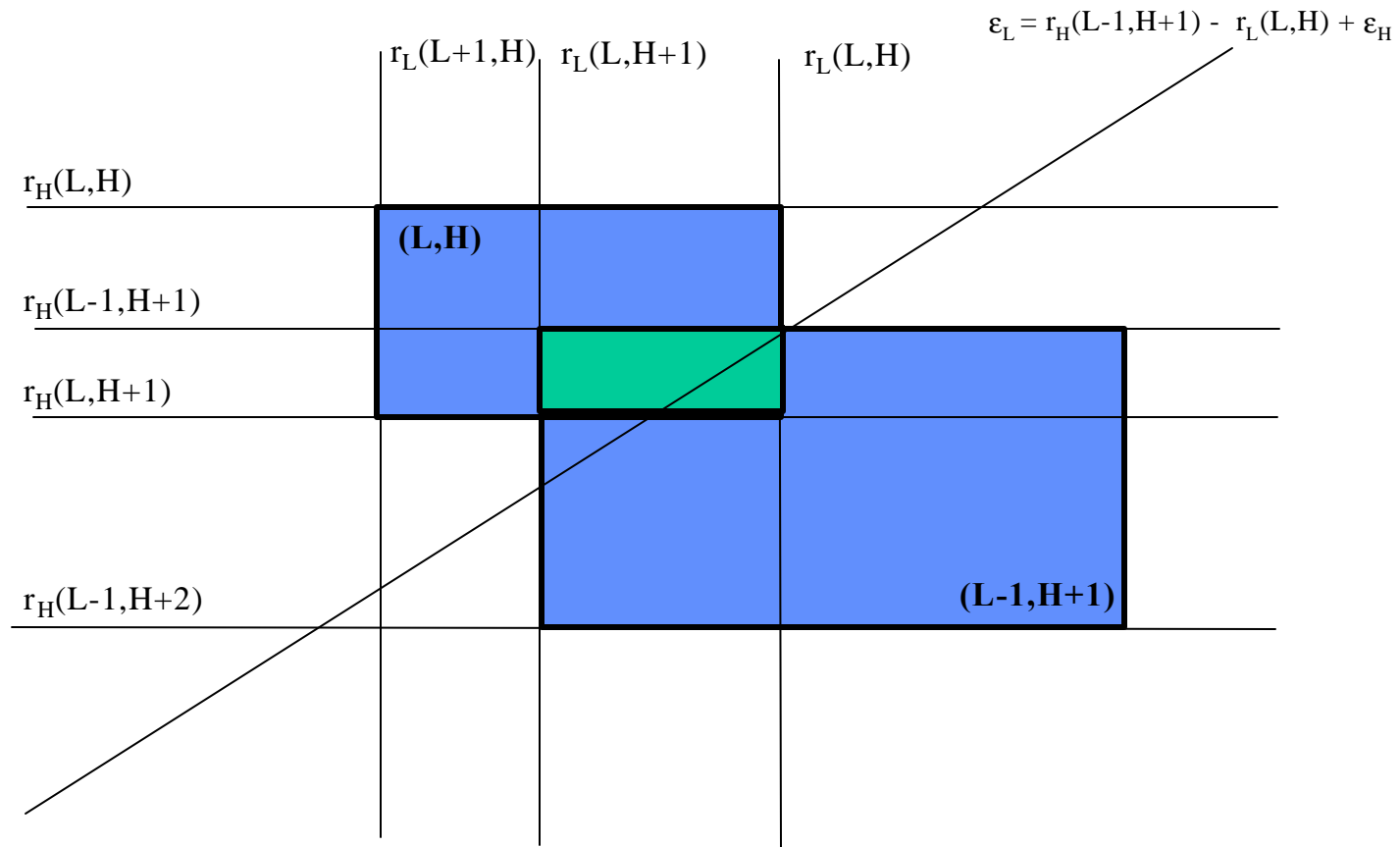
⁴³ The algorithm that calculates the predicted three product-type equilibrium is quite complicated for the sunk-type game. As a result, the simulated likelihood function is extremely nonlinear. I made the above calculation in lieu of estimating this likelihood function; given the result, I anticipate that the estimated parameters in the two models would also be very similar. This comparison was made using the more richly parameterized version.

played by product differentiated oligopolists. The model can accommodate different specifications of this game, to investigate the importance of modeling assumptions on equilibrium outcomes.

The endogenous product choice equilibrium model is estimated using data from a cross-section of differentiated product oligopoly markets from the motel industry. Evidence from oligopoly motel markets strongly supports the product choice theories that predict firms will offer products that are unlike their competitors'. Any additional competitors have a negative effect on firm payoffs, of course, but this effect is up to twice as large if the competitor is the same product type. Payoffs are higher when competing products chosen are less substitutable, coinciding with a price-competition softening incentive for differentiated product choice. Several demand factors also affect product choice; in fact, the effect of demand characteristics can be large enough in some cases to outweigh the relative difference in competitive effects, resulting in an undifferentiated equilibrium product-type configuration.

Finally, the measured competitive and demand effects are robust to changes in the way entry and product choice are modeled. In both the game-theoretic literature and this empirical model, some scenarios exist in which, because of the relative values of payoffs to operating as each product type, the equilibrium market configuration depends critically on assumptions regarding order-of-entry and product-type commitment. Game theory models focus on these scenarios, exploiting them to support particular equilibrium outcomes. The empirical results reveal that the importance of these scenarios is quite small — the competitive and demand effects demonstrated little change when entry and commitment assumptions were altered. By focusing on particularizing results, the theory literature has overemphasized the role of strategic firm behavior in predicting equilibrium product-type outcomes. Evidence from this industry suggests that the simpler forces, as described by Hotelling, dominate.

Figure 2.1: Partitioning for Equilibrium Outcomes



Note: Values for ϵ_L are represented along the horizontal axis and ϵ_H is on the vertical axis

						Counties	Motel Markets
5	Whatcom Cty, WA	San Diego, CA	1,382	34	23	7	6
10	Los Angeles, CA	Jacksonville, FL	2,460	71	40	1	27
15	Toole Cty, MT	San Diego, CA	1,431	29	10	6	9
20	Reeves Cty, TX	Florence Cty, SC	1,537	64	33	2	24
24	Johnson Cty, IL	Marion Cty, TN	317	17	7	1	5
25	Weld Cty, CO	Dona Ana Cty, NM	1,061	25	15	2	8
26	Haywood Cty, NC	Charleston, SC	261	13	7	2	3
29	Pembina Cty, ND	Platte Cty, MO	752	27	6	0	11
30	Dallas, TX	Pulaski Cty, AR	337	15	7	0	7
35	St. Louis Cty, MN	Webb Cty, TX	1,572	63	30	3	29
40	San Bernadino Cty, CA	New Hanover Cty, NC	2,458	81	33	7	34
44	Oklahoma Cty, OK	St. Louis, MO	485	20	11	1	9
55	Chicago, IL	St. Charles Cty, LA	944	28	15	0	23
57	Chicago, IL	Mississippi Cty, MO	381	20	4	0	12
59	Dade Cty, GA	St. Tammany Cty, LA	444	15	6	2	6
64	St. Clair Cty, IL	York Cty, VA	929	43	23	1	10
65	Lake Cty, IN	Mobile, AL	887	45	25	1	18
70	Millard Cty, UT	Baltimore, MD	2,181	76	34	5	36
71	Cleveland, OH	Jefferson Cty, KY	346	20	14	1	3
75	Chippewa Cty, MI	Broward Cty, FL	1,742	76	46	7	24
76	Denver, CO	Deuel Cty, NE	147	6	3	0	4
77	Cleveland, OH	Lexington Cty, SC	598	25	11	0	15
79	Erie Cty, PA	Kanawha Cty, WV	344	16	6	2	6
80	San Francisco, CA	Bergen Cty, NJ	2,909	97	46	13	46
81	Jefferson Cty, NY	Jefferson Cty, TN	856	30	43	2	17
84 (West)	Portland, OR	Summit Cty, UT	765	23	4	2	17
85	Dinwiddie Cty, VA	Mobile, AL	668	42	24	0	11
90	Seattle, WA	Boston, MA	3,088	100	46	14	38
94	Yellowstone Cty, MT	Detroit, MI	1,607	54	27	3	20
95	Aroostook Cty, ME	Miami, FL	1,757	83	61	9	14

Table 3.2 Identification of Motels at Dataset Markets

Number of Motels	Number of Markets	Percent of Total
1	128	26.0 %
2	96	19.5 %
3	73	14.8 %
4	60	12.2 %
5	32	6.5 %
6	22	4.5 %
7	20	4.1 %
8	17	3.5 %
9	13	2.6 %
10	16	3.3 %
11	2	0.4 %
12	4	0.8 %
13	4	0.8 %
14	4	0.8 %
15	1	0.2 %
Total	492	

Sources of Information for Motel Identification:

Information Source	Number of Motels	Percent of Total
AAA Tourbooks	913	50.2 %
Chain Directories	265	14.6%
AHMA Directory	21	1.2%
Telephone Survey	618	34.0 %
Total	1,817	

Table 3.3: Motel Chains and Quality Assignments

Chain Affiliation	Number of Motels				Percent of Total
	Low Quality	Medium Quality	High Quality	Total	
Budget Host	20	15	2	37	2.0 %
Best Western	1	36	138	175	9.6 %
Comfort Inn	0	28	70	98	5.4 %
Days Inn	16	98	31	145	8.0 %
Econolodge	5	60	5	70	3.9 %
Hampton Inn	0	0	17	17	0.9 %
Holiday Inn	0	0	82	82	4.5 %
Holiday Inn Express	0	3	9	12	0.7 %
Howard Johnson	2	13	0	15	0.8 %
HoJo Inn	3	6	1	10	0.6 %
Motel 6	27	0	0	27	1.5 %
Quality Inn	0	3	13	16	0.9 %
Ramada Inn	0	0	25	25	1.4 %
Scottish Inn	12	2	0	14	0.8 %
Super 8	4	142	2	148	8.1 %
Travelodge	2	4	1	7	0.4 %
Other Chains	23	51	30	104	5.7%
Independents	658	98	59	815	44.9 %
Totals	773	559	485	1,817	
Percent of Total	42.5%	30.8%	26.7%		

Table 4.1: Observed Market Configurations for the Two Product-Type Models

Market Configuration	Number of Markets	Percent of Total
(1,0)	61	12.4 %
(0,1)	67	13.6 %
(2,0)	26	5.3 %
(1,1)	40	8.1 %
(0,2)	30	6.1 %
(3,0)	10	2.0 %
(2,1)	22	4.5 %
(1,2)	30	6.1 %
(0,3)	33	6.7 %
(3,1)	13	2.6 %
(2,2)	17	3.5 %
(1,3)	35	7.1 %
(3,2)	20	4.1 %
(2,3)	30	6.1 %
(3,3)	58	11.8%
Total	492	

Table 4.2: Summary Statistics of X - Variables

X - Variables in the Payoff Function		Mean	Std. Dev.	Min.	Max.
PLACEPOP	Population of Town Closest to the Market	5,802.3	6,408.8	100	38,705
TRAFFIC	Average Annual Daily Traffic on Interstate at Market Exit	16,506.6	8,754.4	2040	68,103
SPACING	Sum of Miles from Market Exit to Adjacent Markets Along Highway	53.1	29.9	10	224
WEST	Dummy variable; equals one if Market is in the West Region	0.18	0.39	0	1

X-Variable Transformation:	X_m	X_m^*
$X_m^* = \ln \left[\frac{X_m}{\frac{1}{492} \sum_{m=1}^m X_m} \right]$	Sample Mean	0
	Half the Sample Mean	$\ln(0.5) = -0.693$
	Twice the Sample Mean	$\ln(2) = 0.693$

Table 4.3 **Parameterization of the $g(\mathbf{q}_T; \bar{N})$ Portion of the Payoff Function**

Parameter		Dummy Variable is “Turned On” when $\bar{N} =$													
<u>Effect on Low-Type Payoffs</u>		(1,0)	(0,1)	(2,0)	(1,1)	(0,2)	(3,0)	(2,1)	(1,2)	(0,3)	(3,1)	(2,2)	(1,3)	(3,2)	(2,3)
Low Competitor #1	θ_{LL1}	X		X	X			X	X			X	X		X
Low Competitor #2	θ_{LL2}			X				X				X			X
High Competitor #1 (0 Lows)	θ_{L0H1}		X			X				X					
Addnl. High Competitors (0 Lows)	θ_{L0HA}					1				2					
# of High Competitors (1 Low)	θ_{L1H}				1				2				3		
# of High Competitors (2 Lows)	θ_{L2H}							1				2			3
<u>Effect on High-Type Payoffs</u>															
High Competitor #1	θ_{HH1}		X		X	X		X	X		X	X		X	
High Competitor #2	θ_{HH2}					X			X			X		X	
Low Competitor #1 (0 Highs)	θ_{H0L1}	X		X			X								
Addnl. Low Competitors (0 Highs)	θ_{H0LA}			1			2								
# of Low Competitors (1 High)	θ_{H1L}				1			2			3				
# of Low Competitors (2 High)	θ_{H2L}								1			2		3	

Note: An “X” indicates that the θ -parameter for that row is included (i.e., the dummy variable is “turned on”) in the $g(\mathbf{q}_T; \bar{N})$ portion of the payoff function when the market competitors, \bar{N} , are as given by the column header’s number of low-type and high-type firms. Where there are numbers instead of an “X,” several θ -parameters have been collapsed into one — the dummy variable is turned on that number of times. See sections II.B and IV.B for a full discussion.

Table 4.4: Estimated Parameters — Two Product-Type Models

		SUNK - ENTRY MODEL		SUNK - TYPE MODEL	
Parameter		Estimate	Standard Error	Estimate	Standard Error
<u>Effect on Low-Type Payoffs</u>					
Constant	C_L	1.6254	0.9450	1.5420	0.9192
Low Competitor #1	θ_{LL1}	-1.7744	0.9229	-1.6954	0.8931
Low Competitor #2	θ_{LL2}	-0.6497	0.0927	-0.6460	0.0922
High Competitor #1 (0 Lows)	θ_{L0H1}	-0.8552	0.9449	-0.7975	0.9258
Addnl. High Competitors (0 Lows)	θ_{L0HA}	-0.1247	0.0982	-0.1023	0.0857
# of High Competitors (1 Low)	θ_{L1H}	-0.0122	0.1407	-0.0154	0.0444
# of High Competitors (2 Lows)	θ_{L2H}	-0.0000	0.0000	-1.12E-6	0.0001
PLACEPOP	β_{L-P}	0.2711	0.0550	0.2688	0.0554
TRAFFIC	β_{L-T}	-0.0616	0.1070	-0.0621	0.1069
SPACING	β_{L-S}	0.3724	0.1271	0.3700	0.1271
WEST	β_{L-W}	0.5281	0.1515	0.5246	0.1511
<u>Effect on High-Type Payoffs</u>					
Constant	C_H	2.5252	0.9395	2.5303	0.8925
High Competitor #1	θ_{HH1}	-2.0270	0.9280	-2.0346	0.8810
High Competitor #2	θ_{HH2}	-0.6841	0.0627	-0.6841	0.0627
Low Competitor #1 (0 Highs)	θ_{H0L1}	-1.2261	0.9314	-1.2176	0.8841
Addnl. Low Competitors (0 Highs)	θ_{H0LA}	-5.25E-6	0.0006	-0.0000	0.0000
# of Low Competitors (1 High)	θ_{H1L}	-2.82E-7	0.0001	0.0000	0.0001
# of Low Competitors (2 High)	θ_{H2L}	-0.0000	0.0000	-5.34E-6	0.0003
PLACEPOP	β_{H-P}	0.6768	0.0551	0.6801	0.0570
TRAFFIC	β_{H-T}	0.2419	0.1137	0.2419	0.1142
SPACING	β_{H-S}	0.5157	0.1332	0.5159	0.1328
WEST	β_{H-W}	0.2562	0.1585	0.2588	0.1592
Log-Likelihood		-1143.01		-1143.12	

Figure 4.1: Equilibrium Outcomes Depend on Demand Parameters --
Sunk- Entry Game

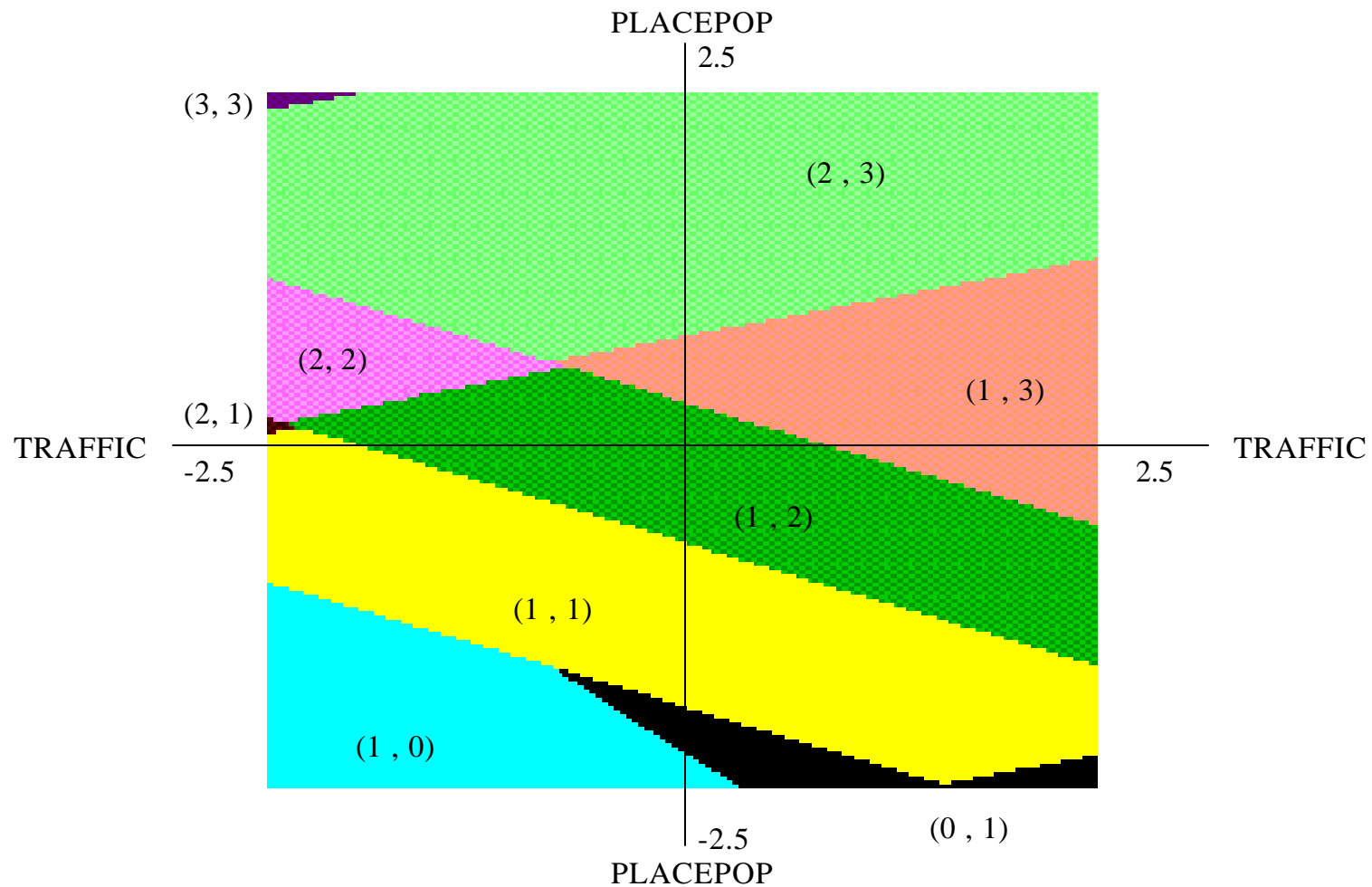


Figure 4.2: Equilibrium Outcomes Depend on Demand Parameters --
Sunk- Type Game

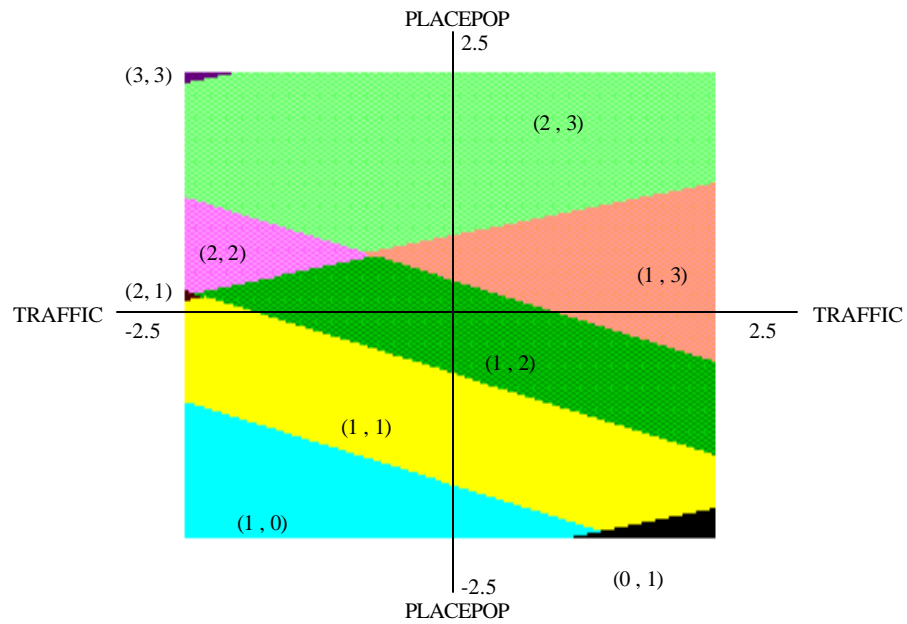


Figure 4.3: Market Structure Prediction Differences --
Sunk-Entry and Sunk-Type Games

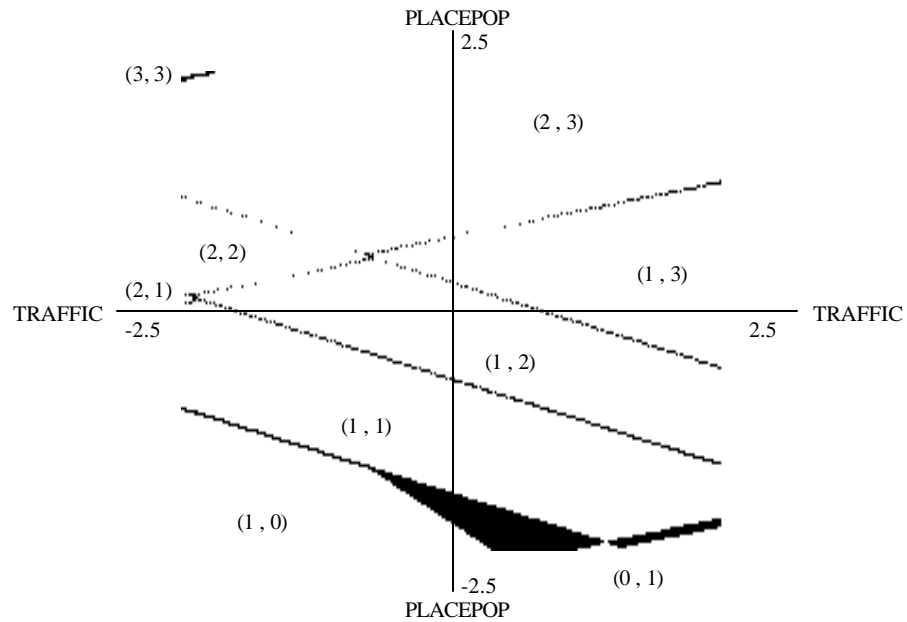


Table 5.1: Observed Market Configurations for the Three Product-Type Models

Number of Motels	Market Configuration	Number of Markets	Percent of Total	Number of Motels	Market Configuration	Number of Markets	Percent of Total
One Motel Markets	1-0-0	61	12.4 %	Five Motel Markets	2-1-2	4	0.8 %
	0-1-0	41	8.3 %		2-2-1	3	0.6 %
	0-0-1	26	5.3 %		1-2-2	2	0.4 %
Two Motel Markets	1-0-1	16	3.3 %		1-3-1	2	0.4 %
	1-1-0	24	4.9 %		3-1-1	10	2.0 %
	0-1-1	16	3.3 %		1-1-3	2	0.4 %
	0-2-0	14	2.8 %		2-3-0	1	0.2 %
	2-0-0	26	5.3 %		0-3-2	1	0.2 %
	0-0-2	0	0.0%		3-2-0	2	0.4 %
	1-1-1	18	3.7 %		0-2-3	1	0.2 %
	1-2-0	9	1.8 %		3-0-2	8	1.6 %
Three Motel Markets	0-2-1	5	1.0 %	Six Motel Markets	2-0-3	1	0.2 %
	2-0-1	10	2.0 %		2-2-2	4	0.8 %
	1-0-2	3	0.6 %		2-3-1	2	0.4 %
	2-1-0	12	2.4 %		1-3-2	4	0.8 %
	0-1-2	4	0.8 %		3-2-1	5	1.0 %
	0-3-0	4	0.8 %		1-2-3	1	0.2 %
	3-0-0	10	2.0 %		3-1-2	4	0.8 %
	0-0-3	1	0.2 %		2-1-3	3	0.6 %
	1-2-1	8	1.6 %		3-0-3	2	0.4 %
	2-1-1	9	1.8 %		3-3-0	4	0.8 %
	1-1-2	9	1.8 %		0-3-3	3	0.6 %
	2-0-2	3	0.6 %	Seven Motel Markets	2-3-2	4	0.8 %
Four Motel Markets	2-2-0	5	1.0 %		3-2-2	4	0.8 %
	0-2-2	7	1.4 %		2-2-3	4	0.8 %
	1-3-0	3	0.6 %		3-3-1	8	1.6 %
	0-3-1	5	1.0 %		1-3-3	2	0.4 %
	3-0-1	11	2.2 %		3-1-3	5	1.0 %
	1-0-3	2	0.4 %	Eight Motel Markets	3-3-2	6	1.2 %
	3-1-0	2	0.4 %		2-3-3	4	0.8 %
	0-1-3	2	0.4 %	Nine Motel Markets	3-2-3	9	1.8 %
					3-3-3	11	2.2 %

Table 5.2: Estimated Parameters — Three Product-Type Models

<u>Parameter</u>	<u>Estimate</u>	<u>Standard Error</u>
<u>Constants</u>		
Low	1.1937	0.0582
Medium	1.4938	0.0512
High	1.0311	0.0542
<u>“Same” Effects</u>		
Effect of Low on Low — θ_{LL}	-1.1881	0.0513
Effect of Med. on Med. — θ_{MM}	-1.4939	0.0473
Effect of High on High — θ_{HH}	-1.6779	0.0469
<u>“Cross” Effects</u>		
“One-Type Away” Effect — θ_{CN}	-0.0243	0.0212
“Two-Types Away” Effect — θ_{CF}	-0.0227	0.0057
<u>X-Variables</u>		
-- PLACEPOP --		
Low	0.1127	0.0238
Medium	0.7681	0.0586
High	0.2603	0.0254
-- SPACING --		
Low	0.0120	0.0565
Medium	0.6145	0.0244
High	0.2901	0.0629

Appendix A Frequency Simulator for the Three Product-Type Likelihood Function

I use a frequency simulation approach to calculate the likelihood function for the three product-type model, because the complexity of the limits of integration make direct computation of the probability of the observed configuration infeasible. For the problem outlined in section V.A, the procedure works as follows: I take a large number, K , of random draws from the trivariate normal distribution. For each random draw k , the particular solution concept of the game generates a simulated equilibrium product-type configuration in each market m using the data for that market, the payoff function parameters and the value of the random draw. I count the number of times P out of K for which the simulated equilibrium equals the observed configuration: $(L, M, H)_{mk}^S = (L, M, H)_m^O$, where $(L, M, H)_{mk}^S$ is the simulated equilibrium configuration at market m for draw k and $(L, M, H)_m^O$ is the observed configuration for market m . The likelihood function is written as:

$$L = \prod_{m=1}^{492} \frac{P_m(\mathbf{b}, \mathbf{q})}{K}$$

where $P_m(\mathbf{b}, \mathbf{q}) = \sum_{k=1}^K I[(L, M, H)_{mk}^S = (L, M, H)_m^O]$. Essentially, parameters are chosen to maximize the number of times the simulated equilibrium configuration “matches” the actual configuration of firms across all the observations in the dataset.⁴⁴

The indicator function component makes the likelihood function difficult to optimize. There are naturally long flat sections where parameters change but the value of the indicator (and thus the likelihood function) does not, followed by discontinuous jumps when the parameter value moves enough to switch the indicator. In my problem, the simulated equilibrium product-type configuration depends on whether a number of profit function inequalities hold. To smooth the likelihood function, the indicator above is replaced with the product of $\Phi\left[\left(\mathbf{p}_A(\bar{N}_A) - \mathbf{p}_B(\bar{N}_B)\right) / h\right]$ for each of the profit function inequalities $\left[\mathbf{p}_A(\bar{N}_A) > \mathbf{p}_B(\bar{N}_B)\right]$, where Φ represents the cumulative normal distribution function. For the estimation in section V.B, $h = 0.1$ and $K = 100$ were used.

⁴⁴ The econometric properties of the frequency simulation estimator are summarized in McFadden and Ruud (1994). Reiss (1996) and Berry (1992) suggest applying this technique to estimate multiple-agent qualitative-response models.

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