Product Differentiation, Collusion, and Empirical Analyses of Market Power

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ABSTRACT

This dissertation comprises three essays on theoretical and empirical issues in industrial organization. Chapter 1 outlines the issues explored in the subsequent chapters and briefly describes their conclusions.

Chapter 2 explores how product differentiation impacts the incentive compatibility condition for firms to sustain implicit collusion in games of repeated interaction where, in contrast to previous studies, I focus on a market which is simultaneously vertically and horizontally differentiated. To achieve this objective, vertical differentiation is incorporated into an otherwise standard Hotelling framework. The ensuing mixed model of differentiation shows how the interrelationships between both forms of differentiation impact the incentives to collude, and is more general since it replicates previous findings throughout the literature.

In Chapter 3, a multiproduct oligopoly model admitting product differentiation and a discrete choice demand model are proposed and estimated to determine if patterns of anti-competitiveness exist across distinct segments of the European car market. This chapter focuses on the evolution of price competition at a finer level than has been studied with a view to empirically challenge the notion that the European car market is wholly anti-competitive. Empirical results show that firm conduct varies due to the intensity of within-segment competition among rival firms. There is evidence of softer competition in the larger, mid- to full-sized segments and more aggressive competition in the smaller, entry-level subcompact segment.

Chapter 4 represents a formal extension of the analysis in Chapter 3. In this chapter I examine the competitive structure of the U.S. automobile market using proprietary data comprising actual dealer-level transaction prices of several models of cars and light trucks sold in the domestic U.S. market between 2004 and 2007. The chapter is the first such study to employ consumer end-prices for automobiles in a structural New Empirical Industrial Organization (NEIO) framework. Empirical results reveal that there is more aggressive pricing in the light truck segments comprising minivans/SUVs and pickups, Bertrand pricing in the smaller, entry-level car segments, and softer competition in the full-size car segment. There is also a strong preference for domestically produced light trucks although consumers generally prefer to drive fuel efficient vehicles.

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CHAPTER 1

Introductory Remarks

> "Product differentiation is a pervasive phenomenon in modern market economies, and explicit recognition of this is central to understanding the nature of oligopolistic interaction." (Anderson, De Palma, and Thisse (1992), p. 143)

> "Detecting collusion is a lot like searching for skeletons in closets. Over the years industrial economists have learned much about which closet doors to try opening, and about how to recognize what they can only imperfectly observe within." (Geroski (1988), p. 119)

Product differentiation is a consistent feature of imperfectly competitive markets and their association remains a topical issue in Industrial Organization (IO). This ongoing debate is fueled by the fact that of all the factors thought to influence firm conduct, product differentiation may perhaps be the most enigmatic.[1] For example, existing evidence regarding the formation of non-cooperative agreements in oligopoly games of repeated interaction reveals that product differentiation generates two countervailing possibilities. First, because it induces heightened brand loyalty and lower product substitutability across product offerings, rival firms are less tempted to initiate price wars since no single firm can gain sufficient control of an entire market by trivially shaving prices. In markets where desirable play is enforced by a punishment scheme, differentiation may also curtail the severity of any punishments precipitated by instances of cheating, thus restricting the ability of firms to effectively punish aberrant behavior.[2] The net effect on the incentive compatibility condition of firms to form non-cooperative agreements is therefore largely dependent on which effect dominates.

Product differentiation arises when consumers do not view related goods as easily substitutable, thereby allowing firms to act as localized monopolies. Local monopolies develop when firms exert market power within a narrowly defined region of some abstract product space which represents the range of potential variants of a particular product.[3]

[1]Product differentiation as a general concept is discussed extensively in Eaton and Lipsey (1986), Ireland (1987), Waterson (1989), Beath and Katsoulacos (1991), and Anderson, De Palma and Thisse (1992) among others.
[2]See, for example, the discussion in Ivaldi et al. (2003).
[3]One distinct feature of localized competition is that cross-price elasticities between neighboring goods are positive and finite but zero between goods which are not nearest neighbors in the product space

Hence, as a direct result, differentiation is central to most marketing strategies because of the competitive edge that it yields. The implicit objective of any differentiation strategy is to build up switching costs so as to discourage consumers from making substitute purchases (Shum (2004)). However, as a form of non-price competition this strategy is only effective if a firm's product mix is, to some degree, uniquely superior in several respects such as performance, quality, or convenience.[4]

Product differentiation has also been credited with resolving the Bertrand paradox whereby the competitive equilibrium obtains in pricing models even in the case of few firms with constant and identical marginal costs. It exists in two polar forms: horizontal and vertical. Horizontal differentiation is manifest in markets where products differ by variety in flavor, color, fragrance, style, motif or brand identity. Participant consumers within these markets express heterogeneous tastes and preferences over an entire outlay of products, even if all products are identically priced, and no product is viewed as indisputably better or worse by *all* consumers. Examples of such markets include ready-to-eat cereals, laundry detergents, snack foods, toiletries, and carbonated soft drinks. In vertically differentiated markets, products are unequivocally ranked by quality as in the markets for automobiles and medical services. A key implication is that even at identical prices, consumers uniformly prefer the good that is of the highest possible quality. According to Economides (1989):

> "Quality is defined as a product feature such that, at fixed prices, all consumers desire higher levels of it. In contrast, all consumers do not want 'more' of a feature of variety." Ibid, p. 22.

Since Hotelling's (1929) seminal piece which advanced the idea that consumers and firms are jointly dispersed over some abstract product space of finite length, the broader IO literature has remained particularly interested in the dynamics of product differentiation within imperfectly competitive markets. For instance, we now know that Hotelling's *Principle of Minimum Differentiation* which implied that firms have a general tendency to agglomerate in the center of the market if given a choice of location in abstract product space is fundamentally flawed. Work subsequent to Hotelling has uncovered evidence to suggest that firms in fact prefer to locate at opposite ends of the product spectrum as no pure strategy price equilibrium can be established when firms locate in close proximity to each other. This alternate view has become known throughout the literature as the *Principle of Maximum Differentiation*.[5] Based on work by Friedman (1971), further emphasis

[4]Differentiation must also be sustainable over a period of time and readily communicable. Van Waterschoot (2000) mentions the case of users of noisy lawnmowers. Somehow, it is widely believed that such lawnmowers are more powerful.

[5]D'Aspremont, Gabszewicz, and Thisse (1979). See also Economides (1989).

has been placed on characterizing the role played by product differentiation in fostering environments conducive to collusion. Several authors including Chang (1991), Ross (1992), Rothschild (1992, 1997), and Häckner (1994, 1995), among others have adapted Friedman's supergame equilibrium concept to the study of collusion to illustrate how product differentiation impacts price competition and ultimately the incentives to form non-cooperative agreements in oligopoly models of repeated interaction. These expositions have yielded mixed outcomes however, prompting a lore in IO that with product differentiation "anything" can happen (Waterson (1989), p 24).

The empirical branch of the IO literature has likewise undergone a metamorphosis. Prior to the mid-1990s, infusing product differentiation into empirical demand-supply equilibrium models presented unique challenges. Under the premise of homogeneous products a representative market level demand-supply specification completely summarizes the relevant partial equilibrium price-quantity responses. But with differentiated products a system of demand-supply relationships, one set for each product $j = 1, ..., J$, must be specified. As J increases however, generating empirical estimates of the parameters of interest from the system becomes exceedingly difficult since the estimation algorithm quickly consumes available degrees of freedom. As a practical matter, consider for example a system with J differentiated products which must yield, at a bare minimum, J^2 own- and cross-price elasticities in addition to any income effects. For industries with hundreds of differentiated products this task is virtually impossible without access to massive amounts of data. In contemporary parlance this non-trivial problem has become known as the "incidental parameters curse" (Spanos (1999)).[6]

The characteristics-based approach to specifying demand, pioneered by Lancaster (1966), McFadden (1978, 1981), Rosen (1974), and later extended to the estimation of such models by Berry (1994), and Berry, Levinsohn, and Pakes (1995) (hereafter BLP) emerges as a viable alternative for differentiated product markets. This strand of the literature presupposes that utility is derived from consuming the attributes of a product. Within this context demand is interpreted as a desire for product attributes and differentiation occurs as a natural consequence of these products possessing various amounts of said attributes. The discrete choice paradigm, which is at the heart of much of the recent advances in empirical IO, represents one such class of characteristics-based demand models. The theory of discrete choice relies on the principle that consumers make indivisible purchases of at most one unit of a particular product on every purchase incidence and

[6]Efforts to combat this problem include imposing ad hoc homogeneity and symmetry restrictions (Deaton and Muellbauer (1980)), some of which are rarely testable, or estimating multi-stage demand systems (Hausman, Leonard, and Zona (1994)).

typifies consumer behavior in markets for automobiles, computers, and even airline tickets. On comparison with the traditional neoclassical approaches to estimating demand, these characteristics-based approaches carry the advantage that they allow demand to be described by a smaller set of unknown parameters since it is projected over a parsimonious space of attributes. This gives way to a more malleable framework within which added structure based on information on product characteristics and consumer preferences can be used in the estimation process along with restrictions on firm conduct.

In light of the above, this dissertation joins the debate on two fronts. First, the relationship between product differentiation and collusion is discussed from a theoretical standpoint using the concept of repeated games. A repeated game (or supergame) comprises constituent one-shot or single-period base games which are played in each period $t \in \{0, 1, 2, ...\}$. Interestingly, whereas the subgame-perfect Nash equilibrium (SPNE) for a finitely repeated supergame is comprised of independent repetitions of the Nash best responses from the constituent base games, infinitely repeated games generate a host of equilibria even if the best responses from the individual base games are unique. Friedman (1971) was perhaps the first to illustrate this by proving that *any* individually rational payoff vector giving a firm strictly higher profits than the one-shot Nash equilibrium from the base games is supportable as a SPNE of the infinitely repeated supergame given that all firms mildly discount the future according to $\delta_i = 1/(1 + r_i)$ with δ_i the firm-specific discount factor and r_i the discount rate. This is the renowned folk theorem result. It has been shown that within an environment with trigger strategies enforcing cooperative behavior, the joint-profit outcome is one such SPNE although it is never a best response in the single-period base games.

Because product differentiation is an important factor influencing the incentive compatibility condition for firms to sustain cooperative outcomes in games of repeated interaction, chapter 2 of this dissertation is aimed at determining whether collusion on some joint-profit outcome is optimal when firms are either in close proximity or widely dispersed in product space. A well established result throughout the literature is that the collusive outcome is more stable under a wider firm dispersion as this relaxes the degree of price competition. In this case, firms are disinclined to enter into prolonged price wars with their rivals and will instead focus on ways to further develop and exploit their localized monopoly power. Häckner (1994) on the other hand demonstrates that the exact opposite result prevails in vertically differentiated markets. Following in the spirit of Shaked and Sutton (1982) he showed that when products are differentiated by quality rather than by their "address" in product space, firms may indeed become more receptive to the idea of colluding as the quality disparity lessens. The difference is largely due to the fact that in models of vertical differentiation, the competitive (Nash) payoffs exert a comparatively greater influence on the incentive compatibility condition for a firm to sustain collusion than in models which employ the horizontal concept of differentiation. Collusion is thus gradually facilitated as an optimal outcome when the competitive payoffs diminish in response to a narrowing quality disparity.

Reconciling these results on the basis of a tractable encompassing model which simultaneously features the above mentioned forms of product differentiation is one of the main contributions of this dissertation. To achieve this objective asymmetry in product quality is incorporated into an otherwise standard Hotelling duopoly framework à la Dos Santos Ferreira and Thisse (1996) by assuming that both firms have access to separate transport technologies. Hence, each firm faces different "product-to-market" costs and will subsequently pass these on to their respective customers. The resulting mixed model is then employed to delineate how the interrelationships between both polar forms of differentiation impact the incentives to form non-cooperative agreements in the duopoly market and remains more general insofar as it replicates previous findings throughout the literature on differentiation and collusion.

Neven and Thisse (1990) and Anderson et al. (1992) both argue that in these so-called mixed models of differentiation, the interplay between horizontal and vertical attributes may generate counter-intuitive comparative statics properties of the price equilibrium. In fact, in both of these studies, softer competition and a concomitant price *increase* occur when both firms approach each other in product space along the *dominated* attribute, a result which runs counter to what obtains in single-dimensional models of horizontal or vertical differentiation. The heightened rivalry engendered by firms locating in close proximity materializes within the mixed model solely when firms approach each other along the *dominant* attribute.[7] The implications of these findings are profound as collusion may indeed be a distinct possibility under a minimal amount of differentiation even if only along a single dimension. Remarkably however, although most products are differentiated along multiple dimensions there is no existing precedent in the literature which uses this idea to examine how firms interface to ultimately form mutually beneficial agreements. Indeed, whereas the papers by Caplin and Nalebuff (1986), Economides (1989),

[7]Presumably, if (q_i, z_i) is a variant specification for firm $i = 1, 2$ where z and q denote the horizontal and quality attributes respectively, then $(z_2 - z_1) > (q_2 - q_1)$ implies *horizontal dominance* whereas *vertical dominance* is implied by a reversal of the inequality (See Neven and Thisse (1990), pp. 179-180 and Anderson et al. (1992), pp. 316-317). In related work by Irmen and Thisse (1998), given a vector of firm locations $\mathbf{a} = (a_1, ..., a_n)$ and $\mathbf{b} = (b_1, ..., b_n)$, the n^{th} characteristic is *dominant* when $t_n(b_n - a_n) \geqslant t_{n-1}(b_{n-1} - a_{n-1}) \geqslant, ..., t_1(b_1 - a_1)$ while $n-1$ are *dominated.* It is important to note however that Irmen and Thisse focused on the more general problem of multi-attribute product positioning and price competition in a spatial setting rather than on how the interrelationships between both forms of differentiation affect the comparative statics of the model's equilibrium outcomes.

Neven and Thisse (1990), Irmen and Thisse (1998), Tabuchi (1994), and Vandebosch and Weinberg (1995) all explore multi-attribute product positioning and price competition, neither of these authors has explicitly extended their discussions to the study of collusion. This dissertation seeks to close this gap in the literature.

The analysis in chapter 2 reveals that under minimal vertical differentiation, increased horizontal differentiation via a wider firm dispersion does in fact preserve the joint-profit outcome as a SPNE of the repeated game, a result which reaffirms the conclusions in Chang (1991), Ross (1992), and Häckner (1995). However, when the market is sufficiently differentiated along both dimensions, there is less collusion on the joint-profit outcome since the high-quality firm's gains from deviating are at a maximum. This result implies that there is an important role for the interplay between both forms of differentiation in oligopoly models of strategic interaction and suggests that earlier predictions regarding product differentiation and collusion should be placed in proper context.

Second, this dissertation delves into an empirical application along the lines of BLP to illustrate the evolution of price competition within the European and United States (U.S.) car markets in chapters 3 and 4 respectively. The application covered in these chapters is also intended to highlight the expedience of the BLP methodology for oligopolistic markets with differentiated products. BLP's work is based on the New Empirical Industrial Organization (NEIO) approach to modeling firm conduct (Bresnahan (1989)). This approach

> "...involves the development and estimation of structural econometric models of strategic, competitive behavior by firms." (Kadiyali, Sudhir, and Rao (2001), p. 162)

Its wide applicability is evidenced by the volume of research it has generated. A list of topics include post-merger simulations and food demand studies (Nevo (2000); Chidmi and Lopez (2007)), new product entry and the demand for durable goods (Petrin (2002); Gowrisankaran and Rysman (2007)), vertical and other forms of strategic relationships (Sudhir (2001b); Draganska and Jain (2005)), and product innovation and market power evaluation (Bresnahan, Stern, and Tratjenberg (1997); Nevo (2001)) is demonstrative of this fact.

Consistent with this line of research, a multiproduct oligopoly model which admits product differentiation in conjunction with a model of discrete choice is proposed and estimated below so as to determine whether or not there exists patterns of anti-competitive pricing across the car markets in Europe and the U.S. The goal is to separately identify demand, cost, and conduct parameters from product level data on the respective car markets and compare the outcomes from both estimation processes. However, in contrast to earlier empirical work focused exclusively on characterizing price competition across broad national markets, the aim here is to uncover whether or not there exist patterns of anti-competitiveness across distinct segments and subsegments of the respective car markets where segments are defined according to standard marketing classifications and subsegments are defined by the country of origin of the particular vehicle.

The implied equilibrium from the models in both chapters 3 and 4 comprises a demand side similar to Brenkers and Verboven (2006) in which preferences are assumed correlated across distinct marketing segments and subsegments and a supply side in which firms interact repeatedly while setting prices according to a Bertrand rule. On the supply side, deviations from standard Bertrand pricing are taken as a measure of the intensity of price competition, as outlined in Sudhir (2001a). On the demand side, endogeneity in prices due to the presence of attributes unobserved by the econometrician is dealt with using a linear instrumental variables procedure advanced by BLP with a view to generating plausible substitution patterns. The parameters of interest generating these substitution patterns are fed into the pricing model to recover marginal costs and the segment-specific conduct parameters which drive the analyses. It is worth mentioning that the supply side in both chapters is based on the *coefficients of cooperation* approach to modeling firm conduct (Cyert and Degroot (1973)), a distinct departure from the literature which assumes that firms compete according to the myopic Betrand rule. Under this approach, no restrictions are placed on the form of competition among rival firms, rather it is loosely inferred based on the value of a *cooperation coefficient* which indicates the weighting a firm places on rival profits in maximizing its own profit function.

These models are estimated using separate data sets. The model in chapter 3 is estimated on product level data comprising pre- and post-tax list prices, quantities (new vehicle registrations), and vehicle characteristics indicating comfort, performance, and safety, of virtually all passenger cars registered in five national markets: Belgium, France, Germany, Italy and the United Kingdom (U.K.), which collectively account for over 80% of annual new vehicle registrations across Europe. The data covers the period 1970 to 1999 and is augmented by macroeconomic data including GDP, exchange rates, population, and price indexes for these five markets. Portions of these data have been used in previous studies of the European car market including Verboven (1996) and Goldberg and Verboven (2001). The model in chapter 4 is estimated on a proprietary data set including similar macroeconomic variables, actual dealer-level transaction prices, quantities (monthly sales), and vehicle characteristics of the base nameplates for over 240 of the best selling models of cars and light trucks offered for sale in the domestic

U.S. market between 3Q 2004 to 1Q 2007. The transaction price data is obtained from J.D. Power's Power Information Network (PIN) while the sales and vehicle characteristics data are sourced from various issues of the Wards automotive handbook and from Crain's Automotive news publication.

The estimation results from both chapters support the hypothesis that conduct varies according to the intensity of within-segment competition from rival firms. More importantly, the results from Chapter 3 cast doubt on the widely held conclusion that the European car market is wholly anti-competitive, as there is more competitive pricing in the compact and intermediate marketing segments, cooperative pricing in the subcompact and standard segments, and Bertrand pricing in the luxury car segments. Estimates from the demand model also reveal that cars belonging to the same subsegment are viewed by consumers as more homogeneous than cars belonging to different subsegments of the same marketing segment. In addition, an included foreign firm effect, intended to capture any potential competitive advantage domestic incumbents have over foreign firms in terms of consumer mean valuation, shows that the foreign competitors indeed face a competitive disadvantage on comparison with their domestic counterparts. Estimates from Chapter 4 show that conduct also varies according to the degree of within-segment competition from rival firms. In particular, there is more aggressive pricing in the light truck segments comprising minivans/SUVs and pickups, evidence of Bertrand pricing in the smaller, entry-level car segments, and more cooperative pricing in the full-size car segment. Consumers also portray a strong preference for domestically produced light trucks even though most prefer to drive fuel efficient vehicles.

CHAPTER 2

Product Differentiation and Non-Cooperative Agreements in a Spatial Duopoly

> "A real problem with both vertical and horizontal product differentiation approaches is their very separation. It seems unlikely that a demand for horizontal product differentiation will occur in the absence of a demand for vertical product differentiation and vice-versa. To combine the two approaches requires us to view individuals as varying in two respects: in their 'ideal' product location as well as their evaluation of quality." (Ireland (1987), pp. 93-94).

2.1. Introduction

This chapter investigates the manner in which product differentiation impacts the incentive compatibility condition for firms to sustain non-cooperative agreements in oligopolistic supergames. As is customary for studies addressing this issue, the goal is to determine whether an implicit joint-profit maximization strategy can be maintained as an optimal market outcome when firms are either in close proximity or widely dispersed in the product space of potential variants. However, in contrast to the previous literature, I proceed by assuming a mixed model which combines the two prevalent forms of differentiation: horizontal and vertical, into one encompassing framework. The model is thus atypical to the extent that products are assumed to simultaneously differ in variety and quality. As a result, what becomes critical to the analysis is the interplay between these two types of differentiation and how this affects the incentive compatibility condition for firms to maintain implicit agreements. Several authors have employed the concept of horizontal differentiation to show that the joint-profit outcome is more stable when firms are widely dispersed in the product space as this mitigates competition among rivals. But similar work based on vertically differentiated markets offers contrasting predictions. These studies show that the joint-profit outcome remains viable even when firms draw closer from a quality perspective. Thus, the current chapter attempts to reconcile these results on the basis of the proposed mixed model of differentiation.[1]

[1]The misnomer, *multi-dimensional* is frequently applied in describing these types of models. However, a purely multi-dimensional model may or may not simultaneously include aspects of both concepts of product differentiation. To avert confusion, I will use the term *multi-dimensional* to refer only to models which feature multiple dimensions of either horizontal or vertical differentiation. Mixed models

In constructing the model I follow in the spirit of Dos Santos Ferrieira and Thisse (1996). Vertical differentiation is incorporated into the well known Hotelling (1929) model by relaxing the assumption that firms have access to the same transportation technology. This departure generates a disparity in the "product-to-market" costs firms incur in bringing their goods to market. The firm facing the lower cost is deemed the high-quality firm in the model as these transportation costs are treated as an inverse measure of quality. The model's implied equilibrium outcomes from joint-profit maximization, competition according to a Bertrand rule, and that which arises when one firm cheats on the implicit agreement are then used to establish the incentive compatibility condition. This condition is based on Friedman's (1971) supergame equilibrium concept whereby the net gain from cheating is compared to an infinite stream of discounted future losses precipitated by the original deviation.

The model is able to reproduce the familiar result that collusion is more stable under increased horizontal differentiation only when there exists a minimal amount of vertical differentiation. However, given a significant disparity in quality, less collusion is supportable under a wider firm dispersion in the horizontal dimension. This last result suggests that the interplay between product features across dimensions is critical to any analysis regarding product differentiation and collusion. The model also reveals that regardless of the degree of horizontal differentiation, collusion at the joint-profit solution is an increasingly likely outcome as the degree of vertical differentiation diminishes.

The roadmap for this chapter is as follows. First, a brief discussion justifying the use of the spatial framework is provided in section 2.2 followed by a historical account of location theory, which is based on the concept of spatial competition, in section 2.3. Section 2.4 relates the idea of spatial competition to the study of collusion whereas the formal model is outlined in section 2.5. Results of the analysis are found in section 2.7 while concluding remarks and directions for future research round out the chapter in section 2.8.

2.2. Background

Although numerous approaches to modeling product differentiation exist in the IO literature, most can be classified under two broad paradigms. The first branch is the explicitly spatial approach whose appeal extends beyond IO into areas such as political science, the economics of print and broadcast media, and economic and marketing geography. The basic premise of this approach is that consumers and products are indexed

will therefore be those which simultaneously feature both polar forms of differentiation regardless of dimensionality.

by their "address" along an abstract space which represents some tangible geographic continuum or the range of potential variants of a particular product.

Geographic and characteristics-based models of differentiation are formally classified under the broadly defined spatial paradigm. Within geographic models, consumers and firms are both differentiated by their respective addresses along the continuum with consumers incurring transportation costs in traveling to their ideal product's location.[2] It is worth mentioning that firm rivalry in this context is localized, which means that there is direct interaction solely with nearest neighbors along the continuum. Differentiation therefore arises mainly as a result of the relative distances between consumers and firms along the continuum since product offerings are otherwise standard. Another fundamental assumption underlying this framework is that the continuum is one-dimensional or linear. Whereas this diminishes the mathematical complexity of the model and ultimately aids in the analysis of the implied equilibrium dynamics, several studies have relaxed this assumption to evaluate the impact of a multi-dimensional continuum on the product positioning process. These are discussed below. In characteristics-based models, consumers express heterogeneous preferences over an array of attributes intrinsic to different products and seek to purchase the product which embodies the ideal amount of desirable attributes. Differentiation is therefore a natural occurrence of products possessing various amounts of these desirable product features. This approach has spawned what has now become known as hedonic demand theory which aims to estimate the relative contribution of each product attribute in the demand system, an idea widely in use in the NEIO framework. Authors such as Lancaster (1966) and later McFadden (1978, 1981), Rosen (1974), and Berry (1994), have set out the theoretical underpinnings of these types of characteristics-based models, and this research program has substantially contributed to the development of the discrete choice models of demand which have now become the standard workhorse of contemporary empirical work on consumer choice. Discrete choice models framed against the backdrop of these characteristics-based models have been brought to the data for empirical validation by BLP, Nevo (2000, 2001), Petrin (2002), among others.

The non-spatial ("non-address") branch assumes that aggregate consumer preferences are broadly defined over a finite or infinite set of products. The class of representative consumer models, which has enjoyed prominence in neoclassical demand theory, falls under this category of models. Within this framework, given the vector of market prices,

[2]The seminal piece by Hotelling (1929) is one of the more widely cited bodies of work in this area. More recently, the idea of spatial competition has been employed to describe different aspects of political rivalry with candidates competing for votes by taking ideological positions in a political spectrum (see Downs (1997)).

demand is obtained as the solution to the standard utility maximization problem in which customers consume a positive amount of all goods offered in the market. Hence, competition is more global than that which prevails in geographically differentiated markets. The models in Dixit and Stiglitz (1977) and Spence (1976) which rely on the assumption of symmetric differentiation among product offerings are both representative of this treatment.

The representative-goods approach is however criticized on the grounds that it masks an admittedly obvious source of market diversity arising from heterogeneity in consumer preferences. As argued in Archibald, Eaton, and Lipsey (1986), one is compelled to ask what implied restrictions on individual consumer preferences justify the aggregate preference relation that is at the heart of the analysis. Few satisfactory explanations exist. Although it is widely thought that the representative consumer model may be derived by aggregating preferences from the address paradigm, the fact that cross elasticities in the former are positive for all goods eliminates the potential for localized competition which is a distinct feature of the latter, thus leading to their exclusion as an acceptable starting point. Moreover, address models are better suited to account for instances in which consumers drop out of the market due to rising prices over and above their reservation utility levels. This is in stark contrast to their representative goods counterpart which is grounded on the premise that consumers purchase positive amounts of everything.[3]

2.3. Spatial Models of Differentiation

Location (or "address") theory has had a long history in economics dating back to work by Launhardt (1885). It relies on a geographical distribution of consumers and firms over some abstract product space which represents the range of product variants. This discourse is concerned with the strategic product positioning process over the product space which is usually taken to be one-dimensional. As in the widely cited paper by Hotelling (1929), the process is depicted as a two-stage duopoly game where firms compete for ideal locations in product space prior to competing in prices. In this two-stage game, given the address of its rival, a firm strategically chooses its location to maximize profits while noting the comparative static effects of both firms' proximity on the price equilibrium. Consumers are uniformly dispersed along the space of characteristics and each incurs a disutility cost associated with traveling to a particular firm's location to purchase one unit of the product which is assumed homogeneous except for its location in product space.

[3]This is illustrated by Salop (1979). In his address model consumers are allowed to purchase given amounts of an "outside" good which results in zero quantities consumed of the "inside" product offerings in the market.

The Hotelling location model is perhaps the most famous representation of spatial differentiation. Its allure is largely based on the fact that it depicts the concept of horizontal differentiation in a rather succinct manner. The model consists of a finite set of firms $F = \{1, ..., f\}$ producing a homogeneous good and a finite set of consumers $J = \{1, ..., j\}$. Firm i, $(i \in F)$, and consumer j, $(j \in J)$ are indexed by their respective addresses s_i and s^j in a linear space S of unit length, i.e. $s_i,\ s^j \in S = [0, 1]$, where c_i is a firm-specific marginal cost and $t(s_i, s^j)$ measures the disutility cost incurred by a consumer to travel to firm i's location. Assuming the reservation price of consumer j is $\overline{p}^j$ it can be shown that firm i's potential market share is defined by the condition $c_i + t(s_i, s^j) \leqslant \overline{p}^j$. The model relies on localized competition, with firms interacting directly with their nearest neighbors in the linear space S by setting f.o.b. or *mill prices*, p_i which are constant across all consumers regardless of their address along the continuum. Consumers patronize firms offering the lowest delivered price which is the mill price plus the transportation cost and have preferences described by a conditional indirect utility function

$$V_i(S) = \overline{p}^j - t(s_i, s^j) - p_i.$$

Consumer j purchases at most one unit of the product from firm i *iff*:

$$V_i(S) \geqslant V_k(S), i, k \in F, i \neq k,$$

with $\overline{s}^j(p_i, p_k)$ denoting the marginal consumer who is indifferent between purchasing from either firm. Thus, $\overline{s}^j$ is the solution to

$$V_i(S) = V_k(S), i, k \in F, i \neq k.$$

The location of the marginal consumer, which stands as the market boundary between both firms is conditional on the prevailing vector of mill prices as price movements may cause consumers to switch to another firm's product or drop out of the market. The position of this consumer also allows the individual demand functions faced by both firms to be defined in a straightforward way. The simplest version of the Hotelling model involves two ice cream vendors located along a beach during a hot day. Both vendors offer fixed prices to consumers who are located at various points along the beach. Consumers have no overriding preference for either vendor except that they dislike having to travel a relatively far distance across the hot sand to purchase ice cream which melts easier in this weather. Central to their decision to purchase from either vendor is therefore the price plus disutility (or transport) costs incurred in traveling to either vendor's location. In response, vendors will choose locations to minimize their relative distance to consumers. Strategic play by both vendors results in the Nash equilibrium of this location-price game where both ice cream vendors locate at the median of the market to capture more of the other vendor's customers. Thus, as Hotelling affirmed, vendors will choose an excessive amount of "sameness" in location.

It is now widely accepted however, that the basic Hotelling framework is fundamentally flawed. In a famous paper, D'Aspremont, Gabszewicz, and Thisse (1979) proved that no pure strategy price equilibrium can be established in the second stage of the location-price game if, as Hotelling concluded, firms agglomerate in the center of the linear "city." The reason being that each firm will always find it profitable to undercut their rival's price so as to gain more market share. They instead proved existence and uniqueness properties of the price equilibrium with quadratic rather than linear disutility costs $t(s_i, s^j)$ as Hotelling originally postulated and a location equilibrium in which firms move to the polar extremes of the product space to relax price competition. The assumption of quadratic transport costs was necessary to obviate the difficulties which arose because of discontinuities in the profit functions of both firms at particular prices. Moreover, absent quadratic disutility costs, firms in the basic Hotelling model chose locations for which no corresponding price equilibrium exists. D'Aspremont et al. (1979) instead demonstrate that the *Principle of Maximum Differentiation* holds for this class of spatial models as firms trade off, in equilibrium, the market share effect of attracting more customers by moving closer to a rival against the intense price competition arising from this action.

Other authors have subsequently relaxed or modified several of the basic propositions of the original model in order to either restore Hotelling's *Principle of Minimum Differentiation* or reaffirm its counterpart. Economides (1989) sets out to achieve the latter by introducing an additional choice variable into the Hotelling framework. He assumed that firms are endowed with a quality variation technology which is independent of the level of output produced. Thus, he endogenizes the choice of location, price, and quality where the latter is independently selected. Economides (1989) was perhaps one of the first studies to successfully incorporate quality variations into an otherwise standard Hotelling model of horizontal differentiation leading to a so-called "mixed model" of differentiation. He proffers two separate versions of his model. The first is a two-stage game with locations chosen in the initial stage and price and quality chosen simultaneously in the second. The other is a three-stage game in which firms choose, in sequential order, locations, quality, then price. In both games, the *max-min* principle was evident as the SPNE had firms choosing to maximally differentiate in locations and minimally differentiate along the quality attribute.

Similar to Economides, Neven and Thisse (1990) proceeded to combine both forms of differentiation into one encompassing model where product locations (or variants) are simultaneously chosen in the first stage of the location-price game followed by prices in the second. In their mixed model they assume a single dimension each of horizontal and vertical differentiation where the range of potential varieties y_i denotes the horizontal aspect, and is represented by the unit interval $[0, 1]$ whereas the corresponding range for quality q_i is given by the interval $[\underline{q}, \overline{q}]$. Thus, each product variant $(y_i, q_i) \in [0, 1] \times [\underline{q}, \overline{q}]$ is indexed by its position along the resulting hypercube. Consumers are themselves indexed by their position $(x, \theta) \in [0, 1] \times [\underline{q}, \overline{q}]$ within the hypercube with x representing an ideal variant in the space of potential variants and θ the consumers' quality valuation. A typical consumer's indirect utility arising from the purchase of one unit of the product from firm i is therefore:

$$U(y_i, q_i; x, \theta) = R + \theta q_i - (x - y_i)^2 - p_i$$

where p_i denotes the mill price charged by firm i and R is a reservation level of utility. The indifferent consumer is thus:

$$\overline{\theta}(x) = \frac{(p_2 - p_1) + (y_2^2 - y_1^2) - 2\,(y_2 - y_1)\,x}{q_2 - q_1},$$

for firm $i = 1, 2$ with $q_2 \geqslant q_1$ (firm 2 is the high-quality firm) and $y_2 \geqslant y_1$. Consequently, for any $x \in [0, 1]$, consumers in the interval $[0, \overline{\theta}(x)]$ purchase from firm 1 whereas those residing within $(\overline{\theta}(x), 1]$ purchase from the other firm.

It becomes important in this setting to distinguish between what is meant by *horizontal dominance* and *vertical dominance* since the model's comparative static properties are heavily dependent on which prevails. As Neven and Thisse point out, the former refers to the case where there is a greater degree of differentiation along the space of varieties than in the quality dimension. Therefore $q_2 - q_1 < 2\,(y_2 - y_1)$ is indicative of horizontal dominance whereas a reversal of the inequality denotes the situation called vertical dominance. One of the remarkable results they obtained which was later highlighted in Anderson et al. (1992) is that under horizontal (vertical) dominance the mixed model's comparative static responses to the horizontal (vertical) aspects of the model are similar to what would prevail in single-dimensional models of pure horizontal (vertical) differentiation. This means that the multi-dimensional model behaves in accordance with a single-dimensional model of horizontal or vertical differentiation depending on whether the disparity in variety or quality is larger. With respect to the form of differentiation that is dominated however, non-standard results obtain. In particular, Neven and Thisse prove that if sufficient differentiation prevails along the vertical dimension, prices often increase along the dominated horizontal dimension as variants draw nearer in the space of potential varieties. The intense price competition this action provokes in models of pure horizontal differentiation is absent from the mixed model since the market share effect of moving closer to rival firms dominates the price effect when firms are already sufficiently differentiated along the vertical dimension. If, however, horizontal dominance prevails, the low-quality firm's price is observed to increase as the disparity in quality diminishes. This contradicts previous results by other authors such as Häckner (1994) who showed that prices in the competitive equilibrium respond negatively to a decrease in the quality disparity for models of pure vertical differentiation. Ultimately however, the paper by Neven and Thisse reaffirms the *max-min* principle that firms only choose to locate in close proximity to their rivals if they are already sufficiently differentiated along some other attribute.

In contrast to the above authors, Rhee et al. (1993) attempt to restore Hotelling's principle using a traditional spatial framework. The twist to their model however is that product offerings within the market embody both observable and unobservable/unmeasured attributes at the firm level. The latter set of characteristics play a significant role in consumer choice but they remain either unobserved or unmeasurable on the part of firms similar to what transpires in the case of probabilistic choice models (McFadden (1981); Anderson et al. (1992)). They propose a two stage location-price game where firms simultaneously determine product locations along the observed attribute in the first stage before competing in prices according to a Bertrand rule in the second stage. Given sufficient consumer heterogeneity along the unobservable attributes, they prove that Hotelling's *Principle* is restored in the location subgame for all location-price pairings. The reason is that as consumer heterogeneity increases along the unobserved attributes, it becomes the dominant force driving consumer choice, thus relegating price competition and product differentiation (along the observed attributes) to the background. This presumably erodes the competitive edge gained from these latter two factors. In response, firms choose softer competition and an increased standardization along the observed attributes to take advantage of the market share effect of locating in close proximity.

The papers by Ansari, Economides, and Steckel (1998) and Irmen and Thisse (1998) take a different route. Both papers analyze product choice and pricing strategy in multi-dimensional product space where both dimensions contain attributes that are fully observed by firms. However, their models are not explicitly mixed models of differentiation. The former examines two and three-dimensional Hotelling models whereas the latter extends the discussion to the analysis of a model with n arbitrary dimensions using a framework similar to Neven and Thisse (1990). In the model by Ansari et al. consumers place weightings on the disutility of distance along each dimension which reflects the relative importance of each attribute in the utility function. Regardless of the number of dimensions, they observe that firms choose to maximally differentiate along the attribute that is deemed most important by consumers and minimally differentiate (i.e. take up central positions) along others.[4] However, multiple equilibria coexist when all attributes are equally weighted. In two dimensions, *max-min* and *min-max*, occur simultaneously whereas in three dimensions *max-min-min* and all its permutations are feasible. Similarly, in their model Irmen and Thisse (1998) showed that Hotelling was "almost" right in affirming his original proposition since minimum differentiation can indeed arise as an equilibrium along all but one possible dimension. They were able to reproduce the familiar *max-min* result given $n = 2$ but also discovered that firms in general chose *max-min-...-min* differentiation given $n > 1$ arbitrary dimensions.[5]

Other variants of the Hotelling model have surfaced in the literature to examine a wide range of issues. Salop (1979) studied the extent of entry on product proliferation across a spatial duopoly similar to Hotelling. He assumed however that the space of characteristics was circular rather than linear to avert "corner" problems that arise when firms are located near the end-points of the finite product space. Firms competing on this circular disc are equidistant from each other and have nearest neighbors on either side. Thus, in contrast to the Hotelling model no location is more desirable than any other. This means that the first stage in the location-price game can be omitted from any further analysis without loss of generality. Indeed, this stage is absent from Salop's (1979) model and is replaced by a phase during which firms with common marginal costs decide whether or not to enter the market and incur a fixed cost of entry.

Gabszewicz and Thisse (1986) and Dos Santos Ferreira and Thisse (1996) have also contributed to this literature by attempting to explicate how vertical differentiation can be precisely incorporated into the Hotelling paradigm. Their approaches are dissimilar as the former assumes that both firms are located outside $S = [0, 1]$ on the same side. Therefore, the firm closest to the inhabitants residing within the city is deemed to be the high-quality firm because of the shorter distance to its location. Gabszewicz and Thisse's (1986) comparison of the outcomes from the location-price game in their specification with the standard Hotelling prediction is revealing. They show that a SPNE exists for all location-price pairings in their model, quite unlike the instability which results when

[4]This may explain the recent proliferation of hybrid automobiles or low-fat, low carbohydrate products by automakers and food manufacturers respectively. Interestingly Ansari et al. use ice cream as an example of such a product. At the time observation, they noted a wide disparity in the fat content per 100-gram serving across all brands at a grocery store, but all more or less had the same 25 grams of carbohydrates and sugar. Presumably consumers placed higher emphasis on fat content per serving and manufacturers responded by differentiating with respect to this characteristic.

[5]Similar conclusions are derived by Tabuchi (1994) in a two-dimensional Hotelling model, and Vandenbosch and Weinberg (1995) who extends the one-dimensional model of Shaked and Sutton (1982) to two dimensions.

firms agglomerate in the center of the Hotelling linear city. The latter two authors assume that both firms are located arbitrarily in $S = [0, 1]$ but due to the presence of firm-specific transport costs, one firm's product is unequivocally less expensive. Their model is based on earlier work by Launhardt (1885) who is arguably the founder of contemporary location theory.[6] The model's key assumption is that transport costs represent an inverse measure of quality and so the firm with the lower "product-to-market" costs is judged the high-quality firm. They extend Launhardt's original work by endogenizing quality choice in a two stage quality-price game. Firms freely choose their transportation technologies before competing in prices in subsequent rounds of the two-stage game. In line with Neven and Thisse (1990), but in contrast to Economides (1989), they only considered two cases: one in which firms were located at either endpoints of the linear city (i.e. maximum horizontal differentiation), and another where firms are identically located at the market center (i.e. minimum horizontal differentiation). This because it was discovered that no pure strategy Nash equilibria could be established for some location-price pairings. Given dissimilar transportation technologies, existence and uniqueness of the location-price equilibrium was only guaranteed when firms were located sufficiently far apart or in close proximity in the horizontal dimension. Similar to Neven and Thisse (1990) they also uncovered a familiar *max-min* tendency of firms in their two-stage game: under maximum horizontal differentiation, firms end up choosing similar transportation rates along the quality dimension whereas they attempt to maximize the disparity in quality under minimum horizontal differentiation.

This dissertation employs the approach advanced by Dos Santos Ferreira and Thisse (1996) to study the effect of price competition on the incentive compatibility condition of firms to sustain collusion in repeated games in section 2.5. This framework is preferred because it retains much of the salient features of the Hotelling model. Hence, the results are directly comparable to those from previous studies which have used a similar model environment.

2.4. Product Differentiation and Collusion in Repeated Games

Firms collude for a number of different reasons. Predominantly, the intent is to expand profits either by jointly restricting output or maintaining collusive prices above their competitive levels. In the absence of binding contracts however, agreements are usually founded on the basis of a tacit understanding among the connected parties. Indeed, adherence is unenforceable through the legal system and depends in large measure on the

[6] See Backhaus (2000) for a brief biographical sketch of the life and work of Launhardt.

existing incentives to deviate. A prospective deviant may unilaterally consider undercutting prices or expanding output to the detriment of other firms within the collective and might only be deterred by a credible punishment mechanism designed to forestall such errant behavior.

Trigger strategies (Friedman (1971)) are often used to enforce desirable behavior in games of repeated interaction. They prescribe deference to the implicit rules of the collective insofar as all competitors agree to abide. However, if cheating is uncovered at time t, all firms revert to the one-shot equilibrium from $t+1$ *ad infinitum*. The allure of these Nash reversion strategies is based primarily on their straightforward interpretation and simplicity although there exists other, possibly more complicated, more stringent forms of punishment. The "carrot-and-stick" penal code (Abreu (1986)) is one such alternative. This symmetric two-phase scheme consists of reward (the carrot) and punishment (the stick) phases where firms return to colluding in time period $t+2$ onwards after episodes of intense competition up to the period immediately preceding in response to earlier deviant play. It is important to note however, that if firms ignore the prescribed rule of play in the punishment phase, it continues indefinitely until all competitors come to their "senses." If cheating is again detected at some point, the two-phase process is repeated.[7]

Several authors including Chang (1991), Ross (1992), and Häckner (1994, 1995, 1996) have adapted Friedman's supergame framework to investigate the implications of differentiated product markets on collusion. Chang (1991), Ross (1992) and Häckner (1995, 1996) all analyze collusive stability in the context of horizontal differentiation whereas Häckner's (1994) study is framed against the backdrop of a vertically differentiated market. With the exception of Häckner (1996) which utilizes Abreu's symmetric punishment scheme, all have employed trigger strategies à la Friedman (1971).

The common theme in these studies which have employed the horizontal concept is that the gains from deviating outweigh any impending punishments as the market becomes less differentiated horizontally. When products are closely substitutable therefore, collusion is an increasingly unlikely prospect. However, according to the survey by Ivaldi et al. (2003) this outcome is not incontrovertible since differentiation generally impacts the gains and punishments from deviating in like fashion. Indeed, they argue that horizontal differentiation has an ambiguous effect on collusive stability because it simultaneously limits the gains from deviating and weakens the credibility of the threat to

[7]Häckner (1996) successfully incorporates this punishment mechanism into his study of differentiation and cartel stability and concludes the standard result that increased differentiation relaxes price competition and preserves cartel stability. This outcome is apparently robust to modifications of the punishment mechanism.

punish deviant behavior. The outcome is thus ultimately determined by the relative impact of the gains versus the punishments from some optimal deviation strategy. Although these countervailing forces are also at play in vertically differentiated markets, Häckner's (1994) results suggest that the punishment payoffs exert a comparatively greater influence. Thus, when the quality disparity is minimal the net punishment from deviating, which is defined as the difference between the payoffs from a one-shot deviation and that earned during the punishment phase, increases as the payoff in the punishment phase is reduced. This increase is sufficient to outweigh any one-time net gains from deviating and contributes to the discovery of more collusion when products are less dissimilar in a quality sense. All in all much sharper predictions can be envisioned for models which employ the concept of vertical differentiation.[8]

Other authors have challenged the above findings on the grounds that they appear to be unrobust and highly sensitive to the underlying model structure. Gupta and Venkatu (2002) departed from the mill pricing assumption often used in spatial models of differentiation and instead presented a model where firms compete in setting delivered prices. Their results were in stark contrast to the literature as they discovered that collusion was more stable under a smaller firm dispersion. In Tyagi (1999), albeit a model with quantity competition, the demand specification was shown to affect the relationship between differentiation and collusion. In particular, for linear and concave demand specifications increased differentiation strengthened the formation of collusive arrangements as the gains from deviating were overbalanced by the incentives derived from adhering to the arrangement. Furthermore, the relationship was non-monotonic for convex specifications as collusion was shown to be unstable only in cases where products were nearly perfectly substitutable.

Deneckere (1983) also explores this model-specificity issue by highlighting the importance of strategic variable choice. He used a linear demand specification to compare predictions under Cournot (quantity) and Bertrand (price) competition and concluded that whereas the relationship between implicit collusion and product differentiation was non-monotonic under Bertrand pricing, increased differentiation actually hindered the sustainability of collusion under Cournot competition. Rothschild (1992) analyzes a similar issue and confirms Deneckere's findings for Cournot games. However, in contrast to the latter, he found that increased product substitutability actually contributed to the instability of the collusive outcome in Bertrand games. Closely related is subsequent work by Rothschild (1995) which extends the discussion in Deneckere (1983) and Rothschild

[8] Gabszewicz and Thisse (1986) also present evidence in support of the claim that the price equilibrium in horizontally differentiated markets is more fragile than in markets segmented by quality.

(1992) by endogenizing the choice of strategic variable. He discovers that the discount factor necessary to sustain collusion is greater when firms choose price rather than quantity competition. This implies that collusion is supportable in Bertrand games if firms are more patient than would have been required under Cournot games. Furthermore, he showed that regardless of the strategic variable selected for deviation, collusion was more easily deterred when the deviant firm opted to compete in prices than in quantities during the punishment phase.

It is worth noting however that the above mentioned papers have all analyzed the current issue from the perspective of single-dimensional models where differentiation is assumed to take the form of either of the two polar cases. Although this overlooks the fact that a large number of product markets are not simply categorized in this manner it eschews the mathematical complexities that arise in the study of multi-dimensional models. Moreover, the results from Neven and Thisse (1990) and Ansari et al. (1998) presumptively justifies proceeding in this manner.

But single-dimensional models of differentiation may also obscure the critical trade-offs associated with consumer product choice. For example, despite the perceived differences in quality and performance among certain brands of computer hardware and software, compatibility with other software or hardware peripherals is an equally important product feature governing the purchase decision. Another classic instance is that of a car buyer who is confronted with several vehicle features such as color, body style, fuel efficiency, and reliability and crash test ratings when contemplating a purchase. Arguably, fuel efficiency, reliability, and crash test ratings could be considered vertical characteristics. One can imagine that *all* consumers would prefer a "better" car which yields 40 mpg with front and side-impact airbags included as standard features to another which only yields 20 mpg with less safety features if both were offered at identical prices. But even after selecting her ideal quality-type, the buyer might still be dissatisfied with the color choices on the lot, or for arguments sake, might prefer a sedan body style to a station wagon. In light of both examples, the salient issue then is how does a consumer trade-off, say, less performance, safety, or quality for a more compatible or ideal product along another given dimension. The analysis of these dynamics are interesting issues worth considering. However, single-dimensional models of horizontal or vertical differentiation discount the interplay between product characteristics and headline only those considered to be immediately important. This greatly reduces the scope of these models and in that sense, they become useful only from the standpoint of adjudicating a first intuition into the role played by product differentiation in oligopolistic environments.

2.5. Model Environment

The repeated game framework is crucial in maintaining an environment conducive to collusion since the joint-profit maximizing price is never a best response in the constituent single-period base games. For any form of implicit agreement to be sustainable, it necessarily must form part of the SPNE of the entire supergame. This is feasible when desired play is enforced by a system of rewards and punishments as outlined in Friedman (1979). According to Friedman, with "grim" trigger strategies cooperative behavior is maintained if the short term gains from cheating are weakly dominated by the present discounted value of joint-maximum profits.

Firm i's trigger strategy φ_i, is defined as:

$$\varphi_i = \begin{cases} p_{i1} = p_i^{\text{coll}} \\ p_{it} = p_i^{\text{coll}} \text{ if } p_{k\rho} = p_k^{\text{coll}} \ (i \neq k) \\ \qquad\qquad \text{for } \rho = 1, ..., t-1 \\ p_{it} = p_i^b \text{ otherwise} \end{cases} \tag{2.1}$$

where the joint-profit maximizing price p_i^{coll} prevails insofar as its rival does the same. Otherwise, firm i reverts to Bertrand pricing p_i^b along the punishment path. Accordingly, the incentive compatibility condition is:

$$\pi_i^d + \sum_{\rho=1}^{\infty} \delta_i^\rho \pi_i^b < \sum_{\rho=0}^{\infty} \delta_i^\rho \pi_i^{\text{coll}} \tag{2.2}$$

or

$$\pi_i^d + \frac{\delta_i \pi_i^b}{1-\delta_i} < \frac{\pi_i^{\text{coll}}}{1-\delta_i} \tag{2.3}$$

with π_i^{coll}, π_i^d, and π_i^b the payoffs from, respectively, cooperating, deviating or charging the punishment price. The right hand side of Eq. (2.2) depicts the payoffs to cooperating whereas the left hand side displays the gains from deviating which include a one-time payoff π_i^d plus an infinite stream of punishment payoffs π_i^b. The following is obtained after some algebraic manipulation:

$$\delta_i > \frac{\pi_i^d - \pi_i^{\text{coll}}}{\pi_i^d - \pi_i^b} \equiv \lambda_i. \tag{2.4}$$

The firm-specific threshold (or critical) discount factor λ_i defines the lower boundary of the set of such factors admitting collusive behavior, and, as the threshold is lowered, the set of discount factors that support collusion widens. Since payoffs to both firms are impacted by product differentiation, it is easy to define:

$$\delta_i > \frac{\pi_i^d(\tau,\sigma) - \pi_i^{\text{coll}}(\tau,\sigma)}{\pi_i^d(\tau,\sigma) - \pi_i^b(\tau,\sigma)} \equiv \lambda_i(\tau,\sigma), \tag{2.5}$$

where τ and σ both represent the levels of vertical and horizontal product differentiation respectively. The restriction in (2.5) is especially useful. The numerator denotes the per-period gain from deviating while the denominator depicts the corresponding per-period net punishment from deviating. It is also readily verifiable that the threshold, $\lambda_i(\tau,\sigma)$ is decreasing in $\pi_i^{\text{coll}}(\tau,\sigma)$ but increasing in $\pi_i^b(\tau,\sigma)$ and $\pi_i^d(\tau,\sigma)$.

Following Tyagi (1999), Eq. (2.5) can be rewritten as

$$\Lambda_i = \frac{\lambda_i}{1-\lambda_i} = \frac{\overbrace{\pi_i^d/\pi_i^{\text{coll}}}^{\mathbf{A}} - 1}{1 - \underbrace{\pi_i^b/\pi_i^{\text{coll}}}_{\mathbf{B}}}, \tag{2.6}$$

(ignoring the arguments τ and σ) where the numerator now represents the percentage gains from deviating rather than colluding and the denominator the percentage gains from cooperating instead of competing. Here, Λ_i is increasing in both $\mathbf{A} \equiv \pi_i^d/\pi_i^{\text{coll}}$ and $\mathbf{B} \equiv \pi_i^b/\pi_i^{\text{coll}}$. The aim is to study how product differentiation impacts the incentive compatibility condition (2.5) through its impact on (2.6).

2.5.1. The Model

Technology

As in standard linear models of spatial differentiation there exists a continuum of consumers uniformly indexed by taste i.e. their "address" along a bounded interval $\mathcal{F} = [0,1]$ of unit mass. Consumers make indivisible purchases of one unit of the product from firm $i = 1,2$. Both firms are symmetrically located at $a_1 = a$ and $a_2 = a + \sigma$ with $a_i \in \mathcal{F} = [0,1]$ and $\sigma \geqslant 0$. Each firm produces a single variety of a homogeneous good, marginal costs are normalized to zero and there are no fixed costs of production. Firms have access to different transport technologies, which is a departure from the standard Hotelling model in which $t_1 = t_2 = t$. It is further assumed that firm 1 incurs a lower cost when shipping its output to the market and therefore $t_1 \leqslant t_2$ ($t_i \in [\underline{t}, \overline{t}] \subset \Re_+$). It is thus straightforward to construct the ratio $\tau \equiv t_1/t_2 \in (0,1]$. Low values of τ are indicative of a wide quality disparity or significant *vertical differentiation* whereas the aforementioned parameter σ represents the distance between both firms in abstract product space and denotes the degree of *horizontal differentiation* within the market. In what follows, firm 1 will be the high-quality firm since the t_i's can be viewed as an inverse measure of quality.

Finally, without loss of generality, firms will choose mill prices p_1 and p_2 strategically and pass on transport costs to their consumers. As outlined, the mixed model is more general than Hotelling's (1929) spatial framework or Häckner (1994) since it nests both within a single encompassing structure. The classic Hotelling "linear city" is a special case when $\tau = 1$ while Häckner's (1994) set-up may be thought of as a limiting case as $\sigma \to 0$. The following definitions are instrumental in describing the market in terms of the parameters of interest τ and σ:

Definition 1. *If $\sigma = 1$ the market is maximally differentiated.*

Under maximal differentiation, both firms are located at opposite ends of the horizontal product spectrum. Maximal differentiation will be short for maximum *horizontal* differentiation.

Definition 2. *If $\tau = 1$ the market is a "standard Hotelling" one.*

Thus, absent vertical differentiation when $\tau = 1$ the model is substantively equivalent to Hotelling (1929).

Definition 3. *If $\sigma = 1$ and $\tau \approx 0$, the market is "absolutely differentiated" and there is maximum differentiation in both dimensions.*

When $\sigma = 1$, there exists maximum horizontal differentiation. Combined with $\tau \approx 0$ the market is maximally differentiated horizontally and vertically.

Preferences

In the model each consumer with taste $\theta \in \mathcal{F} = [0, 1]$ and uniform reservation price V incurs disutility costs $t_i |a_i - \theta|$ measured as the distance from their ideal variant along the horizontal dimension. The utility of the typical consumer θ is given by

$$U(\theta) = \begin{cases} V - t_1 |a_1 - \theta| - p_1 & \text{if buying from firm 1} \\ V - t_2 |a_2 - \theta| - p_2 & \text{if buying from firm 2} \\ 0 & \text{otherwise} \end{cases} \tag{2.7}$$

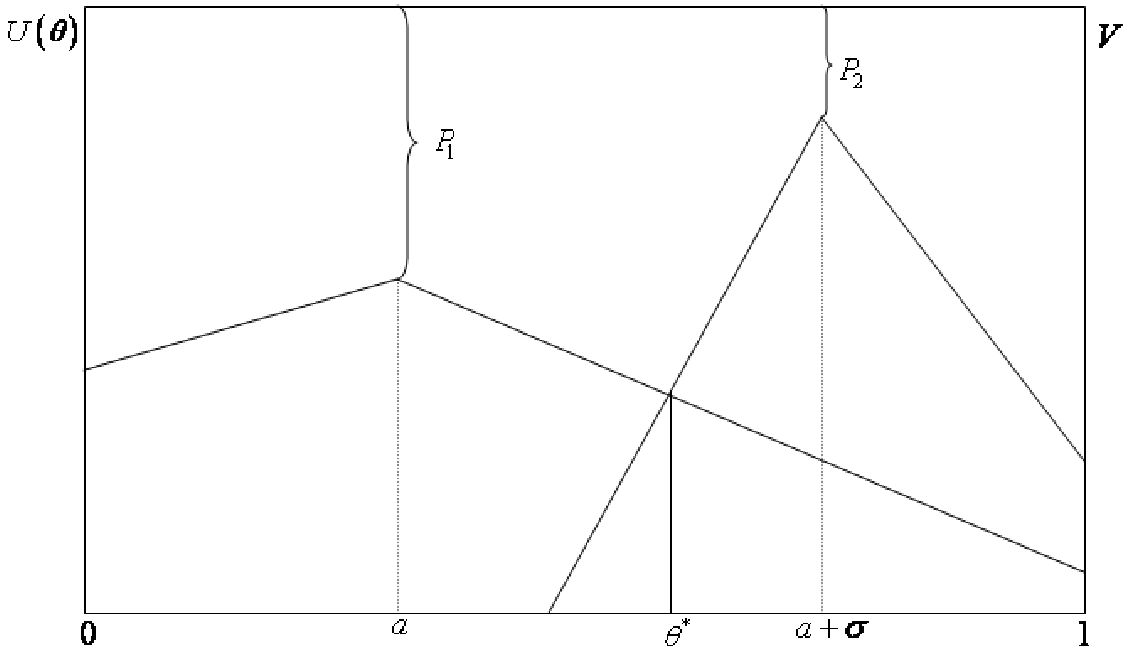
where a consumer purchases from firm i iff:

$$V - t_i |a_i - \theta| - p_i \geqslant V - t_k |a_k - \theta| - p_k, \; i, k = 1, 2, \; i \neq k.$$

Note that $p_i + t_i |a_i - \theta|$ is the delivered price charged by firm i. Algebraically, the market boundary delineating both firms' sphere of influence is given by the position of consumer θ^* who is indifferent between purchasing from either firm. From

$$V - t_1 |a_1 - \theta| - p_1 = V - t_2 |a_2 - \theta| - p_2$$

Figure 2.1. Market areas with a single marginal consumer



it is easy to solve for

(2.8) $$\theta^* = a - \frac{p_1 - p_2}{(1+\tau)\,t_2} + \frac{\sigma}{1+\tau}$$

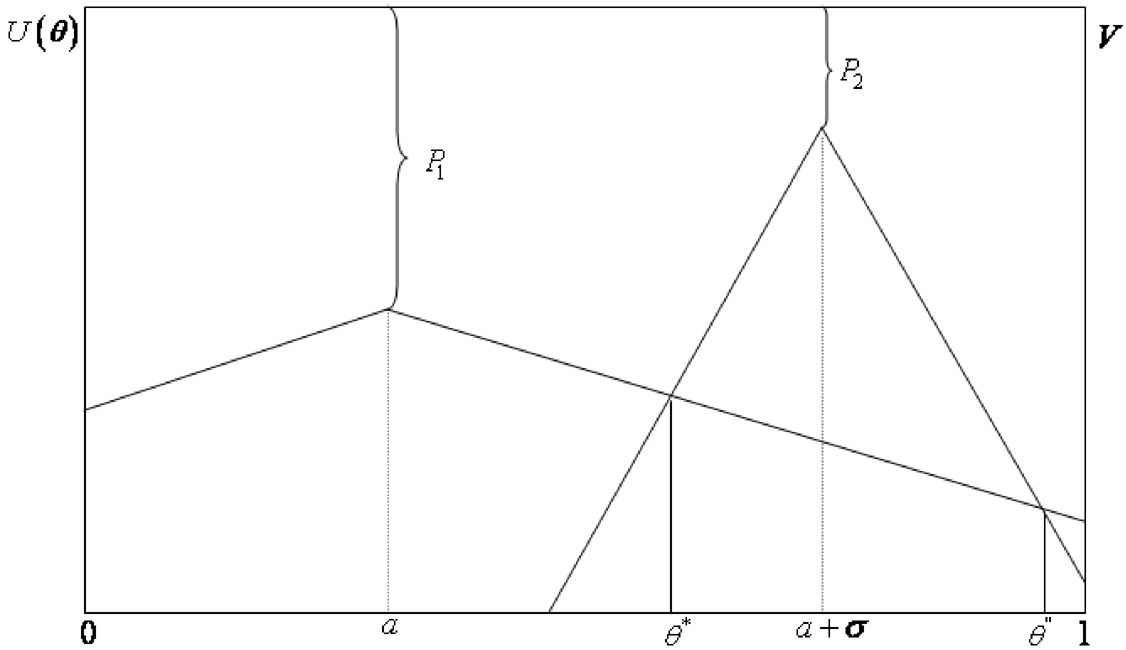
with $p_i + \sigma t_i \geqslant p_k$, $i, k = 1, 2$, $i \neq k$. The assumption

Assumption 4.

$$V \geqslant 3t_2/2$$

completes the characterization of the segmented market. This assumption on the reservation utility ensures full market coverage, and hence strictly positive demand for all consumers, in and out of equilibrium.Figure 2.1 depicts plots of $U(\theta)$ from Eq. (2.7) including the marginal consumer θ^*. As is evident, consumers in the interval $[0, \theta^*]$ patronize the high-quality firm since they earn higher utility while those residing along $(\theta^*, 1]$ buy from the other firm. Additionally, consumers in close proximity to either firm's location achieve higher utility levels than consumers on the outskirts of both firms' market areas. Firm 1's market area is also wider than that of the second firm due to differences in transport rates as reflected by the slopes of the delivered price schedules

Figure 2.2. Market areas with two marginal consumers

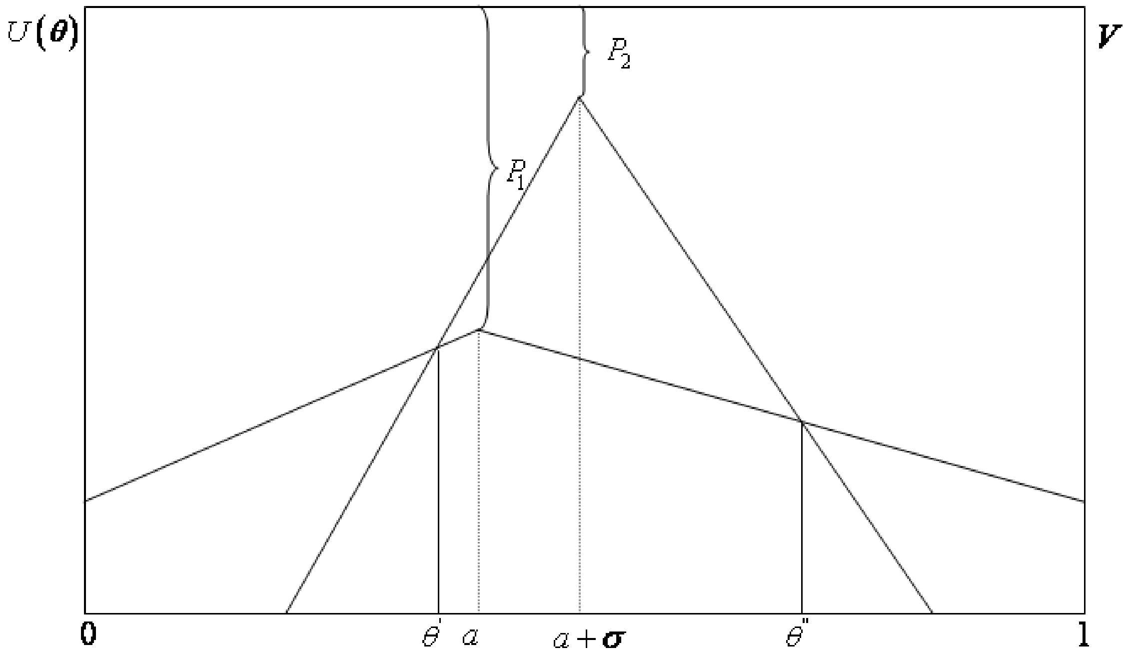


The existing asymmetry in transport rates generates an interesting turn of events. Indeed, since $t_1 \leqslant t_2$ it is possible for Firm 1 to intrude into the hinterland of Firm 2 and capture consumers to the right of Firm 2's location. Hence, there may also be an indifferent consumer, $\theta^{''}$ located to the right of $a+\sigma$ (see Fig. 2.2). Moreover, when both firms are located in close proximity to each other there is a second marginal consumer, $\theta^{'}$ located to the left of Firm 1's location (Fig. 2.3).Demands are summarily represented as

$$(2.9) \qquad D_2(p_1,\ p_2) = \begin{cases} \min\{\theta^{''},\ 1\} - \max\{0,\ \theta^{'}\} \text{ if } 0 \leqslant p_2 + \sigma t_2 \leqslant p_1 \\ \min\{\theta^{''},\ 1\} - \theta^{*} \text{if } p_1 \leqslant p_2 + \sigma t_2 \leqslant p_1 + \sigma t_1 \\ 0 \qquad \text{if } p_1 + \sigma t_1 \leqslant p_2 \end{cases}$$

where $D_1(p_1,\ p_2) = 1 - D_2(p_1,\ p_2)$, $\pi_1 = p_1 D_1(p_1,\ p_2)$ and $\pi_2 = p_2 D_2(p_1,\ p_2)$. As Dos Santos Ferreira and Thisse (1996) point out, on comparison with the market area of the high-quality firm, the low-quality firm's market area is always connected: it is either $[\theta^*, \min\{\theta'', 1\}]$ or $[\max\{0,\ \theta^{'}\},\ \min\{\theta^{''},\ 1\}]$. In contrast, the high-quality firm's market area may be the union of two separate subregions: $[0,\ \theta^{'}]$ and $[\theta^{''},\ 1]$.

Figure 2.3. Market areas with two peripheral marginal consumers



Their study also reveals that equilibria in the location-price game are guaranteed when firms are located sufficiently far apart. Thus, the current analysis proceeds under the assumption that Firms 1 and 2 are located, respectively, in the lower and upper quartiles of the horizontal product spectrum i.e. $\sigma \geqslant 1/2$. Locations are taken as exogenous and focus is then placed squarely on characterizing the impact of price competition in the second stage on the incentive compatibility condition for firms to sustain implicit collusive agreements.

In this case, demands will be expressed as: $D_1(p_1, p_2) = 1-(1-\theta^*)$ and $D_2\,(p_1, p_2) = 1 - \theta^*$ with corresponding profits

(2.10)
$$\pi_1 = p_1 \left[\frac{2(p_2 - p_1) + (1 + \tau + (1 - \tau)\sigma)t_2}{2(1 + \tau)t_2} \right]$$

and

(2.11)
$$\pi_2 = p_2 \left[\frac{2(p_1 - p_2) + (1 + \tau - (1 - \tau)\sigma)t_2}{2(1 + \tau)t_2} \right].$$

2.6. Per-Period Setting

The per-period market outcomes underlying the incentive compatibility conditions in Eqns. (2.5) and (2.6) are derived in this section. These include the payoffs to optimal deviation, joint-profit maximization and the payoffs along the punishment path.

2.6.1. Joint-Profit Maximization

A priori, due to the asymmetric nature of the market, it is not straightforward how one should define the joint-profit maximization problem. Indeed, Friedman argues that *any* individually rational payoff vector giving a firm strictly higher profits than that obtained in the Nash one-shot subgames is supportable as an equilibrium under mild discounting. In the literature, maximization of the sum of individual firm profits is widespread. However, this study adopts a different approach. Following Häckner (1995) it is assumed that the joint-profit maximizing price in the case where firms locate in the upper and lower quartiles of the market is such that the consumer at address $\theta = 1/2$ is made indifferent between buying and not buying. It is readily verifiable that higher prices result in partial market coverage as some consumers around $\theta = 1/2$ will choose not to buy when the price exceeds their reservation utility level whereas lower prices generate no additional demand. This process is analogous to both firms jointly maximizing the size of a hypothetical "pie" which will then be distributed between them according to some pre-arranged agreement.

This restriction yields prices

$$p_1^{\mathrm{coll}} = V - \frac{\sigma\tau t_2}{2}, \qquad p_2^{\mathrm{coll}} = V - \frac{\sigma t_2}{2} \tag{2.12}$$

and corresponding joint-maximum profits

$$\pi_1^{\mathrm{coll}} = \frac{2V - \sigma\tau t_2}{4}, \qquad \pi_2^{\mathrm{coll}} = \frac{2V - \sigma t_2}{4} \tag{2.13}$$

where it is readily verifiable, similar to the Bertrand case, that the high-quality firm charges a higher joint-maximum price and earns higher profits. The following lemma proves that full market coverage prevails at the joint-profit maximizing equilibrium.

Lemma 5. *There is full market coverage under joint-profit maximization.*

Proof. See the appendix. □

2.6.2. Competitive Mill Pricing

Each period within the price subgames, firms simultaneously choose mill prices p_1^b and p_2^b to maximize Eqns. (2.11) and (2.12) respectively, assuming the rival's price is constant. These prices become the solution to the Bertrand problem in the one-shot price subgames and serve as the Nash equilibrium along the punishment path. All firms revert to this Bertrand threat point once an instance of cheating is observed forcing the deviant(s) to do the same. First order conditions for this problem yield reaction functions:

$$p_1 = \frac{2p_2 + (1+\tau+(1-\tau)\sigma)t_2}{4}, \qquad p_2 = \frac{2p_1 + (1+\tau-(1-\tau)\sigma)t_2}{4},$$

implying that both products are strategic complements. These generate candidate solutions to the Bertrand problem:

$$p_1^b = \frac{(3(1+\tau)+(1-\tau)\sigma)t_2}{6}, \qquad p_2^b = \frac{(3(1+\tau)-(1-\tau)\sigma)t_2}{6} \tag{2.14}$$

with profits:

$$\pi_1^b = \frac{(3(1+\tau)+(1-\tau)\sigma)^2 t_2}{36(1+\tau)}, \qquad \pi_2^b = \frac{(3(1+\tau)-(1-\tau)\sigma)^2 t_2}{36(1+\tau)}. \tag{2.15}$$

In this model the high-quality Firm charges a higher price and earns higher profits because it enjoys a greater market share.[9] Were the model a standard Hotelling one however, with $t_1 = t_2 = t$, both firms would charge identical prices and achieve the same level of profits, $\pi_1 = \pi_2 = t_2/2$. The following is in order.

Lemma 6. *The market is fully covered along the punishment path.*

Proof. Follows from Lemma 5. If the market is covered under joint-profit maximization, it will be covered at lower prices when firms adopt the Bertrand rule. □

2.6.3. Optimal Deviation Prices

The joint-profit solution is never a best response in the one-shot price subgames because each firm seeks to win more market share at the expense of its rival once the joint-profit price is set. The solution to a firm's profit maximization problem taking the joint-profit maximizing price of its rival as given represents the optimal deviation price in this setting. Both firms maximize profits:

$$\pi_1 = p_1 \left[\frac{2(p_2^{\text{coll}} - p_1) + (1+\tau+(1-\tau)\sigma)t_2}{2(1+\tau)t_2} \right], \tag{2.16}$$

[9]All second order conditions have been satisfied. Dos Santos Ferrieira and Thisse (1996) show that Eq. (2.14) is indeed an equilibrium when both firms are located near the ends of the linear city (i.e. the degree of horizontal differentiation is large enough).

and

$$\pi_2 = p_2 \left[\frac{2(p_1^{\text{coll}} - p_2) + (1 + \tau - (1 - \tau)\sigma)t_2}{2(1 + \tau)t_2} \right], \tag{2.17}$$

yielding deviation prices:

$$p_1^d = \frac{2V + (1 + \tau - \sigma\tau)t_2}{4}, \qquad p_2^d = \frac{2V + (1 + \tau - \sigma)t_2}{4}. \tag{2.18}$$

Profits are determined by substituting Eq. (2.18) into (2.16) and (2.17) above to give

$$\pi_1^d = \frac{(2V + (1 + \tau - \sigma\tau)t_2)^2}{16(1 + \tau)t_2}, \qquad \pi_2^d = \frac{(2V + (1 + \tau - \sigma)t_2)^2}{16(1 + \tau)t_2}. \tag{2.19}$$

Lemma 7. *The market is fully covered under optimal deviation.*

Proof. By Lemma 5 since the market is fully covered it will remain so if one firm deviates by undercutting the joint-profit price. Thus, it suffices to show that each firm's deviation price is lower than the joint-profit price. A quick comparison of the deviation and joint-profit prices for both firms reveals that this is the case as long as Assumption 4 holds. □

2.7. Restrictions on the Discount Factor

Recall that the main objective is to determine how the parameters of interest, τ and σ, which indicate, respectively, the existing degree of horizontal and vertical differentiation, impact the comparative static properties of the price equilibrium and ultimately the incentive compatibility condition for firms to sustain collusive pricing. Therefore, in this section, the market outcomes obtained above are employed to derive the restriction on the threshold discount factor λ_i.

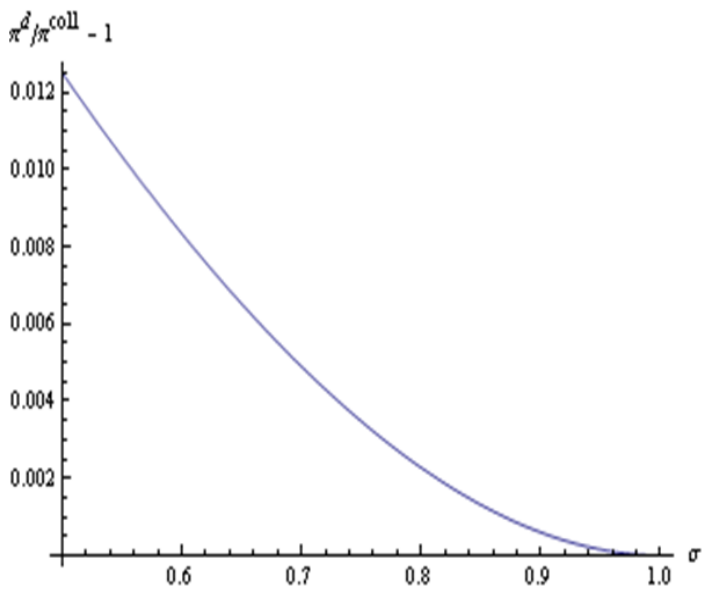
Before proceeding, it is instructive to evaluate the model's implied outcomes when the market is standard Hotelling. First, recall that the percentage gains from cheating rather than cooperating, defined as $A - 1$, $\left(A \equiv \pi_i^d / \pi_i^{\text{coll}}\right)$, in conjunction with the gains from cooperating rather than competing, $1 - B$, $\left(\mathbf{B} \equiv \pi_i^b / \pi_i^{\text{coll}}\right)$ both impact the incentive compatibility conditions for firms to sustain the joint-profit maximum outcome. Depending on the relative magnitudes of these effects, the threshold discount factor may either increase or decrease in response to changes in σ. Absent vertical differentiation, the following expressions

$$\mathbf{A} = \frac{(2V + (2 + \sigma)t_2)^2}{8(2V - \sigma t_2)t_2}$$

and

$$\mathbf{B} = \frac{2t_2}{(2V - \sigma t_2)t_2}$$

Figure 2.4. Gains from cheating over cooperation



are identical across both firms. It is relatively simple to show how σ impacts the above ratios. Both

$$\frac{\partial \mathbf{A}}{\partial \sigma} = -\frac{4V(V-\sigma t_2)-(4-\sigma^2)t_2}{8(2V-\sigma t_2)^2} < 0,$$

and

$$\frac{\partial \mathbf{B}}{\partial \sigma} = \frac{2t_2^2}{(2V-\sigma t_2)^2} > 0$$

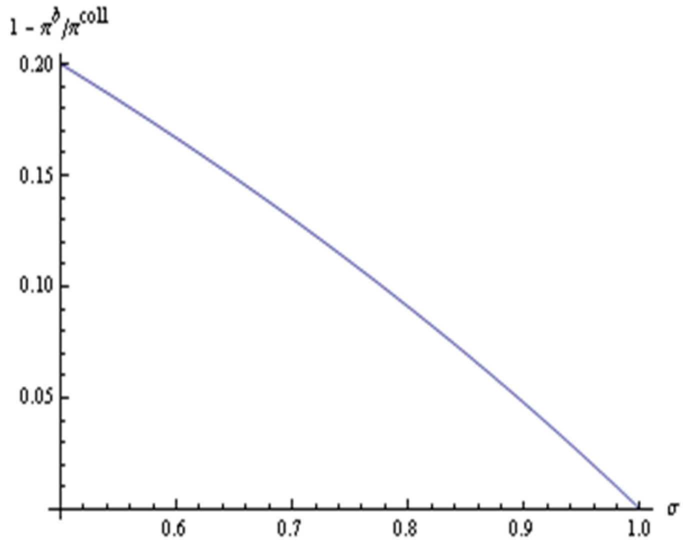
indicate that as the market is maximally differentiated ($\sigma \to 1$), the percentage gains from cheating over cooperation and the percentage gains from cooperation over competition *both* decrease monotonically as can be seen from Figs. 2.4 and 2.5 respectively. Due to the presence of these off-setting effects, the overall impact on the critical discount factor appears ambiguous. When the market is standard Hotelling the expression

$$\lambda_1 = \lambda_2 = \lambda = \frac{2V-(2+\sigma)t_2}{2V+(6-\sigma)t_2} \tag{2.20}$$

represents the critical discount factor restriction which is also necessarily identical for both firms. From Fig. 2.6 the threshold discount factor is inversely related to the existing degree of horizontal differentiation. Indeed, this suggests that even though the percentage gains from cheating over collusion and the percentage gains from collusion over competition both decrease as the market is maximally differentiated, the former effect is the dominant one.On this basis we establish the following.

Remark 8. *When the market is standard Hotelling, the price effect dominates the market share effect. The joint-profit outcome is thus supportable as a SPNE over a wider*

Figure 2.5. Gains from cooperation over competition



set of discount factors when both firms choose to locate further apart in the horizontal dimension.

This is readily apparent after taking the derivative of the expression in Eq. (2.20) with respect to σ, yielding

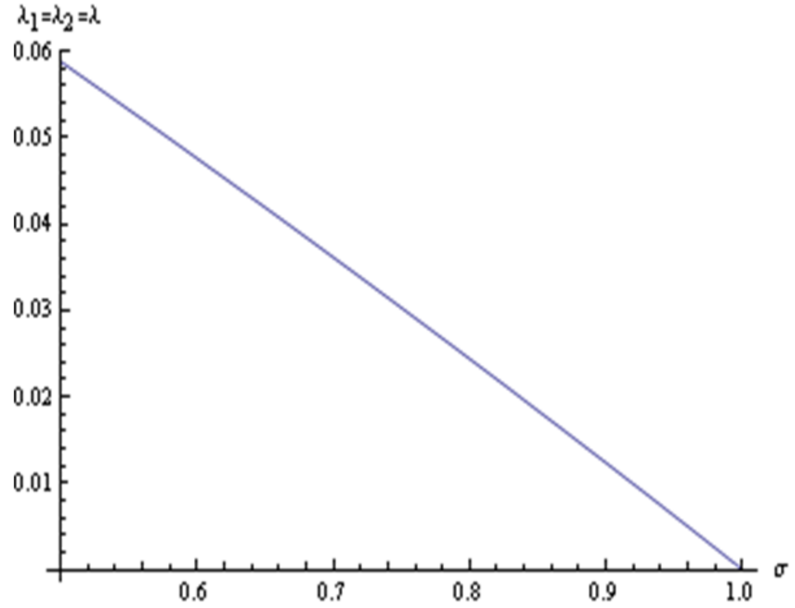
$$\frac{\partial \lambda}{\partial \sigma} = -\frac{8t_2}{(2V - (6-\sigma)t_2)^2} < 0,$$

which reaffirms the familiar result that collusion is more stable, and thus increasingly likely under a wider firm dispersion. It is however more difficult to analytically evaluate the above expressions for the more general case with arbitrary values of τ and σ since the firm-specific threshold discount factors along with the ratios A and B are now complicated functions of both parameters.[10] Henceforth, the analysis proceeds numerically.

First, plots of $\mathbf{A} - \mathbf{1}$ and $\mathbf{1} - \mathbf{B}$ are displayed in Figs. $2.7 - 2.14$. From Figs. 2.7 and 2.8 it appears that for the high-quality firm the incentive to cheat rather than maintain the joint-profit outcome falls sharply over the entire range of σ as the quality disparity diminishes. Therefore, regardless of the existing degree of horizontal differentiation, the high-quality firm increasingly favors cooperation over reneging from the implicit agreement as the degree of vertical differentiation decreases. From Figs. 2.9 and 2.11 however, the gains to collusion over competition for the high-quality firm appear to decrease steadily as *both* τ and σ increase. This means that the high-quality firm, whilst now leaning toward the joint-profit strategy as both firms' products draw nearer from a quality

[10]These are shown in the appendix.

Figure 2.6. Critical Discount Factor in the standard Hotelling Case



perspective, possesses an added (and, somewhat weak) incentive to choose the Bertrand outcome over collusion as the disparity in quality lessens, if the firms are sufficiently differentiated horizontally. Here again the presence of these two off-setting effects makes it difficult to outrightly predict the overall impact of both parameters of interest on the threshold discount factor. A similar situation arises for the low-quality firm as the gains from cheating over collusion (Figs. 2.11 and 2.12) and the gains from collusion over competition (Figs. 2.13 and 2.14) both decrease markedly as τ and σ increase. Typical

Figure 2.7. Gains from cheating over collusion for Firm 1

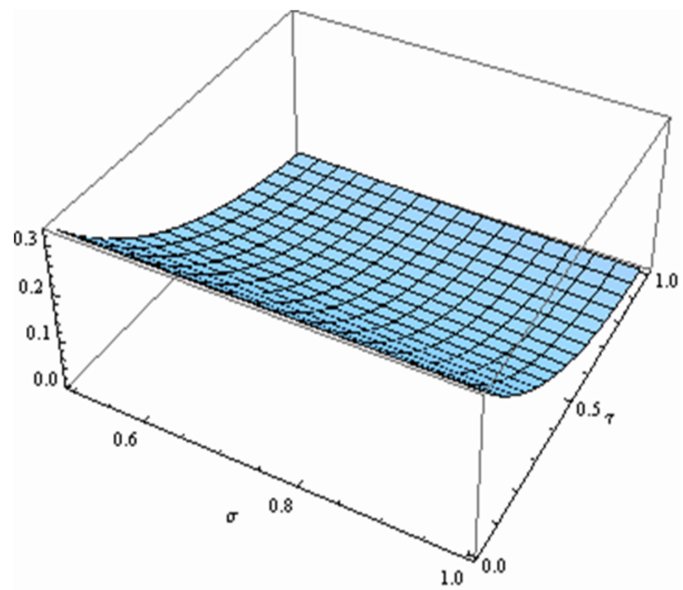


Figure 2.8. Contours of $A-1$, $\left(A \equiv \pi_i^d/\pi_i^{\text{coll}}\right)$ for Firm 1

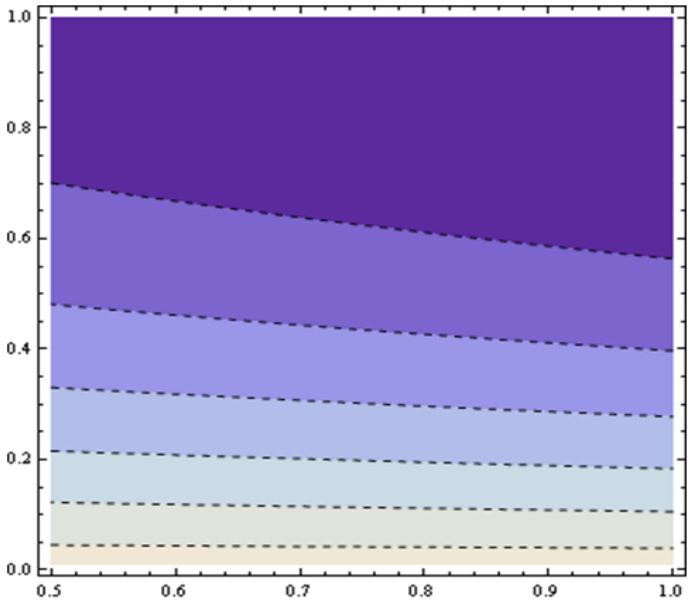
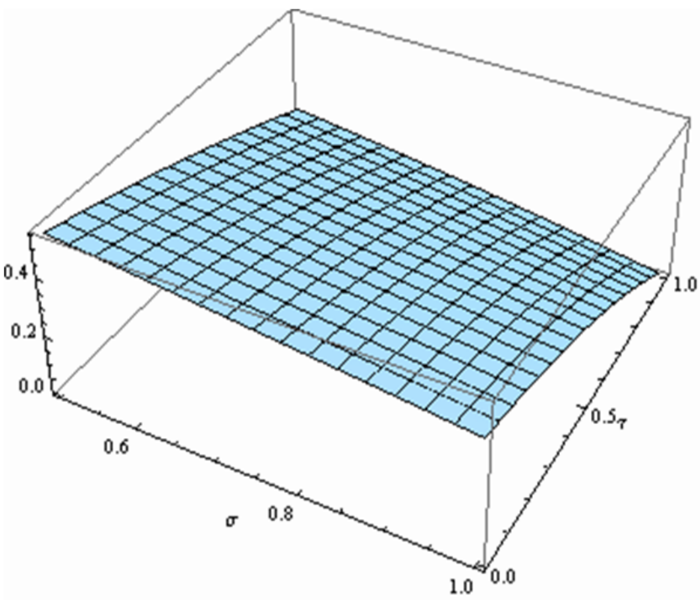


Figure 2.9. Gains from collusion over competition for Firm 1



plots of the threshold discount factors are provided in Figs 2.15. to 2.18. Note that both remain continuous $\forall\ \tau \in (0,1]$, $\sigma \in [1/2,1]$. Additionally, λ_1 achieves a maximum when the market is absolutely differentiated, whereas λ_2 is at its highest when σ is close to $1/2$ and the quality disparity is large i.e. at low values of τ. From the expressions in the appendix, it is also verifiable that $\lambda_1 > \lambda_2 \forall\ \tau \in (0,1]$, $\sigma \in [1/2,1]$ after substituting the boundary condition on the reservation utility level from Assumption 4.

Figure 2.10. Contours of $1 - B$, $\left(\mathbf{B} \equiv \pi_i^b / \pi_i^{\text{coll}}\right)$ for Firm 1

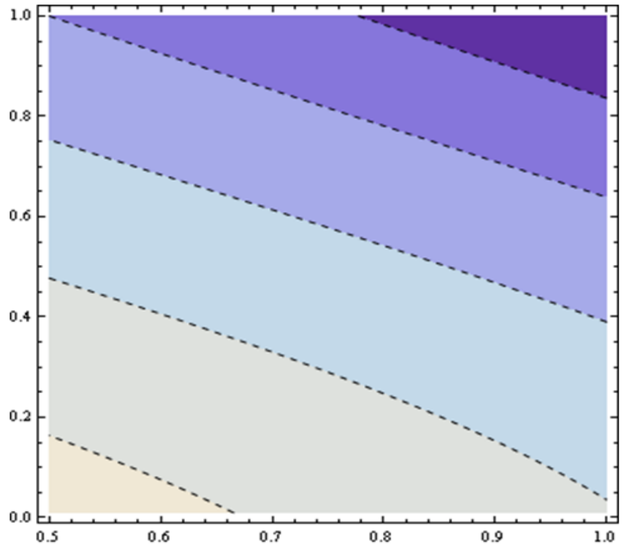
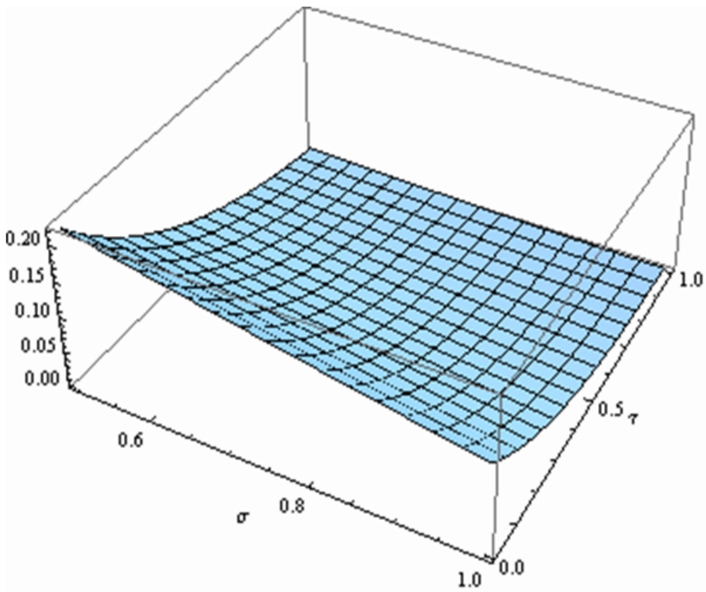


Figure 2.11. Gains from cheating over collusion for Firm 2



Comparing the contours in Figs. 2.16 and 2.18 however, we see that while λ_2 is everywhere decreasing as τ and $\sigma \to 1$, λ_1 increases marginally when $\sigma \to 1$ at low values of τ, but tends to decrease when $\sigma \to 1$ and τ is close to 1. This means that as long as the high-quality firm retains its significant quality advantage, it is less willing to cooperate when the market is maximally differentiated. However, when both firm's products are nearer from a quality perspective, the reverse occurs as the high-quality firm now behaves in accordance with the predictions throughout the literature and portrays a softer stance

Figure 2.12. Contours of $1 - A$, $\left(A \equiv \pi_i^d / \pi_i^{\text{coll}}\right)$ for Firm 2

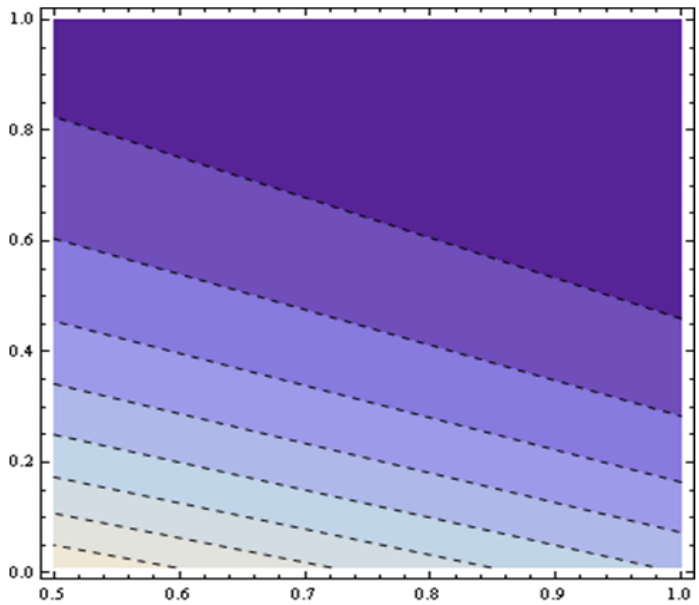
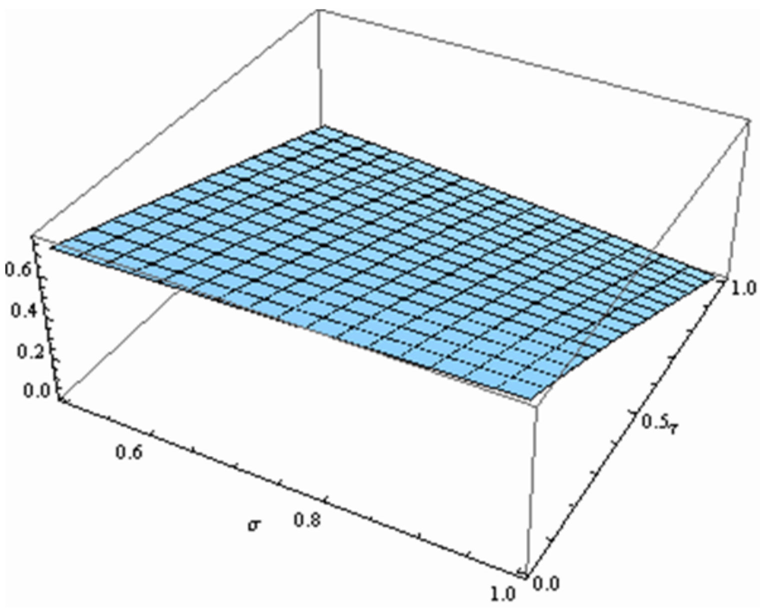


Figure 2.13. Gains from collusion over competition for Firm 2



toward cooperation when both firms locate further apart in the horizontal dimension $\mathcal{F}$. Hence the following:

Theorem 9. *Both functions, $\lambda_1(\tau,\sigma)$ and $\lambda_2(\tau,\sigma)$, are continuous in τ,σ space with $\lambda_2(\tau,\sigma) < \lambda_1(\tau,\sigma)$. The function $\lambda_2(\tau,\sigma)$ decreases monotonically as $\tau,\sigma \to 1$ whereas $\lambda_1(\tau,\sigma)$ increases when $\sigma \to 1$ and $\tau \in (0, 0.6)$ but decreases thereafter as $\sigma \to 1$.*

Figure 2.14. Contours of $1 - B$, $\left(\mathbf{B} \equiv \pi_i^b / \pi_i^{\text{coll}}\right)$ for Firm 2

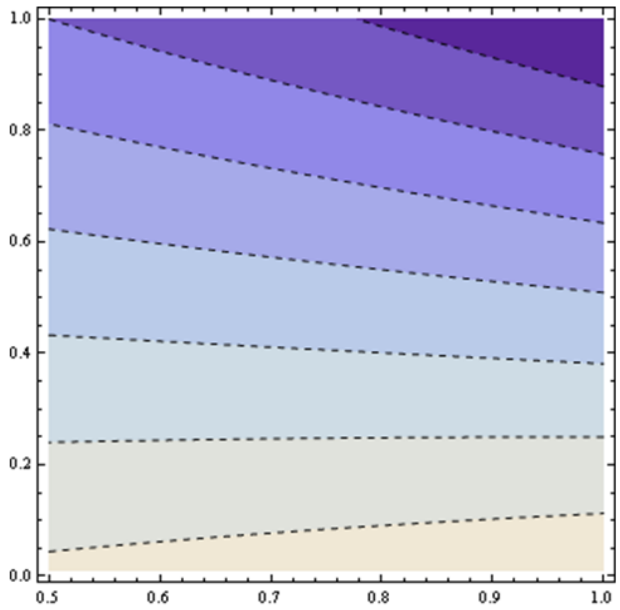
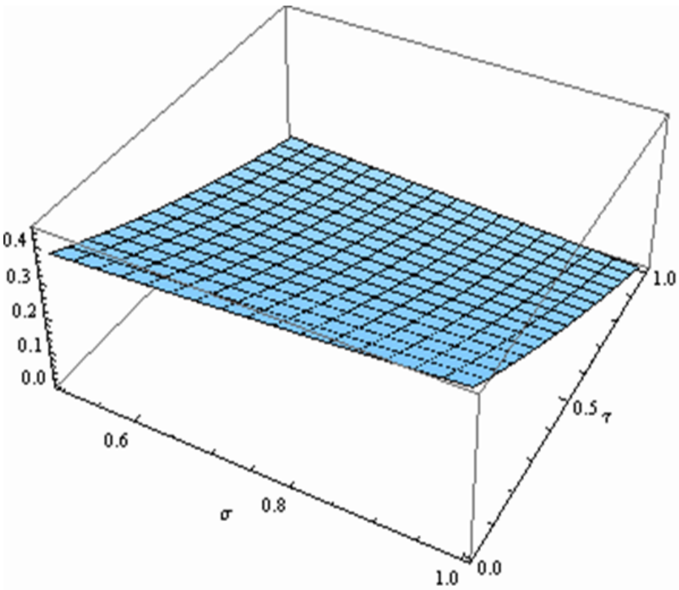


Figure 2.15. Firm 1 Threshold Discount Factor $\lambda_1(\tau, \sigma)$



Proof. Substituting the boundary condition on the reservation utility in Assumption 4 along with the payoffs to joint-profit maximization, deviation and competitive mill pricing into the expressions for $\lambda_1(\tau, \sigma)$ and $\lambda_2(\tau, \sigma)$ is sufficient to show that both are continuous in τ, σ space and that $\lambda_2(\tau, \sigma) < \lambda_1(\tau, \sigma)$ with $\lambda_2(\tau, \sigma)$ everywhere decreasing and $\lambda_1(\tau, \sigma)$ first increasing, and then decreasing over the relevant ranges of τ. □

Figure 2.16. Contours of $\lambda_1(\tau, \sigma)$

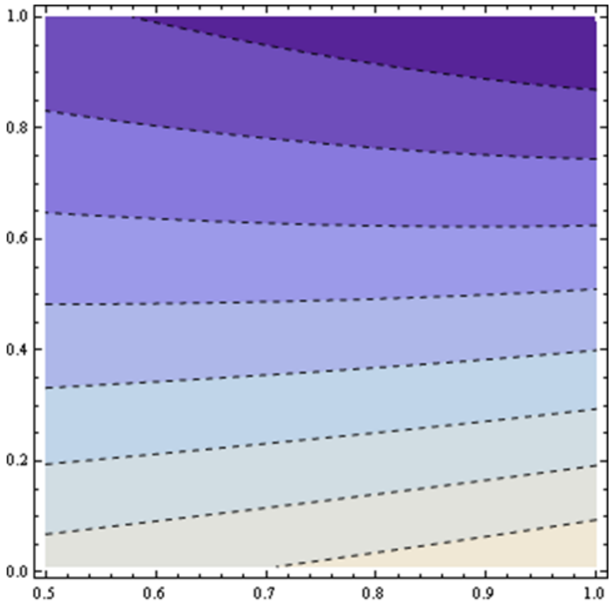
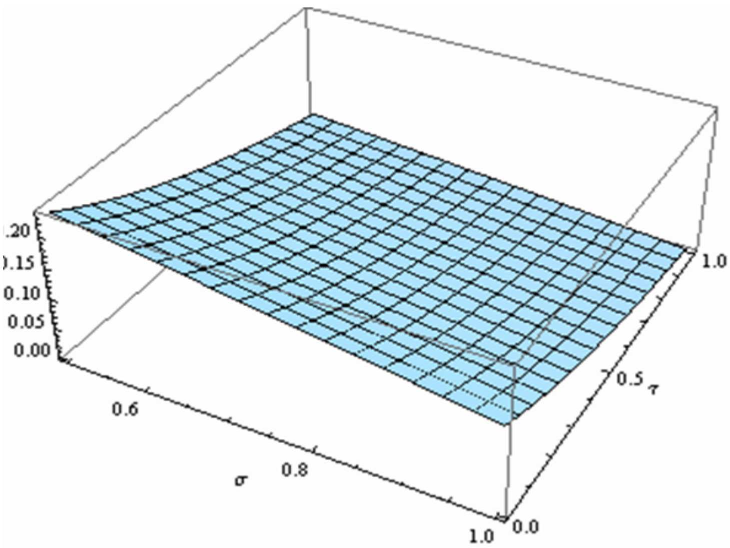
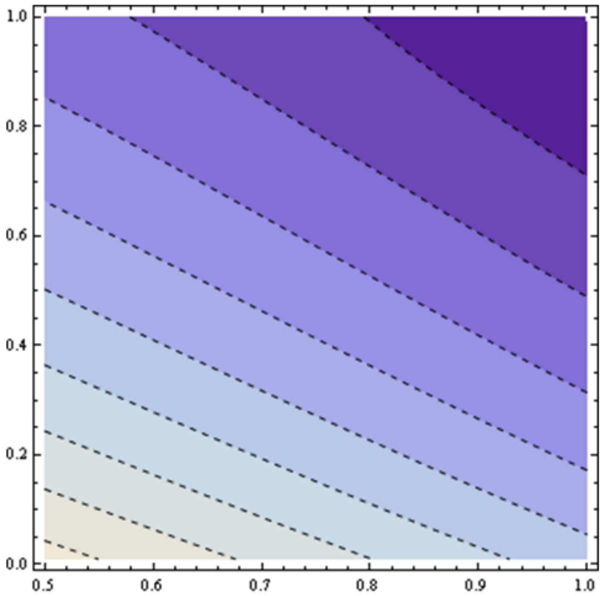


Figure 2.17. Firm 2 Threshold Discount Factor $\lambda_2(\tau, \sigma)$



These conclusions are in stark contrast to the predictions in Chang (1991), Ross (1992), and Häckner (1995) which have all employed the concept of horizontal differentiation to show that collusion at the joint-profit solution is increasingly likely under a wider firm dispersion. Within the current model, with the binding restriction on the high-quality firm since $\lambda_2 < \lambda_1$, this result materializes solely when the disparity in quality is minimal. In this instance, there is a positive relationship between horizontal

Figure 2.18. Contours of $\lambda_2(\tau, \sigma)$



differentiation and collusive stability since λ_1 falls as σ rises. However, when the market is absolutely differentiated there is now a negative relationship between horizontal differentiation and sustainability because the high-quality firm is less receptive to collusion when the market is sufficiently differentiated in both dimensions. The reason is that when the disparity in quality is large the gains from cheating over collusion are at their widest for the high-quality firm because deviation payoffs are at a maximum. As the quality advantage is eroded however it can be shown that deviation payoffs decrease markedly relative to an increase in the payoffs along the punishment path. Indeed, the Nash equilibrium solution from the one-shot price subgames dominates the payoffs to deviating from the joint-profit solution as $\tau \to 1$. Therefore, when the market is a standard Hotelling one, more collusion is facilitated as firms move further apart in the horizontal dimension. This result confirms the claim in Häckner (1994) that more collusion arises when the quality disparity is minimal within a purely vertically differentiated model. In fact this outcome is evident for the current model regardless of the existing degree of horizontal differentiation, further highlighting its generality.

2.8. Summary and Conclusions

This chapter's main goal was to characterize the relationship between product differentiation and collusion within a spatial duopoly market. Thus, the well-known Hotelling model formed the backdrop against which the study was framed. However, the assumption that both firms had access to separate transport technologies was introduced as an important departure from the usual Hotelling set-up. This assumption was crucial in that it allowed the concept of vertical differentiation to be imported into the Hotelling framework in a rather succinct manner. The resulting mixed model of differentiation was then used to explore the impact of price competition on both firms' incentive compatibility to maintain non-cooperative agreements.

Results from the analysis prove that the interplay between both types of differentiation is critical to any analysis regarding product differentiation and collusion. By incorporating vertical differentiation into an otherwise standard Hotelling model it has been shown that the positive relationship between sustainability of the collusive outcome and the degree of horizontal differentiation only materializes when the market is minimally vertically differentiated. However, as the market becomes absolutely differentiated, the high-quality firm is less receptive to the idea of colluding and will indeed prefer to deviate from the joint-profit solution as the gains to doing so increases. This result suggests that any discussion concerning product differentiation and collusion should be placed in proper context. One cannot therefore speculate on the association between both phenomena on the basis of single-dimensional models of differentiation as these are inadequate for the purpose they are intended to serve.

It is also important to note that the analysis can be extended in several meaningful ways. One method is to proceed along the lines of Irmen and Thisse (1998) and assume multiple dimensions of both forms of differentiation. Although such a broadly general model could quickly become unwieldly, it would perhaps be an even more realistic portrayal of consumer product markets rather than the model used in this study. This type of model would allow the researcher to compare the comparative static properties of the price equilibrium when there are either multiple dimensions of horizontal and vertical differentiation or multiple dimensions of a single form of differentiation. This is left for future research.

CHAPTER 3

Competition in the European Car Market

3.1. Introduction

Since 1985 the European Union (E.U.) has given automobile manufacturers throughout Europe the latitude to negotiate selective and exclusive vertical agreements with their dealers. This Block Exemption (BE) system, as it is called, covers the way cars are sold and serviced across the E.U. It allows manufacturers to freely select their own dealers (dealer selectivity) and establish certain criteria such as training of staff and performance and sales targets. Manufacturers are also allowed to assign exclusive territories to their dealers (territorial exclusivity) where no one else is permitted to sell. The dealers benefiting from these selective and exclusive distribution (SED) agreements are however prohibited from selling more than one marque and thus the new car market is but one of a few industries across Europe which explicitly restricts intra- and interbrand competition.[1] Naturally, this exemption system, while providing some relief from competition, has paved the way for anti-competitive practices. Indeed, it has opened the door for manufacturers to establish virtual monopolies in many countries across Europe, prompting observers to refer to the car market as one of the most protected havens of European industry.[2]

Against this background, this chapter is aimed at determining whether or not there exist patterns of anti-competitive pricing across different segments of the European car market. However, unlike previous empirical work focused exclusively on characterizing price competition across national markets, the current study seeks to develop an understanding of how competition evolves at a much finer level. A key motivating factor arises from discussions in Brenkers and Verboven (2005) and Verboven (2007). These studies maintain that because antitrust regulation relies heavily on market shares as a basis for decision making, it is imperative that the relevant product markets yielding these shares are carefully delineated. In their analysis Brenkers and Verboven (2005) show that the relevant markets for cars across Europe are poorly defined at a broad geographic level.

[1]See Verboven (2007) for a complete discussion regarding the evolution of the BE system which was initially based on an earlier system of individually granted exemptions. Importantly, under the BE system there are still a number of clauses, called "black" clauses, that are not tolerated under any circumstance. These include reseale price maintenance or other vertical types of price fixing.
[2]See, for example, Akbar (2003).

In particular, they provide empirical results highlighting the fact that the relevant markets are suitably defined at a more detailed level which includes segments defined by standard marketing classifications and subsegments defined by country of origin.[3] This chapter implements the recommendations in both studies above and thereby creates a more richer structure within which an array of competitive interactions can be studied. Thus, rather than developing broad measures of conduct to describe competition across national markets the chapter seeks to determine whether or not there exists patterns of anti-competitiveness across distinct segments and subsegments of the car market where segments are defined according to standard marketing classifications and subsegments defined by the country of origin (i.e. home or foreign) of the particular vehicle.

It is easy to imagine that firms operating within these segments and subsegments would tailor their strategies in response to competition from closely-located rival firms, therefore paying strict attention to rivals operating within their own segment or subsegment than to other firms outside of their immediate vicinity. This has several interesting implications. For instance, firms competing within atomistic market segments dominated by an overly popular target population may find it difficult to maintain a long-run profitability view of the market in the face of intense competition from close rivals. It is duly noted that firms competing within these segments are likely to be constrained in their ability to price cooperatively over the long term. By a similar argument, if consumers portray heavy brand loyalty because of a reluctance to switch to competing brands, firms are likely to be motivated to price aggressively within segments targeted to first time buyers knowing fully well that they will be able to reap the future potential benefits of a stable customer base. However, in segments dominated by older, repeat buyers who are more loyal and less price sensitive, firms may instead be motivated to soften their competitive stance as the gains in new customers from intense competition is likely to be offset by losses incurred from their existing customer base.

It is worth noting that whereas a large body of empirical literature exploring these issues has developed in reference to the U.S. car market, comparatively less is known about the nature of price competition across its European counterpart. In fact, although the European car market is widely employed as a pedagogical aid in various studies on the evolution of price dispersion across the E.U., the intensity of price competition seldom plays a major role in generating wide disparities in prices and has not been investigated

[3]Various methods can be used to define a relevant market. The most widely applied rule is based on the method used in U.S. merger analysis known as the 5% rule. This “hypothetical monopolist” test entails considering whether demand and supply substitution patterns would prevent firms from profitably raising price above some competitive level, starting from a narrow market definition and progressively enlarging the market until a configuration that generates a profitable price increase is found, (see, for example, Ivaldi and Verboven (2005)).

at a detailed level. But with the recent thrust by the European Commission (E.C.) to legislate complete liberalization of the car market throughout Europe, it is crucial that reliable measures of consumer welfare and the extent of price competition be established in order to evaluate the effect of any proposed policy. This chapter takes an empirical approach to tackling these issues within the context of the European car market and seeks to develop a more finer picture of competition across the market.

Conventional discrete choice methods are employed in conjunction with a multiproduct oligopoly framework which admits product differentiation. The primary focus is on separately identifying demand, cost, and conduct parameters from product level data. The implied market equilibrium brought to the data consists of a demand side modeled in the spirit of Berry (1994) and Brenkers and Verboven (2006) in which preferences are assumed correlated across distinct marketing segments and subsegments and a supply side in which firms interact repeatedly in setting prices according to a Bertrand rule. In the pricing model on the supply side, deviations from standard Bertrand pricing are taken as a measure of the intensity of price competition as outlined in Sudhir (2001a). In terms of the demand side, endogeneity in prices due to the presence of unobserved product attributes is dealt with using a linear instrumental variables procedure advanced by Berry, Levinsohn, and Pakes (1995) (hereafter, BLP) in order to generate plausible substitution patterns. The parameters of interest generating these substitution patterns are then fed into the pricing model in order to recover marginal costs and the segment-specific conduct parameters which drive the analysis. The model is estimated on product level data comprising prices (pre- and post-tax list prices), quantities (new vehicle registrations), and vehicle characteristics indicating comfort, performance, and safety, of virtually all passenger cars registered in five national markets: Belgium, France, Germany, Italy and the United Kingdom (U.K.), which collectively account for over 80% of annual new vehicle registrations across Europe. The data set is also augmented by macroeconomic data including GDP, exchange rates, population, and price indices for these five markets.

The estimation results lend support to the hypothesis that conduct varies according to the intensity of within-segment competition from rival firms and casts doubt on the widely acknowledged school of thought that the European car market is wholly anti-competitive. Specifically, there is evidence of competitive pricing behavior in the compact and intermediate marketing segments, cooperative behavior in the subcompact and standard segments, and Bertrand pricing in the luxury car segments. From the demand model, we also see that cars belonging to the same subsegment are viewed by consumers as more homogeneous than cars belonging to different subsegments of the same marketing segment. In addition, an included foreign firm effect, intended to capture any potential competitive advantage domestic incumbents have over foreign firms in terms of consumer mean valuation, shows that the foreign competitors indeed face a competitive disadvantage on comparison with their domestic counterparts.

The chapter proceeds as follows. Section 3.2 discusses segment-specific competition in the context of the car market and formulates conjectures which will be tested within the model. Section 3.3 provides a brief overview of the European car market and highlights the impact of the B.E. system on competition across Europe. The empirical model is developed in section 3.4 and the estimation strategy is outlined fully in section 3.5. Empirical results based on the product level data set are discussed in section 3.6. Section 3.7 concludes.

3.2. Segment-Specific Competition

For years, Europeans, even more than most Americans, have remained fierce brand and national loyalists. It was typical of French drivers to remain with Renault, Peugeot, and Citroën, Italians with Fiat, Alfa Romeo, and Lancia, and Germans with BMW, Volkswagen, and Mercedes. German manufacturers have been the major beneficiaries of brand loyalty.[4] In fact, almost 60% of polled respondents in a 2005 survey of German car owners by the consulting firm Capgemini stated that they would likely purchase the same brand they are currently driving from the same dealer which provides their after-sales servicing.[5] The study further states that younger car buyers are more savvy in terms of conducting research prior to purchase and have become harder to please in comparison to older buyers who remain loyal to a particular brand and are less likely to use a wide range of sources to inform their purchase decisions. A separate study by Lambert-Pandraud et al. (2005) of French buying patterns lends support to the idea that older car buyers remain loyal to a particular brand. These authors show that age has a strong impact on the probability that a consumer would repurchase the previous brand. Of the young buyers surveyed, 42% repurchased the previous brand versus 54% for middle aged individuals and over 70% for older buyers. Moreover, whereas 6% of young buyers considered only one brand, the corresponding proportion for middle aged and older buyers was 11% and 27% respectively.

An even more recent study by R.L. Polk of U.S. consumer buying patterns for 2006 model year vehicles reveals that these patterns are also relatively consistent for the U.S.

[4]An article appearing in the *Businessweek* magazine concluded that more than two thirds of Mercedes E-class drivers in Germany are repeat buyers. The number of repeat buyers of BMW lines is even greater than this figure. It is widely believed that this type of reputation has allowed BMW to charge prices upwards of 10% to 30% higher than comparable models and to offer incentives significantly lower than the industry average on similar makes and models.

[5]Capgemini: "Cars Online 05/06 - Germany findings."

economy. As Table 3.1 shows, regardless of brand origin, older buyers tend to be more loyal. In fact, whereas consumers aged sixty-five and older represented only 13.4% of new owners returning to the market for another new vehicle in 2006, they typically rated the highest for brand loyalty at just over 50%.[6]

Table 3.1. U.S. Consumer Loyalty by Age: 2006 Model Year Vehicles

Age of Head	*Percentage of Returning consumers loyal to....*		
of Household	*Asian Brands*	*Domestic Brands*	*European Brands*
18 – 24	43.0	39.5	32.2
25 – 34	41.6	39.8	30.3
35 – 44	43.9	40.7	33.6
45 – 54	47.7	43.0	37.9
55 – 64	50.8	45.6	41.1
65 – 74	55.1	47.4	42.5
75+	59.8	51.1	46.4
Overall Loyalty	47.6	43.5	37.3

Source: R.L. Polk

The demographic profile of car buyers is also brought into sharp focus. An empirical study of segment-specific competition in the U.S. car market by Sudhir (2001a) revealed that the market for smaller, entry-level subcompact cars is dominated by first time buyers (approximately 40%) and young professionals, many of whom are in their mid-thirties. In an attempt to encourage purchase and build brand awareness among this key demographic manufacturers offer deeply discounted prices and other incentives in the hope that, once lured, they will be able to charge higher prices to these same consumers in the future.[7] As he points out, the situation is reversed for full and mid-sized lines where buyers have a mean age of just under sixty and forty-five years respectively. Only 2% of consumers buying full-sized cars were actually purchasing their first car versus 10% for buyers of mid-sized lines. This partly explains Sudhir's (2001a) findings of aggressive pricing behavior in the mini and subcompact marketing segments, more cooperative behavior in the markets for mid-sized lines, and Bertrand behavior in the market for full-sized vehicles. The pattern arises because manufacturers remain highly motivated to price aggressively in the smaller car segments to capture first time buyers and young adults. On the other hand, manufacturers are less motivated to compete vigorously for older buyers who are already loyal and will instead price more cooperatively in the segments targeted to older, repeat buyers.

[6]R.L. Polk: "Asian Brands See Dramatic Rise in Owner Loyalty." January 10, 2007.

[7]Recent work by Dubé, Hitsch and Rossi (2007) suggests however, that within mature markets in which consumers incur a cost of switching to a different brand the incentive for a firm to lower price in order to attract new customers may indeed outweigh the incentive to "harvest" its existing customer base by charging higher prices.

The competitive structure of the market which emerges from the interrelationships among rival firms is likewise as important in explaining this pattern. According to Boulding and Staelin (1993), overly crowded market segments in which firms compete aggressively to service the dominant target population may yield more volatile pricing patterns than would have been the case with less vigorous competition. Under these conditions, firms are limited in their ability to charge prices over and above their competitive levels. On the other hand, within segments where consumers portray a great deal of loyalty to a particular brand, firms possess the motivation and the ability to soften their competitive stance as there is less competition for the dominant target population across these segments.

From a game-theoretic perspective, this *ability-motivation* paradigm (Boulding and Staelin (1993)) proves useful in constructing formal hypotheses about price competition and firm conduct. The central premise is that firms need both the ability and the motivation to successfully implement a particular strategy. Sudhir (2001a) is perhaps the only study which combines insights from the theory of repeated games and the ability-motivation paradigm to formulate testable conjectures for the U.S. car market. A similar approach is adopted here to unearth valid conjectures for the European car market. Indeed, one expects that firms which take a long-run profitability view of the market will be constrained in their *ability* to price cooperatively across markets which exhibit intense competition but will be more than able to pursue this type of strategy otherwise. Similarly, firms will be *motivated* to price cooperatively in segments which are less competitive and populated by loyal consumers. In summary therefore, it is clear that firms in the smaller car segments, while limited in their *ability* to price cooperatively, have tremendous motivation to be aggressive. However, in the larger car segments firms are less hampered in their ability to price cooperatively and remain highly motivated to cooperate by keeping price high in order to take advantage of loyalty effects. By the *ability-motivation* paradigm, there should be more aggressive behavior in the smaller car segments and more cooperative behavior in the larger car segments. These conjectures are formally tested for the European car market.

3.3. The European Car Market 1970-1999

Issues relating to market integration and price convergence across the E.U. are still hotly debated throughout Europe. In particular, the European car market has been placed under intense scrutiny due to its well documented episodes of deviation from the Law of One Price, criticism that it has been one of the most protected havens of

European industry, and because of its relatively significant value-added contribution to the European economy.[8]

Automobile manufacturers and their special interest groups across Europe have long sought to convince the E.U. community that the industry warrants special treatment. The basis of their argument was that the automobile was unlike other off-the-shelf consumer goods since after-sales servicing and safety maintenance formed important aspects of the product bundle. Their lobbying led to the E.C.'s adoption of Block Exemption Regulation (BER) 123/85 in 1984 that exempted the industry from Article 81(1) of the Treaty of Rome.[9] This came after the E.C. conceded to the claims of the European manufacturers that investments undertaken to establish dealer networks and offer after-sales maintenance and spare parts could not be made without reasonable financial security and return on investment (Akbar (2003)). Moreover, since an interbrand externality arises because investments by a manufacturer are not specific to a set of brands carried by the dealer, the BER, it was thought, could make investments specific to the manufacturer's brand thus remedying any externality effects (Besanko and Perry (1993)). After much debate, BER 123/85 was later renewed in 1995 as BER 1475/95, the latter representing a preliminary move toward liberalization of the car market, granting to distributors, among other freedoms, the right to sell cars of other manufacturers and to advertise outside of one's territory, both of which were taboo under the previous regime. As reported by the E.C., such changes were necessary in order to "enhance competition."

Although the manufacturers have been resolute in extolling the virtues of the exemption system, maintaining that its restrictive effects are potentially outweighed by consumer benefits, groups such as the European Bureau of Consumer Unions (B.E.U.C.) have been equally steadfast in their criticism. Their contention is that the system restricts competition and is in conflict with E.U. integration initiatives because there are limited opportunities for cross-border arbitrage to eliminate persistent international price differentials. The above concerns have not fallen on deaf ears. Responding to pressure from these large consumer interest groups, the E.C. has since replaced BER 1475/95, which expired in September 2002, with BER 1400/2002 – defined as being stricter than its predecessor. BER 1400/2002 limits the types of agreements exempt under Article

[8]Figures from the European Automobile Manufacturers Association (A.C.E.A.) indicate that A.C.E.A. members alone contribute over €4 billion annually in R&D and investment expenditure to the E.U. economy. The auto industry also accounts for over 7 percent of all manufacturing employment in the E.U.-27.

[9]The Treaty of Rome is also known as the E.C. Treaty. Article 81(1) explicitly prohibits agreements, decisions between associations of undertakings and concerted practices between undertakings which may affect the balance of trade among E.C. member states and which have as their objective the prevention, restriction or distortion of competition across the E.U. common market. Article 81(3) on the other hand allows for exceptions on the condition that consumer benefits outweigh any anti-competitive effects.

81(1) of the Treaty of Rome with a view to remedying the anti-competitive features of the car market. An implication of this change in arrangements between the manufacturers and their respective dealers is the potential for stronger, mostly intra-brand competition which was non-existent under BER 1475/1995. It is the E.C.'s hope that agreements falling within the categories defined by BER 1400/2002:

> "...can improve economic efficiency within a chain of production or distribution by facilitating better coordination between the participating undertakings. In particular, they can lead to a reduction in the transaction and distribution costs of the parties and to an optimisation of their sales and investment levels."[10]

Nevertheless, the jury is out on the supposed welfare gains the new BER will generate as it still allows manufacturers to impose either selectivity or exclusivity although not both simultaneously.[11] Furthermore, there is lingering uneasiness among dealers who remain unprotected against threats to terminate their dealerships. These underhanded practices have arisen in the past whereby manufacturers have either blocked parallel imports or threatened to cut off dealers in lower priced markets who supplied to buyers in higher priced ones. In fact, the E.C. imposed a fine of €102 million on the Volkswagen (V.W.) Group in January 1998 for this type of behavior. This was, at the time, the largest ever fine imposed by the E.C. on an individual company and represented approximately 10% of V.W.'s annual profits. Subsequent to their investigations, the E.C. discovered that V.W. actively tried to block Italian dealers from selling to customers in higher priced markets and systematically reduced profit margins and bonuses of authorized dealers who sold outside their allotted territories. The former DaimlerChrysler and Opel were also fined for separate infringements of E.C. competition rules in the area of car distribution. Daimler was fined €72 million in 2001 for blocking parallel imports and price fixing whereas Opel was fined €43 million in 2000 for obstructing exports of new cars from the Netherlands to other E.U. member states. Interestingly, V.W. was brought up on a separate charge in 2001 for attempting to fix retail prices and was fined a further €30.96 million.[12]

One can make an argument that the degree of market power held by car manufacturers throughout Europe is the abiding factor behind their actions. As outlined in BER 1400/2002:

> "The likelihood that such efficiency-enhancing effects [i.e. from the current Regulation] will outweigh any anti-competitive effects due to restrictions contained

[10]Commission Regulation E.C. No. 1400/2002 of 31 July 2002.

[11]In a recent study, Brenkers and Verboven (2006) attempt to quantify the welfare implications of liberalizing the distribution system. I refer the reader to their paper for details.

[12]See Table 2 in Verboven (2007) for a complete list of infringement cases since BER 123/85.

> in vertical agreements depends on the degree of market power held by the undertakings concerned and therefore on the extent to which those undertakings face competition from other suppliers of goods or services regarded by the buyer as interchangeable or substitutable for one another, by reason of the products' characteristics, prices or intended use."

However, as argued in Verboven (2007) and Goyder (2005), there is no sound basis upon which to base any allegations of extensive market power. Indeed, whereas BER 1400/2002 stipulates that manufacturers are allowed to apply the exemption if their market shares do not exceed a certain threshold level, there is no requirement to define the relevant product market in Article 81(1). How then are these thresholds interpreted? It is worth noting that the concept of demand substitutability largely determines whether a manufacturer holds a dominant position in a particular market. Thus, in determining whether a manufacturer possesses some degree of market power, it becomes necessary to define the relevant market such that from the point of view of the consumer, a Peugeot 205 is considered closely substitutable to a Toyota starlet, for example. This issue highlights the fact that a detailed study on the evolution of competition across the car market is warranted. This chapter embarks on such an investigation taking the relevant product markets as segments defined by marketing classifications and subsegments defined by the country of origin of the vehicle.

A priori, lower prices and reduced markups should prevail in countries with significant import penetration and moderate firm concentration in the car sector. Casual observation suggests this is the case for Belgium, a relatively open country with no domestic producers. This is in stark contrast to the economies of Germany, Italy, and the U.K., for example, which have traditionally featured higher prices, are relatively more concentrated, and by design have experienced relatively little international penetration.

Although manufacturers in these heavily protected domestic markets have remained relatively unscathed from external competition the proliferation over the last several decades or so of Japanese and Asian model ranges across Europe has proved challenging. This is compounded by the fact that Japanese and Asian lines have generally been well represented in the smaller, entry-level segments which form the core business of several European car makers (see Table 3.2). Fiat has suffered the greatest damage because the company relies heavily on its domestic market and has always been viewed as a compact car company despite its attempts at rebranding and image renewal. Fiat controlled over 60% of the Italian car market in the late 1980's but mounting competition in the smaller car segments led to a decline in its market share to just over 47.5% by the early 1990's. To curb Fiat's slumping sales due to heightened external competition, the

Italian government in the mid 1990's embarked on an ambitious campaign to fully match manufacturer rebates of up to two million lire (at the time about $1,320) with government scrappage incentives. The measure was designed to get people to replace their cars 10 years or older with safer, more efficient, cleaner running domestically produced vehicles but the end result was that sales slumped even further after the expiration of the incentive period.

Table 3.2. Firm Distribution in the European Car Market 1970-1999 (percent share)

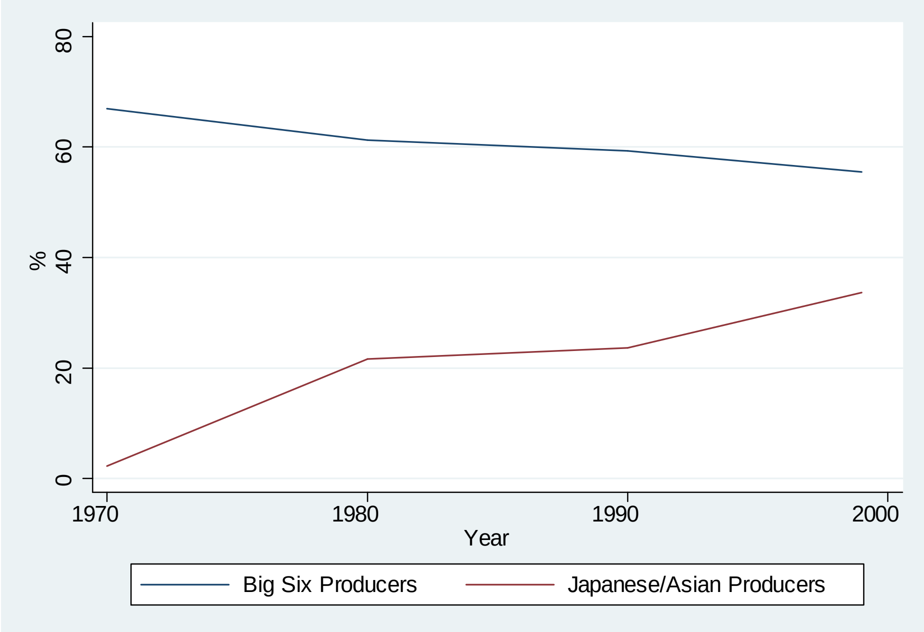
	Big Six Producers						*Japanese Big Three Producers*		
	Fiat	Ford	GM	PSA	Renault	V.W.	Toyota	Honda	Nissan
Subcompact	41.1	20.2	12.8	37.2	43.2	29.2	19.6	1.27	28.75
Compact	18.9	31.2	22.1	15.18	26.5	24.5	33.1	37.14	22.5
Intermediate	20.8	23.7	18.9	23.1	12.9	31.6	25.02	13.3	31.25
Standard	10.1	24.0	29.6	24.4	17.3	12.5	22.2	32.3	10.0
Luxury	8.6	0.7	16.5	–	–	2.03	–	9.5	7.5

French automakers have likewise suffered a similar fate. In 1996 both French giants, Peugeot and Renault rolled out their respective incentive packages and initially gained market share as a result. However, sales plummeted when the first wave of incentives expired. The ensuing price war resulted in reduced profit margins for all those selling cars in France. But whereas the combined market share held by Renault and the PSA group which owns Peugeot fell from 59% to 56% in 1996, overall import sales led by Japanese brands rose by 20% over the same year, increasing importers' market share to 44% up from 41%.

A New York Times piece by Tagliabue (2003) reveals the extent to which Japan's car makers have made life uncomfortable for domestic incumbent firms. Many Japanese firms have actually taken steps to re-engineer their best selling models specifically for the European market in an attempt to persuade more individuals to switch allegiance. Furthermore, the "flexible production system" employed by Japanese car manufacturers whereby a greater number of different models of cars, with fewer units each, are manufactured at a lower cost and in a shorter time than mass production techniques has left many European manufacturers in their wake.

The waning influence of the Big Six producers across Europe as reflected by their declining market share (See Figure 1 and Tables $B.1$ and $B.2$), is directly attributable to the influx of vehicles originating from outside the E.U. The collective market share of the Big Six producers has fallen steadily between 1970-1999 concurrent with a marked increase in the overall share of Japanese and Asian-made vehicles. And yet, given the ongoing process of European integration, Japanese automakers will soon have even more

Figure 3.1. Japanese/Asian Import Penetration (percent market share)



unfettered access to European markets which could spell further trouble for domestic incumbent firms.

3.4. The Empirical Model

In this section, the empirical model which is brought to the data is fully specified. The demand model is formulated under the assumption that preferences are appropriately described by a flexible multi-level nested logit framework. While the nested logit is less sophisticated than the more general random coefficients logit methodology of BLP or Nevo (2001), Berry (1994) shows that it can still be thought of as a random coefficients-type model in which heterogeneity depends on discretely measured characteristics rather than on continuously measured features of the product. Besides, the nested logit is also computationally less burdensome and still yields plausible substitution patterns by mitigating the IIA problem.[13]

On the supply side, the "coefficients of cooperation" approach to measuring firm conduct (Cyert and Degroot (1973)) is employed to identify the segment-specific conduct parameters. The method is based on the notion that firms place a weighting on rival profits upon evaluating their own objective function and encompasses an array of equilibrium assumptions regarding competitive behavior. The standard non-cooperative (Bertrand) outcome is obtained when firms place a zero weight on rival profits. However, if firms place a positive (or negative) weight on rival profits, the result is more (or less)

[13]The IIA problem is also the so-called "red-bus, blue-bus" problem of McFadden (1978).

cooperative relative to the Bertrand outcome. It should also be noted that although the supply side does not take into account the dynamic consequences of firm decisions, these can be crucial given that the study pertains to automobiles, an important durable good.

3.4.1. Specification of Automobile Demand

It is assumed that a typical consumer i within market $m = 1, ..., M$ at time period $t = 1, ..., T$ chooses among the $j = 0, ..., J_{mt}$ different alternatives (model ranges) to maximize conditional indirect utility U_{ijmt} given by:

$$\begin{aligned} \max_{j=0,\ldots,J_{mt}} U_{ijmt} &= \mathbf{X}'_{jt}\beta - \alpha p_{jt} + \xi_{jt} + \epsilon_{ijmt} \\ &\equiv \delta_{jm} + \epsilon_{ijmt} \end{aligned} \tag{3.1}$$

where $j = 0$ is reserved for the "outside" alternative of not purchasing a new car. The inclusion of the outside good is important to the extent that it ensures the overall demand for cars is not perfectly inelastic which allows the aggregate demand curve for new cars to be downward sloping. From Berry (1994) the term δ_j (momentarily dropping the market identifier and time subscripts) denotes the "mean" utility level which is common to all consumers within a particular market. The mean utility is a linear function of vehicle attributes (horsepower, fuel efficiency, etc.) collected within the K-dimensional vector X_j, prices p_j, and the level of unobserved (to the econometrician) vehicle quality ξ_j. The residual term ϵ_{ij} arises due to the effect of maximization errors, personal idiosyncrasies, or unmeasured variables and is identically and independently distributed across consumers and alternatives.

As is standard for models in which consumers make discrete choices, the alternative that yields the greater level of satisfaction will ultimately be purchased. Consumer i will purchase alternative j iff:

$$U_{ij} > U_{ik}, \quad 0 \leqslant k \leqslant J, \quad k \neq j \tag{3.2}$$

Consistent with the recommendations in Berry (1994) the mean utility provided by the outside good is normalized to zero and thus $U_{i0} = \epsilon_{i0}$. Hence, from (3.2) the following is obtained:

$$\begin{aligned} s_{ij} &= \Pr\{\delta_j + \epsilon_{ij} > \delta_k + \epsilon_{ik}, \quad k \neq j\} \\ &= \Pr\{\epsilon_{ik} < \epsilon_{ij} + \delta_j - \delta_k, \quad k \neq j\} \\ &= \int_{-\infty}^{\infty} F_j(\epsilon_{ij} + \delta_j - \delta_0, ..., \epsilon_{ij}, ..., \epsilon_{ij} + \delta_j - \delta_J) \end{aligned} \tag{3.3}$$

where s_{ij} is the probability that consumer i chooses alternative j, the F_j's are the partial derivatives of the joint cdf $F(\epsilon_{i0}, ..., \epsilon_{iJ})$ with respect to its j-th argument, and δ_0 is the mean utility generated by the outside alternative. McFadden (1978) has shown that different parameterizations of the joint cdf produce different types of discrete choice models. In particular, if $F(\epsilon_{i0}, ..., \epsilon_{iJ})$ is of the generalized extreme value (GEV) class and the j alternatives are partitioned into non-overlapping subsets or nests according to some discretely measured characteristic, the nested multinomial logit (NMNL) model is obtained.

In line with the focus of the paper, the alternatives within each market are therefore fully partitioned into G_m mutually exclusive marketing segments defined as subcompact (SC), compact (C), intermediate (I), standard (S), and luxury (L). Table 3.3 gives some examples of typical models within the respective segments.

Table 3.3. Models by Segment Classification

Segment	*Example*
Subcompact	Peugeot 205, Toyota Starlet
Compact	V.W. Golf, Fiat Tipo
Intermediate	Mitsubishi Galant, Mazda 626
Standard	Volvo 240, Citroën CX
Luxury	Audi A8, Saab 9000

Each of these "inside" segments $g = 1, ..., G_m$ is further partitioned into $h = 1, ..., H_{gm}$ country of origin subsegments defined as "home" (H) or "foreign" (F) and thus the model features J_{gm} alternatives within each subsegment and $\sum_{g=1}^{G_m} \sum_{h=1}^{H_{gm}} J_{gm} = J_m$ for each market m. This system of groupings is justified if cars within a particular marketing segment or subgroup share common features or are perceived to be more similar than cars external to the segment or subsegment.

Table 3.4 illustrates the similarities among cars belonging to a particular segment broken down by market. As is evident, subcompact and compacts are more fuel efficient albeit less powerful and constitute the bulk of annual sales across the sample. There are also more subcompact and compact lines to choose from with luxury lines being the least available. In terms of pricing, average pretax prices are lowest within Belgium and highest for Germany and the U.K. This is due to the fact that Belgium is a relatively open economy with no domestic producers unlike the economies of Germany and the UK which have both erected artificial barriers blocking the flow of parallel imports in order to protect domestic producers.

If we assume that the alternatives can indeed be partitioned as specified above, and if it is maintained that $F(\epsilon_{i0}, ..., \epsilon_{iJ})$ is a member of the GEV class of models we obtain

Table 3.4. Average Segment Characteristics (1970 - 1999)

	Subcompact	Compact	Intermediate	Standard	Luxury
Belgium					
Sales (Units)	138	183	130	82	74
Number of Models	25	21	20	17	7
Horsepower (hp)	44.2	66.38	80.30	104.91	131.25
Size (in sq. m.)	7.78	9.30	10.22	11.24	11.76
Fuel Inefficiency (*liters*)	6.7	7.95	8.51	9.64	10.04
Price (€)	3512	4976	6509	8247	13,909
France					
Sales (Units)	1,276	776	676	372	184
Number of Models	21	18	16	14	5
Horsepower (hp)	44.5	67.56	80.63	104.98	129.12
Size (in sq. m.)	7.85	9.28	10.23	11.26	11.71
Fuel Inefficiency (*liters*)	6.74	7.84	8.43	9.6	9.71
Price (€)	3724	5493	6987	8834	14,775
Germany					
Sales (Units)	766	1,454	1,035	767	1,343
Number of Models	21	17	17	14	6
Horsepower (hp)	44.78	65.97	82.94	105.8	132.63
Size (in sq. m.)	7.86	9.28	10.25	11.28	11.77
Fuel Inefficiency (*liters*)	6.7	7.9	8.68	9.61	10.07
Price (€)	4186	5780	7567	9343	13,902
Italy					
Sales (Units)	1,493	835	489	190	299
Number of Models	21	15	14	12	6
Horsepower (hp)	44.72	68.70	83	111.06	129
Size (in sq. m.)	7.77	9.37	10.29	11.32	11.70
Fuel Inefficiency (*liters*)	6.7	7.86	8.42	9.46	10.03
Price (€)	3932	5897	7533	9879	14,523
United Kingdom					
Sales (units)	758	945	709	286	205
Number of Models	20	18	17	14	6
Horsepower (hp)	46.41	66.70	83.40	108.66	133
Size (in sq. m.)	7.89	9.32	10.25	11.3	11.76
Fuel Inefficiency (*liters*)	6.78	7.86	8.5	9.65	9.88
Price (€)	4438	6233	8223	10,117	16,297

the multi-level nested logit probability of choosing $j = 1, ..., J_m$:

$$s_{jm}(\delta, \sigma) = \bar{s}_{j/hgm}(\delta, \sigma) \cdot \bar{s}_{h/gm}(\delta, \sigma) \cdot \bar{s}_{gm}(\delta, \sigma) \tag{3.4}$$

where:

$$(3.5)\quad \begin{aligned} \overline{s}_{j/hgm}(\delta,\sigma) &= \frac{\exp\left(\delta_{jm}/(1-\sigma_{hgm})\right)}{D_{hgm}}, \\ \overline{s}_{h/gm}(\delta,\sigma) &= \frac{D_{hgm}^{(1-\sigma_{hgm})/(1-\sigma_{gm})}}{\sum\limits_{h\in H_{gm}} D_{hgm}^{(1-\sigma_{hgm})/(1-\sigma_{gm})}}, \\ \overline{s}_{gm}(\delta,\sigma) &= \frac{\left(\sum\limits_{h\in H_{gm}} D_{hgm}^{(1-\sigma_{hgm})/(1-\sigma_{gm})}\right)^{1-\sigma_{gm}}}{\sum\limits_{g\in G}\left(\sum\limits_{h\in H_{gm}} D_{hgm}^{(1-\sigma_{hgm})/(1-\sigma_{gm})}\right)^{1-\sigma_{gm}}}, \end{aligned}$$

with $D_{hgm} = \sum\limits_{j\in J_{gm}} \exp\left(\delta_{jm}/(1-\sigma_{hgm})\right)$, where $(1-\sigma_{hgm})$ and $(1-\sigma_{gm})$ are the inclusive value coefficients which are restricted to lie within the unit interval to ensure consistency with the principles of random utility maximization, $\overline{s}_{j/hgm}$, the predicted share of alternative j in its country of origin subsegment h from marketing segment g, $\overline{s}_{h/gm}$, the predicted share of the country of origin subsegment h in marketing segment g, and $\overline{s}_{gm}$, the predicted segment group share.[14]

For this type of hierarchical preference structure, the inclusive value coefficients associated with the country of origin subsegments are constrained to be smaller than the corresponding coefficients associated with the upper level of the nesting structure (the marketing segments); thus, the restriction $0 \leqslant \sigma_{gm} \leqslant \sigma_{hgm} \leqslant 1$ is critical in much of what follows. Both parameters, σ_{gm} and σ_{hgm} also have their own structural interpretation. The first parameter, σ_{gm}, indicates the correlation in consumer preferences across alternatives within a particular marketing segment while σ_{hgm} reveals similar information for alternatives within a common subsegment of a particular segment. In the typical case with $0 < \sigma_{gm} < \sigma_{hgm} < 1$, preferences will be more strongly correlated across alternatives of the same subsegment than across alternatives of a different subsegment within the same marketing segment. In addition, preferences are more correlated across alternatives from the same marketing segment than across alternatives from other segments. As a result, alternatives within the same subsegment are perceived as closer substitutes than alternatives from another subsegment within the same or another segment. Furthermore, as either σ increases (decreases), correlation of consumer preferences across alternatives in the corresponding segment or subsegment increases (decreases) and these alternatives become more (less) substitutable.

[14]The inclusive value coefficients are also referred to as log-sum coefficients throughout the literature.

In the limiting case where σ_{hgm} gets closer to 1, preferences across alternatives within the same subsegment become *perfectly correlated* and these products are perceived as *perfect substitutes*. When all σ_{hgm} approach σ_{gm}, preferences are equally correlated for all products within a common cluster and Eq. (3.4) reduces to a single-level nested logit model in which the marketing segments represent the nests. If all σ_{gm} get closer to 0, preferences over alternatives of the same segment become *uncorrelated* and the model in this instance is also reduced to a single-level nested logit, but with the country of origin subsegments now constituting the nests. Finally, when both σ_{hgm} and σ_{gm} approach 0, preferences for all products are uncorrelated and Eq. (3.4) is reduced to the simple multinomial logit (MNL) model.

Berry (1994) has shown that the right hand side of Eq. (3.4) which is a function of the $J_m \times 1$ vector of prices and unobserved vehicle quality poses problems when it is to be brought to the data for estimation. Fundamentally, the unobserved product characteristics may be correlated with prices which therefore become endogenous to the system Eq. (3.4). Simple instrumental variable (IV) techniques could be utilized to remedy this type of problem but there is an added concern: both unobservable vehicle quality and prices enter Eq. (3.4) in a nonlinear fashion and thus IV methods cannot be applied in the standard manner. The solution is to normalize Eq. (3.4) such that the unobserved product attributes enter linearly.

Lemma 10. *The estimable demand equation resulting from the assumption on* $F(\epsilon_{i0}, ..., \epsilon_{iJ})$ *and equations Eqns.* (3.4) *and* (3.5) *is:*

$$\ln(s_{jmt}) - \ln(s_{0mt}) = \mathbf{X}'_{jmt}\beta - \alpha p_{jt} + \sigma_{hg} \ln\left(\bar{s}_{j/hgmt}\right) + \sigma_g \ln\left(\bar{s}_{h/gmt}\right) + \xi_{jmt}, \tag{3.6}$$

where $s_{0m} = 1 - \sum_{j=1}^{J_m} q_{jm}/L_m$ *is the share of the outside alternative in market* m*,* q_{jm} *represents sales of model* j*, and* L_m *denotes the potential market size.*

Proof. See the appendix. □

3.4.2. Firm Behavior

We now turn attention to the supply side of the model which characterizes firm behavior. To complete our analysis it is assumed that firm $f = 1, ..., F$ in market m seeks to maximize its objective function:

$$\Pi_{ft} = \sum_{j \in J_{ft \cap V_{hg}}} \left(p^w_{jt} - c_{jt}\right) s_{jt}(p) L_{mt} + \sum_{j \notin J_{ft \cap V_{hg}}} \phi_{g(j)} \left(p^w_{jt} - c_{jt}\right) s_{jt}(p) L_{mt}, \tag{3.7}$$

where $p^w_{jt} = p_{jt}/(1+\ t)$ is the wholesale price of model j in market m, t is VAT in the destination country, c_{jt} is the constant marginal cost associated with alternative j, $\phi_{g(j)}$ is the weight on a competitor's profit from model j in segment g, $J_f \subset J_m$ is the subset of models sold by firm f, and V_{hg} is the set of models from subsegment h of segment g. The degree of competition is measured by the amount of deviation from Bertrand pricing. Thus, $\phi_{g(j)} > 0$ implies more cooperative behavior relative to Bertrand in segment g as the firm places a positive weighting on its competitor's profits whereas $\phi_{g(j)} < 0$ implies more aggressive behavior relative to Bertrand in segment g since the resulting outcomes under this scenario will be more competitive relative to that under Bertrand pricing (with $\phi_{g(j)} \approx 0$).

If a pure strategy Nash equilibrium exists at strictly positive prices, the resulting first order conditions are

$$\frac{\partial \Pi_f}{\partial p_{rt}} = (1+t) \sum_{j \in J_{f \cap V_{hg}}} \left(p^w_{jt} - c_{jt}\right) \frac{\partial s_{jt}(p)}{\partial p_{rt}} + (1+t) \sum_{j \notin J_{ft \cap V_{hg}}} \phi_{g(j)} \left(p^w_{jt} - c_{jt}\right) \frac{\partial s_{jt}(p)}{\partial p_{rt}} + s_{rt} = 0,$$

which are summarily presented in vector form as

$$\mathbf{p} - \mathbf{c} = \underbrace{\left[-\nabla_p \mathbf{s}(p) \odot \left(\mathbf{\Theta}^{own}_{j,j'} + \sum_g \mathbf{\Phi}^{comp}_g\right)\right]^{-1}}_{\Delta} \mathbf{s}(p) \tag{3.8}$$

with $\Delta^{-1}\mathbf{s}(p)$ interpreted as the profit margin, $\nabla_p \mathbf{s}(p)$ the $J \times J$ Jacobian matrix of first derivatives $\frac{\partial s_{jt}}{\partial p_{rt}}$, $\odot$ denoting the Hadamard (element-wise) product, $\mathbf{\Theta}^{own}$ the "ownership" matrix with definition

$$\mathbf{\Theta}^{own} = \begin{cases} 1 & \text{if } j \text{ and } j' \text{ belong to the same firm} \\ 0 & \text{otherwise} \end{cases}$$

and

$$\mathbf{\Phi}^{comp}_g = \begin{cases} \phi_{g(j)} & \begin{array}{l}\text{if } j \text{ and } j' \text{ belong to the same segment} \\ g \text{ and are produced by different firms}\end{array} \\ 0 & \text{otherwise} \end{cases}$$

defined as the "competition" matrix.

Existence and uniqueness of the price equilibrium Eq. (3.8) in the context of single-product firms is established by Caplin and Nalebuff (1991). and by Anderson, DePalma, and Thisse (1992). However, as is widely known throughout the empirical I.O. literature, these results cannot be directly extended to the multi-product framework. Sándor (2004) presents results which can be used to show existence and uniqueness in a multi-product framework where the aforementioned studies are inapplicable. The reader is directed to this paper for further details.

3.4.3. Cost Specification

Marginal costs are unknown and will have to be estimated. Following the literature, a log-linear marginal cost function is assumed:

$$\ln\left(c_{jt}\right) = \omega_{jt}'\gamma + \varsigma_{jt} \tag{3.9}$$

where ω_{jt} and ς_{jt} are observed and unobserved cost shifters respectively and γ is a vector of unknown parameters. It may be the case that $\boldsymbol{\omega}_t = \mathbf{X}_t$ in which case the same characteristics will be used as cost shifters. Substituting Eq. (3.9) into Eq. (3.8) yields the following pricing equation:

$$\mathbf{p} = \exp\left\{\boldsymbol{\omega}'\boldsymbol{\gamma} + \boldsymbol{\varsigma}\right\} + \Delta^{-1}\mathbf{s}\left(p\right) \tag{3.10}$$

which can be transformed so that the error term enters linearly:

$$\boldsymbol{\varsigma} = -\,\boldsymbol{\omega}'\boldsymbol{\gamma} + \ln\left\{\mathbf{p} - \Delta^{-1}\mathbf{s}\left(p\right)\right\} \tag{3.11}$$

The implied market equilibrium represented by Eqns. (3.6) and (3.11) form the empirical model which is brought to the data for estimation.

3.5. Data and Estimation Issues

3.5.1. Data

The data spans the period 1970 – 1999 and includes quantities (new vehicle registrations), pre and post tax list prices, and physical characteristics of the base model ranges. Included are physical characteristics indicating comfort (length, width, height, etc.), performance (horsepower, speed, acceleration time, fuel efficiency at different speeds, etc.), and macroeconomic variables such as GDP, tax rates, exchange rates, population, and price indices for five national markets: Belgium, France, Germany, Italy, and the UK, which collectively account for over 80% of annual new vehicle registrations across the Europe. Also included are variables indicating the market in which the model was sold, the brand and model type, the country of origin and production, and the marketing segments and subsegments to which the vehicles belong.[15] The data is thus a three-dimensional panel comprising classifications by market $m = 1, ..., M$, (Belgium, France, Germany, Italy, U.K.), time $t = 1, ..., T$, $(1970, ..., 1999)$, and model $j = 1, ...J_m$. The data set is

[15]Selected variable definitions are given in Table $B.5$ in the Appendix.

assembled from various consumer catalogues and portions of it have been used in previous studies of the European car market.[16]

There are 11549 observations on approximately 350 different models implying an average of roughly 80 models sold each year in each national market. The five national markets comprising the data display sufficient variability across several key features: market size which ranges from approximately 400,000 units sold annually in Belgium to about 3 million in Germany; tax rates from 14% in Germany to 25% in France; import penetration from approximately 30% in France to nearly 100% in Belgium; and Japanese penetration which stretches from 1% in countries such as Italy to 20% in Belgium. In addition the CI-concentration index ranges from 16% in Belgium to around 53% in Italy. For a detailed description of the data set over a shorter time span, the reader is directed to the paper by Goldberg and Verboven (2001).

3.5.2. Endogeneity and Identification

As is well known, a product such as an automobile possesses several attributes which are potentially important to the typical consumer. Of course, the econometrician only observes a small subsample of these attributes as there are others which are not directly observable including style, image, etc. It is highly likely that these unobserved product attributes are correlated with prices. One expects that cars which are perceived as better in terms of styling or image command higher prices. Failure to account for this feedback effect usually results in biased estimates of the coefficient on price and implausible substitution patterns.

A key identification assumption in this context is that the elements of $\mathbf{X}$ and $\boldsymbol{\omega}$ are predetermined and thus uncorrelated with the respective error terms ξ and ς. In the modern parlance, this amounts to assuming that observed product attributes are mean independent of unobserved product attributes. Thus, $E[\xi|\mathbf{X}] = E[\boldsymbol{\varsigma}|\boldsymbol{\omega}] = 0$ yields moment conditions which are useful in undertaking the estimation of both equations. With respect to the demand model, additional instruments are required in order to estimate the elements of the vector β plus the coefficient on price and the 15 segmentation parameters (5 segment correlation parameters (σ_g) plus 10 subsegment two correlation parameters (σ_{hg})). At least $K + 16$ moment conditions are required. Making use of the fact that a particular firm's pricing policy may depend on the characteristics of closely-located rival firms, BLP suggests using basis functions of the continuous product attributes to

[16] See, for example, Verboven (1996), Goldberg and Verboven (2001), Brenkers and Verboven (2005), or Brenkers and Verboven (2006).

generate additional instruments.[17] Following in this vein, and by utilizing the structure of the nested logit model, the additional instruments generated include the number of products and the sums of characteristics of other products of the same firm from the same subsegment, the number of products and the sums of characteristics of competing products from the same subsegment, and the number of products along with the sums of characteristics of competing products from the same segment.

Similar to Brenkers and Verboven (2006), the panel structure of the data is also exploited in the estimation of the empirical model. The error term ξ is specified as a two-way error components model and expressed as $\xi_{jmt} \equiv \xi_j + \xi_{mt} + u_{jmt}$ where ξ_j controls for unobserved product-specific fixed effects that are invariant over time or across geographical markets while the market/time fixed effects ξ_{mt} capture preferences for cars relative to the outside good. The 350 fixed effects, (i.e. the ξ_j's) are controlled for using a within transformation while the ξ_{mt}'s are captured by 30×5 dummy variables (five geographical markets over a 30 year period). The remaining term u_{jmt} controls for other unobserved product attributes varying across geographical markets and time and is assumed to be uncorrelated across both consumers and alternatives.

3.5.3. Estimation

For efficiency purposes, the demand and supply equations should be estimated simultaneously. However, this comes at a potentially higher cost of inconsistency due to the strong assumptions laid out in formulating the supply side. The empirical model is instead estimated recursively. The demand equation is first estimated and the results fed into the pricing model to separately generate estimates of cost and conduct parameters. On the demand side four attributes: horsepower, fuel inefficiency, width, and height are included in $\mathbf{X}_t$ along with 150 market/time dummies and a "foreign firm effect" which captures the impact of foreign cars on consumers' mean valuation. A fixed effects two stage least squares procedure (FE 2SLS) is utilized to estimate the demand equation with overidentifying restrictions arising from the inclusion of the BLP-type instruments mentioned earlier.

A nonlinear GMM framework is used to estimate the supply equation. Included in $\boldsymbol{\omega}_t$ as cost shifters are the same variables that affect the consumers' mean valuation. Letting $\mathbf{Z}$ denote the matrix of valid instruments with $\theta = \{\gamma, \phi_{SC}, \phi_C, \phi_I, \phi_S, \phi_L\}$, the GMM

[17]Prices of other firms have also been used as additional instruments throughout the literature. However, throughout Europe, both demand and marginal costs are independent of prices in other national markets because consumers' arbitrage costs are prohibitive.

estimator $\widehat{\theta}$ minimizes the objective function:

$$J = M(\theta)' WM(\theta) = E\left[Z'\varsigma(\theta)\right]' WE\left[Z'\varsigma(\theta)\right], \tag{3.12}$$

with moment expression $M(\theta)$, W defined as a weight matrix and $\varsigma(\theta)$ the supply side error at different values of θ. Note that the supply side error has mean zero at the true value of θ conditional on the matrix of instruments (i.e. $E[\varsigma(\theta)|\mathbf{Z}] = 0$). This is another key assumption underlying the estimation procedure.

Following the set up in chapter 14 of Hamilton (1994) $\widehat{\theta}$ along with its asymptotic variance is estimated using a two step procedure where the first step yields consistent, but not necessarily efficient, estimates of θ and the optimal weight matrix $W = \Omega^{-1}$. Letting $G = E[\nabla_\theta M(\theta)]$ and $\Omega = \left[M(\theta) M(\theta)'\right]$ the asymptotic variance of $\sqrt{n}\left(\widehat{\theta} - \theta\right)$ is simply defined as $\left(G'WG\right)^{-1} G'W\Omega WG\left(G'WG\right)^{-1}$. The Nelder-Meade nonderivative simplex routine is used to minimize the objective function with respect to the θ's.

3.6. Empirical Results

In this section I present the parameter estimates from the empirical model. The estimates from the demand equation and the implied substitution patterns are reported first. To reduce the number of parameters to estimate I proceeded with a more restricted version of the nested logit where all segments and subsegments are treated similarly. Thus, σ_g and σ_{hg} are equal across all segments and subsegments respectively. The findings from the supply side estimation are presented afterward.

3.6.1. Demand and Substitution Patterns

Estimates from the demand equation (3.6) are reported in Table 3.5 with OLS results included for comparison. OLS generates estimates smaller in magnitude because of the downward bias resulting from endogeneity. Looking at the 2SLS estimates, all parameters are of the expected sign and compare favorable with the results in Brenkers and Verboven (2006).[18]

Horsepower, width, and height all positively impact the consumers' mean valuation whereas fuel inefficiency has a negative impact.[19] The foreign firm effect is also negative and significant which suggests that foreign manufacturers are viewed negatively from the point of view of the consumer and thus face a competitive disadvantage. Brenkers and

[18]In a previous version of their paper, Brenkers and Verboven estimated the demand model without accounting for consumer heterogeneity on the price coefficient term in much the same way as is done here. The results also compare favorably with those from the earlier paper.

[19]Fuel inefficiency measures the liters of fuel used per 100km traveled at different speeds. It is thus the inverse of the variable MPG commonly referred to as miles per gallon.

Table 3.5. Parameter Estimates from the Nested Logit: Dep. Variable $\ln(s_{jm}/s_{0m})$

	OLS		FE 2SLS	
Variable	*Est.*	*S.E.*	*Est.*	*S.E.*
horsepower (kW)	-0.010	0.0005	0.005	0.003
fuel inefficiency	-0.061	0.005	-0.054	0.002
width	0.003	0.001	0.023	0.004
height	-0.004	0.001	0.009	0.005
foreign firm effect	-0.691	0.015	-0.805	0.114
price ($-\alpha$)	1.016	0.029	1.37	0.446
constant	-0.602	0.195	-6.16	1.94
Subgroup segmentation parameter (σ_{hg})				
$\ln\left(\bar{s}_{j/hg}\right)$	0.844	0.004	0.714	0.047
Group segmentation parameter (σ_g)				
$\ln\left(\bar{s}_{h/g}\right)$	0.31	0.010	0.423	0.119

Notes: There are 11,549 observations. Product and market-specific fixed effects included.

Verboven (2006) show that this foreign firm effect has declined substantially in recent times. This is probably due to the ongoing E.U. integration process or the fact that most foreign firms are European and have factories across the E.U.

Viewing the segmentation parameters, both conform to the principle of random utility maximization ($0 \leqslant \sigma_g \leqslant \sigma_{hg} \leqslant 1$), and are significant. Clearly, preferences are more correlated across cars within the same subsegment than across cars within the same subsegment but from a different segment ($0.714 > 0.423$). Thus, consumer valuations are more homogeneous for cars from the same country of origin and marketing segment than for other cars within the same segment. Additionally, given the significance of σ_g, preferences are more correlated for cars from the same marketing segment than for cars from different segments.

The substitution patterns implied by the demand estimates are presented in Table 3.6. These are roughly in line with those in Brenkers and Verboven (2006) and also display the increasing pattern alluded to in their paper whereby elasticities generally increase as we move from subcompacts to luxury vehicles. This pattern results from the assumptions underlying the restricted version of the nested logit model which generates a single estimate each for the segment and subsegment correlation parameters. Brenkers and Verboven (2006) undertake a more flexible specification and discover that the pattern is generally reversed. However, I choose to estimate the more restricted version as my focus is on the supply side.

Table 3.6. Substitution Patterns in 1999 (mean elasticities)

		Cross Elasticities with respect to vehicle from:		
	Own elasticity	Same Subsegment	Same Segment	Different Segment
All	-3.32	0.197	0.009	0.001
Subcompact	-1.96	0.071	0.003	0.001
Compact	-2.78	0.136	0.005	0.002
Intermediate	-3.52	0.157	0.004	0.001
Standard	-4.81	0.383	0.016	0.001
Luxury	-6.45	0.60	0.04	0.002

3.6.2. Cost and Conduct Parameters

Estimates from the pricing equation (3.10) are reported in Table 3.7. The estimates from the pricing equation are also roughly in line with *a priori* expectations. All cost shifters are positive except fuel inefficiency.

Of greater interest is the conduct parameters. *A priori* we expected more competitive behavior in the smaller, entry-level car segments and more cooperative behavior in the larger car segments. The estimates show that there is indeed more competitive behavior in the compact and intermediate segments, more cooperative pricing in the subcompact and standard segments and Bertrand pricing behavior in the luxury segments. These results are roughly in line with Sudhir's (2001) analysis. E.C. surveys suggest that the largest price variations in the E.U. occur among smaller, mid-sized cars while luxury cars have had comparatively level prices for several years (see Andrews (2002)). On this basis, the discovery of more competition among the compact and intermediate segments is hardly surprising.

But the finding of strong cooperative behavior in the subcompact segment is puzzling. This runs counter to what was conjectured based on the *ability-motivation* paradigm: intense competition in the market for small, entry-level cars and more cooperative pricing behavior in the larger marketing segments. Why then, are manufacturers pricing less cooperatively in the subcompact segment? It is instructive to realize that because of generally higher gas prices and more stringent emission standards, European consumers have always had a strong preference for and access to smaller, more fuel efficient cars than the typical U.S. consumer. Figures 3.2 and 3.3 show that the U.S. lags far behind

Table 3.7. Supply Side Estimates

	GMM Estimates	
Variable	*Est.*	*S.E.*
horsepower (kW)	5.36	0.002
fuel inefficiency	-2.13	0.21
width	7.53	0.646
height	10.74	0.761
foreign firm effect	0.084	0.019
constant	-8.694	1.94
Conduct Parameters	*Est.*	*S.E.*
Subcompact (ϕ_{SC})	1.95	0.213
Compact (ϕ_C)	-0.691	0.034
Intermediate (ϕ_I)	-1.295	0.986
Standard (ϕ_S)	0.076	0.045
Luxury (ϕ_L)	0.265	1.88

Notes: No. of observations is 11,549. Fixed effects included.

the E.U. and many other countries in controlling fuel economy and emissions standards[20]. As can be seen, the average fuel economy standard in the E.U. is over 40 MPG while in Japan it is even more stringent at over 45 MPG.[21]The U.S. is far behind at an average of just about 25. In terms of emission standards, the E.U. and Japan are again the leaders. CO_2 emission standards for the E.U. range between 140-160 g/km while in Japan it is even lower. Thus, the need for sleeker, more fuel efficient vehicles may be the driving force underlying the purchasing decisions of European consumers, resulting in loyalty-type effects which are eventually exploited by manufacturers in similar fashion as outlined under the *ability-motivation* paradigm.

It is important to note that in this case these loyalty-type effects are not necessarily confined to a specific consumer demographic. Because gas prices have taken a big bite out of the typical European consumers' operating budget, they behave accordingly, driving when they must, as opposed to aimless wandering. Furthermore, manufacturers realize

[20]Both Figures are reproduced with permission from the Pew Center on Global Climate Change.

[21]Interestingly although most Americans have grown accustomed to criticizing G.M. as a leading producer of gas guzzling vehicles here in the U.S. it is seen as a fuel economy leader in Europe (Brown (2007a)).

Figure 3.2. A Comparison of Fuel Economy Standards

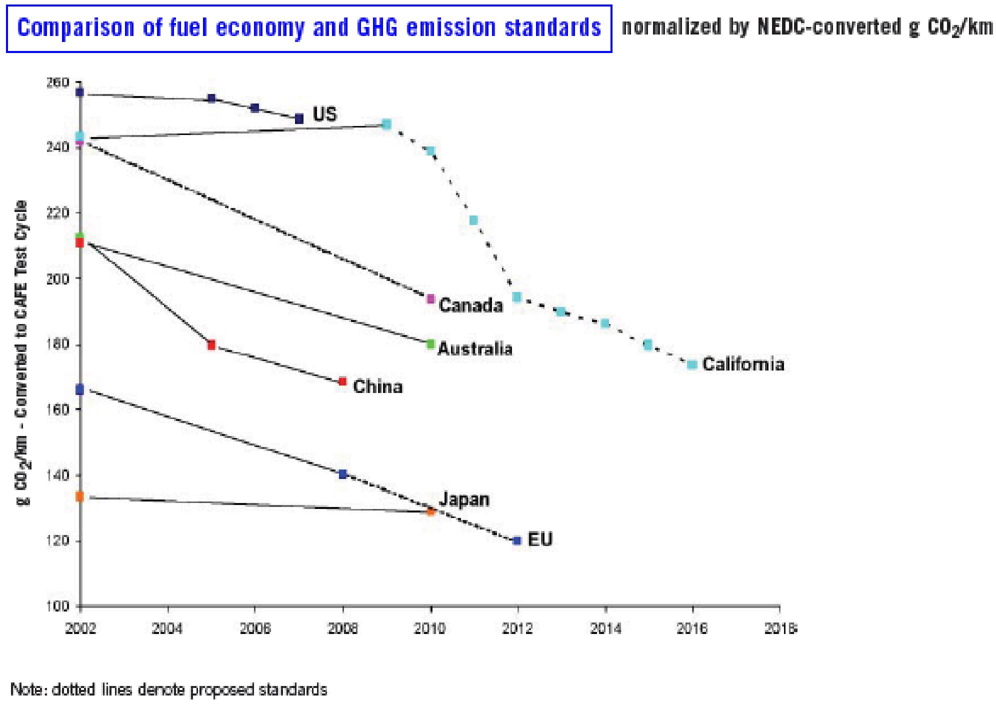
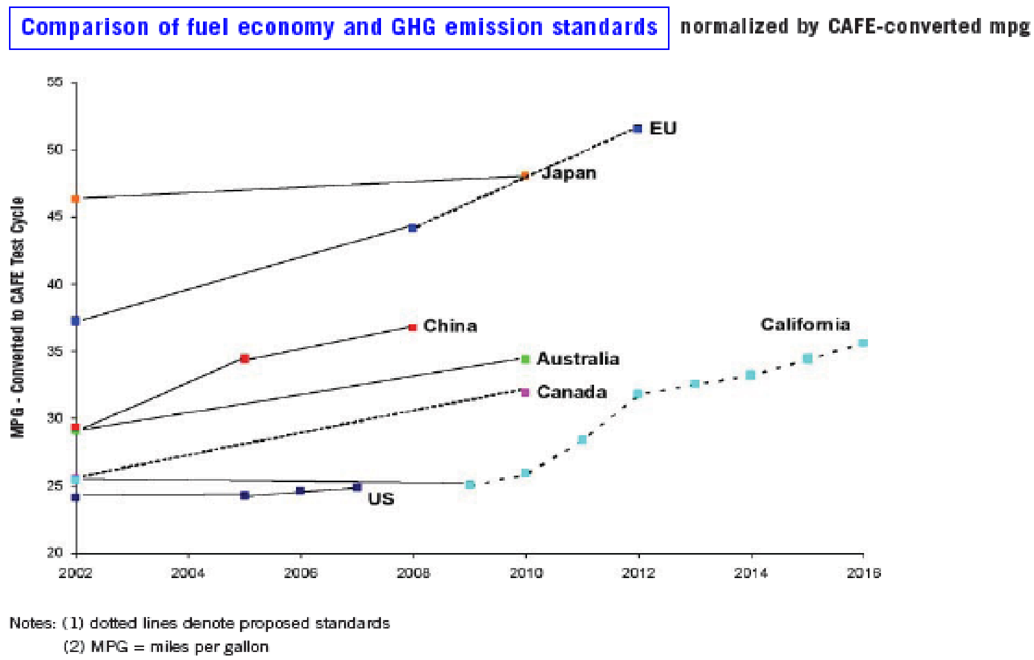


Figure 3.3. A Comparison of CO_2 Emission Levels Based on E.U. Standards



that small, subcompact cars can indeed be sold at a profit because consumers recognize their value in reducing gasoline costs. As a direct result, there will be much softer competition in the markets for these cars since consumers are less price sensitive.

3.7. Concluding Remarks

The system of Block Exemption Regulations that governed distribution and after-sales servicing of cars throughout Europe has contributed to the widely held view that the E.U. car market is anti-competitive. This paper empirically challenges this notion. However, rather than focusing on measures of conduct across broad geographic markets, the paper explores competition across segments and subsegments of the car market where segments are defined according to standard marketing classifications and subsegments defined by the country of origin of the vehicle.

The empirical results show that there is more competition relative to Bertrand pricing in the compact and intermediate segments, more cooperative pricing in the subcompact segment, and standard Bertrand pricing behavior in the standard and luxury segments. These patterns are roughly consistent with the ability-motivation paradigm of Boulding and Staelin (1993) and indicate that manufacturers in the European car market price according to a long run profitability perspective.

This research can be extended in several meaningful ways. Firstly, note that the supply side is formulated in a static setting under the assumption that current pricing strategies have no dynamic consequences. Given that the product market under study is that of a durable good, this assumption may be too strong and could lead to bias in the estimates from the pricing model. A natural step is to pose similar questions in a model within which the transaction costs of purchasing a vehicle, uncertainty about the future, or habit formation factor heavily into the purchase decisions.

Perhaps more important is the fact that we have assumed an exogenous relationship between manufacturers and dealers and concentrated on the strategic interactions between manufacturers. Sudhir (2001b) shows that such channel structures may be modeled in a variety of ways. Indeed, the appropriateness of competing assumptions on the strategic interactions between manufacturer and retailer is essentially an empirical question. A complete analysis of the European car market should include this Vertical Strategic Interaction (VSI) effect to study its impact on the model outcomes.

Finally, as with many studies throughout this literature, we have inferred competition based on vehicle list prices rather than on actual transaction prices. However, access to rebate or other forms of discounts for the European car market could facilitate a more detailed exploration into the competitive dynamics across the market. Considering that proprietary transaction price data is currently available for the U.S. car market through companies such as J.D. Power and Edmunds.com, it is only a matter of time before similar data is compiled for the European car market. With this data, it should be possible to gain more insight into the supply-side behavior of the manufacturers and retailers.

CHAPTER 4

Conflict and Cooperation in the U.S. Automobile Industry

4.1. Introduction

This chapter explores the competitive structure of the U.S. automobile industry by employing an empirical framework similar to that in chapter 3. Hence, this chapter is to be taken as a formal extension of the analysis presented previously. However, the current data set consists of actual dealer-level transaction prices rather than the manufacturer's suggested prices (MSRP) that has been widely used throughout the empirical literature. As is well known, whereas the MSRP is usually not the final price a consumer ends up paying for a car it is frequently the only pricing information available to empirical researchers who do not have access to data on rebates and other forms of incentives. As a direct result, MSRP data has been employed to evaluate market conduct in several studies of the U.S. auto industry including Boyle and Hogarty (1975), and Sudhir (2001a). MSRP data has also been used in the seminal piece by Berry, Levinsohn, and Pakes (1995), by Goldberg (1995), and Petrin (2002). But since consumers rarely end up paying the sticker price on a new car due to dealer add-ins and other forms of incentives, MSRP data may yield a misleading picture of the true nature of competition among firms in the industry and is in fact unsuitable for the purposes for which it is often intended.

This chapter therefore represents the first study of its kind to employ transaction price data comprising actual consumer end prices in a structural NEIO framework to evaluate market conduct in the U.S. automobile industry. This proprietary data is sourced from J.D. Power and Associates and is compiled on the basis of electronic point of sale reports from dealers who are subscribers to the company's Power Information Network (PIN). PIN collects the data in much the same way as how information is gathered from a supermarket bar-code system. They collect price and cost measures such as vehicle price, vehicle cost and customer cash rebates, profit measures such as vehicle profit margin and days to turn, financing/leasing and trade-in measures including APR/IRR and leasing residual, and customer demographics such as age and gender which are all reported for each vehicle transaction. The transaction price data is supplemented by information on vehicle characteristics from various issues of the Wards Automotive handbook, macroeconomic data including price indices, population, and gross domestic product are retrieved from the FRED database at the website of the Federal Reserve Bank of St. Louis, and historical data on retail fuel prices are obtained from the Department of Energy's website.

The empirical equilibrium model brought to the data comprises a demand equation which is grounded in the discrete choice framework and an oligopoly model with product differentiation which specifies the nature of firm interaction on the supply side. As in chapter 3, and following in the spirit of Goldberg (1995), and Brenkers and Verboven (2006), the data is first split into segments distinguished by standard marketing classifications: compacts/subcompacts (CS), mid-size (M), full-size (F), minivans/SUVs (MV), and pickups/vans (P). Thereafter, each segment is further divided into subsegments which represent the country of origin of the particular brand. It is important to note that U.S. owned foreign brands and transplants produced in the U.S. are collectively viewed as foreign vehicles for the purpose of the analysis. The classification is somewhat similar to that which prevails for the European car market and some of the best-selling models under each segment are displayed in Table 4.1.

Table 4.1. Models by Segment Classification

Segment	*Example*
Compacts/Subcompacts	Acura TSX, Audi A3, Chevy Aveo
Mid-Size	Chevy Malibu, Ford Fusion, Honda Accord
Full-Size	Ford Five Hundred, Toyota Avalon
Minivans/SUVs	Ford Expedition, Honda Odyssey
Pickups/Vans	Ford Ranger, GMC Savana

The main aims of this chapter are to first determine the degree of correlation in consumer preferences over the segments and subsegments of the U.S. automobile industry from the demand side, prior to estimating segment-specific conduct parameters which indicate the extent of deviation from the myopic Bertrand pricing rule on the supply side. The estimation results are subsequently compared to those obtained from previous studies and from the empirical model estimated in chapter 3. Thus, both chapters, 3 and 4, are intended to provide a complete explanation of the extent of price competition in the two largest automobile industries currently existing globally. However, whereas chapter 3 covers a much wider time span, i.e. $1970 - 1999$, the current chapter focuses on the more recent period between 3Q 2004 and 1Q 2007. The data therefore spans a much shorter period but at a higher frequency.

This time span is important since it captures events which transpired in the summer of 2005 when the Big Three automakers: General Motors Corp (GM), Ford, and Chrysler (formerly DaimlerChrysler AG), because of eroding market share, became embroiled in a decidedly aggressive campaign to boost sales and clear bloated inventories prior to rolling out the new 2006 model lines. Although rivals including Toyota closed out 2004 on a three-year high of 16.9 million vehicles sold, which represented an increase of 8% over the previous year, it was an especially challenging time for GM and Ford, respectively the nations number 1 and number 2 automakers. At the end of December 2004 GM was still left with over 1.2 million unsold vehicles or about 75 days' supply, prompting them to begin offering loyalty bonuses worth $1,500 each for current owners to buy new GM vehicles. Apparently, this measure was not entirely successful because GM still posted a 3% drop in December sales and an overall 1% decline in 2004 calendar year sales.[1] Ford's sales actually held firm in December but were 5% lower for the calender year 2004 whereas Chrysler, the nation's number 3 automaker escaped relatively unscathed as they posted a 9% increase in December 2004 sales and an overall 4% rise for all of 2004. GM was the first to implement measures to combat this mounting problem. In June 2005 they announced that employee discounts on selected 2005 model lines would be extended to the general public. Figures show that the promotion was effective and well received as GM's posted sales performance for that month was the best on record in over 19 years. After observing the success enjoyed by GM, the other members of the Big Three quickly followed suit. Ford's "Ford Family Plan" and Chrysler's "Employee Pricing Plus" were counter measures implemented in direct response to GM's original posturing in the market, each generating limited sales gains for both manufacturers.

Work by Slade (1989) suggests that this type of market instability precipitated by the shrinking market generates a rich framework that can be employed to yield invaluable information about the underlying market conduct. This view was also shared by Bresnahan (1987) as he sought to explicate the factors underlying the apparent price wars which occurred in the U.S. automobile industry in 1955. The current study therefore focuses on the period between 3Q 2004 and 1Q 2007 because of this reason.

4.2. The U.S. Auto Industry: Trends and Evidence

Consumer demographic reports on the target population within particular markets are extensively scrutinized by oligopoly firms who use them to decide on how to strategically position their product in the marketplace. The automobile market is no different. Moreover, because vehicle purchases usually consume a large fraction of a consumer's

[1]It should be mentioned that new model years are usually offered for sale toward the end of the third quarter of the previous year. A model year therefore differs from a calendar year. Model years run from the third quarter of the previous year to the end of the second quarter of the current calendar year.

budget,[2] the onus is on the manufacturer to show that their product meets all the requirements and needs of their targeted population. "Buyer priority" is therefore a key driver of automobile demand. Different groups of consumers have separate opinions on what feature of the automobile is important and these views must be accommodated by manufacturers who seek to differentiate their products along the lines of those attributes deemed important by the target population in each segment. For example, buyers of entry-level, subcompact vehicles, are apt to be more price sensitive and fuel-economy conscious than persons who purchase high-end, high-perfomance vehicles. The sensible marketing strategy would then be to stress attributes such as MPG and offer incentives to buyers of smaller, entry-level vehicles while highlighting other attributes such as handling, acceleration, and styling to more affluent buyers.

However, competition does not occur in a vacuum. Based on differing "buyer priorities" rival firms also wish to leverage customers to choose their own product. As discussed in detail below, a key implication from work by Boulding and Staelin (1993) is that external pressure as a result of mounting competition from rivals has tremendous impact on a particular firm's *ability* and *motivation* to pursue a long-run profitability view of the marketplace. Indeed, a firm has the *ability* to price cooperatively if there is little to no market share volatility along with minimal external pressure from rival firms. A firm also retains its *motivation* to price cooperatively if customers portray heavy brand loyalty and low price sensitivity. It is therefore critical that automobile manufacturers garner as much information as possible on the target population in each segment in order to formulate their respective marketing strategies.

4.2.1. Profiling the Average US Car Buyer

A 2002 consumer survey report by Simmons National Consumer Survey/Mintel revealed that over 90 percent of American households own some type of automobile, and greater than 70 percent own multiple vehicles. Furthermore, the car remains the vehicle of choice among American consumers despite the growing popularity of light trucks, SUVs and vans. Indeed, roughly 75 percent of households in America own a car and more than a 25 percent own multiple cars.[3] Nearly 34 percent of polled respondents to the survey were from households with annual income exceeding $75,000, greater than 75 percent chose cars with anti-lock brakes or air bags while over 90 percent bought cars that had

[2] According to a 1980 report prepared by the Committee on Technology and International Economic and Trade Issues, automobiles use approximately 42 percent of all the oil consumed in the US and account for over 15 percent of the average household budget. In addition, over 15 percent of the labor force is employed in the automobile industry.

[3] Spring 2002 Simmons National Consumer Survey/Mintel Reports.

air conditioning. Over 80 percent believed that the true value of a car is how long it "lasts" while close to 74 percent preferred their vehicle to be equipped with as many safety features as possible. In terms of attitudes towards foreign and domestic vehicles, a shade over 25 percent of buyers viewed foreign nameplates as superior in quality to domestic nameplates.

Demand for standard-type cars was also weakest among consumers between $70-74$ years, strongest for consumers over 55 years, singles, and couples without children whereas the key age group $35-54$ years, which is believed to account for over 44 percent of new car sales, has contributed to a softening demand for cars because of dwindling numbers over the past two decades.[4] The findings in the report suggest that high priority concerns such as safety, reliability, performance, and after-market sales and servicing were major factors motivating consumer purchase. Manufacturers responded by differentiating their product offerings along these lines. In fact, based on these issues three types of consumer profiles emerged: the family man/woman, whose chief concern was safety and comfort; the young couple without children who preferred small, entry level, performance vehicles; and the older, more affluent individual who preferred prestigious, high-comfort, high-style, high-performance vehicles. A separate report also indicated that 32 percent of pick-up owners fell in the age group $45-54$ years old, while SUVs and vans were favored by households with annual earnings of over $\$75,000$ and $\$50,000$ respectively. Households with five or more occupants including small children preferred the SUV to any other vehicle while minority groups and seniors preferred vans over SUVs.

As the above proves, the population of potential automobile buyers is increasingly diverse. Multiple messages must therefore be sent to appeal to customers who differ on the basis of age, race, gender, lifestyle practices, and income. In fact, generic mass marketing campaigns geared toward the average buyer are no longer relied upon to communicate with potential customers in the US automobile market. Marketers now routinely segment the population into submarkets and employ targeted advertising to appeal to customers in each submarket.

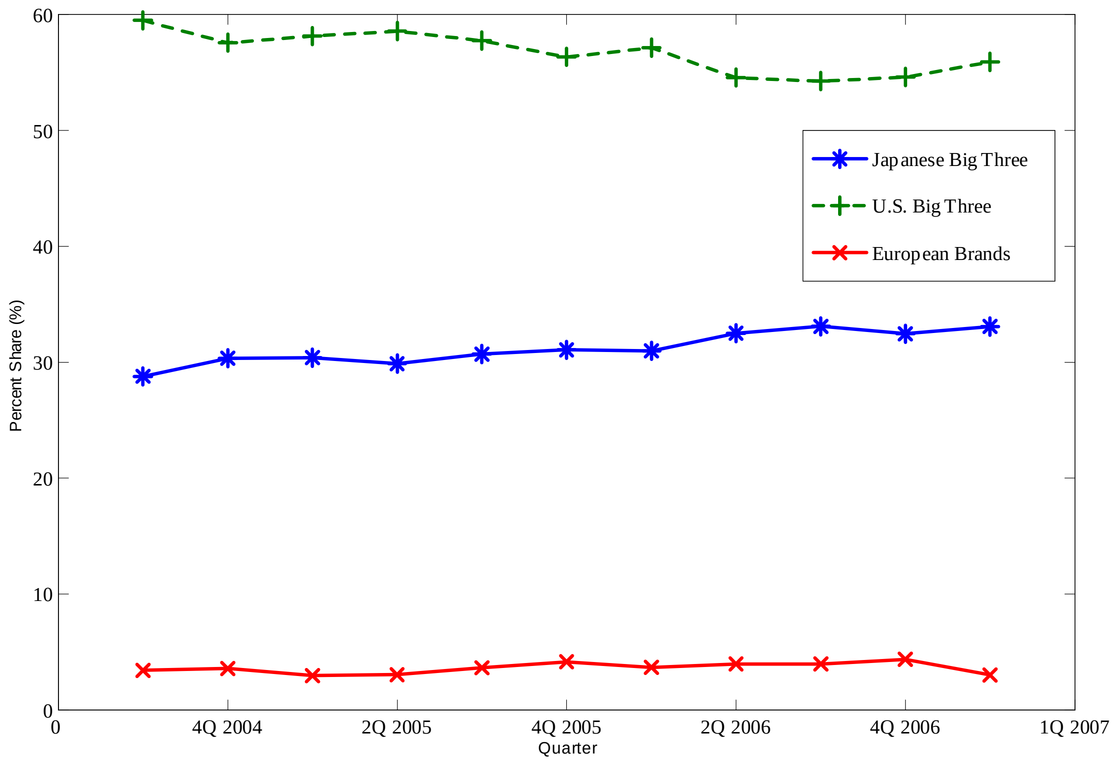
4.2.2. The U.S. Auto Industry: 2004-2007

The U.S. automobile industry has historically been relatively concentrated. In fact, the Big Three manufacturers at one time produced over 80% of all consumer vehicles, i.e. cars and light trucks, sold in the domestic U.S market. However, the industry has recently undergone a series of dramatic changes. The Big Three now produce less than 60% of all

[4]In the report, a standard car is defined as one with four wheels and which is intended for use on public thoroghfares. These cars have base MSRP ranging between $20,000 and $27,000.

consumer vehicles sold in the U.S. and their market share has been steadily declining (see Figure 4.1). Although they still maintain a dominant position in the light truck segment,

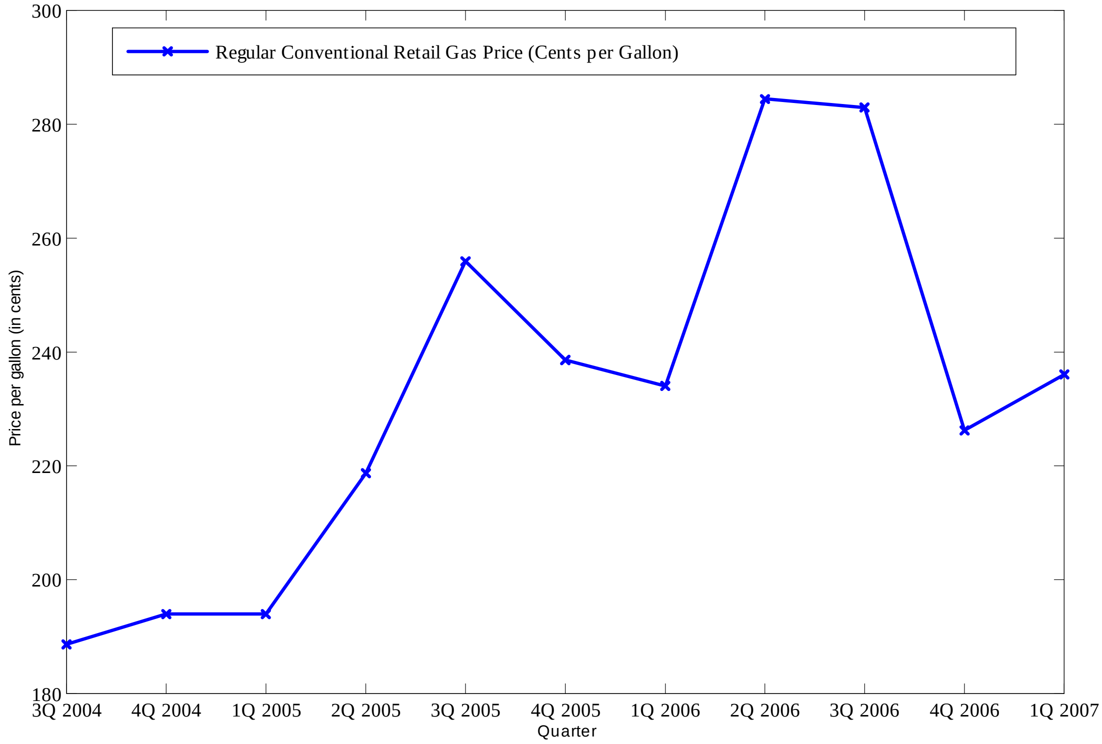
Figure 4.1. Import Penetration into the U.S. Domestic Market (percent share)



rising fuel costs, steadily growing demand for hybrid and alternative-fueled vehicles, and increased competition from transplants, especially from the Japanese Big Three comprising Toyota, Honda, and Nissan, have all contributed to softer demand for light trucks domestically.[5] Figure 4.2 tracks the average price per gallon of fuel between 3Q 2004 and 1Q 2007. Over the period, the average price per gallon of regular, conventional retail gasoline increased approximately 47 cents with the biggest jump occurring between 1Q 2006 and 2Q 2006. Between the first and second quarters of 2006, the average price per gallon of conventional retail fuel experienced an increase of more than 50 cents. This has proved particularly detrimental to GM as sales of light trucks and SUVs form the core of its business. Domestic manufacturers have responded by offering attractive (but profit-eroding) incentive-laden terms of sale including employee pricing discounts and other financing and leasing options to boost flagging sales. Indeed, in the summer of 2005, locked in a battle for market share and inventory-clearing sales, the Big Three embarked

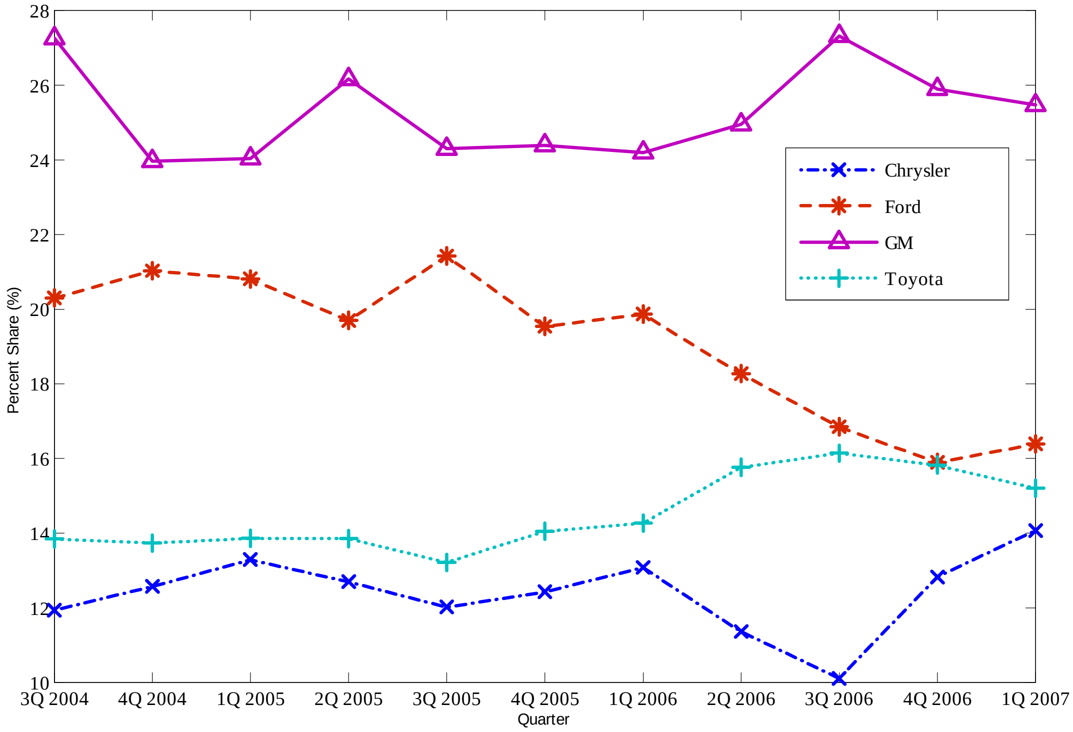
[5]See, for example, the discussion in Cooney and Yacobucci (2005).

Figure 4.2. U.S. Regular Conventional Retail Gasoline Prices 3Q 2004-1Q 2007 (Cents per Gallon)



on several large scale promotional campaigns to remedy anemic consumer demand and clear backlogged inventories. In June 2005 the world's largest automaker, GM announced that it would extend the discounts it offers to employees for car and light truck purchases to the general public for all 2005 models. Although the heavily promoted incentive package, known as the "Employee Discount for Everyone," was to expire in July 2005, GM extended it to August of the same year because of favorable responses from the buying public (Figure 4.3). The campaign actually contributed to an annualized increase of over 41 percent in GM's domestic sales for June 2005, their best sales month since September 1986. In particular, sales of SUVs and light trucks, GM's strength, rose by over 76 percent whereas full size pick-up sales doubled for the same period even against the backdrop of increased fuel prices. Additionally, tempted by the prospect of getting a great deal, owners of late-model Fords, Dodges and even overseas brands flocked to GM showroom in droves. Many of these buyers did not necessarily need new vehicles but the deal was viewed as a once-in-a-lifetime event that could not be ignored. GM's employee price at the time was between 3 – 4 percent lower than the dealer invoice price. To compensate the dealers, each was granted 5 percent of the sticker price which worked out to an average

Figure 4.3. U.S. Domestic Sales (percent share)

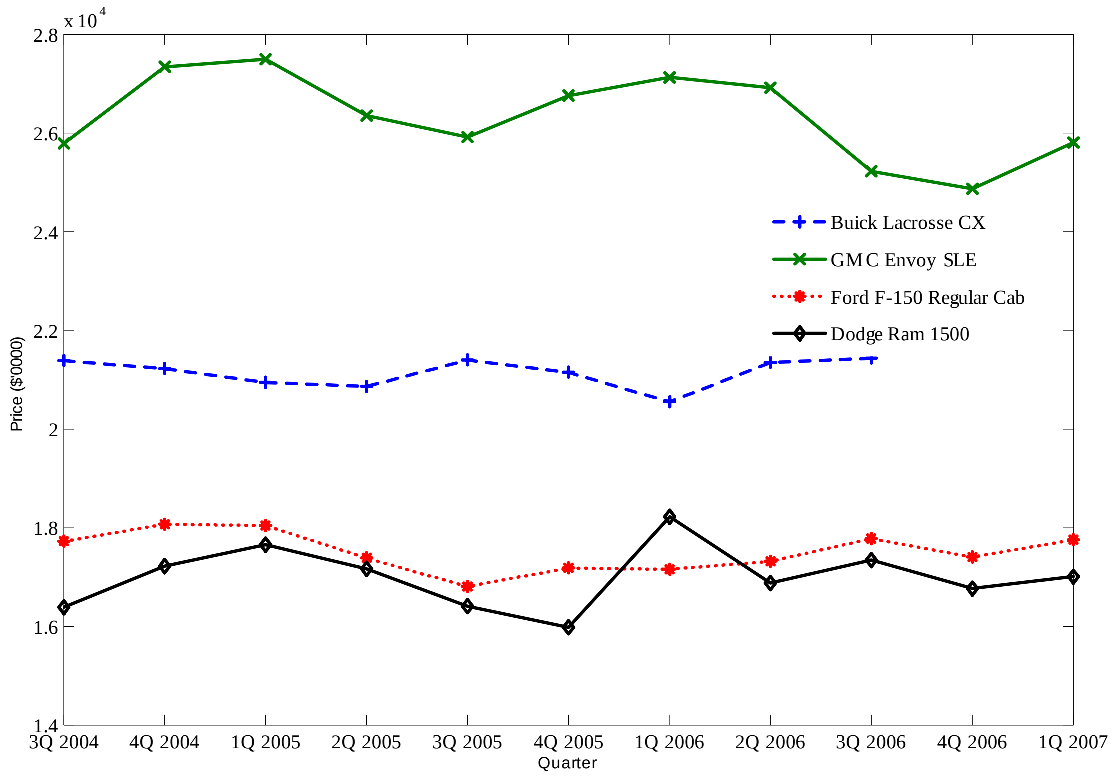


of about $1,500 per vehicle.[6] Some dealers used these manufacturer rebates to offer even further discounts to buyers, in some cases pushing the prices lower than GM's employee price. Under the campaign, popular GM nameplates such as the fully equipped Buick LaCrosse CX that would normally sell for around $23,500 was being sold for roughly $19,000 and a brand new GMC Envoy sold for around $6,000 less than usual (see Figure 4.4). Ford, the nation's number 2 automaker followed suit after initially adopting a wait-and-see approach. Ford's "Ford Family Plan" was similar to GM's promotion and lasted until August 2005. At Ford, the popular Ford Explorer XLT that usually sells for around $32,000 could be bought for around $24,500, while a fully-loaded Lincoln Navigator could be bought for about $42,000, down from its usual price of $51,145. Chrysler joined the bandwagon at around the same time as Ford after observing the successes GM was enjoying. Chrysler's "Employee Pricing Plus" program was intended to match the offerings by GM and blunt the aggressive media campaign stirred up by the latter.[7] But

[6] GM was estimated to spend over $1 billion on the campaign. To offset this cost, they cut incentives per vehicle and encouraged consumers to buy rather than lease. Figures show that GM's average incentive per vehicle for June 2005 was $3,714, marginally lower than the previous month's figure of $3,729.

[7] Lee Iacocca, the "emeriti CEO" for the company appeared in a series of ads during this time to tout the "hipness" of Chrysler brands. These ads featured Iacocca who appeared with a number of media celebrities including Snoop Dogg and Jason Alexander of Seinfeld and even his own grandaughter.

Figure 4.4. Price movements of some Best-selling Models



because of the heavy discounts on SUVs and light trucks being offered by Ford and GM, Chrysler's sales increased marginally by about 1.1% between May and June 2005 while there was an overall 1.5% decline in car sales.

4.3. Previous Literature

Previous studies have uncovered evidence to support the hypothesis of cooperative pricing among the larger players across the industry. Results from Boyle and Hogarty (1975) suggest the presence of cooperative pricing by price leadership on list prices among the Big Three between 1957 – 1971. They also point to the sub-period between 1958 – 1959 during which Chrysler appears to have been cheating, thus eliciting subsequent retaliatory responses from the other Big Three makers. Their argument was based on comparisons across time of hedonic pricing parameters whose estimates were obtained from regressions of list prices on quantifiable vehicle characteristics. If collusion was present for the industry during the period, implicit hedonic prices would not statistically differ by a wide margin and as such, the implied estimates of the hedonic pricing parameters would be reasonably homogenous. Their empirical results showed however, that Chrysler was the only company for which the assumption of homogeneity of the estimates was rejected. Chrysler's price-quality relationship was inconsistent with the assumption of implicit collusion for the years $1958 - 1959$ after they began offering discounts on fleet sales in 1958 following a period of relative calm in the industry. This prompted GM and Ford to eventually begin matching Chrysler's prices for fleet purchases after experiencing steep declines in sales for this market. Both companies also attempted to undercut Chrysler in the leasing and rental markets, areas in which the latter held considerable sway.

But the analysis raises several questions. First, as Boyle and Hogarty (1975) rightly pointed out, the introduction of the Automobile Information Disclosure Act in October 1958 was one event that precipitated a shift in the overall dynamics of price competition across the automobile industry. One therefore questions the role this legislation had in impacting their findings of cooperative pricing across the industry during the period. The Automobile Information Disclosure Act was a mandate requiring that new automobiles carry window stickers indicating important information including the manufacturers suggested price (MSRP), engine and transmission specifications, warranty details, fuel economy ratings under EPA guidelines, and optional equipment with pricing. Under full disclosure, the thinking was that the industry would approximate the idealistic perfectly competitive market on the basis of information sharing by consumers and manufacturers. With complete information, all rivals would be made aware of their competitor's prices in some way or the other. This supposedly would spur competition and handicap attempts at secrecy. However, the Act led to what has been called "price packing" by dealers whereby large amounts are added to the MSRP with the total posted as "sticker prices" so as to permit allowances for customer used car trade-ins. The Act made it more difficult to detect secret undercutting because information on the true MSRPs could hardly be determined. Paradoxically, full disclosure actually promoted cartelization and secrecy across the industry and led to further strengthening of existing cooperative agreements. To the extent that Boyle and Hogarty (1975) fail to adequately address whether or not this actually drove their main results, one remains skeptical about their findings. Another potentially debilitating factor undermining the results may be that the authors employ MSRP or list prices to infer competition rather than the actual transaction prices consumers end up paying. But because the Disclosure Act fostered the practice of price packing across the industry at the time, there is an obvious disconnect between both types of prices. Indeed, this may lead to biased results in favor of more stable pricing when in fact there is none.

Sudhir (2001a) has also analyzed market conduct in the U.S. automobile industry from an empirical perspective. His empirical results implied that competition in the industry varies roughly by marketing segment. He showed evidence of more competitive or aggressive pricing behavior in the markets for smaller, entry-level vehicles than in markets for larger full-sized lines, a pattern he attributed to several factors including consumer demographics of the target population and the long run competitive stance of the manufacturers that are heavily represented in the respective marketing segments. Sudhir's (2001a) approach is appealing because it seeks to determine the origins of price competition at a disaggregated, more finer level rather than has been previously studied. Besides, his empirical framework is theory-driven insofar as he utilizes a structural new empirical industrial organization (NEIO) framework to combine predictions from the theory of repeated games with the *ability-motivation* paradigm of Boulding and Staelin (1993). Boulding and Staelin (1993) assert that in games of repeated interaction, firms have the *ability* to price cooperatively under the right circumstances. If the market is relatively stable and highly concentrated, this type of behavior is sustainable. Absent these conditions, the firm will find it exceedingly difficult to take a long-run profitability view of the market. A firm will also possess the *motivation* to price cooperatively if the target population portrays sufficient consumer loyalty over the long-run. Indeed, in these types of markets, firms initially compete aggressively to court new customers in order to reap the future benefits of a stable customer base. If there is a great deal of consumer loyalty, customers are less price sensitive which means that manufacturers are then able to price more cooperatively in the long run. He showed that segments with low firm concentration and higher market share volatility which are dominated by younger, less loyal customers, featured a high degree of competition on comparison to those segments dominated by older, more affluent and loyal customers. Coincidentally, younger, first-time buyers were more likely to purchase smaller, entry level vehicles, segments in which Japanese and European transplants have traditionally been well represented whereas older, repeat customers preferred larger, full-size nameplates, segments dominated by domestic incumbent manufacturers. By the *ability-motivation* paradigm therefore, firms should price aggressively in the markets for smaller, entry-level vehicles and more cooperatively in the markets for larger, mid to full-sized lines. In fact, this pricing pattern was precisely what Sudhir (2001a) uncovered for the U.S. market between $1981 - 1990$. However, the fact that the study also employs MSRP data to infer competition potentially weakens several of his main conclusions.

This chapter therefore proposes and estimates a multi-product oligopoly model similar to Sudhir (2001a) in an effort to study the competitive structure of the U.S. automobile industry. The model closely resembles that in chapter 3 except that the data used in estimating the equilibrium model consists of actual dealer-level transaction prices of virtually all types of cars and light trucks currently offered for sale in the domestic U.S. market. The data coverage extends between 3Q 2004 to 1Q 2007 but covers a much wider range of vehicles than Sudhir (2001a) who only analyzed the car market.

4.4. Data

The data used in the analysis covers the period 3Q 2004 to 1Q 2007 and comprises actual dealer-level transaction prices exclusive of rebates and other forms of incentives offered to buyers at the time of sale. These transaction prices are determined by averaging the end prices consumers pay for specific trims under a given nameplate over the number of trims sold for a particular month. The data is compiled from daily electronic point of sale reports from dealers who are subscribers to J.D. Power's Power Information Network (PIN).[8] These dealers are based in over 30 U.S. markets including Atlanta, Baltimore/Washington D.C., Boston, north and south California, Chicago, the Dallas/Ft. Worth area, Detroit, Houston, Miami, New York, Seattle, and St. Louis with further expansions planned for Kansas City, Milwaukee, Nevada, San Antonio, and some of the larger cities in Canada.

PIN only releases data and provides reports to those dealers within its network and guarantees data confidentiality by allowing dealers to view their own data but not anyone else's. All a dealer is able to view is an overall market aggregate besides the data for his/her own dealership. Additionally, so as to preserve anonymity, PIN only releases data for markets with three or more participating dealers. The price data is augmented by monthly sales (number of units) and data on the characteristic features of the base trim models which are obtained from various issues of the Wards automotive handbook. Also included are macroeconomic variables such as CPI, GDP, and population retrieved from the St. Louis Fed's FRED database, variables indicating whether or not the particular vehicle is a domestic or foreign brand or a car or light truck, and historical data on retail fuel prices obtained from the website of the Department of Energy.

There are two measures of fuel efficiency. One is the standard miles per gallon (MPG) which is calculated in line with the EPA formulation: $\text{MPG} = \frac{1}{0.55/\text{City MPG} + 0.45/\text{Highway MPG}}$ whereas the other is miles per dollar spent on fuel (MP$). This is found from dividing MPG by the price per gallon of retail fuel with the price normalized by CPI. The variable "size" represents the vehicle footprint and is the product of the length and width of

[8] I am grateful to Tom Libby and Christopher Li at J.D. Power and Associates for their expertise and assistance in sourcing, compiling, and interpreting the data.

the vehicle. A car dummy (car = 1 if the vehicle is a car) indicates whether or not the vehicle sold is a car or light truck while a foreign brand dummy (foreign = 1 if the model is a foreign brand) indicates its origin. There are over $1,700$ observations on approximately 240 of the best-selling cars and light trucks sold in the domestic U.S. market by about 16 manufacturers including the Big Three of GM, Ford, and Chrysler, the Japanese Big Three of Toyota, Nissan, and Honda, and popular European manufacturers such as BMW, Mercedes, Volvo, and VW. Here, in contrast to the data in chapter 3 which is a three-dimensional panel, the current data set is a conventional two-dimensional panel across calender quarters: $t = 1, ..., T$ (3Q $2004, ..., 1$Q 2007) and models $j = 1, ..., J_t$ for each market t. In the analysis, a year-quarter pair is viewed as a market for estimation purposes which means that there are a total of 11 such markets.

Table 4.2 displays a summary of the data which shows that sales in the light truck segments represented over 50% of monthly sales during the period. As expected, light trucks are bigger, relatively more expensive, provide more standard horsepower (HP), and yield less miles per dollar spent on a gallon of fuel.

Table 4.2. Average Segment Characteristics 3Q 2004 - 1Q 2007

	U.S. Sales (Units)	Size ('00 $inch^2$)	MP$	HP	Price ('000 $)
Compacts/Subcompacts	$1,325$	119.083	23.804	152.315	190.41
Mid-Size	$2,219$	134.349	21.295	187.870	224.73
Full-Size	$1,431$	148.586	19.584	206.723	220.39
Minivans/SUVs	$1,621$	140.482	17.524	214.273	238.28
Pickups/Vans	$3,622$	153.221	16.930	217.320	205.25

Source: Wards Automotive Handbook (various years)

Table 4.3 further depicts the average number of units sold per firm per quarter. As is evident, the Big Three automakers dominate the markets for minivans/SUVs and pickups whereas the Japanese Big Three: Toyota, Nissan, and Honda, are well represented in the smaller, entry-level car markets.

Table 4.3. Firm Distribution in the U.S. Automobile Industry 3Q 2004- 1Q 2007 (number of units)

	GM	Ford	Chrysler	Japanese Big Three	European Brands
Compacts/Subcompacts	1,465	1,714	2,214	5,468	3,677
Mid-Size	2,196	1,247	1,681	13,123	1,721
Full-Size	987	1,695	2,003	–	–
Minivans/SUVs	1,390	1,397	2,382	6,740	428
Pickups/Vans	3,235	7,417	8,793	6,181	–

Source: Wards Automotive Handbook (various years)

4.5. Empirical Model

The demand equation

$$\ln\left(s_{jt}/s_{0t}\right) = \mathbf{X}_{jt}^{'}\beta - \alpha^{*}p_{jt} + \sigma_{hg}\ln\left(\overline{s}_{j/hgt}\right) + \sigma_{g}\ln\left(\overline{s}_{h/gt}\right) + \xi_{jt}, \tag{4.1}$$

is consistent with Brenkers and Verboven (2006) with $\alpha^{*} = \alpha/y_t$, where y is per capita household income in market t, and $\delta_j = \mathbf{X}_{jt}^{'}\beta - \alpha^{*}p_{jt} + \xi_{jt}$ denotes the mean utility level which is common to all consumers in market t. The price equation will be derived from the first order conditions of the profit function which is specified as:

$$\Pi_{ft} = \sum_{j\in J_{ft\cap V_{hg}}} \left(p_{jt} - c_{jt}\right) s_{jt}\left(p\right) L_t + \sum_{j\notin J_{ft\cap V_{hg}}} \phi_{g(j)} \left(p_{jt} - c_{jt}\right) s_{jt}\left(p\right) L_t, \tag{4.2}$$

for firm $f = 1, ..., \mathcal{F}$ in market $t = 1, ..., T$. The matrix $\mathbf{X}_{jt}$ includes product characteristics of the base trim models, p_{jt} is the transaction price for model j in market t, s_{0t} is the share of the outside alternative in market t, so called because it denotes the share of all other alternatives to the inside goods available for consumption in the model, s_{jt} is the share of model j in market t, $\overline{s}_{j/hgt}$ is model j's predicted share in subsegment h (foreign or domestic brand) of marketing segment g (compacts/subcompact, mid-size, etc) in market t, $\overline{s}_{h/gt}$ is the predicted share of the country of origin subsegment h in marketing segment g of market t, L_t is the potential market size (the number of households), and ξ_{jt} captures unobserved vehicle quality i.e. product features unobserved to the empirical researcher.

The specification of the supply side is similar to Sudhir (2001a) with c_{jt} being the constant marginal cost associated with model j from market t, $J_{ft} \subset J$ the subset of models sold by firm f in market t, and V_{hg} the set of models from subsegment h of segment g. It is important to note that the parameter $\phi_{g(j)}$ measures the amount of deviation from Bertrand pricing by firm f in segment g of market t. This parameter therefore represents the weight a firm places on the profits of its rivals in segment g. When $\phi_{g(j)} > 0$ firm f places a positive weighting on rival profits which implies more cooperative behavior relative to Bertrand in segment g. When $\phi_{g(j)} < 0$ however, this implies that firm f, in maximizing Eq. (4.2), places a negative weighting on rival profits across the segment leading to more competitive behavior relative to the myopic Bertrand pricing rule. Under Bertrand pricing, firm f maximizes Eq. (4.2) while ignoring rival profits and thus $\phi_{g(j)} = 0$. This method of analyzing competition dates back to Cyert and Degroot (1973). Note that as long as $\phi_{g(j)} > 0$ firm f maximizes a linear combination of its own profits and partial profits of rival firms within the same segment. When $\phi_{g(j)} = 1$ however, this implies outright collusion, i.e. joint-profit maximization and firm f maximizes the overall sum of own firm profits and those of rival firms. Thus, Cyert and Degroot termed the ϕ's *coefficients of cooperation.*

The demand equation is derived from the multi-level nested logit probability of choosing model $j = 1, ..., J_t$:

$$s_{jt}(\delta,\sigma) = \overline{s}_{j/hgt}(\delta,\sigma)\cdot\overline{s}_{h/gt}(\delta,\sigma)\cdot\overline{s}_{gt}(\delta,\sigma) \tag{4.3}$$

with:

$$\begin{aligned}
\overline{s}_{j/hgt} &= \frac{\exp\left(\delta_{jt}/(1-\sigma_{hgt})\right)}{D_{hgt}}, \\
\overline{s}_{h/gt} &= \frac{D_{hgm}^{(1-\sigma_{hgt})/(1-\sigma_{gt})}}{\sum\limits_{h\in H_{gt}} D_{hgt}^{(1-\sigma_{hgt})/(1-\sigma_{gt})}}, \\
\overline{s}_{gt} &= \frac{\left(\sum\limits_{h\in H_{gt}} D_{hgt}^{(1-\sigma_{hgt})/(1-\sigma_{gt})}\right)^{1-\sigma_{gt}}}{\sum\limits_{g\in G}\left(\sum\limits_{h\in H_{gt}} D_{hgt}^{(1-\sigma_{hgt})/(1-\sigma_{gt})}\right)^{1-\sigma_{gt}}},
\end{aligned} \tag{4.4}$$

where $D_{hgt} = \sum\limits_{j\in J_{gt}} \exp\left(\delta_{jt}/(1-\sigma_{hgt})\right)$, $1-\sigma_{hg}$ and $1-\sigma_g$ are inclusive or "log-sum" coefficients which are restricted to lie within the unit interval, $\overline{s}_{gt}$ is the predicted share of marketing segment g in market t, and $\overline{s}_{j/hgt}$ and $\overline{s}_{h/gt}$ as defined previously.[9] The log-sum coefficients are frequently referred to in the literature as "dissimilarity parameters" as they characterize the degree of substitutability among alternatives within a nest. The

[9]Lemma 10 in the appendix shows how the demand equation is obtained from the nested logit specification 4.3.

principles of random utility maximization requires that these parameters lie within the unit interval.[10] Moreover, so as to ensure that the variance components for the alternatives are strictly positive, log-sum coefficients associated with nests higher up in the nesting structure are constrained to be greater than corresponding coefficients associated with nests lower down in the hierarchy. The assumption $0 < 1-\sigma_{hg} < 1-\sigma_g < 1$ further implies that $0 < \sigma_g < \sigma_{hg} < 1$. As a result, both parameters, σ_{hg} and σ_g have their own structural interpretation. These indicate, respectively, the degree of correlation in consumer preferences across the country of origin subsegments and the marketing classification segments. In the typical case where $0 < \sigma_g < \sigma_{hg} < 1$, preferences are more correlated across models belonging to the same country of origin subsegment than across models from a different subsegment within the same marketing segment. In addition, preferences are also more correlated across models belonging to the same marketing segment than across models from other segments. This means that models belonging to the same subsegment are perceived as closer substitutes than models from other subsegments within the same or another segment. Furthermore, as either σ increases (decreases), correlation of consumer preferences across models in the corresponding segment or subsegment increases (decreases) and these alternatives become more (less) substitutable. Finally, as $\sigma_{hg} \to 1$, preferences across models belonging to the same subsegment become *perfectly correlated* and these products are perceived as *perfect substitutes*. When all $\sigma_{hg} \to \sigma_g$, preferences are equally correlated for all models within a cluster and the nested logit probability of choosing model j, s_{jt}, becomes a single-level nested logit model in which the marketing classification segments now represent the nests. If all $\sigma_g \to 0$ however, preferences over models belonging to the same segment become *uncorrelated* and the model is reduced to a single-level nested logit where the country of origin subsegments now constitute the nests. Finally, when σ_{hg}, $\sigma_{gm} \to 0$, preferences for all products are uncorrelated and Eq. (4.3) is reduced to a multinomial logit (MNL) model. Whereas the flexible multi-level nested logit framework (4.3) is less sophisticated than the random coefficients logit methodology highlighted in Berry, Levinsohn, and Pakes (1995), Nevo (2001), and Sudhir (2001a), it is computationally less burdensome and still generates plausible substitution patterns by mitigating the undesirable effects of the IIA problem.

Under the maintained assumption that manufacturers maximize (4.2) taking the product mix as given we obtain:

$$(4.5) \qquad \frac{\partial \Pi_f}{\partial p_{rt}} = \sum_{j \in J_{f \cap V_{hg}}} (p_{jt} - c_{jt}) \frac{\partial s_{jt}(p)}{\partial p_{rt}} + \sum_{j \notin J_{ft \cap V_{hg}}} \phi_{g(j)} (p_{jt} - c_{jt}) \frac{\partial s_{jt}(p)}{\partial p_{rt}} + s_{rt} = 0,$$

[10]An excellent discussion on the formulation of the multinomial and nested logit models is provided in Koppelman and Bhat (2006).

which is presented in vector form as

$$\mathbf{p}-\mathbf{c}=\underbrace{\left[-\nabla_{p}\mathbf{s}\left(p\right)\odot\left(\mathbf{\Theta}_{j,j'}^{own}+\sum_{g}\mathbf{\Phi}_{g}^{comp}\right)\right]^{-1}}_{\Delta}\mathbf{s}\left(p\right) \tag{4.6}$$

where $\Delta^{-1}\mathbf{s}(p)$ is the profit margin, $\nabla_p\mathbf{s}(p)$ is the $J\times J$ Jacobian matrix of first derivatives $\frac{\partial s_{jt}}{\partial p_{rt}}$, and where $\odot$ denotes the Hadamard (element-wise) product. The matrix $\mathbf{\Theta}^{own}$ is the "ownership" matrix defined as

$$\mathbf{\Theta}^{own}=\begin{cases}1 & \text{if } j \text{ and } j' \text{ belong to the same firm}\\ 0 & \text{otherwise}\end{cases}$$

and $\mathbf{\Phi}^{comp}$ is the competition matrix with definition

$$\mathbf{\Phi}_{g}^{comp}=\begin{cases}\phi_{g(j)} & \begin{array}{l}\text{if } j \text{ and } j' \text{ belong to the same segment}\\ g \text{ and are produced by different firms}\end{array}\\ 0 & \text{otherwise}\end{cases} \tag{4.7}$$

Following the literature the model is closed by assuming that marginal costs c_{jt}, evolve according to the log-linear specification

$$\ln\left(c_{jt}\right)=W_{jt}'\gamma+e_{jt}, \tag{4.8}$$

where W_{jt} and e_{jt} are, respectively, observed and unobserved cost shifters, and γ is a vector of parameters to be estimated. Making the substitution for c_{jt} in (4.6) leads to the price equation:

$$\mathbf{p}=\exp\left\{\mathbf{W}'\boldsymbol{\gamma}+\mathbf{e}\right\}+\Delta^{-1}\mathbf{s}\left(p\right), \tag{4.9}$$

which is transformed so that the error term, $\mathbf{e}$, enters linearly:

$$\mathbf{e}=-\mathbf{W}'\boldsymbol{\gamma}+\ln\left\{\mathbf{p}-\Delta^{-1}\mathbf{s}\left(p\right)\right\}. \tag{4.10}$$

The equilibrium model comprising Eqns (4.1) and (4.9) is subsequently brought to the data for empirical validation. The estimation strategy employed to generate the estimates from both equations is discussed in the next section.

4.6. Estimation Strategy

The estimation strategy builds on the recommendations in Berry (1994), and Berry, Levinsohn, and Pakes (1995). The demand and price equation are estimated separately although for efficiency reasons, they should be estimated together. But since the estimation proceeds recursively by feeding the implied substitution patterns from the demand equation into the price equation, misspecification in the former can be disastrous. In this chapter therefore, I pursue the alternative method which is to estimate both equations separately and account for the efficiency loss in the estimates.

Instrumental variable (IV) techniques are employed to estimate the model. On the demand side, IV methods are warranted since prices p_{jt} become endogenous to the system (4.3) due to its correlation with unobserved vehicle quality ξ_{jt}. Unobserved quality may include the stigma attached to owning foreign vehicles or large gas guzzlers, or even the prestige of owning certain automobiles. It is also well documented that many U.S. consumers prefer bigger SUVs and pickups to smaller, entry-level vehicles because of the alleged reputation of bigger vehicles to better protect occupants in the event of an accident. These subjective evaluations are not explicitly observed by the empirical researcher and thus they form part of the unobserved quality characteristics of a vehicle. To the extent that these features are correlated with prices, ignoring their association can potentially generate biased estimates of the demand parameters, and by extension, implausible substitution patterns.

In estimating the demand model the maintained identification assumption is that $E[\xi|\mathbf{X}] = 0$, meaning that unobserved vehicle quality is mean independent conditional on the observed vehicle attributes. Additional moment conditions are however required in order to generate estimates of β plus the segment and subsegment parameters σ_g and σ_{hg}. To achieve this objective use is made of the fact that oligopoly firms are mutually interdependent. This idea of "oligopolistic interdependence" is used in Berry, Levinsohn, and Pakes (1995), Nevo (2001), and Brenkers and Verboven (2006) to generate valid instruments which will become necessary in order to obtain additional moment conditions. All three studies use basis functions of the continuous product characteristics to generate these "oligopolistic interdependence" instruments. Following Brenkers and Verboven (2006) the instruments include the number of products and the sums of characteristics of other products of the same firm from the same subsegment, the number of products and the sums of characteristics of competing products from the same subsegment, and the number of products along with the sums of characteristics of competing products from the same segment. Thus, explicit use is made of the structure of the multi-level nested logit model. The panel structure of the data is also exploited in the estimation of the demand model. The error term ξ_{jt} from Eq. (4.1) representing unobserved vehicle quality is specified as a two-way error components model: $\xi_{jt} \equiv \xi_j + \xi_t + u_{jt}$ where ξ_j controls for unobserved model-specific fixed effects that are invariant over time whereas ξ_t are market-specific fixed effects that capture preferences for cars relative to the outside alternative of not buying a new vehicle. The over 240 fixed effects are controlled for using a within transformation while the market-specific fixed effects are represented by 11 dummy variables. The term u_{jt} controls for other unobserved product attributes varying across markets and is assumed to be uncorrelated across both consumers and alternatives.

The price equation (4.9) is estimated using a non-linear GMM framework. Denoting the matrix of instruments $\mathbf{Z}$, where $\theta = \{\gamma, \phi_{CS}, \phi_M, \phi_F, \phi_{MV}, \phi_P\}$ are the parameters to be estimated from the price equation, the GMM estimator $\widehat{\theta}$ minimizes the objective function:

$$J = E\left[Z'\mathbf{e}(\theta)\right]' \Phi E\left[Z'\mathbf{e}(\theta)\right], \tag{4.11}$$

with moment expression $M(\theta) = Z'\mathbf{e}(\theta)$, Φ defined as a weight matrix, and $\mathbf{e}(\theta)$ the supply side error at different values of θ. Note that the supply side error from the price equation $\mathbf{e}(\theta)$ is interacted to yield the aforementioned moment conditions. The key identification assumption for the price equation is therefore $E[\mathbf{e}(\theta)|\mathbf{Z}] = 0$ at the true value of θ. Following Hamilton (1994) $\widehat{\theta}$ along with its asymptotic variance is estimated using a two step procedure where the first step yields consistent, but not necessarily efficient, estimates of θ and the optimal weight matrix $\Phi = \Omega^{-1}$. Letting $G = E[\nabla_\theta M(\theta)]$ and $\Omega = \left[M(\theta) M(\theta)'\right]$ the asymptotic variance of $\sqrt{n}\left(\widehat{\theta} - \theta\right)$ is simply defined as $\left(G'WG\right)^{-1} G'W\Omega WG \left(G'WG\right)^{-1}$. The Nelder-Meade nonderivative simplex routine is then used to minimize the objective function J with respect to the θ's.

4.7. Empirical Results

This section contains the empirical results from the estimation of the equilibrium model comprising Eqns (4.1) and (4.9) includes a comparative analysis of the results with those obtained in chapter 3. Product characteristics used in the estimation of the demand model include height, the car and foreign brand dummies, miles per dollar (MP$), 240 product-specific fixed effects, and 11 market-specific fixed effects. The product-specific fixed effects are controlled for by a within transformation of the model while 11 dummy variables control for the market-specific effects. Expensive, exotic models are not included in the analysis because they have thin markets. Height is included to capture preferences for vehicles with higher front ends. Li (2006) cites evidence showing that SUVs and pickups with higher front ends inflict disproportionate damage to cars in collisions. This has led to an "Arms Race" on American roads whereby the demand for bigger vehicles is driven by consumers' desire to protect themselves in the event of an accident. The variable MP$ captures fuel economy, the car dummy is intended to account for consumer preferences for cars over light trucks or vice versa, and the foreign brand is included to capture systematic differences in preferences for foreign over domestic brands. All variables used in the estimation of the demand model are employed in estimating the price equation except MP\$. The variable MPG replaces MP\$ in the price model because cost per dollar of fuel is more relevant for consumer decision making. The estimates from the equilibrium model along with their standard errors and t-statistics are given in Table 4.4.

4.7.1. Parameter Estimates from the Equilibrium Model

The estimates from the demand model are consistent with *a priori* expectations. The results in Table 4.4 show that between 3Q 2004 – 1Q 2007, the variables height and MP\$ both positively impact consumers' mean valuation for vehicles. Both variables are positive and significant indicating that consumers prefer high vehicles with their higher front ends in addition to vehicles with more MP\$. The car and foreign brand dummies are also both negative and significant which means that consumers during the period preferred light trucks/SUVs to cars (since car = 1) and also preferred domestic to foreign brands (since foreign =1).[11] This conflicts with the widely held notion that consumers prefer foreign brands because of their superiority in quality. But the result is not far-fetched even when considering that fuel economy seems to be an important factor motivating model choice because of the incentive-laden terms of sale that were in effect for light truck purchases during the period.

Estimates of σ_g and σ_{hg} are also positive and significant and satisfy the assumption $0 < \sigma_g < \sigma_{hg} < 1$.[12] These estimates imply that the equilibrium model is consistent with the principles of random utility maximization. They also indicate that vehicles belonging to the same subsegment are viewed as better substitutes than vehicles from the other subsegment of the same marketing segment. Therefore, broadly speaking, consumers would easily trade a mid-sized domestically produced vehicle for another rather than substituting toward a mid-sized foreign-made brand. The results further reveal that vehicles from a particular segment are viewed as better substitutes than vehicles from other segments regardless of the subsegment under which it is classified. This means, for example, that car owners are less likely to substitute toward light trucks and vice versa. In general however, owners of vehicles under particular marketing segments, regardless of subsegment, are more likely to purchase another vehicle from the same segment than switch to a vehicle from another marketing segment. The estimate on price

[11] It is important to note that U.S.-owned foreign brands are still treated as foreign in the model.

[12] Although the nested logit is flexible to the extent that it yields 15 correlation parameters (5 σ_g's and 10 σ_{hg}'s) I estimate the more restricted version in order to leave enough degrees of freedom to retrieve the conduct parameters from the supply side.

Table 4.4. Demand and Price Equation Estimates with Conduct Parameters

	Estimate	*s.e.*	*t-stat*
DEMAND:			
Car	−0.291	0.052	−5.536
Foreign Brand	−0.077	0.024	−3.144
Miles per $	1.238	0.100	12.290
Height	1.275	0.239	5.334
price ($-\alpha$)	2.509	0.458	5.478
Constant	−17.387	5.438	−3.19
Subgroup segmentation parameter (σ_{hg})			
$\ln\left(\overline{s}_{j/hg}\right)$	0.792	0.1488	5.32
Group segmentation parameter (σ_g)			
$\ln\left(\overline{s}_{h/g}\right)$	0.542	0.281	1.93
COSTS:			
Car	−1.507	0.715	−2.10
Foreign Brand	−0.227	0.051	−4.45
Miles per Gallon	−0.372	0.215	−1.73
Height	0.02	0.015	1.33
Constant	1.981	0.12	16.50
Conduct Parameters			
Compacts/Subcompacts (ϕ_{CS})	−2.87	2.01	−1.42
Mid-Size (ϕ_M)	−0.627	1.521	0.412
Full-Size (ϕ_F)	0.931	0.504	1.84
Minivans/SUVs (ϕ_{MV})	−0.353	0.095	−3.715
Pickups/Vans (ϕ_P)	−0.449	0.201	−2.23

Notes: The number of observations is 1,716. Fixed effects ξ_j and ξ_t included.

in the demand equation is also in line with expectations and is close to the 2.281 estimate for the European car market by Brenkers and Verboven (2006) but higher that the 1.37 estimate obtained in chapter 3. Note that the coefficient on price is used to derive the substitution patterns according to the formula for the elasticities in the appendix. The substitution patterns are then fed into the price equation to derive the mark-up term and to generate estimates on the observed cost shifters.

Estimates from the price equation are also displayed in Table 4.4. These estimates imply that vehicles with higher front ends, domestic vehicles, and SUVs all positively impact firm costs whereas vehicles with higher MPG cost less to produce. This relationship between the MPG and firm costs has also been documented in Sudhir (2001a). He argues that MPG is correlated with curb weight and the number of cylinders insofar as heavier vehicles with more cylinders output less MPG and are usually more costly to produce.

But it is the conduct parameters (the ϕ_g's) that are of greater interest. From the lower half of Table 4.4 all conduct parameters are negative except the one associated with the full-size segment. Of these however, the ϕ_g's associated with the light truck segments: minivans/SUVs and pickup/vans, are the only ones which are significant at conventional levels. Firm rivalry in these two segments is therefore highly competitive in comparison with the myopic Bertrand pricing rule. The finding of intense competition in the light truck segments is hardly surprising when one considers the information in Table 3.2 and the events which transpired during the summer of 2005. As Table 3.2 shows, although the Big Three are well represented in these segments, mounting competition from Japanese and European brands doubled with the Big Three's aggressive push toward bolstering demand has contributed to the overall finding of heightened price competition across these segments. The conduct parameters associated with the smaller, entry-level compact/subcompact and mid-size segments are also negative but remain insignificant. This implies that firms ignore their mutual interdependence while setting prices in these segments. As a result, there is not much deviation from standard Bertrand pricing. The results further indicate the presence of much softer competition in the market for full-sized vehicles. Indeed, this appears plausible since the target population in these segments is usually older, more affluent, wealthy individuals who are less price sensitive. Besides, domestic incumbent firms face less competition from foreign brands in this segment than any other.

4.7.2. Implied Substitution Patterns

Results from the demand model are used to generate substitution patterns that are fed into the pricing model. Table 4.5 depicts the median elasticities for 2005.

From the table it seems that the own price elasticity is larger for full-size lines than for the smaller, entry-level subcompacts and mid-size vehicles. A moment's thought would lead one to question these findings, and rightly so. This is because one expects consumers in the larger car segments who are usually older, repeat buyers, to be less price sensitive

Table 4.5. Substitution Patterns in 2005 (median elasticities)

		Cross Elasticities with respect to vehicle from:		
CARS	Own elasticity	Same Subsegment	Same Segment	Different Segment
Compacts/Subcompacts	6.150	0.0731	0.0010	0.0002
Mid-Size	8.066	0.2665	0.0049	0.0007
Full-Size	8.874	0.0408	0.0114	0.0004
LIGHT TRUCKS	Own elasticity	Same Subsegment	Same Segment	Different Segment
Minivans/SUVs	9.7402	0.2152	0.0028	0.0006
Pickups/Vans	7.4483	0.1965	0.0052	0.0006

than consumers who would more likely purchase a small subcompact car. Indeed, this is often the case. But the structure of the nested logit model is responsible for the pattern displayed in the table. Brenkers and Verboven (2006) encountered a similar issue in their study but found that the pattern was reversed when they introduced consumer heterogeneity in the model through the price parameter on the demand side. The cross elasticities do confirm however that consumers are less sensitive to changes in the price of vehicles belonging to different segments and subsegments and is in line with the results from the demand model.

4.8. Conclusions

The empirical model estimated in this chapter comprised a discrete choice model of demand and a multi-product oligopoly model with product differentiation. The main aim was to show that market segmentation strategies were fundamental factors underlying firm rivalry. The model was estimated using actual transaction price data on over 240 of the best-selling models of cars and light trucks in the domestic US market between 3Q 2004 and 1Q 2007.

Empirical results from the model imply that firm conduct indeed varies by marketing segment depending on the intensity of within-segment competition from rival firms, an outcome which was also evident for the model estimated in chapter 3. In particular, the model reveals that there is more competition relative to Bertrand pricing in the light truck segments based on the values of the corresponding conduct parameters which are negative and statistically significant. There was also evidence of much softer competition in the full-size segment and Bertrand competition in the entry-level compact/subcompact and mid-size segments. This means that during the period, manufacturers competed more aggressively for customers buying minivans, vans, and pickups, than for those customers purchasing other types of vehicles. These findings are roughly comparable to the results in Sudhir (2001a) which utilized MSRP data.

The framework used to motivate the empirical model in this chapter highlights the need for future research. Because whereas the model yields information on the extent of competition relative to the Bertrand benchmark, it does not identify the exact mode of conduct currently in place in the U.S. automobile market. One way to unearth this information is to proceed along the lines of Rojas (2008). He essentially hypothesizes and tests various modes of conduct for the U.S. beer market including collusive price leadership, stackelberg price leadership, Bertrand-Nash pricing, and full collusion. His analysis relies on identifying conjectural variations parameters which take different values depending on the current mode of conduct. A more detailed analysis of firm rivalry in the U.S. automobile market could be constructed in similar fashion.

References

[1] Abreu, D. (1986): "Extremal equilibria of oligopolistic supergames." *Journal of Economic Theory*, **39**, pp.191-225.

[2] Akbar, Y. (2003), "Slip Sliding Away? The Changing Politics of European Car Distribution." *Business and Politics*, **5(2)**, pp. 175-192.

[3] An, F., and A. Sauer (2004), "Comparison of Vehicle Fuel Economy and CHG Emission Standards Around the World." Report prepared for the Pew Center on Global Climate Change.

[4] Anderson, S., DePalma, A., and J.-F. Thisse (1992), *Discrete Choice Theory of Product Differentiation.* MIT Press.

[5] Ansari, A., Economides, N., and Steckel, J. (1998), "The Max-Min-Min Principle of Product Differentiation." *Journal of Regional Science*, **38(2)**, pp. 207-230.

[6] Archibald, G., Eaton, B., and Lipsey, R. (1986), "Address Models of Value Theory." In *New Developments in the Analysis of Market Structure*, (eds) Stiglitz, J., and F. Mathewson, MIT Press.

[7] Backaus, U. (2000), "An engineer's view of economics: Wilhelm Launhardt's contributions." *Journal of Economic Studies*, **27**, pp. 424-476.

[8] Beath, J., and Y. Katsoulacos (1991), *The economic theory of product differentiation.* Cambridge University Press.

[9] Berry, S. (1994), "Estimating Discrete-Choice Models of Product Differentiation." *RAND Journal of Economics*, **25(2)**, pp. 242-262.

[10] Berry, S., Levinsohn, J., and A. Pakes (1995), "Automobile Prices in Market Equilibrium." *Econometrica*, **63(4)**, 841-890.

[11] Besanko, D., and M. Perry (1993), "Equilibrium incentives for exclusive dealing in a differentiated products oligopoly." *RAND Journal of Economics*, **24(4)**, pp. 646-667.

[12] Boulding, W., and R. Staelin (1993), "A Look on the Cost Side: Market Share and the Competitive Environment." *Marketing Science*, **12(2)**, pp. 144-166.

[13] Boyle, S., and T. Hogarty (1975), "Pricing Behavior in the American Automobile Industry." *Journal of Industrial Economics*, **24(2)**, pp. 81-95.

[14] Brenkers, R., and F. Verboven (2005), "Market definition with differentiated products: Lessons from the car market." In *Recent Developments in Antitrust: Theory and Evidence*, (ed.) Choi, J., MIT Press.

[15] Brenkers, R., and F. Verboven (2006), "Liberalizing a Distribution System: The European Car Market." *Journal of the European Economic Association*, **4(1)**, pp. 216-251.

[16] Bresnahan, T. (1987), "Competition and Collusion in the American Automobile Industry." *Journal of Industrial Economics*, **35(4)**, pp. 457-482.

[17] Bresnahan, T., (1989), "Empirical methods for industries with market power." In *Handbook of Industrial Organization Vol II*, (eds.) Schmalensee, R, and R. Willig,North-Holland.

[18] Bresnahan, T., Stern. S., and M. Tratjenberg (1997), "Market segmentation and the sources of rents from innovation: personal computers in the late 1980s." *RAND Journal of Economics*, **28(0)**, pp. S17-S44.

[19] Caplin, A., and B. Nalebuff (1986), "Multi-Dimensional Product Differentiation and Price Competition." *Oxford Economic Papers*, **38**, pp. 129-145.

[20] Chang, M.-H. (1991), "The effects of product differentiation on collusive pricing." *International Journal of Industrial Organization*, **9**, pp. 453-469.

[21] Chidmi, B., and R. Lopez (2007), "Brand-Supermarket Demand for Breakfast Cereals and Retail Competition." *American Journal of Agricultural Economics*, **89(2)**, pp. 324-337.

[22] Cooney, S., and B. Yacobucci (2005), *U.S. Automotive Industry: Policy Overview And Recent History.* Novinka Books.

[23] Cyert, R., and M. DeGroot (1973), "An Analysis of Cooperation and Learning in a Duopoly Context." *The American Economic Review*, **63(1)**, pp. 24-37.

[24] D'Aspremont, C., Gabszewicz, J., and J.-F. Thisse (1979), "On Hotelling's Stability in Competition." *Econometrica*, **47**, pp. 1145-1150.

[25] Deaton, A., and J. Muellbauer (1980), *Economics and Consumer Behavior.* Cambridge University Press.

[26] Deneckere, R. (1983), "Duopoly Supergames with product differentiation." *Economics Letters*, **11**, pp. 37-42.

[27] Dibb, S. (2000), "Market Segmentation." In *The Oxford Textbook of Marketing*, (ed.) Blois, K. Oxford University Press.

[28] Dixit, A., and J. Stiglitz (1977), "Monopolistic Competition and Optimum Product Diversity." *American Economic Review*, **67(3),** pp. 297-308.

[29] Dos Santos Ferreira, R., and J.-F. Thisse (1996), "Horizontal and Vertical differentiation: The Launhardt Model." *International Journal of Industrial Organization*, **14**, pp. 485-506.

[30] Downs, A. (1997) *An Economic Theory of Democracy.* Addison Wesley.

[31] Draganska, M., and D. Jain (2005), "Product Line Length as a Competitive Tool." *Journal of Economics and Management Strategy*, **14(1)**, pp. 1-28.

[32] Dubé, J.-P., Hitsch, G., and P. Rossi (2007), "Do Switching Costs Make Markets Less Competitive?" Working Paper, Graduate School of Business, University of Chicago.

[33] Eaton, B., and R. Lipsey (1986), "Address Models of Value Theory." In *New Developments in the Analysis of Market Structure*, (eds.) Stiglitz, J., and F. Mathewson. MIT Press.

[34] Economides, N. (1989), "Quality Variations and Maximal Variety Differentiation." *Regional Science and Urban Economics*, **19**, pp. 21-29.

[35] Friedman, J. (1971), "A Non-Cooperative Equilibrium for Supergames." *The Review of Economic Studies*, **38**, pp. 1-12.

[36] Gabsezwicz, J., and J.-F. Thisse (1986), "On the Nature of Competition with Differentiated Products." *The Economic Journal*, **96**, pp. 160-172.

[37] Geroski, P. (1988), "In Pursuit of Monopoly Power: Recent Quantitative Work in Industrial Economics." *Journal of Applied Econometrics*, **3(2)**, pp. 107-123.

[38] Goldberg, P. (1995), "Product Differentiation and Oligopoly in International Markets: The Case of the U.S. Automobile Industry." *Econometrica*, **63(4)**, pp. 891-951.

[39] Goldberg, P., and F. Verboven (2001), "The Evolution of Price Dispersion in the European Car Market." *The Review of Economic Studies*, **68(4)** pp. 811-848.

[40] Gowrisankaran, G., and M. Rysman (2007), "Dynamics of Consumer Demand for New Durable Goods." Manuscript.

[41] Goyder, J. (2005), *EU Distribution Law.* Hart Publishing.

[42] Gupta, B., and G. Venkatu (2002), "Tacit Collusion in a Spatial Model with Delivered Pricing." *Journal of Economics*, **76**, pp. 49-64.

[43] Häckner, J. (1994), "Collusive pricing in markets for vertically differentiated products." *International Journal of Industrial Organization*, **12**, pp. 155-177.

[44] Häckner, J. (1995), "Endogenous product design in an infinitely repeated game." *International Journal of Industrial Organization*, **13**, pp. 277-299.

[45] Häckner, J. (1996), "Optimal symmetric punishments in a Bertrand differentiated product duopoly." *International Journal of Industrial Organization*, **14**, pp. 611-630.

[46] Hamilton, J. D. (1994), *Time Series Analysis.* Princeton University Press.

[47] HAUSMAN, J., LEONARD, G., and D. ZONA (1994), "Competitive Analysis with Differentiated Products." *Annales d'Economie et de Statistique*, **34(0)**, pp. 159-180.

[48] HOTELLING, H. (1929), "Stability in Competition." *The Economic Journal*, **39**, pp. 41-57.

[49] IRELAND, N. (1987), *Product Differentiation and Non-Price Competition*. Blackwell Publishers.

[50] IRMEN, A., and J.-F. THISSE (1998), "Competition in Multi-characteristics Spaces: Hotelling Was Almost Right." *Journal of Economic Theory*, **78**, pp. 76-102.

[51] IVALDI, M., JULLIEN, B., REY, P., SEABRIGHT, P., and J. Tirole (2003), "The Economics of Tacit Collusion." Final Report for DG Competition, European Commission. IDEI, Toulouse.

[52] IVALDI, M., and F. VERBOVEN (2005), "Quantifying the effects from horizontal mergers in European competition policy." *International Journal of Industrial Organization*, **23**, pp. 669-691.

[53] KADIYALI, V., SUDHIR, K., and V. RAO (2001), "Structural analysis of competitive behavior: New Empirical Industrial Organization methods in marketing." *International Journal of Research in Marketing*, **18**, pp. 161-186.

[54] KLEMPERER, P. (1987), "Markets with Consumer Switching Costs." *Quarterly Journal of Economics*, **102**, 375-394.

[55] KOPPELMAN, F., and C. BHAT (2006), "A Self-Instructing Course in Mode Choice Modeling: Multinomial and Nested Logit Models." Prepared for the USDOT Federal Transport Administration.

[56] LANCASTER, K. (1966), "A New Approach to Consumer Theory." *Journal of Political Economy*, **74**, pp. 132-157.

[57] LAMBERT-PANDRAUD, R., LAURENT, G., and E. LAPERSONNE (2005), "Repeat Purchasing of New Automobiles by Older Consumers: Empirical Evidence and Interpretations." *Journal of Marketing*, **69(2)**, 97-113.

[58] LAUNHARDT, W. (1885), *Mathematische Begründung der Volkswirtschaftslehre*. B.G. Teubner, Leipzig.

[59] LUTZ, M. (2000), "E.U. Commission versus Volkswagen: New Evidence on Price Differentiation in the European Car Market." *Review of Industrial Organization*, **17**, pp. 313-323.

[60] LUTZ, M. (2004), "Pricing in Segmented Markets, Arbitrage Barriers, and the Law of One Price: Evidence from the European Car Market." *Review of International Economics*, **12(3)**, pp. 456-475.

[61] MCFADDEN, D. (1978), "Modeling the Choice of Residential Location." In *Spatial Interaction Theory and Planning Models*, (eds.) KARLQVIST, A., LUNDQVIST, L., SNICKARS, F., and J. WEIBUL, North-Holland Publishers.

[62] McFadden, D. (1981), "Econometric models of probabilistic choice." In *Structural Analysis of Discrete Data with Econometric Applications*, (eds.) Manski, C., and D. McFadden, MIT Press.

[63] Nelder, J., and R. Mead (1965), "A simplex method for function minimization." *Computer Journal*, **7**, pp. 308-313.

[64] Neven, D., and J.-F. Thisse (1990), "On Quality and Variety Competition." *In Economic Decision Making: Games, Econometrics and Optimization*, (eds.) Gabszewicz, J., Richard, J.-F., and L. Wolsey. North Holland Publishers.

[65] Nevo, A. (2000), "Mergers with Differentiated Products: The Case of the Ready-to-Eat Cereal Industry." *RAND Journal of Economics*, **31(3)**, pp. 395-421.

[66] Nevo, A. (2001), "Measuring Market Power in the Ready-to-Eat Cereal Industry."*Econometrica*, **69**, pp. 307-342.

[67] Petrin, A. (2002), "Quantifying the Benefits of New Products: The Case of the Minivan." *Journal of Political Economy*, **110(4)**, pp. 705-729.

[68] Rhee, B.-D., De Palma, A., Fornell, C., and Thisse, J.-F. (1992), "Restoring the Principle of Minimum Differentiation in Product Positioning." *Journal of Economics and Management Strategy,* **1(3)**, pp. 475–505.

[69] Rojas, C. (2008), "Price Competition in U.S. Brewing." *Journal of Industrial Economics*, **56(1)**, pp. 1-31.

[70] Rosen, S. (1974), "Hedonic Prices and Implict Markets: Product Differentiation in Pure Competition." *Journal of Political Economy*, **82(1)**, pp. 34-55.

[71] Ross, T. (1992), "Cartel Stability and Product Differentiation." *International Journal of Industrial Organization*, **10**, pp. 1-13.

[72] Rothschild, R. (1992), "On the sustainability of collusion in differentiated duopolies." *Economics Letters*, **40**, pp. 33-37.

[73] Rothschild, R. (1997), "Product Differentiation and cartel stability: Chamberlin versus Hotelling." *The Annals of Regional Science*, **31**, pp. 259-271.

[74] Salop, S. (1979), "Monopolistic Competition with Outside Goods." *Bell Journal of Economics*, **10(1)**, pp. 141-156.

[75] Sándor, Z. (2004), "On Price Equilibrium with Multi-Product Firms." Working Paper, Erasmus University Rotterdam.

[76] Shaked, A., and J. Sutton (1982), "Relaxing Price Competition Through Product Differentiation." *The Review of Economic Studies*, **49**, pp. 3-13.

[77] Shum, M. (2004), "Does Advertising Overcome Brand Loyalty? Evidence from the Breakfast-Cereals Market." *Journal of Economics and Management Strategy*, **13(2)**, pp. 241-272.

[78] Slade, M. (1989), "Price Wars in Price-Setting Supergames." *Economica*, **56(223)**, pp. 295-310.

[79] Spanos, A. (1999), *Probability Theory and Statistical Inference: Econometric Modeling with Observational Data.* Cambridge University Press.

[80] Spence, M. (1976), "Product Differentiation and Welfare." *American Economic Review*, **66(2)**, pp. 407-414.

[81] Sudhir, K. (2001a), "Competitive Pricing Behavior in the Auto Market: A Structural Analysis." *Marketing Science*, **20(1)**, pp. 42-60.

[82] Sudhir, K. (2001b), "Structural Analysis of Manufacturer Pricing in the Presence of a Strategic Retailer." *Marketing Science*, **20(3)**, pp. 244-264.

[83] Tabuchi, T. (1994), "Two-stage two-dimensional spatial competition between two firms." *Regional Science and Urban Economics*, **24**, pp. 207-227.

[84] Tagliabue, J. (2003), "Breaking Habits, Europeans Turn to Japan's Cars." *The New York Times*, August 5, 2003.

[85] Tyagi, R. (1999), "On the Relationship between Product Substitutability and Tacit Collusion." *Managerial and Decision Economics*, **6**, pp 293-298.

[86] Van Waterschoot, W. (2000), "The Marketing Mix as a Creator of Differentiation." In *The Oxford Textbook of Marketing*, (ed.) Blois, K. Oxford University Press.

[87] Vandenbosch, M., and C. Weinberg (1995), "Product and Price Competition in a Two-Dimensional Vertical Differentiation Model." *Marketing Science*, **14**, pp. 224-249.

[88] Verboven, F. (1996), "International Price Discrimination in the European Car Market." *The RAND Journal of Economics*, **27(2)**, pp. 240-268.

[89] Verboven, F. (2007), "Efficiency enhancing or anti-competitive vertical restraints? Selective and exclusive car distribution in Europe." Forthcoming in *Cases in European Competition Policy: the Economic Analysis*, (ed.) B. Lyons, Cambridge University Press.

[90] Waterson, M. (1989), "Models of Product Differentiation." *Bulletin of Economic Research,* **41**, pp. 1-27.

APPENDIX A

Derivations and Proofs

A.1. Some Derivations

In the general case, for arbitrary τ and $\sigma \geqslant 1/2$ we obtain the following expressions for A and B for Firm 1:

$$A = \frac{\left(2V + (1 + \tau - \sigma\tau)t_2\right)^2}{4\,(1+\tau)\,(2V - \sigma\tau t_2)} \tag{A.1}$$

and

$$B = \frac{\left(3\,(1+\tau) + (1-\tau)\,\sigma\right)^2 t_2}{9\,(1+\tau)\,(2V - \sigma\tau t_2)} \tag{A.2}$$

while for Firm 2:

$$A = \frac{\left(2V + (1 + \tau - \sigma)t_2\right)^2}{4\,(1+\tau)\,(2V - \sigma t_2)} \tag{A.3}$$

and

$$B = \frac{\left(3\,(1+\tau) - (1-\tau)\,\sigma\right)^2 t_2}{9\,(1+\tau)\,(2V - \sigma t_2)} \tag{A.4}$$

are the relevant ratios. In addition, the expressions for the threshold discount factors are

$$\lambda_1 = \frac{9\left(2V - (1 + \tau + \sigma\tau)t_2\right)^2}{\left(6V + \left(9\,(1+\tau) + (2 - 5\tau)\,\sigma\right)t_2\right)\left(6V - \left(3 + 2\sigma + (3+\sigma)\,\tau\right)t_2\right)} \tag{A.5}$$

and

$$\lambda_2 = \frac{9\left(2V - (1 + \tau + \sigma)t_2\right)^2}{\left(6V + \left(9\,(1+\tau) - (5 - 2\tau)\,\sigma\right)t_2\right)\left(6V - \left(3 + \sigma + (3+2\sigma)\,\tau\right)t_2\right)} \tag{A.6}$$

for firms 1 and 2 respectively.

A.2. Proofs of Lemmas

Proof of Lemma 5. The proof follows that in Häckner (1995). The objective is to establish a condition which indicates that full market coverage is preferred to partial coverage under joint-profit maximization for both firms. For the high-quality firm, if partial market coverage is optimal then

$$U(\theta) = V - (\theta - a_1)\,\tau t_2 - p_1 = 0$$

yields demand

$$\theta = \frac{V - p_1}{\tau t_2} + \frac{1 - \sigma}{2}.$$

Profit maximization results in prices

$$p_1'' = \frac{2V + (1 - \sigma)\,\tau t_2}{4}.$$

If partial market coverage is optimal for firm 1 then $p_1'' > p_1^{coll}$, which implies

$$V < \frac{(1 + \sigma)\,\tau t_2}{2}.$$

Since the right hand side of the above equation is increasing in τ and σ, it is maximized at $\tau = \sigma = 1$, in which case the condition becomes $V < t_2$, violating Assumption 4.

By a similar argument, if partial market coverage is optimal for the low-quality firm then

$$U(\theta) = V - (a_2 - \theta)\,t_2 - p_2 = 0$$

yields demand

$$\theta = \frac{1 + \sigma}{2} - \frac{V - p_2}{t_2},$$

with corresponding profit-maximum price

$$p_2'' = \frac{2V - (1 + \sigma)\,t_2}{4}.$$

This price is optimal in comparison to Firm 2's joint-profit price only if

$$V < -\frac{(1 - \sigma)\,t_2}{2},$$

which also violates Assumption 4. □

Proof of Lemma 10. Rewrite Eq. (3.4) as:

(A.7)

$$s_j = \frac{e^{\delta_j/(1-\sigma_{hg})}}{\left[D_{hg}^{(\sigma_{hg}-\sigma_g)/(1-\sigma_g)}\right]\left[\sum_{h\in H_g} D_{hg}^{(1-\sigma_{hg})/(1-\sigma_g)}\right]^{\sigma_g}\left[\sum_{g\in G}\left(\sum_{h\in H_g} D_{hg}^{(1-\sigma_{hg})/(1-\sigma_g)}\right)^{1-\sigma_g}\right]},$$

(dropping the market and time indicators). With the outside share expressed as:

(A.8) $$s_0 = \frac{1}{\left[\sum_{g\in G}\left(\sum_{h\in H_g} D_{hg}^{(1-\sigma_{hg})/(1-\sigma_g)}\right)^{1-\sigma_g}\right]},$$

we obtain

$$\text{(A.9)} \quad \ln(s_j) - \ln(s_0) = \delta_j/(1-\sigma_{hg}) - \ln D_{hg}^{(\sigma_{hg}-\sigma_g)/(1-\sigma_g)} - \ln \sum_{h \in H_g} D_{hg}^{(1-\sigma_{hg})/(1-\sigma_g)\sigma_g}.$$

Using the fact that

$$\text{(A.10)} \quad \ln\left(\overline{s}_{j/hg}\right) + \ln\left(\overline{s}_{h/g}\right) = \delta_j/(1-\sigma_{hg}) - \ln D_{hg}^{(\sigma_{hg}-\sigma_g)/(1-\sigma_g)} - \ln \sum_{h \in H_g} D_{hg}^{(1-\sigma_{hg})/(1-\sigma_g)},$$

along with

$$\text{(A.11)} \quad \ln\left(\overline{s}_{j/hg}\right) = \delta_j/(1-\sigma_{hg}) - \ln D_{hg}$$

in (A.9) yields the estimable demand equation:

$$\text{(A.12)} \quad \ln(s_j) - \ln(s_0) = \beta' \mathbf{X}_{jt} - \alpha p_{jt} + \sigma_{hg} \ln\left(\overline{s}_{j/hg}\right) + \sigma_g \ln\left(\overline{s}_{h/g}\right) + \xi_{jt}.$$

after making the substitution for δ_j. □

A.3. Elasticities for the Nested Logit Demand Model

Based on the structure of the multi-level nested logit model the own-price elasticity of alternative j is written as:

$$e_{jj} \equiv -\frac{\partial s_j}{\partial \delta_j}\frac{\partial \delta_j}{\partial p_j}\frac{p_j}{s_j} = \alpha p_j \left[\frac{1}{1-\sigma_{hg}} - \left(\frac{1}{1-\sigma_g} - \frac{1}{1-\sigma_{hg}}\right)\overline{s}_{j/hgm} - \frac{\sigma_g}{1-\sigma_g}s_{gm} - s_{jm}\right],$$

while the cross-price elasticities are:

$$e_{jk} \equiv \frac{\partial s_k}{\partial \delta_k}\frac{\partial \delta_k}{\partial p_j}\frac{p_j}{s_k} = \alpha p_j \left[\left(\frac{1}{1-\sigma_{hg}} - \frac{1}{1-\sigma_g}\right)\overline{s}_{j/hgm} + \frac{\sigma_g}{1-\sigma_g}\overline{s}_{gm} + s_{jm}\right],$$

if j and k are from the same subsegment $h = 1, ..., H$ of segment $g = 1, ..., G$,

$$e_{jk'} \equiv \frac{\partial s_{k'}}{\partial \delta_{k'}}\frac{\partial \delta_{k'}}{\partial p_j}\frac{p_j}{s_{k'}} = \alpha p_j \left[\frac{\sigma_g}{1-\sigma_g}\overline{s}_{gm} + s_{jm}\right],$$

if j and k' are from different subsegments within the same segment, and

$$e_{jk''} \equiv \frac{\partial s_{k''}}{\partial \delta k''}\frac{\partial \delta_{k''}}{\partial p_j}\frac{p_j}{s_{k''}} = \alpha p_j s_{jm}$$

if j and k'' belong to different segments.

APPENDIX B

Data Description and Summary

Table B.1. Big Six Producer Shares in New Vehicle registrations 1970-1999 (percent share)

	1970	**1980**	**1990**	**1999**
Fiat	23.53	11.35	17.34	10.58
Ford	8.46	5.28	6.28	8.64
GM	8.46	6.60	7.79	6.48
PSA	5.88	20.58	11.56	8.86
Renault	8.46	8.18	5.78	4.75
V.W.	12.13	9.23	10.55	16.20
Total	**66.92**	**61.22**	**59.3**	**55.51**

Table B.2. Import Penetration across Europe 1970-1999 (percent share)

	1970	**1980**	**1990**	**1999**
Daewoo	–	–	–	4.10
Honda	1.10	2.11	4.52	3.02
Hyundai	–	0.26	1.76	4.10
Kia	–	–	–	2.59
Mazda	–	2.64	3.52	4.54
Mitsubishi	–	3.96	2.76	3.02
Nissan	0.37	5.28	4.27	4.10
Suzuki	–	–	1.51	2.16
Toyota	0.74	7.39	5.28	6.05
Total	**2.21**	**21.64**	**23.62**	**33.68**

Table B.3. U.S. Domestic Monthly Sales 3Q 2004 - 1Q 2007 (percent share)

Period	Ford	GMC	Chrysler	Honda	Toyota	Nissan	European Brands
3Q 2004	20.30	27.26	11.94	9.55	13.84	5.40	3.41
4Q 2004	21.03	23.97	12.57	9.40	13.73	7.23	3.57
1Q 2005	20.81	24.04	13.29	8.40	13.86	8.14	2.95
2Q 2005	19.70	26.17	12.70	8.97	13.85	7.07	3.04
3Q 2005	21.43	24.30	12.02	10.34	13.21	7.16	3.63
4Q 2005	19.54	24.39	12.43	10.57	14.05	6.46	4.15
1Q 2006	19.87	24.20	13.08	9.70	14.27	7.03	3.67
2Q 2006	18.27	24.95	11.36	10.79	15.76	5.96	3.96
3Q 2006	16.85	27.32	10.11	11.08	16.14	5.88	3.96
4Q 2006	15.89	25.90	12.82	10.39	15.82	6.25	4.35
1Q 2007	16.39	25.47	14.07	10.73	15.20	7.15	3.01

Table B.4. Selected Variable Definitions from Chapter 3

Variable	**Definition**
Price	Pre-tax list price of base model
Quantity	Sales (number of new car registrations)
Hp	Horsepower (in kw)
Tax	Percentage V.A.T. (in destination country)
Pop	Population
Rgdp	Real GDP
Org	Origin Code (country with which consumers associate the model)
Loc	Location code (country where producers produce the model)
Brand	Name of Brand
Model	Name of Model
Cla	Class or Segment Code
Foreign	foreign car dummy (1 = car is foreign made)
Frm	Firm Code
We	Weight (in kg)
He	Height (in cm)
Le	Length (in cm)
Wi	Width (in cm)
Li	Fuel Inefficiency (litres/100km)
Avexr	Average exchange rate of exporter country (currency per SDR)
Avcpr	Average consumer price index of exporter country

Table B.5. Selected Variable Definitions from Chapter 4

Variable	**Definition**
Price	Average Transaction price exclusive of dealer add-ins and other incentives
Quantity	Sales (monthly sales)
HP	Horsepower (in HP)
Pop	Population (Civilian Non-Institutional population over 16 years)
GDP	US Domestic GDP
Car	Car Dummy (car = 1 indicates vehicle is a car)
Foreign	Foreign Brand Dummy (foreign =1 indicates vehicle is a foreign brand)
Name	Model name
Brand	Model Brand
Cla	Segment Code
Frm	Firm Code
We	Vehicle curbweight (in lbs)
He	Height (in inches)
Le	Length (in inches)
Wi	Width (in inches)
Fuel	Retail fuel cost (cents per gallon)
MPG	Miles per gallon (EPA formulation)
MP$	Miles per dollar spent on fuel
CPI	Consumer Price Index (1996 = 100)
Age	Average age of vehicle