C. 1

STRATEGIC POSITIONING IN PRODUCT-SERVICE FIRMS

by

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abstract

This dissertation consists of three essays related to positioning issues in product-service firms. A product-service firm is defined as a company which is responsible for providing both the physical product and the associated services of an offering. This situation is typical of many companies manufacturing industrial and commercial products. The first essay develops a game theoretic analysis of two firms competing in a two-dimensional product market. Firms compete on price and both product dimensions. Models incorporating alternative differentiation assumptions (vertical, horizontal, and mixed) are analyzed with the results indicating the prevalence of maximum differentiation on one product dimension and minimum differentiation on the other. In the second essay, many of the assumptions of the economic models are relaxed in the development of a model which assesses the issue of how a product-service firm should choose its offering improvement strategy. The model addresses the strategic question of whether to invest in product or service improvements. In the third essay, one component of the model outlined in the second essay is developed further and an empirical application is undertaken. This essay develops an individual level customer decision model which estimates an individual's brand preferences as a function of brands' perceptual locations and prices. The model performed well in an empirical study of the western Canada combine harvester market.

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Chapter 1

Introduction

Product positioning has been a major focus for marketing researchers and practitioners for over 20 years. Throughout the years, interest in positioning issues has remained high. In this dissertation, three essays concerned with positioning issues in product-service firms are presented.

The notion of a *product-service firm* is an important component of this research. A product-service firm is defined as a company which is responsible for providing both the physical product and the associated services of an offering. This situation is typical of many companies manufacturing industrial and commercial products. For example, the empirical study described in Chapter 4 focuses on a single offering, combine harvesters, in the farm equipment industry. Manufacturers of combines, like John Deere, manufacture combines in centralized production facilities and market them through a proprietary dealer network. In the John Deere combine example, poor service at the dealer level causes customers to have a lower evaluation of the John Deere offerings. Contrast this situation with a shoe manufacturer. To the customer, service may be an important feature when purchasing shoes. However, when poor service is delivered, it is attributed to the retailer, not the manufacturer. The customer may choose to buy the same shoes from a different retailer. Hence, at this level, the shoe manufacturer is not responsible for service.

The need to study positioning issues in product-service firms is based on the premise that there is a differential impact of product and service changes within the company.

These differences imply that it is necessary to analyze positioning issues from both the customer and company perspectives. Traditionally, positioning research in marketing has concentrated on the customer's view of the offerings in a market. Customers are assumed to consider a number of features or attributes of the offerings. Whether the attributes are related to the product features or service has very little impact on the nature of the analytical procedures employed. However, from the company's perspective, the distinction between product and service features is very important. For example, in a product oriented company, the ability to improve the service component of an offering requires the development of new skills and capabilities. This implies costs over and above the variable costs associated with the service improvement. In addition, the transition towards a more service oriented company may be impeded by an entrenched corporate culture. In order to better understand the impact of these differential changes, it is important to look at positioning strategy from several more general product and service dimensions. This level of analysis enables the research to concentrate on some of the important strategic tradeoffs are faced by product service firms.

This dissertation consists of three essays related to positioning issues in product-service firms. These essays are presented in chapters 2-4. Each of these chapters can be considered as an independent research paper. However, there are strong links between each chapter. In chapter 2, entitled *Product and Price Competition in a Two- Dimensional Market*, three economic models are analyzed to assess the equilibrium positioning implications of alternative product differentiation assumptions. In chapter 3, entitled *Setting the Strategic Direction in a Product-Service Firm*, many of the assumptions of the economic models are relaxed in the development of a model which assesses the issue of how a product-service firm should choose its offering improvement strategy. Finally, in chapter 4 , entitled *An Individual Level Customer Decision Model*, one component of the model developed in chapter 3 is developed further and an empirical application is undertaken. Each of these chapters will be described in more detail below.

The economic models developed in chapter 2 expand on recent analytical marketing models which study product and price competition in markets characterized by multiple product dimensions (e.g., Hauser 1988; Kumar and Sudharshan 1988; Carpenter 1989; Choi, DeSarbo and Harker 1990, Horsky and Nelson 1989). In these articles, the optimal competitive behavior with respect to product positioning has not been fully addressed. None of the current models characterize a product equilibrium where firms are able to choose freely in the allowable product space. In addition, there has been very little research into the competitive implications of various product differentiation assumptions when products are characterized by multiple dimensions. It is on these positioning issues that the models developed in chapter 2 concentrate.

An economic analysis of a market with two competitors competing on price and two product dimensions is undertaken. Although the two product dimensions can represent product and service characteristics of an offering, the models are general enough to represent any product which can be described on two characteristics. Both the one-dimensional vertical differentiation model (Shaked and Sutton 1982, Moorthy 1988) and one-dimensional horizontal differentiation model (Hotelling 1929, d'Aspremont et al 1979) are extended to two dimensions and an analysis of product and price competition is undertaken. In addition, the hybrid model containing one vertical and one horizontal characteristic is analyzed. A two-stage game theoretic analysis in which two firms compete first on product positions and then on price is undertaken for each of the models. Closed form equilibrium solutions are obtained for each stage in which competitors are unrestricted in their choices of price or product positions.

Chapter 3 develops a model which can be used to aid a firm determining the strategic direction it should pursue. A *strategic direction* is defined as the company's overriding focus for improvements relating to its product-service offering(s). For example, a company may choose a service oriented strategic direction. This implies that, in the medium term, the majority of offering improvements will be related to service. The development of a technical service department, an improvement in the parts delivery system and/or an increase the number of dealerships may all be part of this "service" emphasis. The need for a strategic direction stems from the assumption that companies must continuously improve their offerings in order to remain competitive. In a world of increasing global competition, this assumption appears to be reasonable.

The strategic direction model (SDM model) considers both the customer and company perspective in determining the optimal strategic direction for a firm. At the customer level, customer perceptions and preferences for the offerings in the market are assessed. At the company level, implementation managers propose promising product and service improvements to the existing product-service offering. The strategic direction decision is based on the expected market impact of these proposed improvements. This incrementalism approach to offering improvement recognizes the need to consider the current positioning of the company's offering in any improvement strategy.

The SDM model relaxes many of the assumptions used in the economic models developed in chapter 2. Customer preferences are described by a vertical differentiation (vector) model which includes product, service and price factors. Unlike the economic models, the methodology allows customers to have heterogeneous perceptions of the offerings. In addition, the SDM model allows for multiple competitors, multiple regions and the inclusion of both fixed and variable costs in the profit and return calculations. This added generality prevents the determination of a positioning equilibrium, but is appropriate for the assessment of optimal strategic direction.

Chapter 4 develops and empirically tests an individual level customer decision model which can be used as part of the SDM model. The customer decision model is unique in a number of respects. First, confirmatory factor analysis is used to define the perceptual space. Like other factor analytic techniques, confirmatory factor analysis allows for heterogeneous perceptions through the estimation of individual factor scores. In addition, confirmatory factor analysis allows for a priori specification of number of perceptual dimensions and the measurement of their inter-correlation. Second, the model uses conjoint measurement to estimate customers' preference weightings for each of the perceptual dimensions and price. Parameters are estimated at the individual level and applied to an individual's brand perceptions to determine the individual's relative preference for each of the brands in the market. Finally, the model allows for the incorporation of price competition between brands. Because the price parameter is estimated over a range of price levels, the customer decision model is still valid as current prices are adjusted to Nash equilibrium prices.

Building on the SDM model developed in chapter 3, the customer decision model is specifically designed for markets which are characterized by product-service firms. However, its general formulation allows it to be applied in many settings.

The empirical application of the customer decision model focuses on a single offering, combine harvesters, in the farm equipment industry. A computer driven questionnaire was administered to combine owners attending the 1990 Canada Western Agribition in Regina, Saskatchewan. The Agribition is a major agricultural trade show which is attended by an estimated 30,000 farmers annually. Using this data, the customer decision model is parameterized. The predictive ability of the model is assessed through a comparison with respondents choices on a number of preference questions.

The dissertation concludes with a summary chapter. In this chapter (chapter 5), contributions, limitations and future research are discussed for each of the essays.

To date, research on positioning issues in product-service firms has been limited.

Yet, as the importance of services in traditional manufacturing operations increases, the competitive success (and possibly the survival) of many companies depends on an understanding of these issues. It is believed that the research developed in this dissertation contributes to our understanding of this research topic.

Chapter 2

Product and Price Competition in a Two-Dimensional Market

2.1 Introduction

Recently, a number of analytical marketing models have been developed to study product and price competition in markets characterized by multiple product dimensions (Hauser 1988; Kumar and Sudharshan 1988; Carpenter 1989; Choi, DeSarbo and Harker 1990, Horsky and Nelson 1989). Collectively, these models provide a number of important insights into the optimal behavior of competing firms with respect to pricing, product positioning and, in some models, advertising and distribution.

Intuitively, it would seem that one of the primary reasons for developing analytical models in a multidimensional context would be to study product design decisions. However, the optimal competitive behavior with respect to product positioning has not been satisfactorily addressed. None of the current models characterize a product equilibrium where firms are able to choose freely in the allowable product space. In addition, there has been very little research into the competitive implications of various product differentiation assumptions when products are characterized by multiple dimensions.

In this chapter, a generalized two-dimensional model of product and price competition is developed. Both the one-dimensional vertical differentiation model (Shaked and Sutton 1982, Moorthy 1988) and one-dimensional horizontal differentiation model (Hotelling 1929, d'Aspremont et al 1979) are extended to two dimensions and an analysis of product and price competition is undertaken. In addition, the hybrid model containing one vertical and one horizontal characteristic is analyzed. A two-stage game theoretic analysis in which two firms compete first on product positions and then on price is undertaken for each of the models. Closed form equilibrium solutions are obtained for each stage in which competitors are unrestricted in their choices of price or product positions.

Although there are substantial differences in the structures of the three models, there are strong similarities in the nature of their equilibrium solutions. The most significant finding is that there is a prevalence of *MaxMin* product differentiation. That is, in equilibrium, the two firms tend to choose positions which will represent maximum differentiation on one dimension and minimum differentiation on the other dimension. The notable exception to this type of equilibrium occurs in the two-dimensional vertical differentiation model where, under certain conditions, maximum product differentiation occurs. In addition to generating similar product equilibria, the price equilibria for the three models share a generalized form with some parameter values depending on the product differentiation assumptions used. Comparisons are made between these models and their one-dimensional counterparts as well as other two-dimensional models of product positioning and price (e. g. Economides 1986b; Hauser 1988; Carpenter 1989; Lane 1980).

In order to highlight both the similarities and differences, each of the models is developed in tandem. Specifically, the chapter is structured as follows. Section 2.2 reviews the relevant literature in both economics and marketing. Section 2.3 develops the three different models by outlining their assumptions and comparing them to existing models. Section 2.4 develops the price equilibrium while sections 2.5-2.7 develops the product equilibria for each of the three models. Implications and model summaries are also included in these sections. Section 2.8 summarizes the chapter.

2.2 Literature Review

In marketing, the Lancasterian view of product space is widely accepted (Lancaster 1966, 1971, 1979). Lancaster posited that products are comprised of a set of characteristics and that the consumer's utility for this product is a function of the levels of these characteristics. This assumption is the basis for many marketing research techniques including conjoint analysis and multidimensional scaling. Using Lancaster's notion of product space, two variants of product differentiation can be distinguished: horizontal differentiation and vertical differentiation. In a horizontally differentiated product space, tastes vary across the population resulting in a distribution of individual ideal characteristic levels. Thus, this type of differentiation has been termed variety differentiation. Characteristics like sweetness, color and physical location are horizontal in nature. In a vertically differentiated product space, all consumers agree that more of a characteristic is always better. This results in a natural ordering over the characteristic space (Tirole 1988). Characteristics like quality and efficacy are vertical in nature. Accordingly, this type of differentiation has been termed quality differentiation.

Marketers have traditionally modeled horizontal and vertical characteristics using the vector model and the ideal point model respectively (Shocker and Srinivasan 1979). Ratchford (1979) shows how the development of these empirically based models are linked to Lancaster's goods- characteristics theory.

The models based on these two types of product differentiation are reviewed in more detail. This is followed by a review of competitive models in which markets are characterized by a multidimensional product space. Interested readers are also directed to Lancaster (1990) and Ratchford (1990) who review the literature on product differentiation in economics and marketing respectively.

2.2.1 Horizontal Differentiation

The horizontal differentiation model was developed by Hotelling (1929). Indeed, his article "Stability in Competition" has inspired much of the research in spatial economics. The basic assumption behind a horizontal differentiation model is that consumers are heterogeneous with respect to their ideal level of a characteristic. Consumers decrease their valuation of a product as a function of "distance" from their ideal level of the characteristic to the product's level. Though they vary with respect to their notion of an ideal product, all consumers value an ideal product equally and have the same utility reducing distance function. Thus, consumers use both product prices and distance from their respective ideal points to decide which product to purchase.

The basic ideas behind Hotelling's horizontal differentiation model are as follows: Two firms, selling the same physical good with equal (zero) production costs, compete on store location and price. The environment for competition is a *linear city*, represented by a line of length 1. The two firms are located at respective distances x_1 and x_2 from the zero end of this line such that: $x_2 \geq x_1$, $0 \leq x_1, x_2 \leq 1$. Consumers, who purchase one unit of the good each period, are assumed to be uniformly "located" along the line and value a firm's offering based on a combination of its price and the distance to the store. Thus, each consumer has an ideal store location (where the distance to the store is zero). Let p_1 and p_2 represent the respective prices of the two products and let c represent the transportation rate. Then consumers choose the product which minimizes their total cost for the product: Min $C = p_i + c|x^* - x_i|$, for $i = 1, 2$.

The main finding of Hotelling's paper is the equilibrium choice of location for the two firms. At equal prices, consumers located to the left of x_1 (between 0 and x_1) would always purchase from firm 1. This region can be termed firm 1's hinterland. As x_1 moves toward x_2, firm 1's market share would increase as more consumers would be in its hinterland. The same force would draw firm 2 towards firm 1 making the product equilibrium $x_1 = x_2$ (i. e. minimum differentiation). This *Principle of Minimum Differentiation* has been used widely to explain why some businesses (like banks and gas stations) seem to locate very close to one another and why political parties tend to have similar platforms.

Hotelling's location result was generated when prices were equal. Though Hotelling discussed the possibility of price cutting in his article, he did not elaborate. As illustrated by d'Aspremont, Gabszewicz and Thisse (1979), minimum differentiation in a Hotelling environment leads to severe price cutting and a price equilibrium only at $p_1^* = p_2^* = 0$ (assuming marginal cost=0). The notion here is that because the products are physically identical and at the same location, Bertrand price competition will result. In addition, these researchers prove that a price equilibrium (with prices > 0) will not exist unless the firms are located far enough from each other.

D'Aspremont et al modify the consumer's minimization function to

$$\text{Min } C = p_i + c|x^* - x_i|^2, \quad \text{for } i = 1, 2$$

This modification of the distance function obtains a unique locational equilibrium which implies maximum product differentiation. This result is primarily due to a strategic force: the desire to reduce price competition. That is, firms make more profits if they are able to obtain "local monopolies".

From the analyses of Hotelling and d'Aspremont et al, two forces seem to shape the locational equilibrium: a demand force (a desire to increase one's hinterland) which draws the firms together and a strategic force (a desire to reduce price competition) which causes the firms to differentiate. A number of researchers have extended the horizontal differentiation model in an attempt to understand the nature of these forces. Economides (1986a) shows that the results of both Hotelling and d'Aspremont et al are sensitive to the transportation cost function used. He studies the Hotelling model with a transportation cost function of cd^a where d is the distance from the consumer to the store location and $a \in [1, 2]$. He finds that a pure-strategy price equilibrium exists for $a > 1.26$ and that locational differentiation is not maximal for $1.26 < a < 1.67$.

dePalma et al (1985) show that the *Principle of Minimum Differentiation* is restored when "products and consumers are sufficiently heterogeneous". Under Hotelling's original formulation, the competing products were identical (i.e. they both generate an equal consumer surplus for all consumers). However, dePalma et al assume that there are inherent characteristics within firms which cause differentiation; that consumer preferences for these products are not identical; and, that specific consumer tastes cannot be determined a priori. They model the consumer surplus derived from consuming a given product as $\hat{s} + me_i$ where m is a parameter and e_i is a consumer-and-firm specific random variable which accounts for the lack of information regarding the tastes of particular consumers. As m becomes large, products are differentiated even though they have the same location. Therefore, the strategic effect (the desire to soften price competition) is minimized and the demand effect dominates. The authors state that the inclusion of heterogeneity in both firms and consumers amounts to adding a second non-spatial dimension.

Economides (1986b) extended Hotelling's model to two dimensions by having the consumer's utility depend on the distance from the product's location to the consumer's location in a circular market space. He shows that a price equilibrium exists for all symmetrical locations whereas such an equilibrium does not in the linear model. His analysis restricts products to symmetrical locations on the axis through the centre of the market and he does not attempt to find the product equilibrium.

Other important extensions to the one-dimensional horizontal differentiation model warrant mention but do not directly impact on the issues studied in this thesis. Salop (1979) studied a form of monopolistic competition by "connecting" the two ends of the *linear city* to form the *circular city*. Economides (1984) analyzed the Hotelling model in an environment where consumer demand was rectangular in nature (i.e. the consumer only purchases if a commodity is available at a delivered price which is below an upper limit). Eaton and Lipsey (1975) extend Hotelling's analysis to the case where there are more than two firms while Prescott and Visscher (1977) analyze the problem of sequential entry of firms. For a more complete review of the one-dimensional horizontal differentiation literature see Graitson (1982) and Tirole (1988, chapter 7).

2.2.2 Vertical Differentiation

Vertical differentiation models have only recently begun to appear in the literature (Mussa and Rosen 1978, Gabszewicz and Thisse 1979; Shaked and Sutton 1982). The basic assumption behind the vertical differentiation model is that all consumers agree that more of a specific characteristic is always better. Thus, all consumers have the same ideal point: an infinite level of the characteristic. Economists call this characteristic "quality", but it can refer to any attribute or perceptual dimension which can be viewed in a "more is better" framework. In contrast with the horizontal differentiation model, at equal prices, only one product (the one with the highest quality) will have a positive market share. Consumers are heterogeneous with respect to their willingness to pay for the product. Therefore, though all consumers can agree on which product has more of the desired characteristic, the actual product that the consumer will buy is dependent on the prices charged by the competitors.

Using Tirole's (1988) terminology, the general format of the one-dimensional vertical differentiation model is as follows. Two firms, selling a substitutable product produced with equal (zero) costs, compete on quality and price. Each product (indexed 1, and 2) has a particular quality, s, in the range $[s_l, s^h]$ and a price, p. All consumers buy one unit per period and they choose the product which maximizes $V = \theta s_i - p_i$, for $i = 1, 2$. The parameter θ represents the consumer's willingness to pay or taste and can have any distribution among the population. Gabszewicz and Thisse (1979) and Shaked and Sutton (1982) assume that this parameter varies with income with consumers having higher incomes preferring higher quality products. However, nothing is lost by considering a willingness to pay distribution independent of income.

This environment leads to a division of the market into two segments with each segment purchasing a different product. Consumers with a taste parameter $\hat{\theta} \geq (p_2 - p_1)/(s_2 - s_1)$ will prefer to purchase the higher quality product whereas the remaining consumers will purchase the lower quality product. Because of the desire to reduce price competition (the strategic effect mentioned above), the resulting product equilibrium has firms located at the extreme ends of the quality spectrum.

The basic vertical differentiation model has been extended in a number of ways. Shaked and Sutton (1982) extend earlier work by Gabszewicz and Thisse (1979, 1980) by analyzing a three stage game in which the first stage was entry followed by product and price competition. They find that the only perfect equilibrium in the three stage game results when only two firms enter the market. Shaked and Sutton (1983) generalize this result by proving that in any vertically differentiated market, there can be at most a finite number of competitors. This "finiteness result" occurs because price competition among high quality firms drives price down to a level where lower quality firms cannot enter and make a profit.

Moorthy (1988) extends the basic model by incorporating variable production costs and allowing consumers the opportunity not to buy. His equilibrium analysis shows that firms choose products which are differentiated (though not maximally). In addition, the firms choose not to provide offerings which appeal to the entire market (not all consumers purchase). Moorthy also analyzes a sequential entry product equilibrium. His results show that the first entrant chooses the lowest quality possible while ensuring that it remains the high quality product.

In addition to studying market structure problems, the vertical differentiation model has been used extensively in agency theory. Papers by Mussa and Rosen (1978) and Maskin and Riley (1986) illustrate how a group of consumers differentiated vertically on a characteristic are used in the analysis of adverse selection (hidden characteristics) problems. Solutions to these problems allow monopolists to exercise partial price discrimination by offering a range of products at different qualities as consumers self select their most preferred price and quality option.

2.2.3 Combined Vertical and Horizontal Differentiation

Because of the recognition that products often vary both in variety and quality, there have been a few models developed to study the combined effects of these types of product differentiation. Ireland (1987) studied price competition in a model in which there are two groups of consumers who have different ideal product varieties. Though he allows for the possibility of firms to set varying quality levels, he does not analyze the product equilibrium. Ginsburgh et al (1987) analyze the situation where firms compete on prices and quality for given varieties of a product.

Neven and Thisse (1988) analyzed a two-dimensional vertical and horizontal differentiation model in which firms compete on quality, variety and price. Firms first choose their product, consisting of two characteristics, and subsequently choose their price. The models described later in this paper employ similar analysis procedures to those used by Neven and Thisse.

2.2.4 Competitive Models in Multi-dimensional Product Space

Kuehn and Day (1962) noted that if a firm differentiates its product from competitors, it will occupy a separate position and capture its own market segment rather than share the market with other firms. In the years since Kuehn and Day's article, a number of sophisticated methodologies for measuring consumer preferences and analyzing product spaces have been developed. Methods including conjoint analysis, multidimensional scaling and other perceptual mapping techniques have led to a significant body of research on product positioning issues (e. g. Hauser and Urban 1977, Green and Kreiger 1985, Shocker and Srinivasan 1979, Day, Shocker and Srivistava 1979, DeSarbo and Rao 1986, Urban and Hauser 1980). The models which address product and price competition in multi-dimensional product markets will be reviewed in more detail (note also the earlier reviews of Economides (1986b) and Neven and Thisse (1988)).

The models proposed by Hauser (1988) and Lane (1980) represent variations of the horizontal differentiation model. Hauser analyzes pricing and positioning strategies using the DEFENDER consumer model (Hauser and Shugan 1983) in which products are differentiated in a two-dimensional *per dollar* perceptual map. Although the *per dollar* perceptual map permits only "more is better" attributes similar to a vertical differentiation model, the limited product positioning options makes the resulting positioning equilibrium behave in much the same way as the horizontal differentiation model. Hauser imposes the restriction that feasible products must lie on the circumference of a quarter circle inscribed in the positive quadrant. This reduces the positioning decision to one dimension as each location on the quarter circle can be expressed in terms of the angle which a line from the location to the origin makes with the horizontal axis. Like Hotelling's model, each consumer has an ideal product in this dimension under equal prices. The product equilibrium consists of minimum differentiation at equal prices and maximal differentiation when both prices and product positions are considered.

Lane represents brands in two-dimensional space on the basis of product characteristics where price is considered separately. Consumer heterogeneity is modeled in the parameters of a Cobb-Douglas utility function of the two "more is better" characteristics. Lane's assumption of a single technology curve restricts the product choice to a one-dimensional decision in much the same way as Hauser's "quarter circle" assumption. The major focus of Lane's paper is the product entry and deterrence strategies. Thus, he uses a sequential entry with foresight product equilibrium concept which results in an equilibrium solution which tends towards maximum differentiation.

Kumar and Sudharshan (1988) use Lane's model to discuss defensive pricing, advertising and distribution (but not positioning) responses to an optimal attack by a new market entrant. The goal of this research is to extend some of the results forwarded by the DEFENDER model (Hauser and Shugan 1983) to situations where there is one attacker and n defenders.

Carpenter (1989) analyzes a two brand, two-dimensional horizontal differentiation model in which individual ideal points are unimodally distributed over the allowable product space. He makes the assumption that a consumer only considers purchasing a product if it is within a specified distance, D_{max} from that consumer's ideal point. Therefore, dramatic price reductions in a particular product's price will not be effective in attracting consumers whose ideal points are further than D_{max} from the product's location. In this environment, Carpenter outlines the conditions which would cause firms to choose the same product location: the midpoint of the ideal point distribution. When the rate of change in demand is greater for a product movement towards the distribution midpoint than the rate of change in demand for a movement away from the competitor, both firms choose to locate at the distribution midpoint. If the reverse is true, Carpenter concludes that products will locate at opposite corners of the allowable product space.

Choi, DeSarbo and Harker (1990), study the problem of optimal product positioning in the presence of price competition. Although Choi et al develop an analytical model which exhibits vertical differentiation (the assumption of a single ideal point at maximum quality), their numerical approach to the Nash price equilibrium solution exhibits horizontal differentiation. It is unclear whether the comparative static results for the analytical model hold under their numerical approach. Using a Stackelberg-Nash equilibrium concept, these researchers develop a numerical procedure which enables them to calculate the optimal product position (in multi-dimensional space) and price of a new entrant and optimal response prices of any number of incumbents. Horsky and Nelson (1989) also study the optimal product positioning problem using a vector model (vertical differentiation). Like Choi et al, their main emphasis is the incorporation of price competition in the search for an optimal product position rather than the characterization of the equilibrium solution.

2.2.5 Summary of Literature Review

The horizontal and vertical differentiation models have generated a significant amount of research in economics. The majority of this research has been concerned with analyzing the equilibrium implications of variations to the one dimensional models with known (and often uniform) distribution of consumers. The models of Lane (1980), Economides (1986b) and Neven and Thisse (1988) represent the only attempts extend the differentiation models to two dimensions.

Researchers in marketing have viewed the emphasis on a one dimensional product to be the most limiting feature of this stream of economics research. In response, most of the marketing models concerned with product and price competition have included multiple product dimensions. Because of the difficulty in obtaining closed form equilibrium solutions in these more complex environments, researchers have relied on numerical analysis (Hauser 1988; Choi et al 1990; Horsky and Neslon 1989) or functional approximations (Carpenter 1989) to augment their analytical work. Though significant progress has been made regarding the incorporation of competition into pricing and product positioning models, research in this area is still in its early stages. Of particular importance to current research is the fact that, although models of multi-dimensional product markets have been developed, limiting conditions imposed by the authors have reduced the product decision to a single dimension. Thus, the implications of product (rather than price) competition in multi-dimensional product markets has not been adequately researched.

2.3 The Models

Three different models will be analyzed, each incorporating different product differentiation assumptions. Though there are substantial differences in the model structures, there are strong similarities in the nature of their equilibrium solutions.

2.3.1 Two-Dimensional Vertical Differentiation Model

Assumptions

The two-dimensional vertical differentiation model analyzed in this paper is based on the following assumptions:

1. There are 2 firms, indexed 1 and 2, who each choose one product to market. Products are comprised of non-negative valuations on 2 characteristics, $\boldsymbol{x}$ and $\boldsymbol{y}$. The characteristics are analogous to perceptual dimensions or product attributes and

are assumed to be orthoganol. Thus, each firm's product is defined as a point (x_i, y_i), where $x_i \in [x_{min}, x^{max}]$ and $y_i \in [y_{min}, y^{max}]$.

2. Consumers are assumed to prefer more of each characteristic to less. For example, personal computers may be described on two dimensions like "power" and "portability" in which consumers always prefer more powerful and more portable computers holding all other attributes constant. It is assumed that price enters negatively into the consumer's valuation equation.

3. Consumers are able to observe product characteristics and prices before they make their purchase decision. Consumers' reservation prices (R) for a product in this market are high enough to ensure that all consumers buy. In addition each consumer is restricted to purchasing one unit — either from firm 1 or firm 2. A typical consumer's valuation equation can be described by a standard individual level vector model in which utility is expressed in dollar units (Srinivasan 1982). Consumer heterogeneity is captured by two parameters $\Theta = (\theta_1, \theta_2)$:

$$U = R + \theta_1 x_i + \theta_2 y_i - p_i, \text{ for } i = 1, 2. \tag{2.1}$$

where: p_i is the price of firm i's product

The consumer will choose the product from the firm which maximizes (2.1).

4. The parameters, $\Theta = (\theta_1, \theta_2)$, are assumed to be uniformly distributed over the population. Since one characteristic may, on average, be more important than the other, the range of the parameter distribution may be different for each characteristic. Without loss of generality, both of these ranges can be restricted to [0,1]. This can be accomplished by choosing the appropriate scale for each of the characteristics (x, y).

5. Products are assumed to have a constant marginal cost set, without loss of generality, to zero regardless of product position. Though this situation is obviously unrealistic, the analysis is significantly simplified while retaining the strategic effects of product positioning. The price equilibrium is unaffected by this assumption.

Comparison with Other Models

The two-dimensional vertical differentiation model discussed in this section is designed to provide a direct extension of the one-dimensional vertical differentiation model. It is most similar to the model presented by Shaked and Sutton (1982) because costs are assumed to be constant (equal) for all product positions. Since the major emphasis of this research is to assess the nature of competitive behavior in the presence of different differentiation assumptions, this reduction in complexity seems reasonable. An obvious extension of the model would be to incorporate position-dependent variable costs in a manner similar to Moorthy (1988).

The model presented here is also quite similar to Hauser (1988). Both models use two dimensions to characterize the product space and assume that consumers have homogeneous perceptions of the products. Hauser assumes that perceptions can be ratio scaled and thus, similar to the above model, higher levels on a perceptual attribute are always better. However, there are a number of important differences. Hauser divides the products' perceptual characteristics by price whereas price enters in a linear fashion in my model. This difference represents different methods of comparing prices between products. Hauser's model assumes consumers compare relative prices where my model assumes consumers compare absolute price differences. Empirical research by Hauser and Urban (1986) has shown that these two criteria have performed equally well in assessing price response to durables.

Consumers tastes in Hauser's model are defined by one parameter, the angle between the consumer's (linear) utility curve and the horizontal axis in per dollar perceptual space. In the two-dimensional vertical differentiation model, two parameters, (θ_1, θ_2), are used to define consumer tastes.

Another notable difference between Hauser's model and the one presented here has to do with Hauser's quarter circle assumption in which he imposes the restriction that feasible products must lie on the circumference of a quarter circle inscribed in the positive quadrant. No such positioning restriction is present in the current model.

Many of the same distinctions that are made between Hauser's model and my model can be extended to Lane's model (Lane 1980). For a more complete description of the similarities between Lane (1980) and Hauser (1988), see Kumar and Sudharshan (1988).

Defining the Indifference Surface for both Asymmetric and Dominated Characteristics Competition

In the analysis of the vertical differentiation model, there are two generic types of product positioning competition: asymmetric characteristics and dominated characteristics. *Asymmetric characteristics competition* is defined as competition between firms when each firm has a relative advantage on one of the two characteristics (Figure 2.1a). For example, if the two characteristics which describe the personal computer market are "ease of use" and "power", Apple computers would have a relative advantage over IBM on the "ease of use" dimension while IBM would have the relative advantage over Apple on the "power" dimension. *Dominated characteristics competition* is defined as competition between firms when one firm has a relative advantage on both characteristics (Figure 2.1b). This situation is typical of competition between different "models" of a similar technology. Competition between XT, AT and 386 personal computers would be an example of

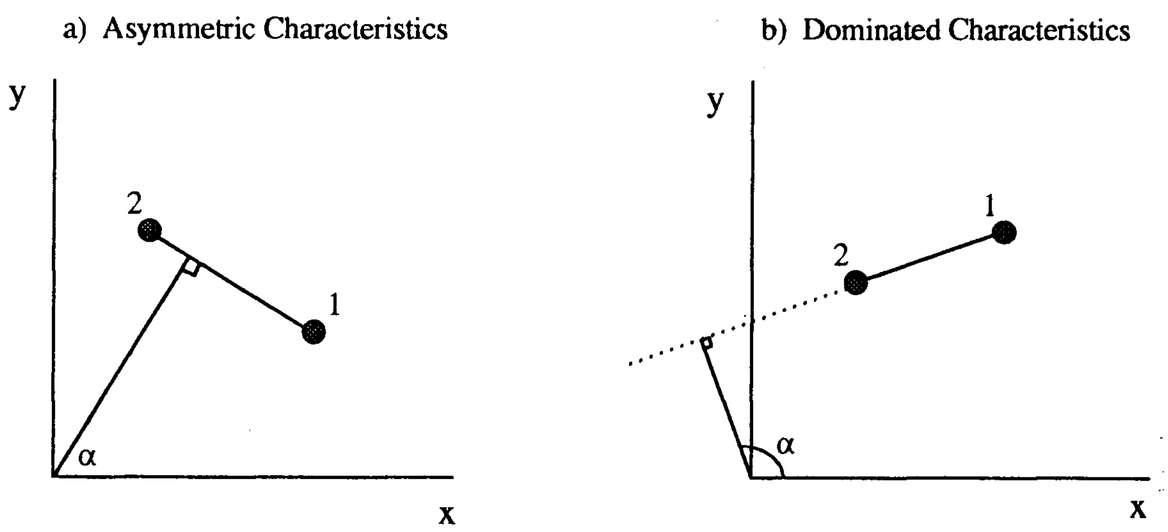


Figure 2.1: Alternative Product Positionings

dominated characteristics competition.

For both types of competition, the relative positions of the products can be described by taking a ratio of the absolute differences in the characteristic levels of the two products. The ratio $(x_1 - x_2)/(y_2 - y_1)$ is equal to the tangent of the angle between the horizontal axis and a line from the origin perpendicular to a line joining the two products (α in Figures 2.1a, 2.1b). This *angle of competition* illustrates the relative positioning advantage of the firms and becomes important in the determination of the demands for each product.It should be noted that each angle represents the set of alternative product positionings that maintain the same relative separation.

Figure 2.2a provides an example of asymmetric characteristics competition. Without loss of generality, it is assumed that firm 1's product has the advantage on x and firm

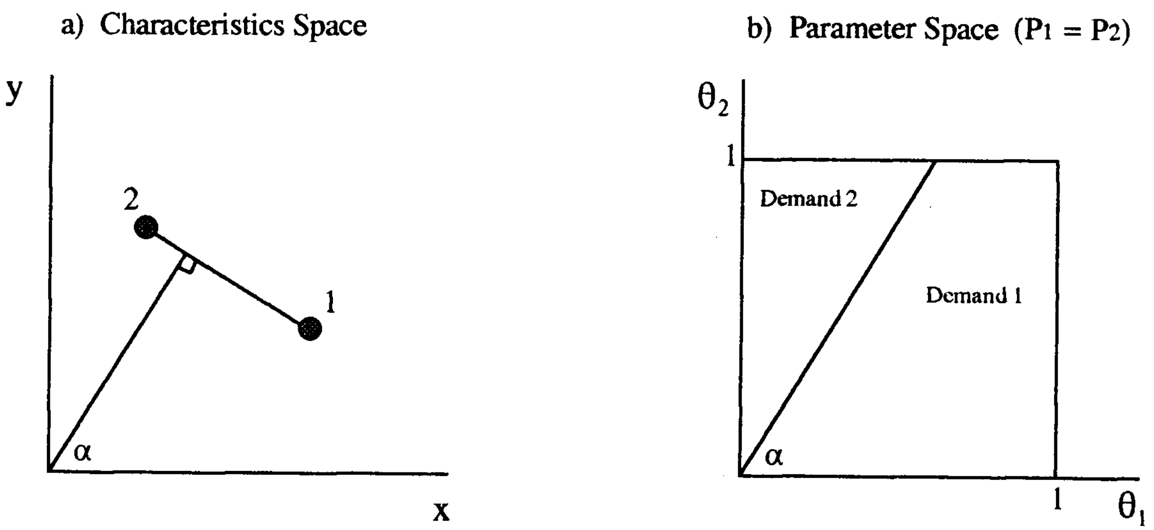


Figure 2.2: Relationship Between Characteristics Space and Parameter Space in the Two-dimensional Vertical Model with Asymmetric Characteristics

2's product has the advantage on y. Consumers in this market decide to purchase the product which maximizes their utility as defined in (2.1). This comparison leads to a set of consumers who are indifferent to choosing either product. This set is a line which intersects the set of consumer types. Consumers types above the indifference line choose product 2 and consumers below the line choose product 1. In $\theta_1 \times \theta_2$ space, this indifference line is defined as:

$$\hat{\theta}_2(\theta_1) = \frac{(p_2 - p_1)}{(y_2 - y_1)} + \frac{\theta_1(x_1 - x_2)}{(y_2 - y_1)} \tag{2.2}$$

The fact that this indifference surface is a line is the point of convergence for the vertical differentiation, horizontal differentiation and mixed models. Figure 2.2b illustrates this indifference line at equal prices. The slope of this indifference line is the negative of the slope of the line connecting the the two products in $x \times y$ space. Thus, the market share of each of the products is dependent on the angle of competition defined by the relative product positions (α in Figures 2.2a and 2.2b). In addition, the terms $(x_1 - x_2)$ and $(y_2 - y_1)$ provide a measure of absolute product differentiation. The difference between prices, $p_2 - p_1$, shifts the indifference line up or down. Firms deviate from equal prices to the extent that their respective profitability is increased. The demand for each product is defined by the area above (product 2) or below (product 1) the indifference line. Profits are calculated by multiplying demand by price and subtracting by the (constant) variable costs.

The relationship between $x \times y$ space and $\theta_1 \times \theta_2$ space (via the *angle of competition*) clearly illustrates the advantage of a superior product position. Intuitively, the desirability of a firm's product is dependent on the relative characteristics of the two products. If one product has more of x but both product have virtually the same amount of y, it would be expected that, at equal prices, this product would capture most of the market. Conversely, if the each product had approximately equal absolute product differentiation advantages on their respective dominant characteristics, at equal prices, they would each obtain approximately 50% of the market.

Dominated characteristics competition differs slightly from asymmetric characteristics competition due to the presence of a superior and an inferior product (Figure 2.3a). Without loss of generality, it is assumed that firm 1's product is the superior product. Analysis proceeds in the same manner as with asymmetric characteristics competition. As equation (2.2) holds, the slope of the indifference line is the negative of the slope of the line connecting the the two products in $x \times y$ space. The slope of the indifference line

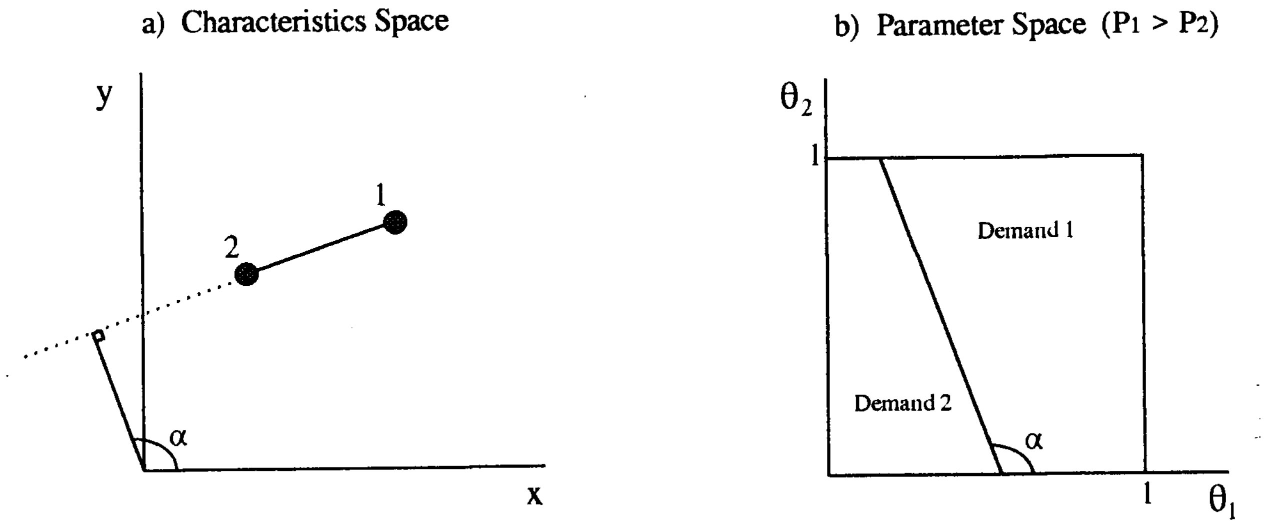


Figure 2.3: Relationship Between Characteristics Space and Parameter Space in the Two-dimensional Vertical Model with Dominated Characteristics

is negative, with the angle of competition being greater than 90° (Figure 2.3b). As would be expected, at equal prices product 1 captures the entire market. There must exist a lower price for the inferior product before any consumer will purchase it. This is similar to results obtained using the one dimensional vertical differentiation model (Moorthy 1988).

2.3.2 Two-Dimensional Horizontal Differentiation Model

Assumptions

The two-dimensional horizontal differentiation model analyzed in this paper is based on the following assumptions:

1. There are 2 firms, indexed 1 and 2, who each choose one product to market. Products are defined by their locations (non-negative valuations) on 2 characteristics, $\boldsymbol{x}$ and $\boldsymbol{y}$. It is assumed that the ranges of both characteristics is [0,1]. The characteristics are assumed to be orthoganol and continuous within the defined range. Thus, each firm's product is defined as a point (x_i, y_i), where $x_i, y_i \in [0, 1]$.

2. Consumers have ideal characteristic levels (x^*, y^*), where $x^*, y^* \in [0, 1]$ and are assumed to prefer products whose characteristics most closely match their ideal levels. For example, a food product can be defined by its level of *sweetness*. Consumers have different opinions on the ideal level of sweetness such that two products with different levels of sweetness would be preferred (at equal prices) by a non-zero group of consumers. It is assumed that price enters negatively into the consumer's valuation equation.

3. Consumers are able to observe product characteristics and prices before they make their purchase decision. Consumers' reservation prices (R) for a product in this market are high enough to ensure that all consumers buy. In addition each consumer is restricted to purchasing one unit — either from firm 1 or firm 2. A typical consumer's valuation equation can be described by a standard individual level ideal point model in which utility is expressed in dollar units (Srinivasan 1982). Consumer heterogeneity is captured the distribution of ideal points (x^*, y^*).

$$U = R - (x^* - x_i)^2 - (y^* - y_i)^2 - p_i \text{ for } i = 1, 2. \tag{2.3}$$

where: p_i is the price of firm i's product

The consumer will choose the product from the firm which maximizes (2.3).

4. The consumer ideal points, (x^*, y^*), ideal points are assumed to be uniformly distributed over both characteristics. The uniform distribution assumption coupled with the assumption regarding the range of the characteristics means that consumers value each characteristic equally. Though this equal valuation may be unrealistic, the analytical results derived in the analysis section are not structurally affected.

5. As in the vertical differentiation model described above, products are assumed to have a constant marginal cost regardless of product position.

Comparison with Other Models

As was outlined in the literature review, the horizontal model is very sensitive to the choice of the distance function (Economides 1986a). The two-dimensional horizontal differentiation model described here uses a quadratic distance function. This function is different than the linear function used in the two-dimensional vertical differentiation model and the linear model proposed by Hotelling. The quadratic distance function was chosen to conform with ideal point models which are common in the marketing literature (e. g. Gavish, Horsky and Srikanth 1983; Choi, DeSarbo and Harker 1990, Green and Srinivasan 1978). The model is a direct extension of the one-dimensional model analyzed by d'Aspremont et al (1979). These researchers used a quadratic term in order to eliminate a non-existence problem with the original Hotelling formulation. The extension of Hotelling's (1929) model to two dimensions is left for future research.

The models by Economides (1986b) and Carpenter (1989) represent alternative two-dimensional horizontal differentiation models. Economides uses a circular market to analyze the two-dimensional case. He assumes that a consumer whose ideal point is identical to a product location will be the last consumer to choose the alternative product as prices increase. The resulting set of consumers who are indifferent between the two products is defined by a hyperbola. The model described here (defined by (2.3)) indicates that a consumer whose ideal point is identical to a product position will not choose his ideal product if the price is too high relative to the competition. The indifference surface in the current model is a line and the distance function meets Economides' condition for continuity of the demand and profit functions.

The purpose of Carpenter's model is substantially different than the model analyzed here. Instead of seeking closed form equilibrium solutions to both product and pricing decisions, Carpenter analyzes a number of scenarios to show how firms can reposition to increase profits. In addition, he analyzes the situation where firms can compete with the full marketing mix. The major structural difference between Carpenter's model and the one analyzed here is Carpenter's assumption that a consumer will only consider purchasing a product if it is within a specified distance, D_{max} from that consumer's ideal point limits the strategic effect of price. Price will enter into the consumer's decision process only when there are two products within D_{max} of the his ideal point. In addition, Carpenter uses a unimodal distribution of ideal points in the allowable product space whereas a uniform distribution is assumed here.

Defining the Indifference Surface

Using the terminology introduced with the two-dimensional vertical differentiation model, all initial configurations of products can be represented by either asymmetric or dominated characteristics competition. To facilitate comparisons between models, asymmetric characteristics competition will be modeled. Since it is neither an advantage nor a disadvantage to have "more" of a specific characteristic, the scales of the characteristics' axes and firm indexes can be adjusted (without loss of generality) such that firm 1's product has the greater locational value on x and firm 2's product has the greater locational value on y. This manner of representing products in joint (product and consumer) space allows for easy comparison of results with the two-dimensional vertical model and the mixed model.

Figure 2.4 provides an example of products represented in joint space. Consumers choose the product which maximizes their utility as defined in (2.3). This comparison leads to a set of consumers which are indifferent to choosing either product. As with the vertical differentiation model, this set is defined by a line which divides the joint space. Consumers with ideal points above the indifference line choose product 2 and consumers below the line choose product 1. The indifference line is defined as:

$$\widehat{y^*}(x^*) = \frac{(p_2 - p_1) + (x_2^2 - x_1^2) - (y_2^2 - y_1^2)}{2(y_2 - y_1)} + \frac{x^*(x_1 - x_2)}{(y_2 - y_1)} \tag{2.4}$$

Figure 2.4 illustrates this indifference line at equal prices. The slope of this indifference line is the negative of the slope of the line connecting the the two products in joint space. Thus, the market share of each of the products is dependent on the angle of competition (α) defined by the relative product positions. However, unlike the vertical differentiation model, market share is dependent on absolute rather than relative product positions.

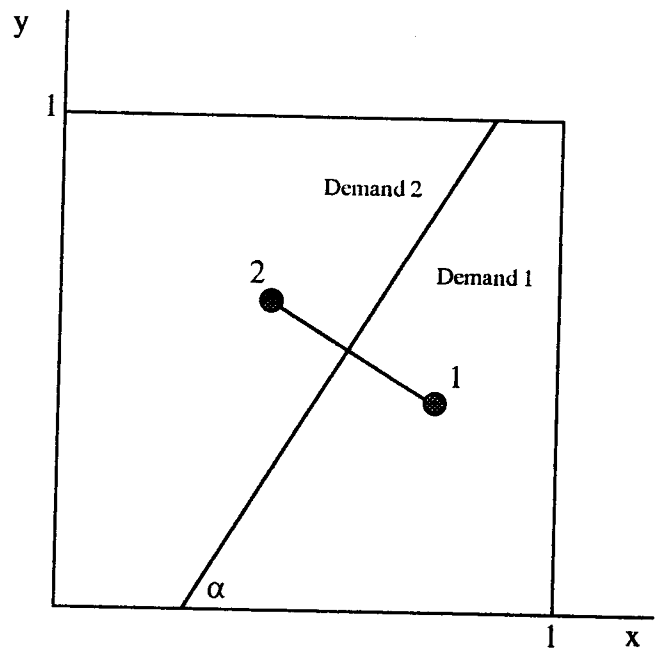


Figure 2.4: Joint Space Representation of the Two-Dimensional Horizontal Differentiation Model

This is evidenced by the expression $(x_2^2 - x_1^2) - (y_2^2 - y_1^2)$ in (2.4). As was the case with the vertical differentiation model, the difference between prices, $p_2 - p_1$, shifts the indifference line up or down with firms deviating from equal prices to the extent that their respective profitability is increased. The demand for each product is defined by the area above (product 2) or below (product 1) the indifference line. Profits are calculated by multiplying demand by price and subtracting the (constant) variable costs.

2.3.3 Mixed Vertical – Horizontal Differentiation Model

Assumptions

The mixed model analyzed in this paper is based on the following assumptions:

1. As in the previously defined models, there are 2 firms, indexed 1 and 2, who each choose one product to market. Products are defined by their non-negative valuations on 2 characteristics, $\boldsymbol{x}$ and $\boldsymbol{y}$. It is assumed that the characteristic $\boldsymbol{x}$ exhibits horizontal differentiation and thus (as above) has a range of [0,1]. The $\boldsymbol{y}$ characteristic is assumed to exhibit vertical differentiation. The characteristics are assumed to be orthoganol. Thus, each firm's product is defined as a point (x_i, y_i), where $x_i \in [0, 1]$ and $y_i \in [y_{min}, y^{max}]$.

2. Consumers have an ideal level of characteristic $\boldsymbol{x}$, $x^* \in [0, 1]$, and are assumed are assumed to prefer more of characteristic $\boldsymbol{y}$ to less. It is assumed that price enters negatively into the consumer's valuation equation.

3. Consumers are able to observe product characteristics and prices before they make their purchase decision. Consumers' reservation prices (R) for a product in this market are high enough to ensure that all consumers buy. In addition each consumer

is restricted to purchasing one unit — either from firm 1 or firm 2. When utility is expressed in dollar units, a typical consumer's valuation equation can be described by:

$$U = R - (x^* - x_i)^2 + \theta y_i - p_i, \text{ for } i = 1, 2. \tag{2.5}$$

where: p_i is the price of firm i's product

The consumer will choose the product from the firm which maximizes (2.5).

4. The consumer ideal levels of $\boldsymbol{x}$, (x^*), are assumed to be uniformly distributed over $[0, 1]$. The parameter, θ, is assumed to be uniformly distributed over the population. Without loss of generality, the range of θ can be restricted to [0,1]. This can be accomplished by choosing the appropriate scale for the characteristic $\boldsymbol{y}$.

5. As in the models described above, products are assumed to have a constant marginal cost regardless of product position.

Comparison with Other Models

The mixed model defined here represents a combination of the one-dimensional models of D'Aspremont et al (1979) and Shaked and Sutton (1982). Aside from differences in terminology, the model is identical to the model analyzed by Neven and Thisse (1988). The model is re-analyzed in this research to demonstrate the generality of equilibrium results under different differentiation assumptions.

Defining the Indifference Surface

Similar to the two-dimensional horizontal differentiation model, all initial configurations of products can be represented by asymmetric characteristics competition. Without loss of generality, the scales of the characteristics' axes and firm indexes can be adjusted such that firm 1's product has the greater locational value on x and firm 2's product has the positioning advantage on y. This representation of the products facilitates comparison of results between the three models.

One of the issues in the analysis of the mixed model concerns the cognitive task required by consumers to determine their maximum utility. Consumers must use two separate cognitive strategies to evaluate the products: distance from ideal characteristic level as well as product of their willingness to pay and vertical characteristic levels. It is likely that consumers analyze both characteristics using the same heuristic by transforming one of the characteristics. An example in the spirit of Hauser and Gaskin (1984) would be the transformation of *sweetness*, a horizontal characteristic, to *right amount of sweetness*, a vertical characteristic. For the purposes of the current analysis, it is assumed that the defined compensatory model accurately represents the consumer decision making process even if the actual process is quite different (Green and Srinivasan 1978).

In the mixed model described here, consumers choose the product which maximizes their utility as defined in (2.5). Figure 2.5 provides a representation of the indifference line which represents the set of consumers who are indifferent to choosing either product. Consumers types (ideal level of x, and taste parameter, θ) above the indifference line choose product 2 and consumers below the line choose product 1. The indifference line is defined as:

$$\hat{\theta}(x^*) = \frac{(p_2 - p_1) + (x_2^2 - x_1^2)}{(y_2 - y_1)} + \frac{2x^*(x_1 - x_2)}{(y_2 - y_1)} \tag{2.6}$$

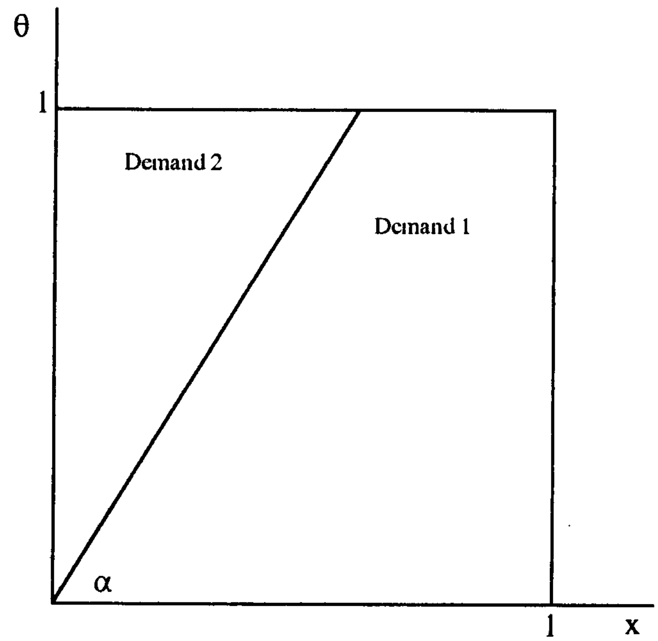


Figure 2.5: Representation of the Indifference Line in the Mixed Vertical-Horizontal Differentiation Model

Unlike the vertical and horizontal models, the slope of this indifference line for the mixed model represented in Figure 2.5 does not equal the negative of the slope of the line connecting the the two products in product space. However, the market share of each of the products is still dependent on the relative product positions. The angle of competition, the angle created by vertical axis and the line joining the two products in product space (γ in Figure 2.6), is 1/2 the size of the angle between the indifference line and the horizontal axis in the space defining consumer types (α in Figure 2.5). This different interpretation of the mixed model is the result of the presence of one rather than two (or no) quadratic expressions in the consumers' utility functions. In all other respects, the mixed model behaves in a similar manner to the horizontal and vertical differentiation models.

2.3.4 General Form of the Indifference Line

For the three models, equations (2.2), (2.4), and (2.6) define the indifference lines in the spaces which defines consumer types. Essentially, competition between the two firms adjusts the location of the indifference line with the resulting location determining the market share for each firm. All three indifference lines have the following general form:

$$F(G) = \frac{(p_2 - p_1) + j}{m\boldsymbol{b}} + \frac{k\boldsymbol{a}}{\boldsymbol{b}}G \tag{2.7}$$

where:

firm i's product is (a_i, b_i)

$\boldsymbol{a} = (a_1 - a_2)$

$\boldsymbol{b} = (b_2 - b_1)$

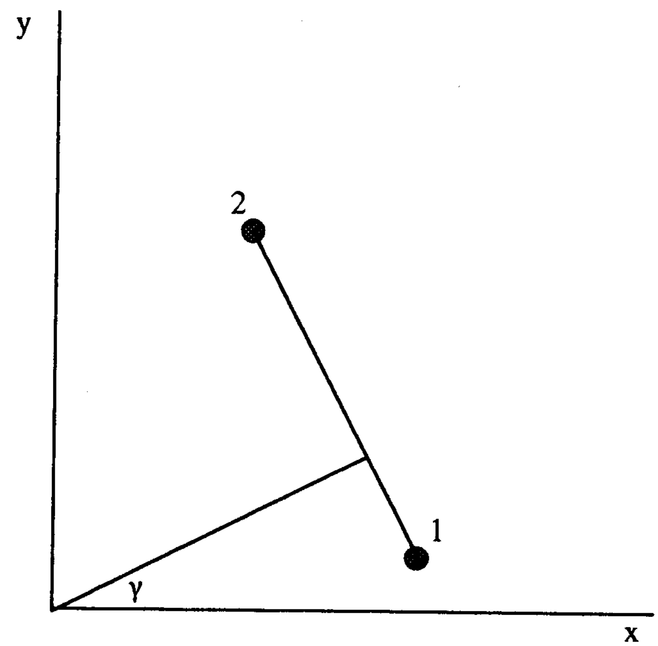


Figure 2.6: Characteristics Space Representation of the Mixed Vertical-Horizontal Differentiation Model

k, m are parameters

$$j = \begin{cases} 0 & \text{for vertical model} \\ (a_2^2 - a_1^2) + (b_2^2 - b_1^2) & \text{for horizontal model} \\ (a_2^2 - a_1^2) & \text{for mixed model} \end{cases}$$

The variables F and G are introduced in (2.7) for purposes of generality.[1] Depending on the model under consideration, these variables represent y^*, x^*, θ, θ_1 or θ_2 (see (2.2), (2.4), (2.6)). Assuming *asymmetric characteristics competition*, the indifference line is positively sloped with angle $\alpha = \tan^{-1}(\frac{k\boldsymbol{a}}{\boldsymbol{b}})$. When product positions are fixed, the indifference line is shifted up or down with changes in $(p_2 - p_1)$ These shifts alter the demand (and profits) for each firm. The demand effects of price changes will be analyzed from the perspective of firm 1. Thus, p_2 will be taken as given (denoted $\hat{p}_2$). Analysis undertaken from the perspective of firm 2 would yield parallel results.

Given $\hat{p}_2$, four key price levels for firm 1 can be defined. p_1^l is defined as the highest price at which all consumers purchase from firm 1. This occurs when the indifference line passes through (0,1) in Figure 2.7. p_1^u is defined as the lowest price at which no consumers are willing to purchase from firm 1. At this price, the indifference line passes through (1,0). The two remaining key price levels, p_1^n and p_1^m, occur when the indifference line passes through (0,0) and (1,1) respectively. At each of these two prices, one of the most extreme consumer types is indifferent between the two products. These prices also define levels at which the shape of the demand functions change.

As firm 1 decreases its price from p_1^u, two distinct cases arise depending on the size of α. *Characteristic $\boldsymbol{x}$ dominance* occurs when $\alpha \geq 45°$. This occurs when $k\boldsymbol{a} \geq \boldsymbol{b}$. For both vertical and horizontal differentiation, this means that the absolute product

[1]Note the definitions of $\boldsymbol{a}$ and $\boldsymbol{b}$. $\boldsymbol{a}$ is defined by subtracting firm 2's characteristic level from firm 1's level whereas $\boldsymbol{b}$ is defined in the reverse fashion with firm 1's characteristic level being subtracted from firm 2's level. Under *asymmetric characteristics competition*, both $\boldsymbol{a}$ and $\boldsymbol{b}$ are positive.

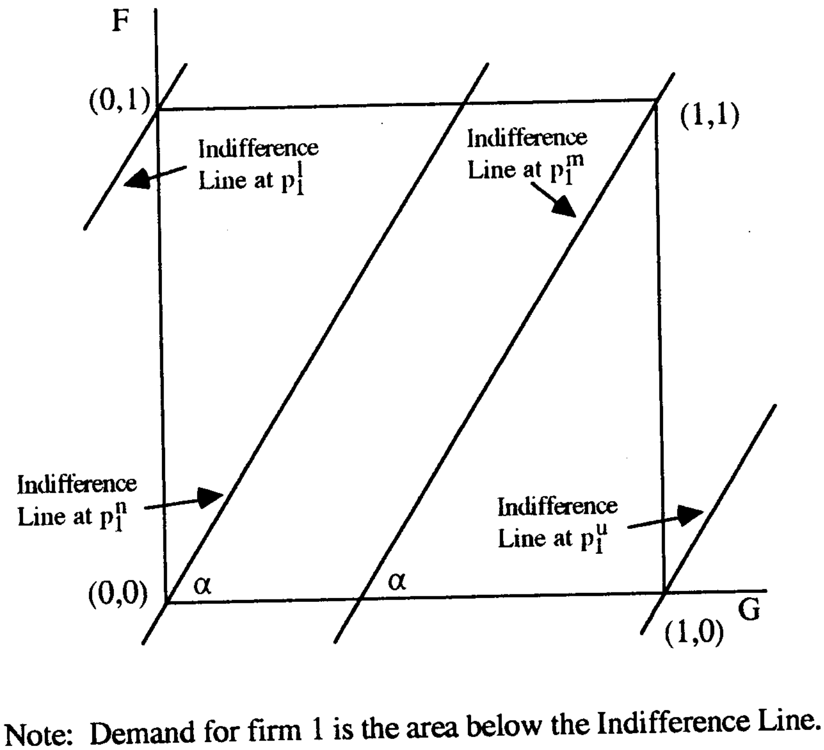


Figure 2.7: Location of the Indifference Line at Boundary Levels of p_1 (given p_2)

differentiation on characteristic x, $(a_1 - a_2)$, is greater than or equal to the absolute product differentiation on characteristic y, $(b_2 - b_1)$. For the mixed model, $2(a_1 - a_2) \geq (b_2 - b_1)$. When *Characteristic x dominance* holds, $p_1^l < p_1^n \leq p_1^m < p_1^u$. That is, the indifference line passes through (1,1) in the space defining consumer types before it passes through (0,0) when prices are decreased from p_1^u.

When $\alpha \leq 45°$, *Characteristic y dominance* holds and $p_1^l < p_1^m \leq p_1^n < p_1^u$. This alternative ordering of key prices has an impact on the price equilibrium calculations. Therefore, the *Characteristic x dominance* and *Characteristic y dominance* cases are analyzed separately. Note that the case when neither characteristic dominates, $\alpha = 45°$, can be represented by either type of dominance. When $\alpha = 0°$ or $90°$, the product choice reduces to one dimension.

2.4 A Generalized Price Equilibrium

There are a number of approaches open to the analysis of product design and price competition in the environment described in the previous section (see Moorthy 1985, Tirole 1988 for reviews). This paper will analyze a sequential game in which firms first choose their product characteristics and subsequently choose their price. In this approach, the subgame-perfectness criterion is used. A subgame perfect equilibrium consists of a product choice for each of firm 1 and 2 such that neither firm would choose a different product unilaterally, recognizing that the profitability of all product selections will be determined on the basis of the price equilibrium that follows (Moorthy 1985). The analysis procedure proceeds by backwards induction. The price equilibrium will be analyzed first followed by the product choice equilibrium.[2]

[2]The following analysis describes the price equilibria. In some instances, second order conditions are calculated to show that they are satisfied. In all other instances, second order conditions have been analyzed by inspection.

The price equilibrium under *Characteristic* $\boldsymbol{x}$ *dominance* will be analyzed before *Characteristic* $\boldsymbol{y}$ *dominance.*

2.4.1 Characteristic x Dominance

Demand Analysis

In each of the models described above, the parameter space defining the consumers consists of a unit square of uniform density. To assess the demand of firm 1 as a function of p_1 (given $\hat{p}_2$), the 4 key prices outlined in the previous section must be specified. At p_1^u, the lowest price at which no consumers are willing to purchase from firm 1, the indifference line passes through $(1,0)$ (see Figure 2.7). The functional form of p_1^u can be found by substituting 1 and 0 for G and F respectively in (2.7). This yields

$$p_1^u = \hat{p}_2 + j + mk\boldsymbol{a} \tag{2.8}$$

Similar substitutions for p_1^m, p_1^n and p_1^l result in the following equations:

$$p_1^m = \hat{p}_2 + j + mk\boldsymbol{a} - m\boldsymbol{b} \tag{2.9}$$

$$p_1^n = \hat{p}_2 + j \tag{2.10}$$

$$p_1^l = \hat{p}_2 + j - m\boldsymbol{b} \tag{2.11}$$

All of these prices are increasing in $\hat{p}_2$. When the terms appear, the price equations are also increasing in $\boldsymbol{a}$ and decreasing in $\boldsymbol{b}$. Indirectly this implies that the prices are increasing in α. That is, the greater firm 1's relative positioning advantage over firm 2, the higher the price firm 1 is able to charge to generate a similar demand level. Intuition supports this finding as one would expect that a positioning advantage should lead to less reliance on pricing to generate demand. It is interesting to note that the density function of consumer types does not influence these price relationships.

p_1^l and p_1^u can be considered to be the lower and upper bounds on the prices that firm 1 will charge for its product given $\hat{p}_2$ as it would not be optimal to charge a price outside of this range. As firm 1 decreases its price from p_1^u, the indifference line shifts upward. Three distinct demand regions can be defined on the basis the geometric structure of the model. These regions correspond to the rate of change in demand for a unit shift in price (see Figure 2.8). In region R_x^1, demand for firm 1 increases (as a function of prices) at an increasing rate. This region is defined by the price range $p_1^m \leq p_1 \leq p_1^u$. In R_x^2, where $p_1^n \leq p_1 \leq p_1^m$, demand for firm 1 increases at a constant rate. Finally, in R_x^3, where $p_1^l \leq p_1 \leq p_1^n$, the demand for firm 1 increases at a decreasing rate.[3]

In R_x^1, the possible prices that can be charged by firm 1 can be viewed as a continuum from p_1^u to p_1^m. Let z_1 represent the proportion of the distance p_1 is from the p_1^u end of the continuum. At $p_1 = p_1^u, z_1 = 0$ and at $p_1 = p_1^m, z_1 = 1$. In the space defining the consumer types, z_1 represents the distance from the horizontal axis to the point where the indifference line meets the right side of the "square" of consumer types (see Figure 2.9). Mathematically z_1 is defined as follows:

$$z_1 = \frac{p_1^u - p_1}{p_1^u - p_1^m} = \frac{\hat{p}_2 - p_1 + j + mka}{mb} \tag{2.12}$$

The demand for firm 1 in R_x^1, D_1^1, is the triangle formed by the indifference line and the edges of consumer types (see Figure 2.9). In this triangle, the angle α is known as well as the height of the triangle (z_1). The formula for the area of a triangle, $A = \frac{1}{2}$(base)(height),

[3]Firm 2's rate of change in demand in these regions is the compliment to firm 1 since $Demand_2 + Demand_1 = 1$.

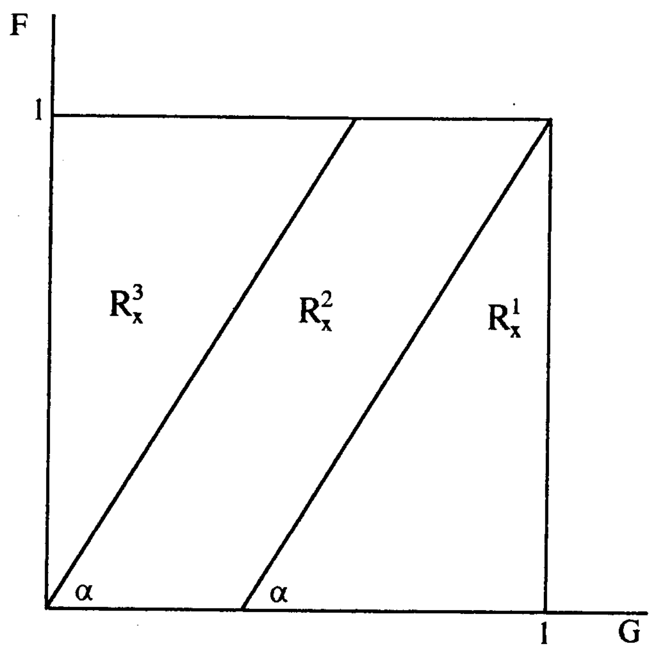


Figure 2.8: Three Demand Regions Under Characteristic x Dominance

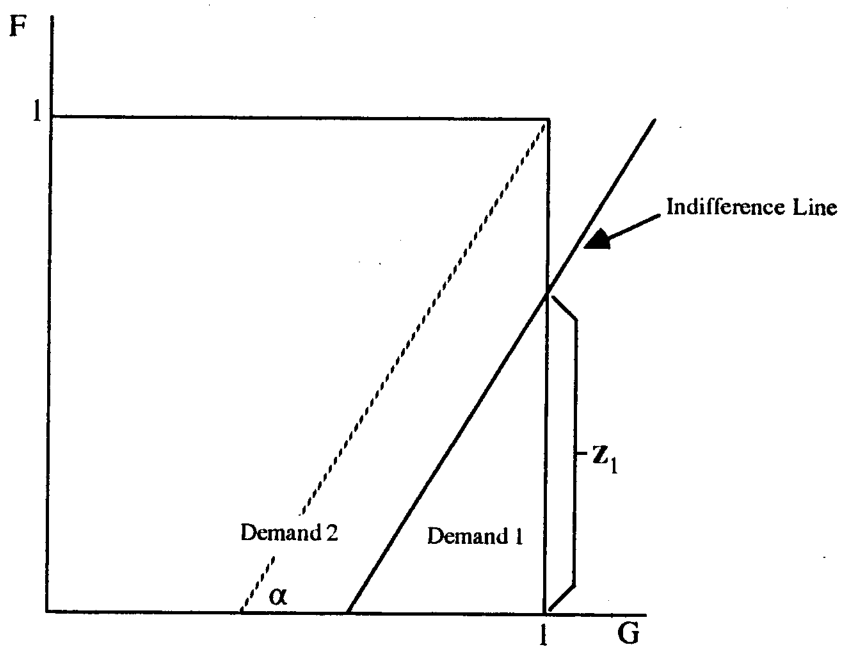


Figure 2.9: Determination of Demand in R_x^1

is used to calculate D_1^1. Since $\cot\alpha = \frac{(\text{base})}{(\text{height})}$, D_1^1 can be defined as

$$\begin{aligned} D_1^1 &= \frac{1}{2}(z_1)^2 \cot\alpha \\ D_1^1 &= \frac{1}{2}\left(\frac{\hat{p}_2 - p_1 + j + mk\boldsymbol{a}}{m\boldsymbol{b}}\right)^2 \cot\alpha \end{aligned} \quad (2.13)$$

From (2.13), it can be seen that demand depends on both prices and product positions.

In R_x^2, let z_2 represents the location of p_1 on the price continuum from p_1^m to p_1^n. In the space defining the consumer types, z_2 is the proportion of the distance from (1,1) to the point where the indifference line at $p_1 = p_1^n$ meets the top edge of the consumer types (see Figure 2.10). Demand for firm 1 in this region, D_1^2, is the maximum area of R_x^1 plus the relevant proportion of R_x^2. The equations for z_2 and D_1^2 are:

$$z_2 = \frac{p_1^m - p_1}{p_1^m - p_1^n} = \frac{\hat{p}_2 - p_1 + j - m\boldsymbol{b} + mk\boldsymbol{a}}{mk\boldsymbol{a} - m\boldsymbol{b}} \quad (2.14)$$

$$D_1^2 = \frac{1}{2}\cot\alpha + \left(1 + \frac{\hat{p}_2 - p_1 + j}{mk\boldsymbol{a} - m\boldsymbol{b}}\right)(1 - \cot\alpha) \quad (2.15)$$

The procedures used to calculate the demand in the other regions apply to R_x^3 as well. Let z_3 represents the location of p_1 on the price continuum from p_1^n to p_1^l. In the space defining the consumer types, z_3 is the proportion of the distance from the point where the indifference line at $p_1 = p_1^n$ meets the left edge of the consumer types to (0,1) (see Figure 2.11). Demand for firm 1 in this region,D_1^3, the maximum area of R_x^1 and R_x^2 plus the relevant proportion of R_x^3. The equations for z_3 and D_1^3 are:

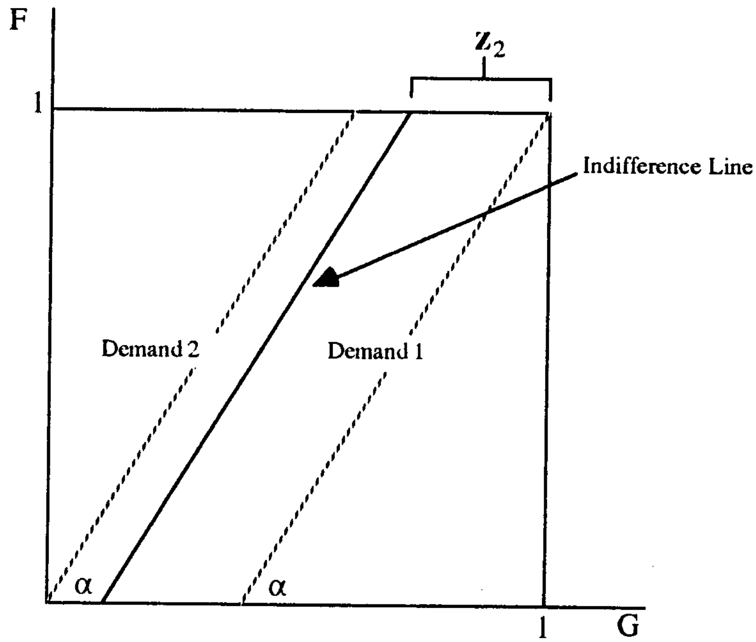


Figure 2.10: Determination of Demand in R_x^2

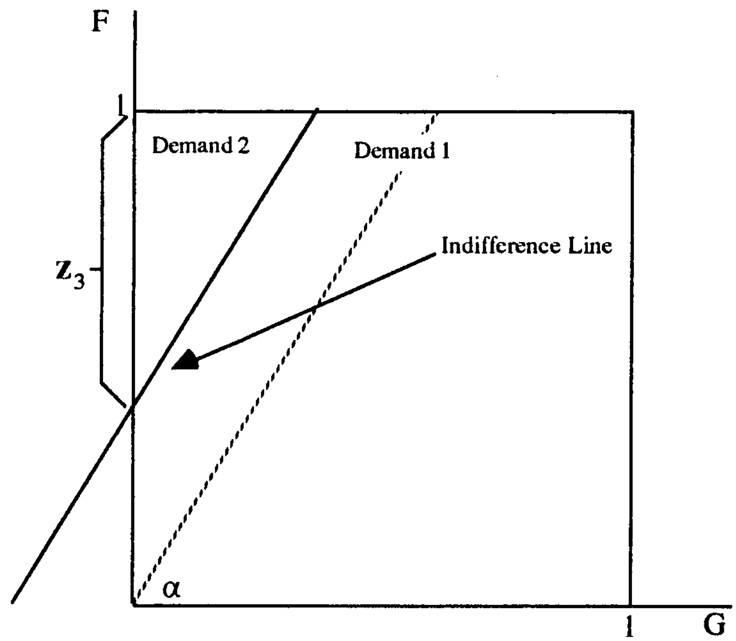


Figure 2.11: Determination of Demand in R_x^3

$$z_3 = \frac{p_1^n - p_1}{p_1^n - p_1^l} = \frac{\hat{p}_2 - p_1 + j}{mb} \tag{2.16}$$

$$D_1^3 = 1 - \frac{1}{2}\cot\alpha + \frac{1}{2}\left(\frac{\hat{p}_2 - p_1 + j}{mb}\right)^2 \cot\alpha \tag{2.17}$$

Price Equilibria

Combining equations (2.13), (2.15) and (2.17), the demand for firm 1 as a function of p_1 can be determined. Since it is assumed that all consumers buy, the demand for firm 2 is simply $1 - D_1$. Both of these curves are shown in Figure 2.12. Each demand curve is comprised of a convex, linear and concave segment (corresponding to the regions defined above). Therefore, one of three possible price equilibria may result under characteristic x dominance. These equilibria will be denoted by the price regions in which the equilibria lie:[4] strictly convex segment of firm 1's demand curve– strictly concave segment of firm 2's demand curve (R_x^1); linear segments of firm 1's and firm 2's demand curves (R_x^2); and, strictly concave segment of firm 1's demand curve– strictly convex segment of firm 2's demand curve (R_x^3).

Since costs are assumed to be constant (and zero) regardless of position, the profit function for firm i ($i = 1, 2$) is defined as $\Pi_i(p_i, p_j) = p_i D_i(p_i, p_j)$ for $i \neq j$. A noncooperative (or Nash) price equilibrium is a pair of prices (p_i^*, p_j^*) such that:

$$\Pi_i(p_i^*, p_j^*) \geq \Pi_i(p_i, p_j^*), \qquad \forall \quad p_i \geq 0;\ i, j = 1, 2\ ;\ \text{and, } i \neq j$$

Analysis of the price equilibria will proceed by considering each of the regions starting with region 2. The mathematical proofs are contained in Appendix A. In R_x^2, the demand

[4] An analysis from the perspective of firm 2 shows that the same regions apply for both firms.

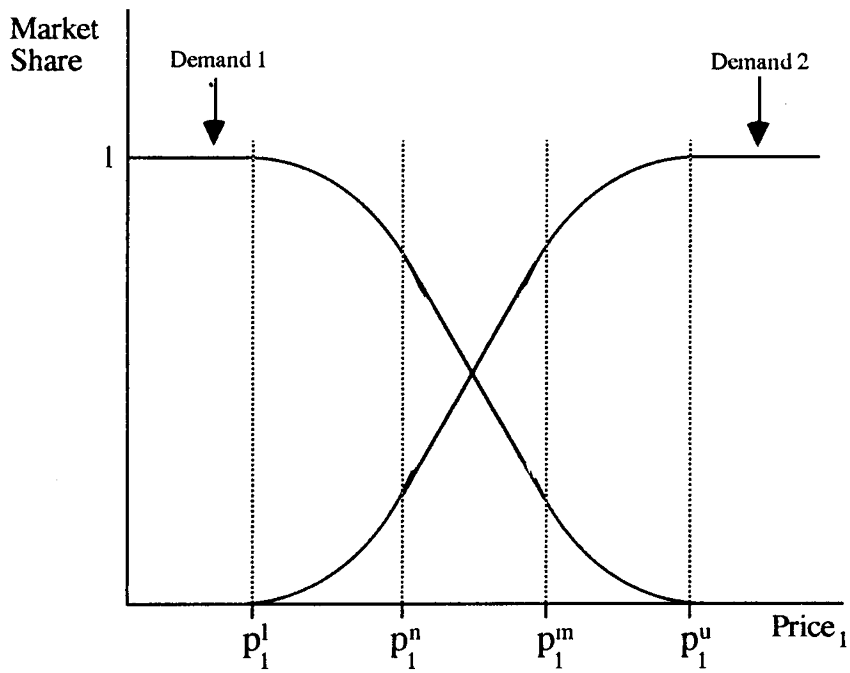


Figure 2.12: Demand as a Function of p_1 (given p_2) Under Characteristic x Dominance

equations for the two firms are linear in prices. This results in profit functions for the two firms which are quadratic in prices and first order conditions of the profit functions which are linear in prices. The first order conditions of the profit functions have a single solution given by:

$$p_1^* = \frac{4mk\boldsymbol{a} - m\boldsymbol{b} + 2j}{6} \tag{2.18}$$

$$p_2^* = \frac{2mk\boldsymbol{a} + m\boldsymbol{b} - 2j}{6} \tag{2.19}$$

Since the first order conditions are necessary, these prices are the price equilibrium prices provide they belong to the intervals defining R_x^2. These intervals are:

$$p_1^* \in [p_1^n(p_2^*), p_1^m(p_2^*)]$$

and

$$p_2^* \in [p_2^n(p_1^*), p_2^m(p_1^*)]$$

These restrictions yield two conditions which must be satisfied for equations (2.18) and (2.19) to represent the price equilibrium in R_x^2. First, $p_1^* \geq p_1^n(p_2^*)$ (as given by equation 2.10) is satisfied when:

$$mk\boldsymbol{a} - m\boldsymbol{b} \geq j \tag{A}$$

Second, $p_1^* \leq p_1^m(p_2^*)$ (as given by equation 2.9) is satisfied when:

$$2(m\boldsymbol{b} - mk\boldsymbol{a}) \leq j \qquad (B)$$

By reformulating the pricing equations, it can be shown that $p_2^* \in [p_2^n(p_1^*), p_2^m(p_1^*)]$ only when both conditions (A) and (B) are satisfied.

In region R_x^1, the demand equations for the two firms are quadratic in prices. This results in profit functions for the two firms which are cubic in prices. The first order condition for firm 1's profit function is a quadratic in p_1. This equation can be factored into the following two roots:

$$p_1 = p_2 + j + mk\boldsymbol{a} \qquad (2.20)$$

and

$$p_1 = \frac{p_2 + j + mk\boldsymbol{a}}{3} \qquad (2.21)$$

The root defined in (2.20) is equal to equation (2.8), the price at which demand equals zero. Therefore the second root is used in the equilibrium calculation. Substituting (2.21) into the first order condition of firm 2 yields:

$$4p_2^2 + p_2(5j + 5mk\boldsymbol{a}) + (j + mk\boldsymbol{a})^2 - \frac{9}{2}m^2k\boldsymbol{a}\boldsymbol{b} = 0 \qquad (2.22)$$

The function defined in (2.22) is quadratic in p_2. The larger of the two roots maximizes Π_2 ($\frac{\partial^2 \pi_2}{\partial p_2^2} \leq 0$ only for the larger root). Solving for this root and substituting this value of p_2 into (2.21) yields the following price equilibrium:

$$p_1^\star = \frac{j + mk\boldsymbol{a} + \sqrt{(j + mk\boldsymbol{a})^2 + 8m^2k\boldsymbol{ab}}}{8} \tag{2.23}$$

$$p_2^\star = \frac{-5j - 5mk\boldsymbol{a} + 3\sqrt{(j + mk\boldsymbol{a})^2 + 8m^2k\boldsymbol{ab}}}{8} \tag{2.24}$$

The price equilibrium in region R_x^1 defined by (2.23) and (2.24) is valid provided $p_1^\star \geq p_1^m(p_2^\star)$ and $p_2^\star \geq p_2^m(p_1^\star)$. These inequalities are satisfied when condition (B) is violated or holds with equality. Condition (A) will continue to hold as will characteristic x dominance. Notice that when condition (B) holds with equality, $p_1^* = p_1^\star$ and $p_2^* = p_2^\star$.[5] This indicates that equilibrium prices move continuously when parameters change such that the equilibrium moves from region R_x^2 to R_x^1.

In region R_x^3, the first order conditions of the profit functions are quadratic in prices. The price equilibrium is not easily derived in this region as neither of the first order conditions factor into simple functional forms. The exact solution has not been calculated as it is not required for the determination of the product equilibrium solutions. This is due to the arbitrary choice of firm numbers. Region R_x^1 from the perspective of firm 2 is identical to region R_x^3 from the perspective of firm 1.

[5]Note the equilibrium price notation. In region R_x^2, equilibrium prices are denoted by an asterisk (*) whereas in region R_x^1, equilibrium prices are denoted by a star (*). As defined below, the price equilibrium in region R_y^2 is denoted by a double asterisk (**).

2.4.2 Characteristic y Dominance

Demand Analysis

The assessment of demand under characteristic y dominance proceeds in much the same manner as the analysis for characteristic x dominance. Under characteristic y dominance, the angle of competition (α) is less than 45° (see Figure 2.13). This implies that $k(a_1 - a_2) \leq (b_2 - b_1)$. The same price equations hold (equations 2.8-2.11) but now

$$p_1^u > p_1^n \geq p_1^m > p_1^l$$

since as firm 1 decreases its price from p_1^u (given p_2), the indifference line passes through the origin before it passes through point (1, 1). Using the same procedure as outlined under characteristic x dominance, demand in each of the regions can be defined as a function of prices and α.

In R_y^1, the possible prices that can be charged by firm 1 can be viewed as a continuum from p_1^u to p_1^n. Let z_4 represent the proportion of the distance p_1 is from the p_1^u end of the continuum. At $p_1 = p_1^u, z = 0$ and at $p_1 = p_1^n, z_4 = 1$. In the space defining the consumer types, z_4 represents the distance from the (1, 0) to the point where the indifference line meets the horizontal axis in the "square" of consumer types (see Figure 2.14). Mathematically z_4 is defined as follows:

$$z_4 = \frac{p_1^u - p_1}{p_1^u - p_1^n} = \frac{\hat{p}_2 - p_1 + j + mka}{mka} \tag{2.25}$$

The demand for firm 1 in R_y^1, D_1^1, is the triangle formed by the indifference line and the edges of consumer types. Using the fact that $\tan\alpha = \frac{\text{height}}{\text{base}}$ and $z_4 = \text{base}$,

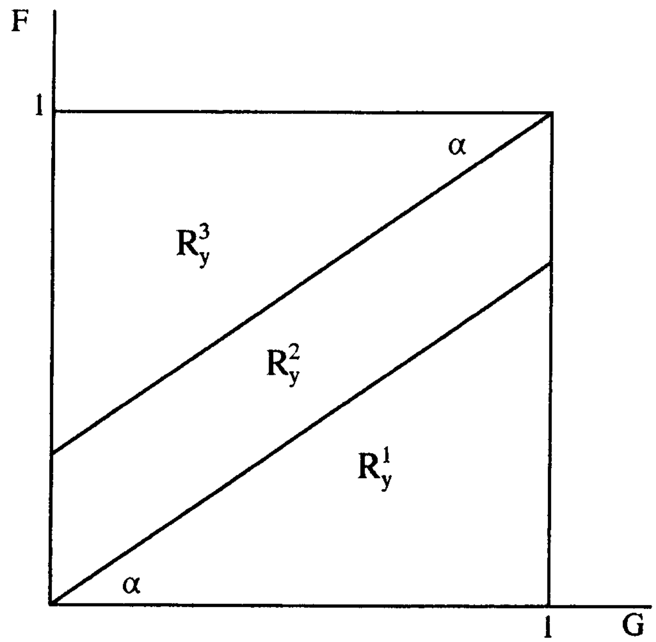


Figure 2.13: Three Demand Regions Under Characteristic y Dominance

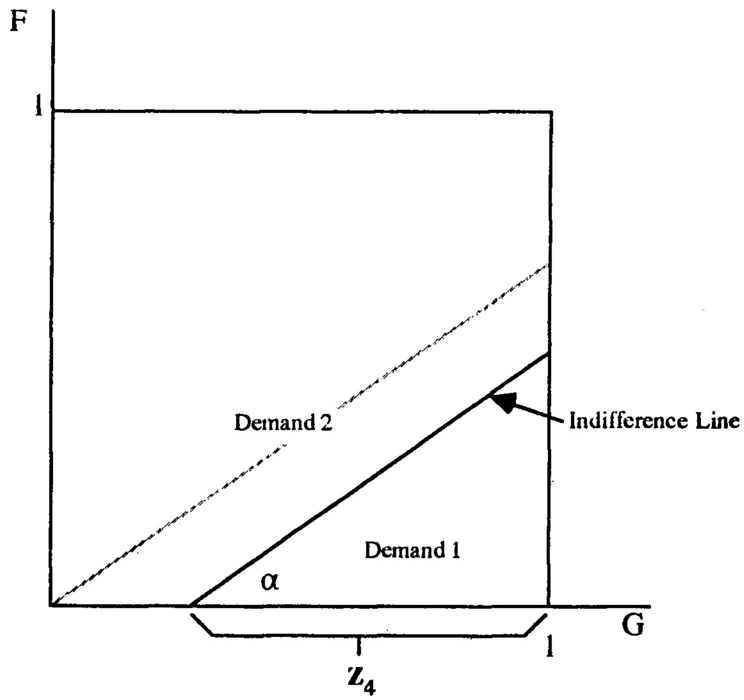


Figure 2.14: Determination of Demand in R_y^1

$$D_1^1 = \frac{1}{2}(z_4)^2 \tan\alpha$$

$$D_1^1 = \frac{1}{2}\left(1 + \frac{\hat{p}_2 - p_1 + j + mk\boldsymbol{a}}{mk\boldsymbol{a}}\right)^2 \tan\alpha \tag{2.26}$$

In a similar manner, the demand for firm 1 in R_y^2 and R_y^3 can be calculated. The resulting demand equations are:

$$D_1^2 = \frac{1}{2}\tan\alpha + \left(\frac{\hat{p}_2 - p_1 + j}{m\boldsymbol{b} - mk\boldsymbol{a}}\right)(1 - \tan\alpha) \tag{2.27}$$

$$D_1^3 = 1 - \frac{1}{2}\tan\alpha + \frac{1}{2}\left(\frac{\hat{p}_2 - p_1 + j + m\boldsymbol{b} + mk\boldsymbol{a}}{mk\boldsymbol{a}}\right)^2 \tan\alpha \tag{2.28}$$

Price Equilibria

Equations (2.26), (2.27) and (2.28) define the demand for firm 1 as a function of p_1. The demand for firm 2 is simply $1 - D_1$. These demand curves have the same shape and properties of the demand curves defined under characteristic x dominance (see Figure 2.12). The determination of the price equilibrium proceeds in the same manner as well.. The mathematical proofs are contained in Appendix A. Since costs are assumed to be zero regardless of position, the profit function for firm i ($i = 1, 2$) is defined as $\Pi_i(p_i, p_j) = p_i D_i(p_i, p_j)$ for $i \neq j$. A noncooperative price equilibrium is a pair of prices (p_i^*, p_j^*) such that:

$$\Pi_i(p_i^*, p_j^*) \geq \Pi_i(p_i, p_j^*), \qquad \forall \quad p_i \geq 0;\ i, j = 1, 2\ ;\ \text{and, } i \neq j$$

In R_y^2, the demand equations for the two firms are linear in prices. The first order conditions of the profit functions have a single solution given by:

$$p_1^{**} = \frac{2m\boldsymbol{b} + mk\boldsymbol{a} + 2j}{6} \tag{2.29}$$

$$p_2^{**} = \frac{4m\boldsymbol{b} - mk\boldsymbol{a} - 2j}{6} \tag{2.30}$$

Since the first order conditions are necessary, these prices are the price equilibrium prices provide they belong to the intervals defining R_y^2. These intervals are:

$$p_1^{**} \in [p_1^m(p_2^{**}), p_1^n(p_2^{**})]$$

and

$$p_2^{**} \in [p_2^m(p_1^{**}), p_2^n(p_1^{**})]$$

These restrictions yield two conditions which must be satisfied for equations (2.29) and (2.30) to represent the price equilibrium in R_y^2. First, $p_1^{**} \geq p_1^m(p_2^{**})$ (as given by equation 2.9) is satisfied when:

$$2(m\boldsymbol{b} - mk\boldsymbol{a}) \geq j \qquad (C)$$

Second, $p_1^{**} \leq p_1^n(p_2^{**})$ (as given by equation 2.10) is satisfied when:

$$mka - mb \leq j \qquad (D)$$

By reformulating the pricing equations, it can be shown that $p_2^{**} \in [p_2^n(p_1^{**}), p_2^m(p_1^{**})]$ only when both conditions (C) and (D) are satisfied. Notice that conditions (C) and (D) are the reverse of (B) and (A) respectively.

In R_y^1, it can be shown that the demand equations for the two firms are identical to the demand equations in R_x^1 ((2.26)=(2.13)). Therefore, the price equilibrium solution in this region is identical as well. This price equilibrium is defined by (2.23) and (2.24) and is valid provided $p_1^* \geq p_1^n(p_2^*)$ and $p_2^* \geq p_2^n(p_1^*)$. These inequalities are satisfied when condition (D) is violated or holds with equality. Notice that condition (C) will continue to hold as will characteristic y dominance. Similar to the analysis for characteristic x dominance, when condition (D) holds with equality, $p_1^{**} = p_1^*$ and $p_2^{**} = p_2^*$. This indicates that equilibrium prices move continuously when parameters move between R_y^2 and R_y^1.

In R_y^3, the first order conditions of the profit functions are quadratic in prices. The price equilibrium is not easily derived in this region as neither of the first order conditions factor into simple functional forms. The exact solution has not been calculated as it is not required for the determination of the product equilibrium solutions.

2.4.3 Dominated Characteristics Competition

As was outlined earlier, the two-dimensional horizontal differentiation model and the mixed model can always be set up to conform with asymmetric characteristics competition. However, the two- dimensional vertical differentiation model allows for dominated characteristics competition. As the generalized price equilibrium analysis assumes asymmetric characteristics competition, the dominated characteristics case for the vertical model must be analyzed separately. This section will outline the demand analysis and price equilibria for both characteristic x dominance and characteristic y dominance for the dominated characteristics case of the vertical model.

Characteristic x Dominance

The dominated characteristics case is analyzed in much the same way as the asymmetric characteristics case. The general form of the indifference line (defined in (2.7)) applies as do the key price levels defined in (2.8)-(2.11). Since the dominated characteristics analysis is only required for the vertical model, the parameters $k = 1$, $m = 1$ and $j = 0$ are substituted into these equations. The modified versions of the indifference line and key prices are:

$$F(G) = \frac{(p_2 - p_1)}{\boldsymbol{b}} + \frac{\boldsymbol{a}}{\boldsymbol{b}}G \tag{2.31}$$

where:

firm i's product is (a_i, b_i)

$\boldsymbol{a} = (a_1 - a_2)$

$\boldsymbol{b} = (b_2 - b_1)$

$$p_1^u = \hat{p}_2 + \boldsymbol{a} \tag{2.32}$$

$$p_1^m = \hat{p}_2 + \boldsymbol{a} - \boldsymbol{b} \tag{2.33}$$

$$p_1^n = \hat{p}_2 \tag{2.34}$$

$$p_1^l = \hat{p}_2 - \boldsymbol{b} \tag{2.35}$$

Without loss of generality, it is assumed that firm 2's product is dominant. That is, $a_2 \geq a_1$ and $b_2 \geq b_1$. This implies that $\boldsymbol{a} = (a_1 - a_2) \leq 0$ and slope of the indifference curve is negative. Under characteristic x dominance, $90° \leq \alpha \leq 135°$. Alternatively, the angle of competition can be described by an angle $\beta \geq 45°$ where $\beta = 180° - \alpha$ (see Figure 2.15). This implies that $-(a_1 - a_2) \geq (b_2 - b_1)$. Under these conditions, the ordering of the price equations is:

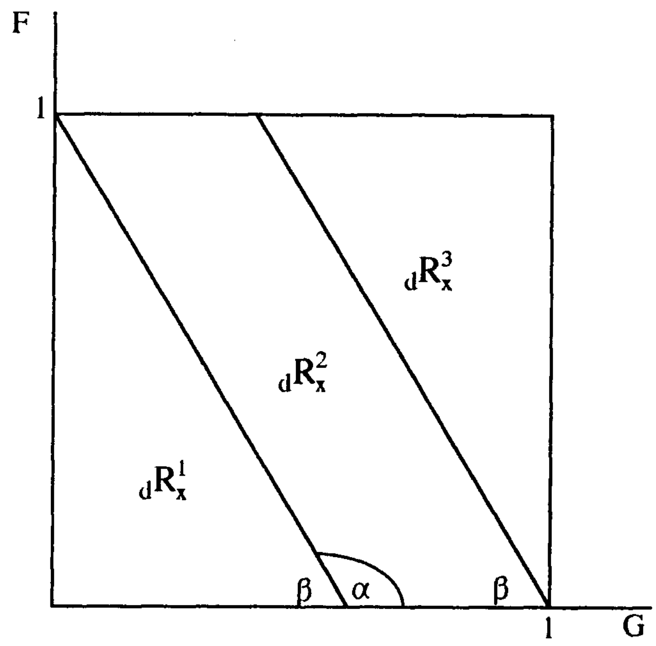
$$p_1^m < p_1^u \leq p_1^l < p_1^n$$

As firm 1 decreases its price from p_1^n, the indifference line shifts upward. Like the asymmetric characteristics case, three distinct demand regions can be defined on the basis of the geometric structure of the model (see Figure 2.15). In region ${}_dR_x^1$, demand for firm 1 increases at an increasing rate. This region is defined by the price range $p_1^l \leq p_1 \leq p_1^n$. In ${}_dR_x^2$, where $p_1^u \leq p_1 \leq p_1^l$, demand for firm 1 increases at a constant rate. Finally, in ${}_dR_x^3$, where $p_1^m \leq p_1 \leq p_1^u$, the demand for firm 1 increases at a decreasing rate.

Using the same analytical techniques as described in the asymmetric characteristics case, the price equilibrium solutions in ${}_dR_x^2$ and ${}_dR_x^1$ are determined. Appendix A contains the mathematical proofs.

In ${}_dR_x^2$, the price equilibrium is defined by:

$$p_1^{***} = \frac{-2\boldsymbol{a} - \boldsymbol{b}}{6} \tag{2.36}$$



Note: The demand for firm 1 is the area below the Indifference Line

Figure 2.15: Three Demand Regions Under Dominated Characteristics Competition

$$p_2^{***} = \frac{-4\boldsymbol{a} + \boldsymbol{b}}{6} \tag{2.37}$$

This equilibrium is valid provided

$$p_1^{***} \in \left[p_1^u(p_2^{***}), p_1^l(p_2^{***})\right]$$

and

$$p_2^{***} \in \left[p_2^u(p_1^{***}), p_2^l(p_1^{***})\right]$$

These restrictions yield two conditions. First, $p_1^{***} \geq p_1^u(p_2^{***})$ is satisfied when:

$$-2\boldsymbol{a} \geq \boldsymbol{b} \qquad (E)$$

Second, $p_1^{***} \leq p_1^l(p_2^{***})$ is satisfied when:

$$2\boldsymbol{b} \leq -\boldsymbol{a} \qquad (F)$$

By reformulating the pricing equations, it can be shown that $p_2^{***} \in \left[p_2^u(p_1^{***}), p_2^l(p_1^{***})\right]$ only when both conditions (E) and (F) are satisfied.

In ${}_dR_x^1$, the price equilibrium is defined by:

$$p_1^{***} = \frac{\sqrt{-8\boldsymbol{ab}}}{8} \tag{2.38}$$

$$p_2^{\star\star\star} = \frac{3\sqrt{-8ab}}{8} \tag{2.39}$$

This price equilibrium is valid provided $p_1^{\star\star\star} \geq p_1^l(p_2^{\star\star\star})$ and $p_2^{\star\star\star} \geq p_2^l(p_1^{\star\star\star})$. These inequalities are satisfied when condition (F) is violated or holds with equality. Condition (E) will continue to hold as will characteristic x dominance. As was the true for the asymmetric characteristics case, when (F) holds with equality, $p_1^{***} = p_1^{\star\star\star}$ and $p_2^{***} = p_2^{\star\star\star}$.[6] This indicates that equilibrium prices move continuously when parameters change such that the equilibrium moves from region ${}_dR_x^2$ to region ${}_dR_x^1$.

The price equilibrium solutions in ${}_dR_x^2$ and ${}_dR_x^1$ illustrate the fact that the firm with dominated product (firm 1) must charge a lower price in order to achieve positive sales.

The price equilibrium in ${}_dR_x^3$ has not been calculated as it is not required for the determination of the product equilibrium solutions.

Characteristic y Dominance

Characteristic y dominance in the dominated characteristics case follows the same pattern established in previous sections. The complete derivation of the price equilibria is given in Appendix A. In this case, $\beta \leq 45°$. This implies that $-(a_1 - a_2) \leq (b_2 - b_1)$ The price equations (2.32)-(2.35) hold but

$$p_1^m < p_1^l \leq p_1^u < p_1^n$$

In ${}_dR_y^2$, the price equilibrium is defined by:

[6] Note the equilibrium price notation. Similar to the ***asymmetric characteristics*** case, In region ${}_dR_x^2$, equilibrium prices are denoted by a triple asterisk (***) whereas in region ${}_dR_x^1$, equilibrium prices are denoted by a triple star (***). As defined below, the price equilibrium in region ${}_dR_y^2$ is denoted by a quadruple asterisk (****).

$$p_1^{****} = \frac{2\boldsymbol{b} + \boldsymbol{a}}{6} \tag{2.40}$$

$$p_1^{****} = \frac{4\boldsymbol{b} - \boldsymbol{a}}{6} \tag{2.41}$$

This equilibrium is valid provided

$$p_1^{***} \in \left[p_1^l(p_2^{***}), p_1^u(p_2^{***})\right]$$

and

$$p_2^{***} \in \left[p_2^l(p_1^{***}), p_2^u(p_1^{***})\right]$$

These restrictions yield two conditions. First, $p_1^{***} \geq p_1^l(p_2^{***})$ is satisfied when:

$$-2\boldsymbol{a} \leq \boldsymbol{b} \qquad (G)$$

Second, $p_1^{***} \leq p_1^u(p_2^{***})$ is satisfied when:

$$2\boldsymbol{b} \geq -\boldsymbol{a} \qquad (H)$$

These conditions are simply the reverse of conditions (E) and (F).

In ${}_dR_y^1$, the demands equations for each firm are identical to those derived in ${}_dR_x^1$. Therefore the price equilibrium defined by equations (2.38) and (2.39) apply in this region as well.

This price equilibrium is valid provided condition (H) is violated or holds with equality. Condition (G) will continue to hold as will characteristic y dominance. In addition, when (H) holds with equality, $p_1^{****} = p_1^{***}$ and $p_2^{****} = p_2^{***}$.

In both ${}_dR_y^2$ and ${}_dR_y^1$, because it controls the dominated product, the equilibrium price for firm 1 is less than than the equilibrium price for firm 2. The price equilibrium in ${}_dR_y^3$ has not been calculated as it is not required for the determination of the product equilibrium solutions.

2.5 Product Equilibrium for the Two-Dimensional Vertical Model

Once the equilibrium prices have been established, it is possible to analyze the firms' positioning choices. Since the parameters used in the price equilibrium analysis vary by model, the three differentiation models will be analyzed separately. This section will describe the two-dimensional vertical model.

Because the perfect Nash equilibrium solution is used, the firms' choice of product positions is dependent on the set of equilibrium prices. This requires an analysis of the each of the possible price equilibria. For the two-dimensional vertical model, this includes both the asymmetric and dominated characteristics cases. To understand the nature of the product equilibrium, it is important to understand how changes in product positions affect equilibrium prices.

2.5.1 Asymmetric Characteristics

In the asymmetric characteristics case, conditions (A)-(D) define the boundaries of the various price equilibria (see section 2.4). By substituting the parameter values pertaining to the vertical model ($j = 0, m = 1, k = 1$), (A)-(D) can be restated as follows:

$$(b_2 - b_1) \leq (a_1 - a_2) \qquad (A_V)$$

$$(b_2 - b_1) \leq (a_1 - a_2) \qquad (B_V)$$

$$(b_2 - b_1) \geq (a_1 - a_2) \qquad (C_V)$$

$$(b_2 - b_1) \geq (a_1 - a_2) \qquad (D_V)$$

Note that (A_V) and (B_V) are equal and that (C_V) and (D_V) are equal and the reverse sign of (A_V) and (B_V). By altering the values of a_1, a_2, b_1 and b_2, it is possible to determine the relevant price equilibrium regions for use in the product positioning subgame.

Consider the situation where a_1 and a_2 are given ($a_1 > a_2$) and b_2, b_1 are varied.

1. When $b_2 = b_1$, characteristic x dominance holds and conditions (A_V) and (B_V) are satisfied. The price equilibrium is in R_x^2.

2. As $(b_2 - b_1)$ is increased (by either raising b_2 or lowering b_1), $(b_2 - b_1)$ will eventually become larger than $(a_1 - a_2)$ so characteristic y dominance will hold. A and B are violated and (C_V) and (D_V) hold. The price equilibrium is in R_y^2.

Now consider the situation where b_1, and b_2 are given and a_1, a_2 are varied.

1. When $a_1 = a_2$, characteristic y dominance holds and conditions (C_V) and (D_V) are satisfied. The price equilibrium is in R_y^2.

2. When $(a_1 - a_2)$ is increased, $(a_1 - a_2)$ will become larger than $(b_2 - b_1)$ so characteristic x dominance will hold. (A_V) and (B_V) become satisfied and the price equilibrium will be in R_x^2.

Several points are worth noting. First, the sequences described above can be terminated at any step depending of the range of possible product positions. For example, the allowable increase in b_2 (given b_1, a_1 and a_2) may be restricted by the maximum level of b, (y^{max}). Second, since (A_V)=(B_V) (and (C_V)=(D_V)), the relevant regions for the price equilibrium move directly from R_x^2 to R_y^2. In this model, the optimal positioning equilibrium will not occur in R_x^1, R_y^1, R_x^3 or R_y^3. Finally, since both the demand functions and the equilibrium prices are continuous across regions, it follows that the profit functions are continuous as well.

The above analysis indicates that the profit functions in R_x^2 and R_y^2 must be considered in the derivation of the product equilibrium. In R_x^2, the demand for firm 1 is given by (2.15) and the equilibrium price is given by (2.18). Substituting the vertical model parameters yields

$$\Pi_1^* = \frac{(4\boldsymbol{a} - \boldsymbol{b})^2}{36\boldsymbol{a}} \tag{2.42}$$

For firm 2, the demand is given by $D_2^2 = 1 - D_1^2$ and the equilibrium price is given by (2.19). This yields a profit of

$$\Pi_2^* = \frac{(2\boldsymbol{a} + \boldsymbol{b})^2}{36\boldsymbol{a}} \tag{2.43}$$

In R_y^2, the demand for firm 1 is given by (2.27) while the demand for firm 2 is $1 - D_1^2$. The equilibrium prices for the two firms are given by (2.29) and (2.30). Combining these equations yield the firms' profit functions in R_y^2:

$$\Pi_1^{**} = \frac{(2\boldsymbol{b} + \boldsymbol{a})^2}{36\boldsymbol{b}} \tag{2.44}$$

$$\Pi_1^{**} = \frac{(4\boldsymbol{b} - \boldsymbol{a})^2}{36\boldsymbol{b}} \tag{2.45}$$

2.5.2 Dominated Characteristics

In the dominated characteristics case, conditions (E)-(H) define the boundaries of the various price equilibria (see section 2.4.3). By altering the values of a_1, a_2, b_1 and b_2, the relevant price equilibrium regions for use in the product positioning subgame can be determined.

Consider the situation where a_1 and a_2 are given ($a_2 > a_1$) and b_2, b_1 are varied.

1. When $b_2 = b_1$, characteristic x dominance holds and (E) and (F) are satisfied. The price equilibrium is in ${}_dR_x^2$.
2. As $(b_2 - b_1)$ is increased, condition (F) is the first to fail, but characteristic x dominance still holds. The price equilibrium is in ${}_dR_x^1$.
3. $(b_2 - b_1)$ can be increased until characteristic y dominance holds. Since (E) still holds, the price equilibrium is in ${}_dR_y^1$.
4. Finally, $(b_2 - b_1)$ can be increased until (E) fails. Now (G) and (H) hold and the price equilibrium is in ${}_dR_y^2$.

Similar to the asymmetric characteristics case, the reverse procedure of varying $(a_2 - a_1)$ and holding b_1 and b_2 constant yields the same relevant regions.

As with the asymmetric characteristics case, several points are worth noting. First, the sequence described above can be terminated at any step depending of the range of possible product positions. Second, since (E)$\neq$ (F) (and (G)$\neq$(H)), there are 4 relevant regions for the price equilibrium which need to be considered: ${}_dR_x^2$, ${}_dR_x^1$, ${}_dR_y^1$ and${}_dR_y^2$. The product equilibrium will not occur in ${}_dR_x^3$ or ${}_dR_y^3$. Finally, since both the demand functions and the equilibrium prices are continuous across regions, it follows that the profit functions are continuous as well.

The profit functions for the relevant regions are as follows (see Appendix A for details). In ${}_dR_x^2$,

$$\Pi_1^{***} = \frac{(-2\boldsymbol{a} - \boldsymbol{b})^2}{-36\boldsymbol{a}} \tag{2.46}$$

$$\Pi_2^{***} = \frac{(-4\boldsymbol{a} + \boldsymbol{b})^2}{-36\boldsymbol{a}} \tag{2.47}$$

The same demand functions and equilibrium prices for the two firms apply in both ${}_dR_x^1$ and ${}_dR_y^1$. At equilibrium prices (defined by (2.38) and (2.39)), the demand for firm 1 is $\frac{1}{4}$ and the demand for firm 2 is $\frac{3}{4}$ (see Appendix A). The resulting profit functions are:

$$\Pi_1^{***} = \frac{\sqrt{-8\boldsymbol{ab}}}{32} \tag{2.48}$$

$$\Pi_2^{***} = \frac{9\sqrt{-8\boldsymbol{ab}}}{32} \tag{2.49}$$

Finally, in ${}_dR_y^2$, the relevant profit functions are:

$$\Pi_1^{****} = \frac{(2\boldsymbol{b} + \boldsymbol{a})^2}{36\boldsymbol{b}} \tag{2.50}$$

$$\Pi_2^{****} = \frac{(4b - a)^2}{36b} \tag{2.51}$$

2.5.3 Product Equilibria

The product equilibria that are possible in the two-dimensional vertical model are determined by simultaneously comparing all possible price equilibrium regions. Equilibrium solutions occur when neither firm can improve its profits by unilaterally altering its chosen position.

In each of the regions, a two step procedure is used to analyze a firm's optimal position (subject to the competitor's position). First, the restrictions which determine the range of product positions which are allowable in each region are considered. These include: (i) asymmetric or dominated characteristics; (ii) characteristic x or characteristic y dominance; and (iii) conditions (A_V)-(D_V) and (E)-(H) described above. Second, the derivatives of the relevant profit functions are taken with respect a firm's own characteristics. The signs of these derivatives determine whether a firm's profits are improved by increasing or decreasing a characteristic's positioning value in the range (x_{min}, x^{max}) or (y_{min}, y^{max}) (subject to region restrictions). Following this analysis, the profits in each of the relevant regions are determined.

The signs of the profit function derivatives in the relevant regions are summarized in the following table.

	Firm 1			Firm 2		
Region	Profit Function Equation No.	$\frac{\partial \Pi_1}{\partial a_1}$	$\frac{\partial \Pi_1}{\partial b_1}$	Profit Function Equation No.	$\frac{\partial \Pi_2}{\partial a_2}$	$\frac{\partial \Pi_2}{\partial b_2}$
R_x^2	2.42	>0	>0	2.43	<0	>0
R_y^2	2.44	>0	<0	2.45	>0	>0
${}_dR_x^2$	2.46	>0	>0	2.47	<0	>0
${}_dR_x^1$ or ${}_dR_y^1$	2.48	<0	<0	2.49	>0	>0
${}_dR_y^2$	2.50	>0	<0	2.51	>0	>0

There are four possible product equilibrium solutions in the two-dimensional vertical model. These solutions are defined and proven in *Propositions 1* to *4*.

Proposition 1: If $(x^{\max} - x_{\min}) \leq \frac{128}{81}(y^{\max} - y_{\min})$, *there exists a product equilibrium such that*

$$a_1 = x^{\max} \qquad a_2 = x^{\max}$$

$$b_1 = y_{\min} \qquad b_2 = y^{\max}$$

Proof:

I Consider Firm 1 and assume $a_2 = x^{\max}, b_2 = y^{max}$.

(i) In R_x^2, since $a_1 - a_2, \geq b_2 - b_1$, the only response for firm 1 is $a_1 = x^{\max}, b_1 = y^{\max}$. This results in a zero profit.

(ii) In R_y^2, the best response is $a_1 = x^{\max}, b_1 = y_{\min}$.

This results on a profit of

$$\Pi_1^{**} = \frac{y^{\max} - y_{\min}}{9} \tag{2.52}$$

(iii) In ${}_dR_x^2$, the best response is $a_1 = x^{\max}, b_1 = y_{\min}$. This results in a zero profit.

(iv) In ${}_dR_x^1$, and ${}_dR_y^1$, the best response is $a_1 = x_{\min}, b_1 = y_{\min}$

To remain within this region, this response is only valid when $x^{\max} - x_{\min} \in [\frac{1}{2}(y^{\max} - y_{\min}), 2(y^{\max} - y_{\min})]$ as conditions (E) and (G) must hold.

This results in a profit of

$$\Pi_1^{***} = \frac{\sqrt{8(x^{\max} - x_{\min})(y^{\max} - y_{\min})}}{32} \tag{2.53}$$

When $(x^{\max} - x_{\min}) > 2(y^{\max} - y_{\min})$, the best response for firm 1 in this region is to choose $b_1 = y_{\min}$ and $a_1 = x^{\max} - 2(y^{\max} - y_{\min})$.

This results in a profit of

$$\Pi_1^{***} = \frac{y^{\max} - y_{\min}}{8} \tag{2.54}$$

(v) In ${}_dR_y^2$, the best response is $a_1 = x^{\max}, b_1 = y_{\min}$. This results in a profit of

$$\Pi_1^{****} = \frac{y^{\max} - y_{\min}}{9}$$

This is the same strategy as in R_y^2 and yields the same profit.

(vi) Compare (2.52) and (2.53)

Firm 1 will choose $a_1 = x^{\max}, b_1 = y_{\min}$ when

$$\frac{y^{\max} - y_{\min}}{9} \geq \frac{\sqrt{8(x^{\max} - x_{\min})(y^{\max} - y_{\min})}}{32}$$

which reduces to,

$$(x^{\max} - x_{\min}) \leq \frac{128}{81}(y^{\max} - y_{\min}) \tag{2.55}$$

II Now consider Firm 2 and assume $a_1 = x^{\max}, b_1 = y_{\min}$.

(i) In R_x^2, the best response for firm 2 is $a_2 = x_{\min}, b_2 = y^{\max}$. This response is valid as long as $(x^{\max} - x_{\min}) \geq (y^{\max} - y_{\min})$. If this condition is not true, the best response for firm 2 is $a_2 = x_{\min}$ and $b_2 = y^{\max} - (x^{\max} - x_{\min})$.

The profits associated with these responses are maximized when the above condition holds with equality. This results in a profit of

$$\Pi_2^{*} = \frac{x^{\max} - x_{\min}}{4} \tag{2.56}$$

(ii) In R_y^2, the best response for firm 2 is $a_2 = x^{\max}, b_2 = y^{\max}$.

This results in a profit of

$$\Pi_2^{***} = \frac{4(y^{\max} - y_{\min})}{9} \tag{2.57}$$

(iii) In ${}_dR_x^2$, since $a_2 \geq a_1$ and $(a_2 - a_1) \geq (b_2 - b_1)$, the only response in this region is $a_2 = x^{\max}, b_2 = y_{\min}$. This results in a zero profit.

(iv) In ${}_dR_x^1$ and ${}_dR_y^1$, the best response is $a_2 = x^{\max}, b_2 = y^{\max}$. This results in a zero profit. It is also the same strategy as R_y^2.

(v) In ${}_dR_y^2$, the best response is $a_2 = x^{\max}, b_2 = y^{\max}$

This results in a profit of

$$\Pi_2^{****} = \frac{4(y^{\max} - y_{\min})}{9}$$

This is the same strategy and profits as in R^2_y.

(vi) Compare (2.56) and (2.57). (2.56) is maximized when $(x^{\max} - x_{\min}) = (y^{\max} - y_{\min})$. Subbing the equality into (2.57) yields

$$\Pi_2^{**} = \frac{4(x^{\max} - x_{\min})}{9}$$

This profit is always greater than (2.56). If $(y^{\max} - y_{\min}) > (x^{\max} - x_{\min})$, (2.57) becomes relatively larger when compared with (2.56).

III The only condition on the product equilibrium of

$$a_1 = x^{\max} \qquad a_2 = x^{\max}$$

$$b_1 = y_{\min} \qquad b_2 = y^{\max}$$

is (2.55) which requires $(x^{\max} - x_{\min}) \leq \frac{128}{81}(y^{\max} - y_{\min})$

Proposition 2

(a) *If* $(x^{\max} - x_{\min}) \in \left[\frac{128}{81}(y^{\max} - y_{\min}), 2(y^{\max} - y_{\min})\right]$, *there exists as product equilibrium such that*

$$a_1 = x_{\min} \qquad a_2 = x^{\max}$$

$$b_1 = y_{\min} \qquad b_2 = y^{\max}$$

(b) *If* $(x^{\max} - x_{\min}) > 2(y^{\max} - y_{\min})$, *these exists a product equilibrium such that*

$$a_1 = x^{\max} - 2(y^{\max} - y_{\min}) \qquad a_2 = x^{\max}$$

$$b_1 = y_{\min} \qquad b_2 = y^{\max}$$

Proof:

I Consider firm 1 and assume $a_2 = x^{\max}, b_2 = y^{\max}$

(i) From (2.55), firm 1's best response is $a_1 = x_{\min}, b_1 = y_{\min}$ when

$$(x^{\max} - x_{\min}) \geq \frac{128}{81}(y^{\max} - y_{\min})$$

(ii) When $(x^{\max} - x_{\min}) > 2(y^{\max} - y_{\min})$, the best response for firm 1 in ${}_dR_y^1$ is $a_1 = x^{\max} - 2(y^{\max} - y_{\min}), b_1 = y_{\min}$.

This results in a profit defined in (2.54). This profit is always the largest for firm 1 when compared to the profits generated by other strategies.

II Now consider firm 2 and assume $a_1 = x_{\min}, b_1 = y_{\min}$.

(i) In R_x^2, since $a_1 \geq a_2$ and $a_1 - a_2 \geq b_2 - b_1$, the only response is $a_2 = x_{\min}, b_2 = y_{\min}$. This results in a zero profit.

(ii) In R_y^2, the best response is $a_2 = x_{\max}, b_2 = y^{\max}$ since a restriction is that $a_1 \geq a_2$. This results in a profit of

$$\Pi_2^{**} = \frac{4(y^{\max} - y_{\min})}{9} \tag{2.58}$$

(iii) In ${}_dR_x^2$, the best response is $b_2 = y^{\max}$ and a_2 at the minimum value possible within the region. Since $(a_2 - a_1) \geq (b_2 - b_1)$, this occurs when $a_2 = (y^{\max} - y_{\min}) + x_{\min}$.

This results in a profit of

$$\Pi_2^{***} = \frac{25(y^{\max} - y_{\min})}{36} \tag{2.59}$$

This profit is always greater than (2.58).

(iv) In ${}_dR_x^1$ and ${}_dR_y^1$, the best response is $a_2 = x^{\max}, b_2 = y^{\max}$. This results in profit of

$$\Pi_2^{***} = \frac{9\sqrt{8(x^{\max} - x_{\min})(y^{\max} - y_{\min})}}{32} \tag{2.60}$$

(2.60) is valid if $(x^{\max} - x_{\min}) \in \left[\frac{1}{2}(y^{\max} - y_{\min}), 2(y^{\max} - y_{\min})\right]$

(v) In ${}_dR_y^2$, the best response is $a_2 = x^{\max}, b_2 = y^{\max}$.

This is the same strategy and yields the same profits as in R_y^2.

vi) Compare (2.59) and (2.60). (2.59) is maximized when $(a_2 - x_{\min}) = (y^{\max} - y_{\min})$. Subbing this into (2.60) yields

$$\Pi_2^{***} = \frac{\sqrt{648}}{32}(y^{\max} - y_{\min}) > (2.59).$$

This proves Proposition 2(a).

III Consider firm 2. Assume $(x^{\max} - x_{\min}) > 2(y^{\max} - y_{\min})$ and $a_1 = x^{\max} - 2(y^{\max} - y_{\min}), b_1 = y_{\min}$.

(i) In R_x^2, the best response for firm 2 is the maximum possible value of a_2 and the minimum value of b_2 with the restriction that $(a_1 - a_2) = (b_2 - b_1)$.

This results in a profit of

$$\Pi_2^* = \frac{b_2 - y_{\min}}{4} \tag{2.61}$$

(ii) In ${}_dR_x^2$, the best response for firm 2 occurs when $(a_2 - a_1) = (b_2 - b_1)$ where firm 2 chooses the maximum possible level of b_2 and the minimum level of a_2.

This results in a profit of

$$\Pi_2^{***} = \frac{25}{36}(b_2 - y_{\min}) \tag{2.62}$$

This level of profit is always greater than (2.61).

(iii) In regions $R_y^2, {}_dR_y^2, R_x^1$ and ${}_dR_y^1$, the best response for firm 2 is $a_2 = x^{\max}, b_2 = y^{\max}$.

Since the choice of a_1 assures that ${}_dR_x^1$ and ${}_dR_y^1$ are feasible regions, firm 2's profit is maximized at

$$\Pi_2^{***} = \frac{36}{32}(y^{\max} - y_{\min}) \tag{2.63}$$

(iv) Compare (2.62) and (2.63). In (2.62), the maximum value of b_2 is $y^{\max}$. Thus (2.62) is always less than (2.63). Firm 2 will choose $a_2 = x^{\max}, b_2 = y^{\max}$.

Proposition 3:

If $(x^{\max} - x_{\min}) \geq \frac{81}{128}(y^{\max} - y_{\min})$, *then exists a product equilibrium such that*

$$a_1 = x^{\max} \qquad a_2 = x_{\min}$$
$$b_1 = y^{\max} \qquad b_2 = y^{\max}$$

Proof: The dominated characteristics analysis was conducted with $a_2 \geq a_1$ and $b_2 \geq b_1$. This analysis resulted in Proposition 1 being true. The dominant characteristics analysis with $a_1 \geq a_2$ and $b_1 \geq b_2$, by symmetry, yields Proposition 3. Note that this product equilibrium occurs when the maximum profits are in R_x^2.

Proposition 4:

(a) *If* $(x^{\max} - x_{\min}) \in \left[\frac{1}{2}(y^{\max} - y_{\min}), \frac{81}{128}(y^{\max} - y_{\min})\right]$, *there exists a product equilibrium such that*

$$a_1 = x^{\max} \qquad a_2 = x_{\min}$$
$$b_1 = y^{\max} \qquad b_2 = y_{\min}$$

(b) *If* $(x^{\max} - x_{\min}) < \frac{1}{2}(y^{\max} - y_{\min})$, *there exists a product equilibrium such that*

$$a_1 = x^{\max} \qquad a_2 = x_{\min}$$
$$b_1 = y^{\max} \qquad b_2 = y^{\max} - 2(x^{\max} - x_{\min})$$

Proof: The dominated characteristics analysis was conducted with $a_2 \geq a_1$ and $b_2 \geq b_1$. This analysis resulted in Proposition 2 being true. The dominant characteristics analysis with $a_1 \geq a_2$ and $b_1 \geq b_2$, by symmetry, yields proposition 4.

2.5.4 Summary and Implications

The product equilibria described in *Propositions 1–4* can be summarized as follows (see Figure 2.16):

I If firm 2 is positioned at (x^{max}, y^{max}), there exists an equilibrium where firm 1 is positioned at:

(i) (x^{max}, y_{min}) if $(x^{max} - x_{min}) \leq \frac{128}{81}(y^{max} - y_{min})$

(ii) (x_{min}, y_{min}) if $(x^{max} - x_{min}) \in \left[\frac{128}{81}(y^{max} - y_{min}), 2(y^{max} - y_{min})\right]$

(iii) $(x^{max} - 2(y^{max} - y_{min}), y_{min})$ if $(x^{max} - x_{min}) \geq 2(y^{max} - y_{min})$

II If firm 1 is positioned at (x^{max}, y^{max}), there exists an equilibrium where firm 2 is positioned at:

(i) (x_{min}, y^{max}) if $(x^{max} - x_{min}) \geq \frac{81}{128}(y^{max} - y_{min})$

(ii) (x_{min}, y_{min}) if $(x^{max} - x_{min}) \in \left[\frac{1}{2}(y^{max} - y_{min}), \frac{81}{128}(y^{max} - y_{min})\right]$

(iii) $(x_{min}, y^{max} - 2(x^{max} - x_{min}))$ if $(x^{max} - x_{min}) \leq \frac{1}{2}(y^{max} - y_{min})$

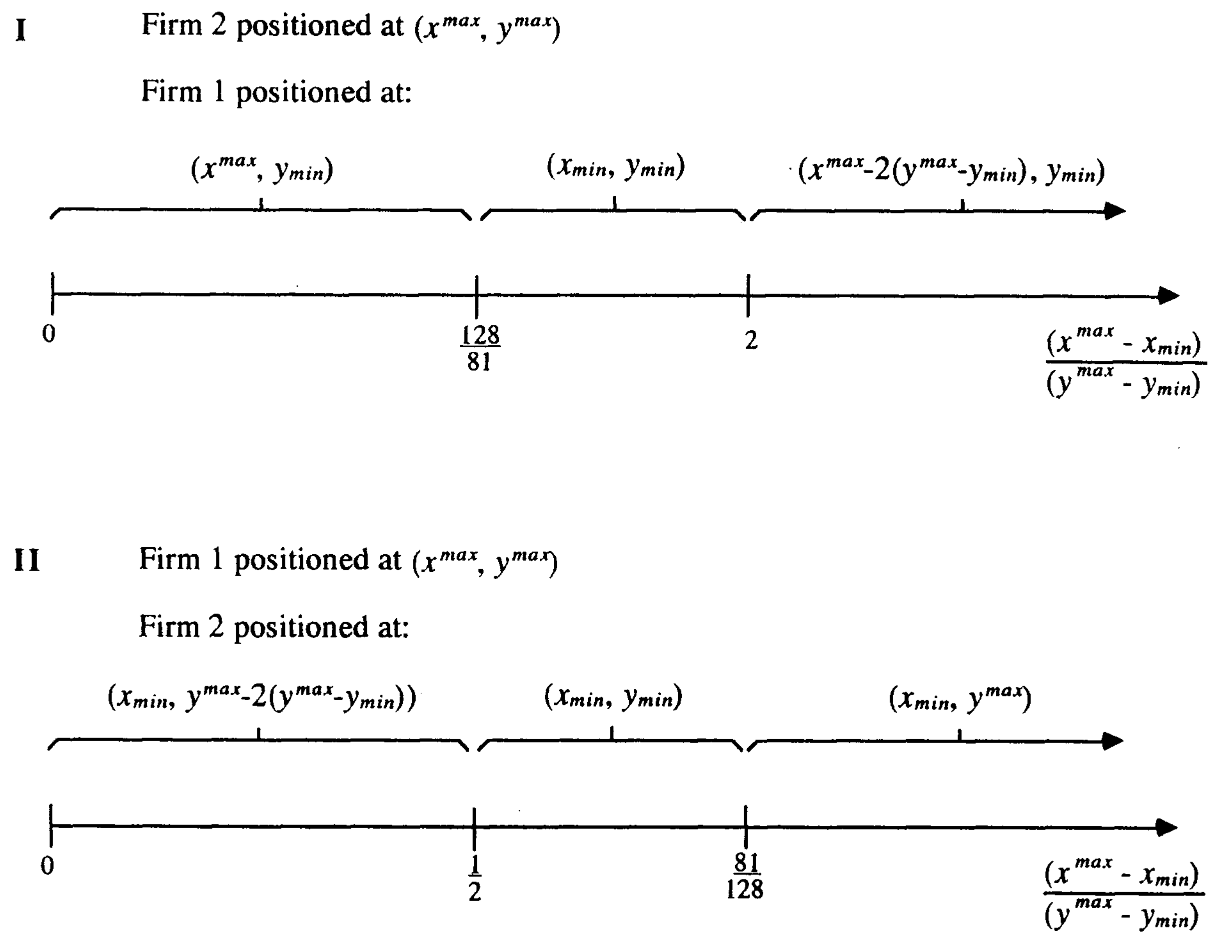


Figure 2.16: Summary of Product Equilibria for the Two-Dimensional Vertical Model

These results have a number of interesting features. As expected, one firm is always positioned at the maximum value on both dimensions which is considered by consumers to be of the highest quality. Like Shaked and Sutton (1982), the firm positioned in this location has the highest profits. Since both firms would prefer this high profit position, without including some other characteristics in the model, it is impossible to determine towards which equilibrium (if any) firms will tend.

Recall that previous research has suggested that two forces seem to shape the product equilibrium: a demand force (a desire to increase ones hinterland) which draw the firms together and a strategic force (a desire to reduce price competition) which causes firms to differentiate. These effects on the product equilibria derived in the two-dimensional vertical model can be analyzed. Under certain conditions, there exists an equilibrium which exhibits maximum differentiation on one dimension and minimum differentiation on the other (*MaxMin* differentiation).[7] The *MaxMin* equilibrium can be considered the normal case. This is because this equilibrium spans the region in which the range of the x characteristic ($x^{max} - x_{min}$) equals the range of the y characteristic ($y^{max} - y_{min}$). The *MaxMin* result appears to be in the spirit of dePalma et al (1985) who suggest that firms will locate next to one another provided that the products are differentiated on other dimensions. Following this line of reasoning, both firms want to have the highest quality; but because of the strategic force, only one firm will locate there. The firm which is unable to choose the highest quality position differentiates its product by choosing the minimum quality on only one dimension because of the demand force. This choice reduces price competition while at the same time maintains a sufficiently high quality level for the differentiating firm's product to appeal to a number of consumers.

[7] *MaxMin* differentiation was found in the mixed horizontal-vertical model analyzed by Neven and Thisse (1988). For details, see the analysis of the mixed model product equilibrium.

The second type of product equilibrium possible in the vertical model exhibits maximum differentiation. That is, one firm chooses the maximum level on both dimensions while the other firm chooses the minimum level on both dimensions. The decision to change from *MaxMin* differentiation to full differentiation is a unilateral decision made be the firm not located at the highest quality level. However, the profits for both firms increase (as compared to the *MaxMin* equilibrium) when this equilibrium holds. This suggests that the strategic effect is quite strong. In choosing *MaxMin*, the differentiating firm traded off increased demand for a lower price (because of increased price competition). This choice affects the profitability of the firm located at maximum quality as both demand and price are lowered. When the differentiating firm moves to maximum differentiation, its demand decreases (from $\frac{1}{3}$ to $\frac{1}{4}$) but its price increases to the extent that profits increase. Since both demand and price increase for the high quality firm, it appears that the strategic effect is reduced.

The final type of product equilibrium has the two firms maximally differentiated on one characteristic and partially differentiated on the other. This equilibrium shows that the strategic effect does not always dominate. That is, with sufficient product differentiation, the demand effect becomes more important than the strategic effect. The firm with the lower quality product chooses the position at which these two opposing forces are offset. The relative prices and demands remain constant with $p_2 = 3p_1$ and $D_2 = 3D_1$. This result adds an important dimension to the maximum versus minimum differentiation debate. It suggests that traditional one- dimensional positioning models may not be adequate to understand the opposing demand and strategic effects.

The product equilibrium results from the two-dimensional vertical model provide some important insights into the competitive behavior of firms competing on more than one dimension. The results are consistent with past research findings which suggest differentiation. In addition, new insights in the analysis of competitive product positioning are advanced. Though the results point to specific patterns of differentiation, it is important to note that the findings of this model are affected by the Nash price game in the second stage. This non-cooperative assumption gives firms a strong motivation to differentiate. A comparison with an alternative two-dimensional model, which lessens the price competition aspect, would be of value in this area.

2.6 Product Equilibrium for the Two-Dimensional Horizontal Model

As was the case in the two-dimensional vertical model, the choice of product positions is dependent on the set of equilibrium prices. For the two-dimensional horizontal model, the ordering of products along a characteristic (from 0 to 1) is arbitrary. Therefore, an analysis of only the asymmetric characteristics case is required. In addition, there is no need to consider characteristic y dominance since this case can be converted to characteristic x dominance by reverse scaling one dimension.

An important feature of the horizontal model is the fact that products located in any position are of equal quality. Since cost is independent of location, this feature results in the product subgame being played between 2 symmetric competitors who each choose a position (x_i, y_i) in the allowable product space. Because of this symmetry and the fact that there are no fixed costs, there exists a product equilibrium where the competitors will have equal demand, equal prices and equal profits (since there are no fixed costs). A symmetric equilibrium is described below. Though it is believed that this equilibrium is unique, the existence of other equilibria cannot be ruled out.

In a symmetric equilibrium, the demands for the two firms are equal. Therefore, an analysis of R_x^2 is required since equal demands are not possible in either R_x^1 or R_x^3. In R_x^2, the demand for firm 1 is given by (2.15) and the equilibrium price is given by (2.18). Substituting the horizontal model parameters ($j = (a_2^2 - a_1^2) + (b_2^2 - b_1^2), m = 2, k = 1$)

yields:

$$\Pi_1^* = \frac{(4\boldsymbol{a} - \boldsymbol{b} + (a_2^2 - a_1^2) + (b_2^2 - b_1^2))^2}{18\boldsymbol{a}} \tag{2.64}$$

For firm 2, the demand is given by $D_2^2 = 1 - D_1^2$ and the equilibrium price is given by (2.19). This yields a profit of

$$\Pi_2^* = \frac{(2\boldsymbol{a} + \boldsymbol{b} - (a_2^2 - a_1^2) - (b_2^2 - b_1^2))^2}{18\boldsymbol{a}} \tag{2.65}$$

Proposition 5: For the two-dimensional horizontal model, there exists a product equilibrium such that

$$a_1 = 1 \qquad a_2 = 0$$

$$b_1 = \frac{1}{2} \qquad b_2 = \frac{1}{2}$$

Proof:

(i) Consider firm 1 and assume that $b_2 = \frac{1}{2}$ and $a_2 = 0$.

The derivative of firm 1's profit function (2.64) with respect to a_1 is:

$$\frac{\partial \Pi_1^*}{\partial a_1} = \left(\frac{4\boldsymbol{a} - \boldsymbol{b} + (a_2^2 - a_1^2) + (b_2^2 - b_1^2)}{18\boldsymbol{a}^2} \right) (2\boldsymbol{a} - (4 - 2a_1) - 4\boldsymbol{a} + \boldsymbol{b} - (a_2^2 - a_1^2) - (b_2^2 - b_1^2)) \tag{2.66}$$

The fraction in (2.66) is positive, the second term reduces to

$$\boldsymbol{a}(4 - 3a_1 + a_2) + \boldsymbol{b} + (b_2^2 - b_1^2)$$

Since all of these terms are positive, $\frac{\partial \Pi_1^*}{\partial a_1} > 0$. Therefore, the best response for firm 1 is $a_1 = 1$.

The derivative of (2.64) with respect to b_1 is:

$$\frac{\partial \Pi_1^*}{\partial b_1} = \frac{1}{9\boldsymbol{a}}(4\boldsymbol{a} - \boldsymbol{b} + (a_2^2 - a_1^2) + (b_2^2 - b_1^2))(1 - 2b_1) \tag{2.67}$$

Π_1^* is optimized when $b_1 = \frac{1}{2}$ (note that (2.67)=0 and $\frac{\partial^2 \Pi_1^*}{\partial b_1^2} < 0$). Therefore, the best response for firm 1 is $b_1 = \frac{1}{2}$.

(ii) Now consider Firm 2 and assume that $b_1 = \frac{1}{2}$ and $a_1 = 1$. The derivative of firm 2's profit function (2.65) with respect to b_2 is:

$$\frac{\partial \Pi_2^*}{\partial b_2} = \frac{1}{9\boldsymbol{a}}(2\boldsymbol{a} + \boldsymbol{b} - (a_2^2 - a_1^2) - (b_2^2 - b_1^2))(1 - 2b_2) \tag{2.68}$$

Π_2^* is optimized when $b_2 = \frac{1}{2}$ (Note that (2.68) = 0 and $\frac{\partial^2 \Pi_1^*}{\partial b_2^2} < 0$). Therefore, the best response for firm 2 is $b_2 = \frac{1}{2}$. At $b_1 = b_2 = \frac{1}{2}$,

$$\begin{aligned} \Pi_2^* &= \frac{(2(a_1 - a_2) + (a_1^2 - a_2^2))^2}{18(a_1 - a_2)} \\ &= \frac{(a_1 - a_2)(2 + a_1 + a_2)^2}{18} \end{aligned}$$

Π_2^* is maximized when $a_2 = 0$. Therefore, the product equilibrium defined in *Proposition 5* holds.

There are a number of points worth noting about the product equilibrium described above. First, profits for the firms are equal ($\Pi_1^* = \Pi_2^* = \frac{1}{2}$) as are demands ($D_1 = D_2 = \frac{1}{2}$) and prices ($p_1 = p_2 = 1$). Second, since the ordering of characteristics is arbitrary, a parallel equilibrium with $a_1 = a_2 = \frac{1}{2}, b_2 = 1$ and $b_1 = 0$ also exists. Therefore, without including some other characteristics in the model, it is impossible to determine which equilibrium will emerge. Third, the product equilibrium described above exhibits *MaxMin* differentiation. This is similar to *Propositions 1* and *3* as well as the results of dePalma et al (1985). Finally, the equilibrium can be analyzed in terms of the two forces (demand and strategic) discussed in the analysis of the vertical model. The strategic force (the desire to reduce price competition) ensures that there does not exist an equilibrium at $a_1 = a_2 = b_1 = b_2 = \frac{1}{2}$: the point which would be chosen if prices were fixed and equal. The demand force (the desire to increase one's hinterland), though dominated by the strategic force, pushes the firms towards equality on one dimension.

2.7 Product Equilibrium for the Mixed Vertical-Horizontal Differentiation Model

The product equilibrium for the mixed model is similar to the analysis completed by Neven and Thisse (1988).[8] It is included here to allow for comparisons between the three models. Recall that characteristic x is the horizontal characteristic (thus $(a_1 - a_2)$ has a range of 1) and characteristic y is the vertical characteristic (thus $(b_2 - b_1)$ has a range of $(y^{max} - y_{min})$). Since the ordering of products along the horizontal characteristic (from 0 to 1) is arbitrary, only an analysis of the asymmetric characteristics case is necessary. However, since a vertical characteristic is present, both characteristic x dominance and characteristic y dominance need to be considered.

In the asymmetric characteristics case, conditions (A)-(D) define the boundaries of the various price equilibria (see section 2.4). By substituting the parameter values pertaining to the mixed model ($j = (a_2^2 - a_1^2), m = 1, k = 2$), (A)-(D) can be restated as follows:

$$(b_2 - b_1) \le (a_1 - a_2)(2 + (a_2^2 - a_1^2)) \qquad (A_M)$$

$$(b_2 - b_1) \le (a_1 - a_2)(4 - (a_2^2 - a_1^2)) \qquad (B_M)$$

$$(b_2 - b_1) \ge (a_1 - a_2)(4 - (a_2^2 - a_1^2)) \qquad (C_M)$$

$$(b_2 - b_1) \ge (a_1 - a_2)(2 + (a_2^2 - a_1^2)) \qquad (D_M)$$

[8] Although similar results are obtained, the procedure used to determine the product and price equilibria is different.

Note that (A_M) and (B_M) are equal and that (C_M) and (D_M) are equal and the reverse sign of (A_M) and (B_M). By altering the values of a_1, a_2, b_1 and b_2, it is possible to determine the relevant price equilibrium regions for use in the product positioning subgame.

Consider the situation where a_1 and a_2 are given ($a_1 > a_2$) and b_2, b_1 are varied.

1. When $b_2 = b_1$, characteristic x dominance holds and (A_M) and (B_M) are satisfied. The price equilibrium is in R_x^2.

2. As $(b_2 - b_1)$ is increased (either by increasing b_2 or decreasing b_1), condition (B_M) is the first to fail, but characteristic x dominance still holds. The price equilibrium is in R_x^1.

3. $(b_2 - b_1)$ can be increased until characteristic y dominance holds. Since (A_M) still holds, the price equilibrium is in R_y^1.

4. Finally, $(b_2 - b_1)$ can be increased until (A_M) fails. Now (C_M) and (D_M) hold and the price equilibrium is in R_y^2.

Now consider the situation where b_1 and b_2 are given ($b_2 > b_1$) and a_2, a_1 are varied.

1. When $a_2 = a_1$, characteristic y dominance holds and (C_M) and (D_M) are satisfied. The price equilibrium is in R_y^2.

2. As $(a_2 - a_1)$ is increased, condition (D_M) is the first to fail, but characteristic y dominance still holds. The price equilibrium is in R_y^1.

3. $(a_2 - a_1)$ can be increased until characteristic x dominance holds. Since (C_M) still holds, the price equilibrium is in R_x^1.

4. Finally, $(b_2 - b_1)$ can be increased until (C_M) fails. Now (A_M) and (B_M) hold and the price equilibrium is in R^2_x.

Several points are worth noting. First, the sequence described above can be terminated at any step depending of the range of possible product positions. Second, since $(\mathrm{A}_M)\neq(\mathrm{B}_M)$ (and $(\mathrm{C}_M)\neq(\mathrm{D}_M)$), there are 4 relevant regions for the price equilibrium which need to be considered: R^2_x, R^1_x, R^1_y andR^2_y. The product equilibrium will not occur in ${}_dR^3_x$ or ${}_dR^3_y$. Finally, since both the demand functions and the equilibrium prices are continuous across regions, it follows that the profit functions are continuous as well.

Before the product equilibrium can be calculated, it is necessary to determine the profit functions in each of the relevant regions. In R^2_x, the demand for firm 1 is given by (2.15) and the equilibrium price is given by (2.18). Substituting the mixed model parameters $(j = (a_2^2 - a_1^2), m = 1, k = 2)$ yields:

$$\Pi_1^* = \frac{(8\boldsymbol{a} - \boldsymbol{b} + 2(a_2^2 - a_1^2))^2}{72\boldsymbol{a}} \tag{2.69}$$

For firm 2, the demand is given by $D_2^2 = 1 - D_1^2$ and the equilibrium price is given by (2.19). This yields a profit of

$$\Pi_2^* = \frac{(4\boldsymbol{a} + \boldsymbol{b} - 2(a_2^2 - a_1^2))^2}{72\boldsymbol{a}} \tag{2.70}$$

In R^2_y, the demand for firm 1 is given by (2.27) while the demand for firm 2 is $1 - D_1^2$. The equilibrium prices for the two firms are given by (2.29) and (2.30). Combining these equations yield the firms' profit functions in R^2_y:

$$\Pi_1^{**} = \frac{(\boldsymbol{a} + \boldsymbol{b} + (a_2^2 - a_1^2))^2}{9\boldsymbol{b}} \tag{2.71}$$

$$\Pi_1^{**} = \frac{(2\boldsymbol{b} - \boldsymbol{a} - (a_2^2 - a_1^2))^2}{9\boldsymbol{b}} \tag{2.72}$$

Since the same price equilibrium applies in both R_x^1 and R_y^1, profits for the firms in these regions are equal as well. These profit functions are not presented here as they are not required in the determination of the product equilibrium. This is discussed in more detail below.

2.7.1 Product Equilibria

The product equilibria that are possible in the mixed model are determined by simultaneously comparing the relevant price equilibrium regions. Equilibrium solutions occur when neither firm can improve its profits by unilaterally altering its chosen position.

The first step in the product equilibrium analysis is determination that there does not exist a product equilibrium in the interior of R_x^1 or R_y^1. By the lemma proved in Appendix B, it is illustrated that the first order condition of the profit function for firm 1 (firm 2) evaluated at p_1^*, p_2^*, with respect to b_1 (b_2) can never be satisfied in the interior of R_x^1 or R_y^1. Therefore, only R_x^2 or R_y^2 need to be considered in the product equilibrium analysis. In each of the regions, a two step procedure is used to analyze a firm's optimal position (subject to the competitor's position). First, the restrictions which determine the range of product positions which are allowable in each region are considered. These include both characteristic x or characteristic y dominance and conditions (A_M)-(D_M) described above. Second, the derivatives of the relevant profit functions are taken with respect a firm's own characteristics to determine the profit maximizing location on a characteristic (subject to region restrictions).

There are two possible product equilibrium solutions in the mixed model. These solutions are defined and proven in *Propositions 6* and *7*.

Proposition 6: For the mixed model, if $(y^{\max} - y_{\min}) \geq (\frac{27}{32})^2$*, there exists a product equilibrium given by*

$$a_1 = \frac{1}{2} \qquad a_2 = \frac{1}{2}$$
$$b_1 = y_{\min} \qquad b_2 = y^{\max}$$

Proof:

I. Consider Firm 1 and assume $a_2 = \frac{1}{2}$ and $b_2 = y^{\max}$.

(i) In R_x^2, profits for firm 1 are given by (2.69). From this equation, it is apparent that the best response for firm 1 with respect to the vertical characteristic is $b_1 = y^{max}$. Substituting $b_1 = b_2 = y^{max}$ into (2.69) reduces the profit function to:

$$\Pi_1^* = \frac{(a_1 - a_2)(4 - a_2 - a_1)^2}{18}$$

Differentiating this function with respect to a_1 yields:

$$\frac{\partial \Pi_1^*}{\partial a_1} = \frac{1}{18}(4 - a_2 - a_1)(4 - 3a_1 + a_2) > 0 \tag{2.73}$$

Since $\frac{\partial \Pi_1^*}{\partial a_1} => 0$, the best response for firm 1 with respect to the horizontal characteristic is $a_1 = 1$. With $a_1 = 1$ and $a_2 = \frac{1}{2}$, Π_1^* becomes:

$$\Pi_1^* = \left(\frac{5}{12}\right)^2 \tag{2.74}$$

(ii) In R_y^2, profits for firm 1 are given by (2.71). Differentiating with respect to a_1 yields:

$$\frac{\partial \Pi_1^{**}}{\partial a_1} = \frac{1}{9\boldsymbol{b}}(2(\boldsymbol{a} + \boldsymbol{b} + (a_2^2 - a^2 - 1))(1 - 2a_1)) \tag{2.75}$$

Π_1^{**} is optimized when $a_1 = \frac{1}{2}$ (note that (2.75)=0 and $\frac{\partial^2 \Pi_1^*}{\partial a_1^2} < 0$). Since it is assumed that $a_2 = \frac{1}{2}$, inserting $a_1 = a_2 = \frac{1}{2}$ into the profit function yields:

$$\Pi_1^{**} = \frac{b_2 - b_1}{9}$$

Facing this equation, the optimal response for firm 1 with respect to the vertical characteristic is $b_1 = y_{\min}$. Therefore the profit for firm 1 will be:

$$\Pi_1^{**} = \frac{y^{\max} - y_{\min}}{9} \tag{2.76}$$

(iii) Comparing (2.74) and (2.76), firm 1 will prefer to choose $a_1 = \frac{1}{2}, b_1 = y_{\min}$ when:

$$y^{\max} - y_{\min} \geq \left(\frac{5}{4}\right)^2 \tag{2.77}$$

II. Now consider Firm 2 and assume $b_1 = y_{\min}$ and $a_1 = \frac{1}{2}$.

(i) In R_x^2, the profit for firm 2 is defined in (2.70). Faced with this equation, the best choice of b_2 for firm 2 is the highest level of b_2 such that the solution remains in R_x^2.This means that condition (B) will be satisfied with equality:

$$(b_2 - b_1) = (a_1 - a_2)(4 - (a_2^2 - a_1^2))$$

Subbing the equality into the profit function yields:

$$\Pi_2^* = \frac{(a_1 - a_2)(4 + \frac{4-(a_1+a_2)}{2} + 2(a_1 + a_2))^2}{72} \tag{2.78}$$

From (2.78), it is obvious that the best response for firm 2 is $a_2 = 0$. Subbing $a_1 = \frac{1}{2}$ and $a_2 = 0$ into (2.78) yields

$$\Pi_2^* = \left(\frac{9}{16}\right)^2 \tag{2.79}$$

(ii) In R_y^2, the profit for firm 2 is defined by (2.72). Differentiating this function with respect to

$$\frac{\partial \Pi_2^{**}}{\partial a_2} = \frac{1}{9\boldsymbol{b}}(2(2\boldsymbol{b} - \boldsymbol{a} - (a_2^2 - a^2 - 1))(1 - 2a_2)) \tag{2.80}$$

Π_2^{**} is optimized when $a_2 = \frac{1}{2}$. Inserting $a_1 = a_2 = \frac{1}{2}$ yields:

$$\Pi_2^{**} = \frac{4(b_2 - b_1)}{9}$$

The optimal response for firm 2 is $b_2 = y^{\max}$. Given $b_1 = y_{min}$, the profit for firm 2 in this region is:

$$\Pi_2^{**} = \frac{4(y^{\max} - y_{\min})}{9} \tag{2.81}$$

(iii) Comparing (2.79) and (2.81), firm 2 would prefer to choose $a_2 = \frac{1}{2}$ $b_2 = y^{\max}$ when

$$\begin{aligned} \frac{4(y^{\max} - y_{min})}{9} &\geq \left(\frac{9}{16}\right)^2 \\ y^{\max} - y_{\min} &\geq \left(\frac{27}{32}\right)^2 \end{aligned} \tag{2.82}$$

III. Since (2.82) is more restrictive than (2.77), the proposition is proven.

Proposition 7: For the mixed model, if $(y^{\max} - y_{\min}) \leq 2 + \frac{\sqrt{63}}{4}$, *there exists a product equilibrium given by:*

$$a_1 = 1 \qquad a_2 = 0$$

$$b_1 = y^{\max} \qquad b_2 = y^{\max}$$

Proof:

I. Consider firm 1 and assume $a_2 = 0, b_2 = y^{\max}$.

(i) In R_x^2, the analysis in the proof of *Proposition 6* (part I.(i)) indicated that faced with the profit function defined in (2.69), the best response for firm 1 would be $a_1 = 1, b_1 = y^{max}$. Substituting these values, as well as the assumed values for firm 2, into (2.69) yields:

$$\Pi_1^* = \frac{1}{2} \tag{2.83}$$

(ii) In R_y^2, the profit for firm 1 is defined by (2.70). As shown in (75), the best response for firm 1 with respect to the horizontal characteristic is $a_1 = \frac{1}{2}$. Setting $a_1 = \frac{1}{2}$ and $a_2 = 0$, (70) reduces to:

$$\Pi_1^{**} = \frac{(\frac{1}{4} + \boldsymbol{b})^2}{9\boldsymbol{b}}$$

Differentiating with respect to b_1 yields:

$$\frac{\partial \Pi_1^{**}}{\partial b_1} = \left(\frac{\frac{1}{4} + \boldsymbol{b}}{9\boldsymbol{b}^2}\right)\left(\frac{1}{4} - \boldsymbol{b}\right) \tag{2.84}$$

The first term of the derivative is always positive. The second term is negative if $b_2 - b_1 \leq \frac{1}{4}$. However, for a solution to be in this region, condition D must hold. Inserting $b_2 = y^{\max}, a_1 = \frac{1}{2}, a_2 = 0$ into condition D yields:

$$\begin{aligned} y^{\max} - b_1 &\geq (a_1 - a_2)(2 + (a_1 + a_2)) \\ y^{\max} - b_1 &\geq \frac{5}{4} \end{aligned}$$

Given this result, $\frac{\partial \Pi_1^{**}}{\partial b_1} < 0$ and the best response for firm 1 is $b_1 = y_{\min}$ provided that $y^{\max} - y_{\min} \geq \frac{5}{4}$. This yields a profit of

$$\Pi_1^{**} = \frac{(\frac{1}{4} + y^{\max} - y_{\min})^2}{9(y^{\max} - y_{\min})} \tag{2.85}$$

Note that if $y^{\max} - y_{\min} < \frac{5}{4}$, the admissible characteristic values which can be chosen by firm 1 (a_1, b_1) is the proper subset of the admissible values considered above. Therefore, (2.85) represents the maximum profit possible for firm 1 in this region.

(iii) Compare (2.83) and (2.85). For firm 1 to choose $a_1 = 1, b_1 = y^{\max}$, it must be true that:

$$\begin{aligned} \frac{(\frac{1}{4} + y^{\max} - y_{\min})^2}{9(y^{\max} - y_{\min})} &\leq \frac{1}{2} \\ \frac{1}{16} - 4(y^{\max} - y_{\min}) + (y^{\max} - y_{\min})^2 &\leq 0 \end{aligned}$$

Using the quadratic formula and selecting the largest root,

$$y^{\max} - y_{\min} \leq 2 + \frac{\sqrt{63}}{4} \tag{2.86}$$

II. Now consider Firm 2 and assume that $a_1 = 1$ and $b_1 = y^{\max}$.

(i) In R_x^2, the profit for firm 2 is defined by (70). By observation, the best response for firm 2 with respect to the vertical characteristic is $b_2 = y^{max}$. This reduces (2.70) to:

$$\Pi_2^* = \frac{(a_1 - a_2)(4 + 2(a_1 + a_2))^2}{72} \tag{2.87}$$

Given (2.87), the best response for firm 2 with respect to the horizontal characteristic is $a_2 = 0$. Substituting firm 2's best response (given firm 1's position) into (2.87) yields:

$$\Pi_2^* = \frac{1}{2} \tag{2.88}$$

(ii) In R_y^2, since $b_1 = y^{max}$ is given and $(b_2 - b_1) \geq 0$, the only response for firm 2 in this region with respect to the vertical characteristic is $b_2 = y^{max}$. Since characteristic y dominance holds in this region $((b_2 - b_1) \geq (a_1 - a_2))$, firm 2's only response with respect to the horizontal characteristic is $a_2 = a_1 = 1$. The choice of these characteristic levels would result in a zero profit.

(iii) Given $a_1 = 1$ and $b_1 = y^{\max}$, firm 2 would always prefer $a_2 = 0$ and $b_2 = y^{\max}$.

III. Since the only restriction to the product equilibrium is (2.86), the proposition is proven.

2.7.2 Summary and Implications

The product equilibria described in *Propositions 6* and *7* can be summarized as follows (see Figure 2.17):

I. If $y^{\max} - y_{\min} \leq \left(\frac{27}{32}\right)^2$, the product equilibrium is

$$a_1 = 1 \qquad a_2 = 0$$
$$b_1 = y^{\max} \qquad b_2 = y^{\max}$$

II. If $y^{\max} - y_{\min} \geq 2 + \frac{\sqrt{63}}{4}$, the product equilibrium is

$$a_1 = \frac{1}{2} \qquad a_2 = \frac{1}{2}$$
$$b_1 = y_{\min} \qquad b_2 = y^{\max}$$

III. If $y^{\max} - y_{\min} \in \left[\left(\frac{27}{32}\right)^2, 2 + \frac{\sqrt{63}}{4}\right]$, either product equilibrium is possible.

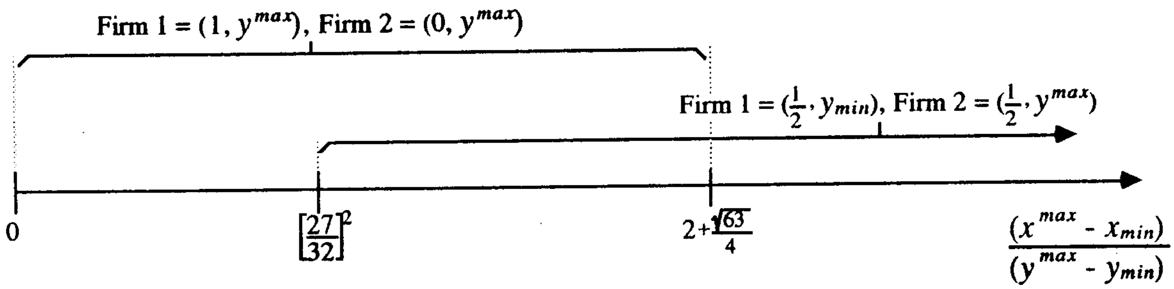


Figure 2.17: Summary of Product Equilibria for the Mixed Vertical-Horizontal Model

These results have a number of interesting features. First, an analysis of the equilibrium profits indicates that, regardless of equilibrium, firm 2 (which always chooses y^{max} on the vertical characteristic) has profits which are at least as high as firm 1. Since the choice of firm was arbitrary in the definition of the asymmetric characteristics case, both firms would want to choose the product which is always located at y^{max}. Therefore, without including some other characteristics in the model, it is impossible to determine equilibrium will emerge. Second, both of the identified product equilibria exhibit maximum differentiation on one dimension and minimum differentiation on the other (*MaxMin* differentiation). As was mentioned in the sections dealing with the vertical and horizontal models, this result appears to be in the spirit of dePalma et al (1985) who suggest that firms will agglomerate provided that the products are differentiated on some other dimension. Finally, an analysis of the two equilibria indicates that when the firms differ only on the horizontal characteristic, the two firms have equal prices, demands and profits. Profits for the firms are equal ($\Pi_1^* = \Pi_2^* = \frac{1}{2}$) as are demands ($D_1 = D_2 = \frac{1}{2}$) and prices ($p_1 = p_2 = 1$). This is similar to the horizontal model in which all locations on the horizontal characteristics are viewed as having equal quality by consumers. When the firms differ on the vertical characteristic, the firm with the high quality product has higher profits than the firm with the lower quality product. This is similar to the situation described in the vertical model.

2.8 Summary

In this chapter, three models were developed to study the competitive implications of various product differentiation assumptions in markets characterized by multiple dimensions. The one-dimensional horizontal and vertical models were extended to two dimensions. In addition, a two-dimensional mixed vertical-horizontal model was developed. Each model was analyzed using a two-stage game theoretic analysis in which two firms compete first on product positions and then on price. Closed form equilibrium solutions were obtained for each stage in which competitors are unrestricted in their choices of price or product positions.

The research yielded a number of interesting findings. Perhaps the most significant finding was that, in equilibrium, there is a prevalence of *MaxMin* product differentiation. That is, the two firms tend to choose positions which will represent maximum differentiation on one dimension and minimum differentiation on the other dimension. This solution implies that the maximum differentiation solutions found in one-dimensional models (d'Aspremont et al 1979, Shaked and Sutton 1982) do not extend to two dimensions. Although there was a prevalence for *MaxMin* product differentiation, it was found that in the two-dimensional vertical differentiation model, under certain conditions, maximum product differentiation does occur. Furthermore, there are conditions in which the firms differentiate on both dimensions, but not fully. This latter finding appears to illustrate that there are limits to the strategic effect (the desire to reduce price competition) which leads to maximum differentiation in the one-dimensional case. Finally, the price equilibria for the three models share a generalized form with some parameter values depending on the product differentiation assumptions used. This finding accentuates the similarities between the three models.

In recent years, there has been a growing literature on product and price competition in markets characterized by multiple product dimensions (e.g. Hauser 1988; Kumar and Sudharshan 1988; Carpenter 1989; Choi, DeSarbo and Harker 1990, Horsky and Nelson 1989). As was outlined earlier, none of the current models characterize a product equilibrium where firms are allowed to choose freely in the allowable product space. Consequently, the two-dimensional product equilibrium solutions obtained in this chapter lead to a better understanding of competitive markets.[9]

[9]Chapter 5 includes a discussion of model limitations and future research.

Chapter 3

Setting the Strategic Direction in a Product-Service Firm

3.1 Introduction

Companies competing on a global basis increasingly need to decide whether competitive success requires them to emphasize product features or service. An increased emphasis on either of these components requires the development of unique skills and capabilities. While neither the product nor services can be neglected, setting resource allocation priorities often necessitates some trade-offs. To ensure the maximum impact of potential investments, a strategic direction needs to be set.

The purpose of this research is to develop a model to help a firm determine the strategic direction it should pursue. A *strategic direction* is defined as the company's overriding focus for improvements relating to its product/service offering(s).[1] For example, a company may choose a service oriented strategic direction. This implies that, in the medium term, the majority of offering improvements will be related to service. The development of a technical service department, an improvement in the parts delivery system and/or an increase the number of dealerships may all be part of this "service" emphasis. The need for a strategic direction stems from the assumption that companies must continuously improve their offerings in order to remain competitive. In a world of increasing global competition, this assumption appears to be reasonable. Major corporations are recognizing this need to improve as well; for example, DuPont recently created the position of

[1]The term *offering* is used to describe what the customer is purchasing. Since both product and service features are often important in the customer's purchase decision, it was felt that the terms *product* or *product offering* placed undo emphasis on the product component.

Vice President for Continuous Improvement (Wall Street Journal 1990).

Besides satisfying the need to improve a firm's offering, a strategic direction can have other benefits. Top management support for a particular strategic direction should allow for the coordination of the sometimes diverse functional areas of production, R&D, marketing. In addition, if implementation managers have had input into the selection of the strategic direction, a stronger commitment to its success should result. Both of these features should have a positive impact on the company's corporate culture.

Determining the optimal strategic direction for a company is difficult. Pragmatically, the goal is to choose the strategic direction (either product or service) which will lead to the maximum return on investment. However, assessing the impact of a particular strategic direction is complicated by the fact that cost and technological requirements often demand global sourcing while customer needs and competitive intensity vary on a regional market basis. These features lead to a differential impact of changes in the company's product-service offering. Often, product improvements affect all markets (albeit with various degrees of effectiveness) while service improvements only affect the markets in which they are implemented. Therefore, to enable the appropriate comparisons, the local effects of proposed improvements must be aggregated on a global basis. It is at this global level that the strategic direction decision is made.

The strategic direction model (SDM model) developed in this chapter, limits the strategic direction decision to the choice between a product orientation and a service orientation. The model is based on a consideration of market by market competitive analyses, but concentrates on the more strategic issues. The model is relevant to companies who are responsible for providing both the physical product and the associated services. This situation is typical of many companies manufacturing industrial and commercial products. For example, the empirical study described in the next chapter focuses on a single offering, combine harvesters, in the farm equipment industry. Manufacturers of combines, like John Deere, manufacture combines in centralized production facilities and market them through a proprietary dealer network.

The scope of this chapter is limited to the development and description of the SDM model structure. In order for the SDM model to be implemented, additional research is necessary. Part of this additional research is addressed by the empirical study described in the next chapter. Other areas requiring additional research are beyond the scope of this dissertation. These areas are highlighted during the model development and summarized at the end of the chapter.

This chapter is organized as follows. First, the relevant literature is reviewed. This is followed by the development of the model structure. The chapter concludes with a summary of the model and its contributions. In addition, the next steps in the overall development of an implementable SDM model are discussed.

3.2 Literature Review

The literature review is organized as follows. First, a short review of the global marketing and the services marketing literatures will be presented to illustrate the nature of the global- local and product-service trade offs which represent important features of the model. This will be followed by a review of the optimal product positioning literature.

3.2.1 Global Marketing

Over the last several years, academic interest in the study of global and international marketing issues has grown dramatically. Several important research streams have been developed. These include the study of cultural effects (Tse, Lee, Vertinsky and Wehrung

1988), country of origin effects (Hong and Wyer 1989), international negotiations (Campbell, Graham, Jolibert and Meissner 1988) and market entry strategies (Ryans 1988). One of the most widely debated globalization issues is that of international standardization of marketing strategies. Within marketing, the merits of global standardization versus market- specific strategies has been discussed extensively. It is this aspect of the global marketing literature which is most related to the current research.

Prior to discussing standardization issues, it is necessary to the define what is meant by global and local strategies. A globally standardized marketing strategy can be defined as a strategy which uses a common offering, price, distribution and promotion strategy worldwide (Jain 1989). Stated in these terms, most researchers have argued against "total" standardization (e.g., Ohmae 1989, Jain 1989). A local marketing strategy has been referred to as a multidomestic strategy (Yip 1989). In this strategy, the products offered in a particular country are tailored to the local needs. In addition, all marketing activities, including pricing, promotion and distribution are guided by the local (or country) situation. Participation in a market is determined by that country's stand-alone potential for revenues and profits (Yip 1989, p.31)

The recent debate over the need for standardized marketing strategies was initiated by Levitt's (1983) article, "The Globalization of Markets". In this article, Levitt argues that international markets were homogenizing into worldwide market segments. He called for the standardized production of products to serve the global market. Through this strategy, higher quality products could be produced at lower costs. Levitt argues that the consumer attraction to these affordable, high quality products will dominate products which are designed to meet the needs of individual markets.

Levitt's article was met with mixed reaction. On the one hand, the economies of scale which could be achieved through standardization was generally accepted as it had already been recognized in many industries (e.g. the automobile industry, lead by Japanese companies). On the other hand, the call for the development of a standardized strategy (including services, pricing and promotion), given the structural and cultural differences between markets was questioned. Douglas and Wind (1987) argue that implementing a standardized global strategy would be inappropriate in most situations. These authors note that product strategies can range anywhere from globally standardized to locally customized and that the choice of extreme strategies is rarely the most appropriate.

An objective assessment of the appropriateness of a global or local strategy has been hampered by the inability to generate empirical evidence (other than anecdotal) in support of either position. As such, researchers have proposed contingency frameworks which enable managers to decide what type of strategy is most appropriate for their own organizations. Yip (1989) presents a framework which could be used to assess the merits of global and local strategies in various situations. Quelch and Hoff (1986), though supportive of a more globalized product strategy, recognize the existence of structural and/or organizational barriers which inhibit the accomplishment of this goal. These authors present a framework to aid companies in the transition from a multinational orientation to a more global orientation.

Since little empirical evidence has been generated, the global standardization versus market-specific strategies debate has been largely descriptive in nature. The SDM model presented here takes a somewhat different approach. Instead of arguing for or against global standardization, an analytical model is developed to study the strategic pricing and positioning implications of competing in markets in which some variables are chosen globally and others on a market by market basis. The research conceives of strategies as being multi-dimensional in nature as they include both global and local dimensions. This approach does not lessen the importance of continuing the global-local debate. Rather, the research addresses a specific issue (i.e., the choice of strategic direction) which is relevant to a significant subset of international competitors.

3.2.2 Services Marketing

Like global marketing, the literature on services marketing has grown dramatically in recent years. Much of this research has dealt with the operation and management of service organizations. Specific emphasis has been placed on the classification of services (Lovelock 1983), the service encounter (Zeithaml, Berry and Parasuraman 1988), complaint handling (Singh 1988) and service bundling (Guiltinan 1987).

There has been relatively little research concerned with combined product and service organizations despite the fact that such research has been considered a Marketing Science Institute priority (MSI 1988). This may be due to the fact the services marketing researchers have tended to concentrate on consumer rather than industrial markets. In consumer markets, where the distribution channels tend to be long, the product manufacturer has limited control over the services provided to the end user. In addition, there are a significant number of organizations which offer only services. In industrial markets, where distribution channels tend to be shorter, the manufacturer of the product may also be responsible for offering many of the associated services. At a recent Marketing Science Institute conference, the importance of both the product and service components was recognized by many of the industry participants (Guiry 1989).

The importance of services in traditional manufacturing organizations has not gone unnoticed by academic researchers. Chase and Garvin (1989) introduced the service factory concept which portrays the manufacturing facility as a center for the development of services which aid in the marketing of the company's products. These services include using factory personnel as a resource in aiding customers with installation, maintenance and troubleshooting. In addition to these service opportunities, Chase and Garvin illustrate how the factory can be used as a laboratory to test new product designs and manufacturing processes; as a showroom to demonstrate the quality of the products; and, as an information source in providing after sales service support to customers.

In order to implement the service factory concept, Chase and Garvin argue that significant changes must be made in the skills, capabilities and attitudes of employees and managers. This implies that the corporate culture is an important ingredient in the successful implementation of this increased service orientation. Corporate culture is also important in the development of a strategic direction. At both the top management and implementation levels, managers and employees must work together to evaluate current skills and capabilities as well as identify promising avenues for improvement. This requires teamwork across different functional areas (production, R &D, marketing).

Like Chase and Garvin (1989), Quinn, Doorley and Paquette (1990) also comment on the importance of services in traditional manufacturing organizations. These researchers state that 65% to 75% of employees in manufacturing industries "perform service tasks ranging from critical production-related activities like research, logistics, maintenance, and product and process design to indirect staff services like accounting, law, financing and personnel". Quinn et al argue that because most manufacturing industries are primarily service organizations, companies should focus on the tasks that gives them a competitive edge and outsource the rest.

In both of the articles reviewed here, the authors believe that the improved management of services can lead to success in manufacturing organizations. However, it is important to note that both papers have defined services to include activities which serve other departments within the company as well as activities which serve the customer directly. Despite this expanded definition of services, it appears that both papers are advocating an increased emphasis on the service component of the customer offering. As these papers are primarily descriptive, they provide neither an analysis of the relative importance of product and service components of the customer offerings nor a discussion of the financial and organizational tradeoffs which must be made in developing the product and service strategies. The analytical model presented here assumes the existence of these tradeoffs in the characterization of the strategic direction decision and suggests an increased emphasis on services only when a significant increase in return can be expected.

3.2.3 Optimal Product Positioning

Over the past two decades, marketing researchers have developed a number of models which have the potential to aid managers in the optimal design of new products. The research stream has tended to concentrate primarily on the development of computational algorithms which search for optimal product positions. This review will trace the development of optimal product positioning models and discuss the limitations of this research stream. Special emphasis will be placed on discussing those models which are most closely related to the current research.

Early Optimal Product Positioning Models

Many of the early optimal product positioning models were concerned with developing algorithms which optimized a new product location in joint perceptual space. A joint space perceptual map illustrates the location of both products and consumer ideal points in the same space (see Figure 3.1). This representation is usually accomplished using multi-dimensional scaling techniques (MDS) (Carroll 1972; Srinivasan and Shocker 1973, DeSarbo and Rao 1986). Empirical applications like Green and Carmone (1970) and models like PERCEPTOR (Urban 1975) illustrate how this approach can be used to describe a particular product market.

The basic optimal product positioning problem in joint space is as follows. Given a

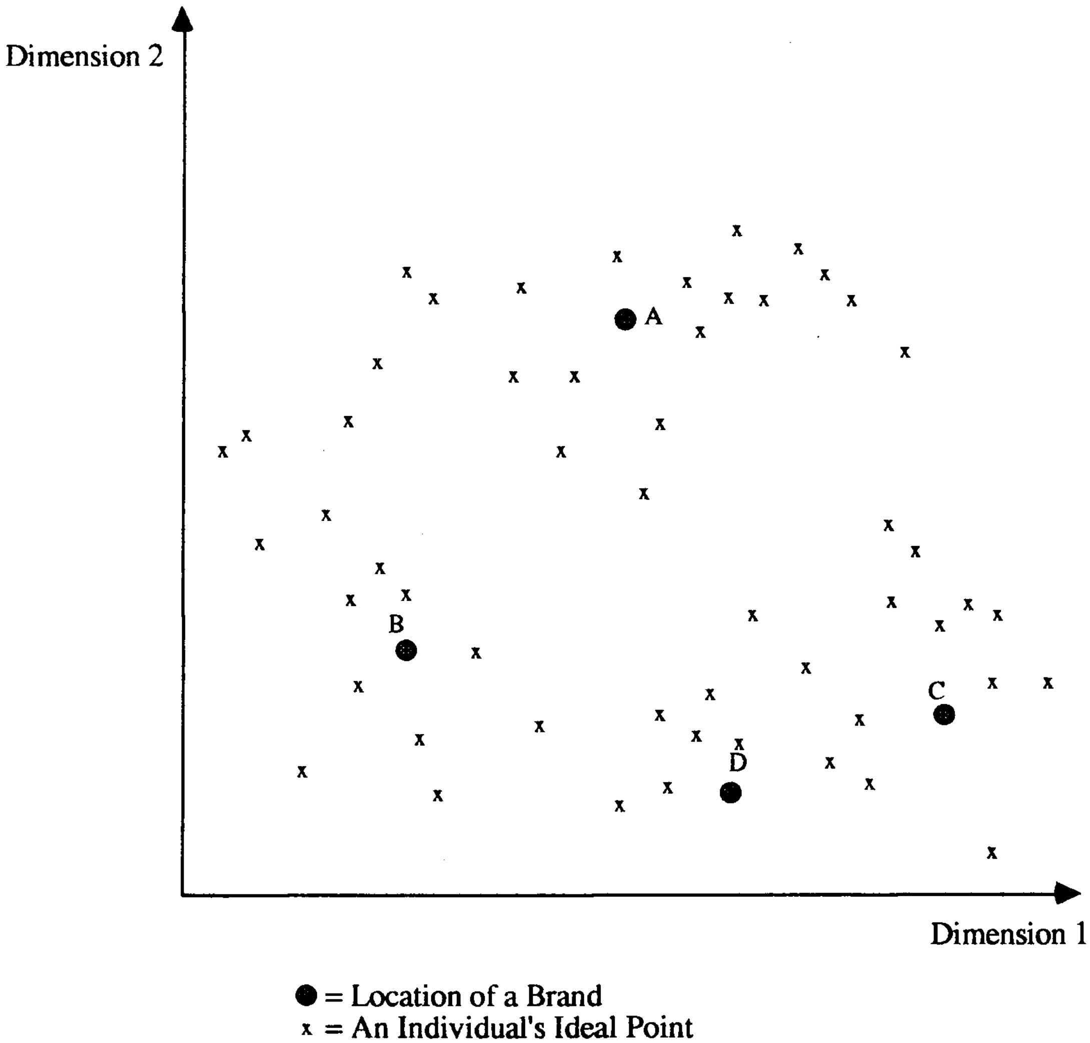


Figure 3.1: A Joint Space Perceptual Map Illustrating Product Locations and Consumer Ideal Points

representation of brands and consumer ideal points and a consumer choice rule, what new product location in the joint space map would yield the highest share of demand? The simplest version of this problem is the deterministic choice problem where the choice rule is simply that the consumer will choose the product which is closest to his/her ideal point. To solve this problem, the potential demand of each product location can be evaluated with the optimal location of a new product being the one with the highest expected demand.

Though the procedure for locating the optimal product position seems straightforward, searching every possible location, even in relatively small problems, is impossible. Not only is there an infinite number of possible locations, a unique solution is unlikely as there would ordinarily be an optimal region rather than an optimal point (Gavish, Horsky and Srikanth 1983). Thus, the thrust of early research was the development of efficient computational algorithms to solve the joint space problem described above. Papers by Albers (1979), Albers and Brockhoff (1977), Gavish, Horsky and Srikanth (1983), and Zufryden (1979) all present solutions to the basic problem by employing various simplifying heuristics to reach a solution which can be considered "optimal".

The basic joint space optimal product positioning model has been extended in a number of ways. The basic model assumes that all consumers perceive the current brands similarly but have idiosyncratic ideal points. In addition, distance is valued equally in all dimensions for all consumers. Albers (1979) extended the assumption of equal dimension weights by allowing these weights to vary at the individual level. This additional variation better captures the nature of differences in consumer preferences. Most models which were developed after Albers' article incorporated this feature.

Another major enhancement to the basic model was the incorporation of a probabilistic choice rule. Such a choice rule posits that the probability that a consumer chooses a specific brand from a set of brands is a decreasing function of the distance of the brand from the consumer's ideal point. Research in number of areas including variety seeking behavior (McAlister and Pessemier 1982) and consideration sets (Silk and Urban 1978) has indicated that for frequently purchased goods (and possibly other product categories) a probabilistic choice rule is more reasonable. A probabilistic choice rule has been implemented in a number of optimal product positioning algorithms including PROPOPP (Albers 1982) and PRODSRCH (Sudharshan, May and Shocker 1987).

Though the probabilistic choice rule appears more realistic for the analysis of frequently purchased goods, the deterministic choice rule may be more applicable in certain situations. Gavish, Horsky and Srikanth (1983) proposed a deterministic choice model specifically designed for infrequently purchased goods or durables. They argue that in these situations, consumers evaluate all alternatives and choose the most preferred alternative with certainty. Interestingly, in Sudharshan, May and Shocker's (1987) simulation comparison of optimal product positioning algorithms, Gavish, Horsky and Srikanth's algorithm performed well regardless of whether simulated consumers utilized a probabilistic or deterministic choice rule.

Optimal Product Positioning and Spatial Economics

A number of researchers have recognized the similarities between the optimal product positioning problem and problems in spatial economics and have developed models which attempt to integrate the two literatures. In order to do this, some of the shortcomings of the basic model require modification. The basic joint space model uses the simple objective function of maximizing share of demand. This objective has been criticized because firms would typically consider profitability, rather than demand, when designing new products. In addition, the joint space model relies on characteristics with finite ideal points (termed "horizontal" characteristics in economics). Equally as relevant are models which consider characteristics with infinite ideal points (vertical characteristics). The models which address these issues in a more economics oriented framework will be reviewed in more detail.

Hauser and Simmie (1981) propose a profit maximizing product positioning model based on attributes with infinite ideal points. Their model provides an operationalization of Lancaster's goods-characteristics economic theory (Lancaster 1971, 1979). Assuming homogeneous product perceptions, Hauser and Simmie model product perceptions in a ratio scaled, per- dollar perceptual map. Increasing (decreasing) a product's price moves the perceptual position of that product toward (away from) the origin of the per-dollar perceptual map. Consumers are assumed to have linear utility functions whose arguments are the per-dollar perceptual dimensions. Heterogeneous preferences are incorporated by assuming a (or measuring the) distribution of the utility function dimension weights. Costs are assumed to be a function of the locations in per-dollar perceptual space with increased distance from the origin representing higher product costs. Hauser and Simmie outline a procedure by which this information, which includes prices, costs and a consumer choice rule, can be used to find the profit maximizing perceptual position.

Hauser and Simmie's approach, though theoretically appealing, exposes a number of difficult problems. Although they discuss how their model can incorporate heterogeneous perceptions and preferences, the profit maximizing procedure which they suggest incorporates homogeneous preferences and perceptions. Solving for the optimal solution when heterogeneity is allowed appears to be very difficult. In addition, Hauser and Simmie note that a number of measurement issues must be addressed before the model can be successfully implemented. The most significant of these is the identification of the relationship between product costs and perceptual location.

Schmalensee and Thisse (1988) integrate the optimal product positioning literature in marketing with product differentiation literature in economics and location theory literature in operations research. Their basic objective is to develop an analysis program which can lead to the identification of promising new product designs. As such, no specific algorithms or approaches are presented. Instead, the authors argue that optimal product positioning models should contain a number of key features. Then, the authors provide a number of suggestions as to how these features might be incorporated. Schmalensee and Thisse suggest that optimal new product design models should have the ability to handle characteristics with either finite and infinite ideal points; have a profit maximizing objective function in which costs are incorporated; and, have the ability to incorporate competitive reactions. In addition, they discuss many of the issues relating to optimization. The main contribution of this paper comes from its development of pragmatic approaches to the generation of new product designs while adhering to the theoretical arguments presented in the marketing, economics and operations research literatures.

Two recent models by Choi, DeSarbo and Harker (1990) and Horsky and Nelson (1989) present what can be referred to as the state of the art in optimal product positioning models. Both models incorporate competitive reactions and many other feature which address the criticisms of earlier models. In addition, there appears to be a more concerted effort in these articles to apply the optimal product positioning approaches to actual problems. This is especially true of Horsky and Nelson's paper.

Choi, DeSarbo and Harker (1990) develop an optimal product positioning model which incorporates price competition. The model they analyze is closely related to the theoretical model suggested by Schmalensee and Thisse (1988). Choi et al measure a joint brand-ideal point perceptual space using an MDS unfolding algorithm (DeSarbo and Rao 1986) and incorporate a probabilistic choice rule based on the multinomial logit model. Using a Stackelberg-Nash equilibrium concept, these researchers develop a numerical procedure which enables them to calculate the optimal product position (in multi-dimensional space) and price of a new entrant and optimal response prices of any number of incumbents. The authors provide a limited application of the methodology to the analgesics market to demonstrate the power of their algorithm. In the application, an optimal product position and price equilibrium solution for a new analgesic is found in a market with 4 perceptual dimensions and 15 competitors. Though the model uses a profit maximization objective function, costs are assumed to be equal for all competitors. Therefore, Choi et al avoid the difficult problem of estimating the cost of perceptual positions.

Horsky and Nelson (1989) develop an optimal product positioning model which incorporates a number of features not present in earlier research. Using automobile market survey data (which included choice information), several functional forms of a preference model with infinite ideal points are estimated (vector models). The authors select a functional form which incorporates consumer uncertainty and recognizes attribute satiation. From this preference model, a consumer's expected utility is updated using the multinomial logit model to account for the observation that stated preferences do not perfectly reflect choice. The resulting choice probabilities are used to form demand functions for each brand.

The objective function of the firm considering the development of the new automobile is the net present value of earnings stream (less investment) over the life of the brand. In order to calculate this value, the start up costs and yearly overhead are assumed to be at industry standards. The variable costs associated with different perceptual positions are estimated using Rosen (1974). Rosen proved that by assuming that there is a price equilibrium in the current market and that firms have the same variable cost function, variable costs as a function of attributes can be measured. Sen (1982) commented on the theoretical appeal of this procedure for optimal product positioning models, but Horsky and Nelson's paper represents the first application of this procedure. The optimal product location is derived via a mathematical program which calculates the profitability of all possible attribute bundles (defined as unit values from 3 to 7 on six attributes) while allowing for price competition.

A number of theoretical and measurement issues are raised by Horsky and Nelson's paper. The most important of these is the applicability of Rosen's model in an actual market situation. The assumption that the current market (of 14 brands) is at a price equilibrium is questionable. In addition, the attribute position assigned to a brand (and subsequently a cost) is based on the mode of the sample of consumer perceptions rather than on more objective measures. Despite these concerns, Horsky and Nelson's paper provides a theoretically appealing approach to the optimal product positioning problem.

Limitations of the Optimal Product Positioning Models

As was mentioned at the outset of this section, optimal product positioning models have not been frequently applied in actual situations. This lack of industry acceptance appears to stem from two important shortcomings of optimal product position models: the lack of a one to one relationship between perceptual and physical space and the inability to accurately estimate the cost of a perceptual position. These issues will be discussed in more detail.[2]

Perhaps the most severe criticism of optimal product positioning models is the inability of these models to determine the physical product associated with an optimal product position. For example, the optimal new automobile location in Horsky and Nelson's (1989) paper is defined as (on a 7 point scale): performance = 7; dependability = 7; comfort = 3; exterior style = 3; prestige = 4; and, familiarity = 4. Engineers faced

[2]Other issues, like the limited consideration of time dynamics or "product" competition, also represent shortcomings of optimal product positioning models. Discussion of these issues is beyond the scope of this dissertation.

with the task of designing this automobile are given few practical guidelines. Development of the optimal product must proceed by determining the relationship between the perceptual dimension which describe the optimal product and physical attributes which can be altered. Hauser and Clausing (1988) describe a procedure (Quality Function Deployment) determining these relationships and measuring the impact of quality improvements. However, it is difficult to determine what physical change will lead to the desired perceptual location.

All optimal product positioning models rely on the optimization of new product locations in reduced perceptual space.[3] Whether the perceptual space is developed through MDS, discriminant analysis (Pessemier 1975) or factor analysis (Hauser and Urban 1977), the objective is the same: the representation of products which are comprised of many attributes in a space bounded by a small number of dimensions. The result of this compacting of data is that each point in perceptual space relates to many (possibly very different) products in physical space. For example, a line in two dimensions is represented by a point in one dimension. A cubic region in three dimensions is represented by a line in two dimensions, and so on. The problem for optimal product positioning models is that the preciseness of the search algorithm is lost in the description of the optimal physical product.

The inability of optimal product positioning models to adequately incorporate costs is also a severe limitation. Most firms interested in the development of new products utilize a profit objective. Therefore, the incorporation of product costs into the optimal product positioning model is essential. Though a number of authors have emphasized the importance of cost information, the existing literature provides little direction as to how that information might be gathered or used. As illustrated above, even Horsky and

[3]Green, Carroll and Goldberg (1981) can be considered an exception. These researchers attempt to identify an optimal new product concepts via conjoint analysis.

Nelson's application of Rosen's model, though theoretically correct, requires a number of questionable assumptions. The primary reason for the inability to accurately estimate costs is related to the first criticism of optimal product positioning models. That is, each point in perceptual space relates to many products in physical space. These physical products may have very different costs. Even if costs could be defined as a function of perceptual location. The problem of incorporating costs into the models does not disappear. Perceptual positions of the brands are determined by consumer perceptions rather than by objective measures. Since consumers differ in their perceptions of a brand, it is difficult to determine which specific perceptual location on which to base the cost estimate.

The two limitations described in this section apply to the optimal product positioning literature in general. As long as optimal product positioning models analyze some type of reduced space, a resolution to these problems does not appear to be possible. Therefore, the analytical procedures need to be altered if optimal product positioning models are to become more accepted in industry.

Summary

This review of the optimal product positioning literature has not been exhaustive. The goal was to provide an overview of the literature and a discussion of the models which impact on the current research. Therefore, a number of other important models have not been discussed because either their focus was different than the current research (e.g. Urban (1975) and Green Carroll and Goldberg(1981)) or the models were similar to those reviewed (e.g. Pessemier (1982) and Bachem and Simon (1981)). More information on models not reviewed here can be found in the literature review sections of Schmalensee and Thisse (1988) and Sudharshan, May and Shocker (1987).

3.3 Structure of the SDM Model

The SDM model developed through this research is related to research on optimal product positioning. Like optimal product positioning models, the model SDM utilizes consumer preference and perception data to estimate the desirability of different locations in perceptual space. However, where optimal product positioning models seek to optimize a product's position, the goal of our research is to optimize a more fundamental decision: the choice of strategic direction. Although it appears that the strategic direction decision is merely a choice between two types of improvement strategies, it is believed that this choice is crucial. The change from, say, a product oriented company to a more service oriented company requires the development of new skills and capabilities. In addition, all functional areas must adjust their focus in order ensure that the effects of the strategic shift are successfully implemented in the company's offerings. The offering positioning decision is viewed as taking place within the bounds defined by the company's strategic direction.

An important component of the SDM model is the recognition that there are three distinct levels at which analysis can take place (see Figure 3.2). The model conducts analysis at each of these levels. At the strategic level, senior managers provide strategic direction to the managers in marketing, research and development and production. The choice of strategic direction based on an estimate of the incremental profitability and return associated with prospective product or service improvements. At the implementation level, managers in the functional areas develop the product and the components of the marketing mix associated with the customer offering. Prices and costs for both current and improved offerings are estimated at this level. Finally, at the customer or market level, potential customers analyze the various offerings on the basis of price and the relevant product and service features. At this level, an estimate of demand for the current and improved offerings can be obtained.

At the current stage of development, the SDM model is designed to analyze a single offering. That is, the company must determine its strategic direction as it relates to a single product offering. The model is described as it relates to a single market. A second order algorithm would be needed to incorporate multiple markets or regions. In principal, this extension is straightforward. In fact, throughout the chapter, the procedure for extending the model to multiple markets is discussed.

For many companies, the situation analyzed by the SDM model represents a simplification of the problems they face because they market a range of products in many markets. Though a multiple product – multiple markets model would be more realistic, it is believed that SDM model concentrates on the core of the strategic direction problem. This provides insights for managerial use. The extension of the current model to a company marketing an entire product line will be left to future research.

Figure 3.3 provides an overview of the SDM model. The first phase of the SDM model is conducted at the customer level. Here information on customer perceptions and preferences are collected on all brands in the market(s) under consideration. From this information, a customer decision model is developed (Shocker and Srinivasan 1979). The customer decision model is a sub-model within the SDM model. The customer decision model estimates brand preferences as a function of brands' perceptual locations and prices. The customer information (as well as other R&D and production information) is used by managers at the implementation level in the next phase of the SDM model. In this phase, managers develop a list of promising product and service improvements along with the associated cost estimates. Then, using procedures which link physical characteristics to perceptions (see e.g., Hauser and Clausing 1988, Narasimhan and Sen 1990), each of the proposed improvements is mapped back into the customer decision model. A re-analysis of the customer decision model, incorporating a specific pricing

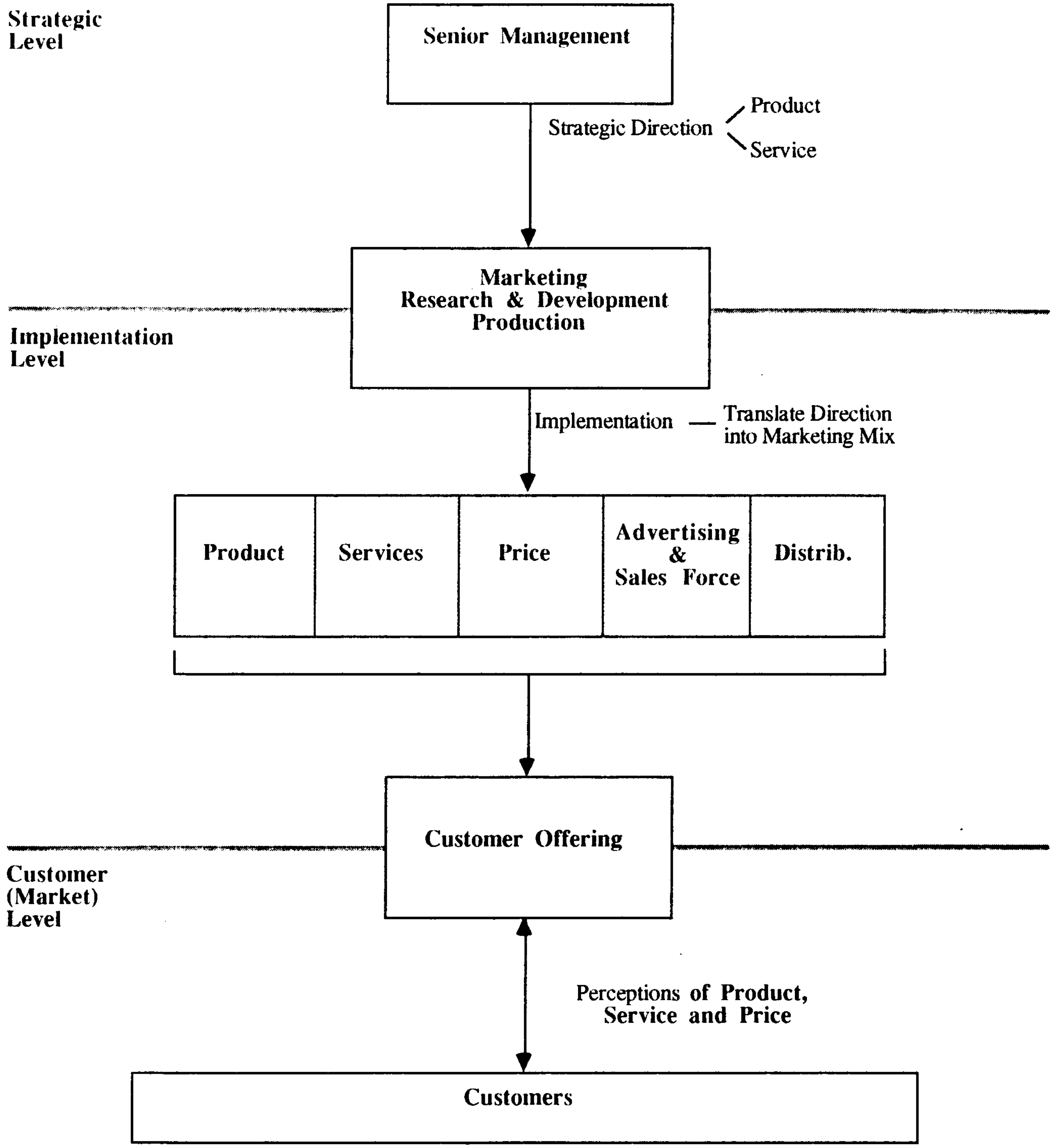


Figure 3.2: Levels of Analysis in the SDM Model

assumption (e.g., Nash equilibrium pricing), allows for the estimation of the demand effects related to each of the proposed offering improvements. Finally, using price and demand information determined in the previous step and cost information estimated by the implementation managers, the expected profitability and ROI of the product and service improvements can be assessed. This information guides the strategic direction decision.

Each of the components of the SDM model will be discussed in more detail.

3.3.1 Product-Service Setting

As was outlined in the introduction, the SDM is most relevant to companies who are responsible for providing both the physical product and the associated services. In this type of setting, the company is directly responsible for both product and service features of the offering.[4] In addition, it is possible to improve a company's market position by emphasizing either product or service features. A significant number of manufacturers of industrial and commercial products fall into this category. For example, in the empirical study outlined chapter 4, the customer decision model is applied in the combine harvester market of the farm equipment industry. This market is provides a good example of a product-service setting. Each of the competitors in the market, like John Deere, manufacture a line of combine harvesters and market them through a network of exclusive dealerships. Customers (farmers) consider both product related attributes (e.g., *durability*) and service related attributes (e.g., *parts availability*) when making a purchase decision. Therefore, it is important to consider the entire *offering* (consisting of both product and service features).

[4]Contrast this with a shoe manufacturer. To the customer, service may be an important feature when purchasing shoes. When poor service is delivered, it is the responsibility of the retailer, not the manufacturer. The customer may choose to buy the same shoes from a different retailer.

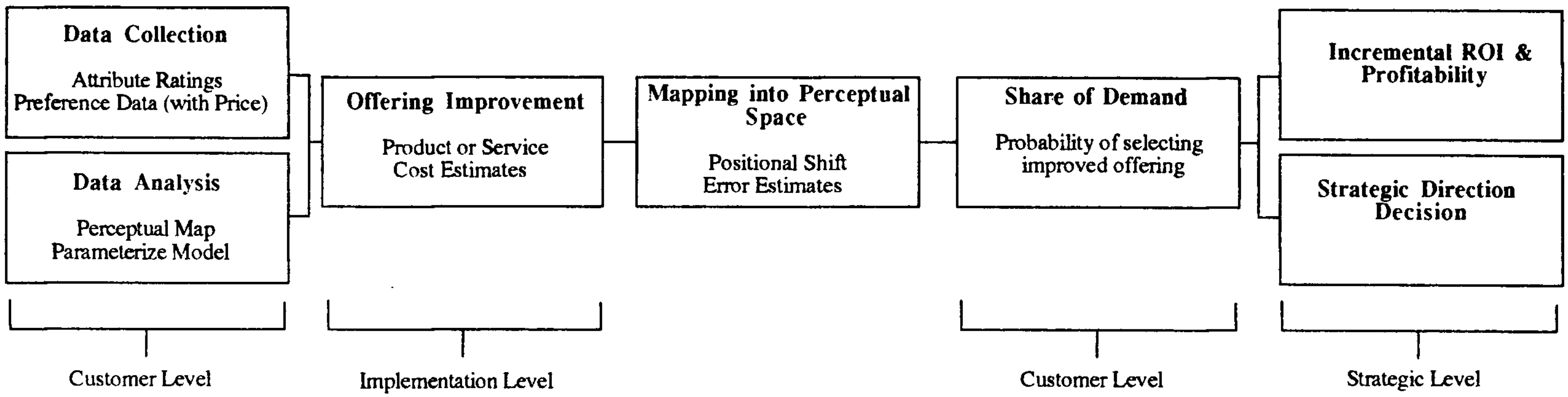


Figure 3.3: Overview of the SDM Model

3.3.2 Development of a Customer Decision Model

The first phase of the SDM model requires the collection of customer perception and preference data. This information is used to develop a customer decision model (Shocker and Srinivasan 1979). The major components of the customer decision model are the perceptual map of the product market and the customer value function which defines customer preferences for various locations in perceptual space. These two components will be discussed in more detail.

The perceptual structure for the customer decision model is developed through the use of confirmatory factor analysis: a specific form of factor analysis. Empirical research conducted by Hauser and Koppelman (1979) indicated that perceptual maps derived via factor analysis are superior to those developed via MDS and discriminant analysis in terms of interpretability and predictability.

The confirmatory factor model differs from common factor analysis (and principal components factor analysis) in that it allows for the specification of constructs or dimensions. In the context of the SDM model, two constructs, *product* and *service*, are defined.[5] These constructs are assumed to be summary dimensions which measure a customer's overall perception of product quality and service quality. The composition of the *product* and *service* constructs is based on a categorization of the important attributes of the offering. The list of attributes is categorized into groups of attributes which are affected by either a product or a service improvement. For example, *durability* will only be affected by a change in the product while *parts availability* will only be affected by a change in the company's service capabilities. It is possible for attributes to be categorized in both the product and service groups. For example, an attribute like *speed of repairs* may be affected by both a product improvement (e.g. a design change to make repair

[5]The modeling approach here easily extends to more dimensions. This would accommodate several dimensions of product quality and service quality (see Garvin 1987).

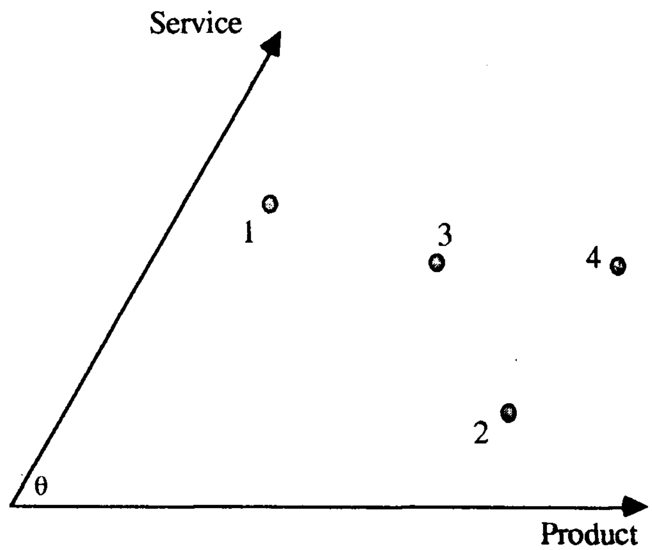


Figure 3.4: An Individual's Perceptual Map

easier) and a service improvement (e.g. better trained technicians).

The group of attributes which are affected by a product (service) change are combined using a confirmatory factor model to develop the product (service) construct. Factor scores are used to determine the offering locations. Figure (3.4) provides and example of a perceptual map developed using this procedure. Notice that the *product* and *service* dimensions may be correlated. This implies that higher levels of product quality are perceived to be associated with higher levels of service quality. This correlation (r) is estimated during the confirmatory factor analysis and is reflected in the angle (θ) between the product and service dimensions in the perceptual map ($\theta = \cos^{-1} r$).

The second major component of the customer decision model is a value function which defines customer preferences for various locations in perceptual space. The value function also incorporates price which is assumed to be objective (i.e., known with certainty and perceived accurately by all customers). Since the *product* and *service* constructs are measured as qualities, a vector model (incorporating price) is assumed to be the form of the value function (Shocker and Srinivasan 1979). The vector model allows only "more is better" attributes. The optimal product positioning models of Hauser and Simmie (1981) and Horsky and Nelson (1989) use similar models to describe customer perceptions and preferences. The value, U, that customer i places on k's offering is defined as follows (the customer subscript, i is excluded):

$$U_k = w_1\xi_{pk} + w_2\xi_{sk} - w_3p_k \tag{3.1}$$

where:

ξ_{pk}, ξ_{sk} = offering k's location on the product and service dimensions respectively.

p_k = price of offering k.

w_1, w_2, w_3 = parameters to be estimated (≥ 0).

There are a number of points worth noting about the value function described in (3.1). First, income effects are not included. Models based on the Lancaster tradition incorporate price by subtracting it from income. This yields a term, $Y - p_k$, which represents the amount of funds available for expenditure on all other goods. A similar formulation would also apply in the current model. However, since (3.1) is estimated at the individual level, income becomes redundant (see Ratchford 1979, p.80).

Second, no interaction term is included in the value function. Though it is common in models of this type not to include interaction terms (e.g., Hauser and Shugan 1983, Horsky and Nelson 1989), the importance of interactions remains an open question (see

Green and Srinivasan 1990, p.5). The most relevant interaction term to include would be between the *product* and *service* factors. However, this interaction term is not included in model because the correlation between these factors (as determined by the confirmatory factor analysis) already captures some of the interactive effect.[6] Nevertheless, a test of whether the *product-service* interaction term adds to the predictive validity of the model is included in the empirical study discussed in chapter 4.[7]

Finally, a deterministic choice rule is incorporated into the customer decision model. It is assumed that when the customers purchase, they will choose the offering for which (3.1) is maximized. As discussed in the literature review, Gavish, Horsky and Srikanth (1983) suggest that a deterministic model is appropriate for durable goods. Most offerings provided by product-service firms, including the example presented in the empirical study, fall into this category. The models proposed by Gavish, Horsky and Srikanth (1983) and Hauser and Shugan (1983) also incorporate a deterministic choice rule.

The value function is parameterized via conjoint measurement. Conjoint measurement techniques have received widespread acceptance in both academia and industry as a set of methods for measuring customer's tradeoffs between multi-attribute offerings (Wittink and Cattin 1989). Green and Srinivasan (1978, 1990) review the major developments in conjoint analysis and discuss implementation procedures. The major advantage of using conjoint measurement is the parameters are measured on the basis of a customer's response to a range of levels on each of the dimensions (*product*, *service* and *price*). This allows for a more reliable estimate of say, price sensitivity, than a method which estimates the price parameter based on customer preferences at a single price level.

[6]This is particularly true when improved offerings are being assessed.

[7]Chapter 4 outlines an empirical study which was undertaken in the combine harvester market. Using the procedure developed by Hagerty and Srinivasan (1991), it was found that the model described in (3.1) had a higher predictive validity than a model incorporating the product-service interaction.

More details of the measurement procedure are given in Chapter 4.

The customer decision model is analyzed at the individual level. That is, individual differences in both perceptions and preferences are permitted. Most models of this type allow for either heterogeneous perceptions or heterogeneous preferences, but rarely both simultaneously (Shocker and Srinivasan 1979). In a product-service setting, it is expected that there will be significant differences in preference. It appears reasonable to expect variation in the importance that customers place on the product, service and price components of an offering. In addition, it is expected that there will be considerable differences in the customer perceptions of the offerings. This prediction is primarily due to the fact that there is a service component. There are two causes which can lead to differences in the customer perceptions. First, unlike "products", the offerings vary across customers due to individual experiences with service providers. In addition, in many situations (including the one analyzed in the empirical study), there are multiple service centers (of varying quality) for each of the manufacturers. This implies that there are true differences in the offerings across customers. Second, individual differences in customers' evaluations of the offerings lead to perceptual heterogeneity even when the offerings are identical. These two causes imply that it is important to allow for differential perceptions (including alternative rankings) between customers.

In addition to incorporating individual differences, the customer decision model can be extended to incorporate differences across regions or countries. An assumption of the factor analytic technique described above is that all respondents share the same perceptual space, but vary in their perceptions of individual brands. By segmenting the global market into distinct regions and conducting a separate analysis in each region, a new layer of heterogeneity is included. For example, the set of attributes considered important in forming the product dimension may differ across regions. In the combine harvester market, differences in crops and growing conditions in the prairies versus the midwest imply that customers place significantly different emphasis on attributes like *power* and *threshing technology*. By allowing these differences to enter into the factor model, regional conditions can be incorporated into the SDM model.

3.3.3 Offering Improvement

It is at this stage that the SDM model described here departs most significantly from the standard optimal product positioning literature. Optimal product positioning models search for an optimal product position in perceptual space and attempt to relate this perceptual position to a physical product. This approach has been criticized because of the lack of a one to one relationship between perceptual (reduced) space and physical product attributes (see the literature review, section 3.2.3). Typically, a location in perceptual space can be obtained by many different physical products. This problem, coupled with the heterogeneity of consumer perceptions, makes it difficult to define the optimal product let alone estimate its costs. The SDM model described here reverses the direction of the relationship between perceptual and physical space. Specifically, the physical characteristics of improved offerings are defined in detail. Following this specification, their location is estimated in perceptual space. This procedure allows for more precise cost estimation of an improved offering while sacrificing the ability to search for an optimal perceptual position. Since the objective of the model is the optimization of strategic direction rather than product position, this trade-off is acceptable.

The offering improvement phase of the SDM model occurs at the implementation level of the company. Managers at this level are given the objective of developing a list of the most promising product and service improvements which could be made to the company's offering. This listing is divided into a product improvement program and a service improvement program. For example, a service improvement program may include the development of a technical service department, an improvement in the parts delivery system and/or an increase the number of dealerships in a particular country/region. Each of these programs can be considered as a medium-term agenda of improvements to the offering should a product or service oriented strategic direction be chosen. Each item in the product (service) improvement program should include three characteristics: an outline of the exact product (service) adjustments which need to be made; an estimate of the fixed and variable costs associated with the improvement; and, an estimate of the improvement's effect on perceived product (service) quality.

The global nature of the product-service firm can be illustrated by the composition of the improvement programs. Product improvements tend to be changes to the manufactured product and would apply in all regions while service improvements can be tailored to specific markets. This allows for more flexibility in the choice of service improvements as service improvements can be targeted to markets in which they will have the greatest impact.

The development of the product and service improvement programs represents a significant task for the managers at the implementation level. However, this step of the model is not restrictive as a number of firms are already implementing similar procedures (Hauser and Clausing 1988). A key component in the successful development of improvement programs is an understanding of the relationship between engineering attributes[8] and perceptual characteristics. A significant amount of research has been undertaken to understand this relationship (e.g. Holbrook 1981, Huber 1975, Hauser and

[8]The term "engineering" is used to designate both product and service attributes. Engineering attributes are attributes which are under the product and service designer's control.

Simmie 1981, Neslin 1983). Two approaches which can be incorporated into the SDM model are briefly outlined below.

Quality Function Deployment (QFD) has received considerable attention at a number of major manufacturers including Toyota, Ford, Hewlett-Packard and AT&T (Hauser and Clausing 1988, Sullivan 1986, Orsini 1991). QFD is a set of planning and communication routines which provide a means of translating customer desires into the appropriate technical requirements at each stage of the planning and production processes. QFD begins by defining a detailed listing of what the customer wants in the offering. These wants or desires are a set of attributes which are usually expressed in the customer's own words. Using the example from Hauser and Clausing (1988), two desirable attributes of a car door may be *easy to close from the outside* and *stays open on a hill.* Next, the relative importance of these attributes is determined either through managerial experience or customer surveys/experiments. With this set of perceived needs, the company can analyze the changes in engineering characteristics which will lead to improvements in satisfying these perceived needs. For example, a car door attribute like *easy to close from the outside* can be related to engineering characteristics like *energy to close door* and *door seal resistance.*[9] Additional surveys and/or experimentation is necessary to determine the amount of change in engineering characteristics needed per unit change in a customer attribute. The process of relating customer attributes to engineering characteristics is undertaken for all aspects of the product. Through a series of relationship matrices, the customers "voice" can linked to other areas of the manufacturing process including parts deployment, process planning and production planning. Because of these strong linkages, the cost of the improved product can be estimated with a considerable

[9]The relationship between physical features and engineering characteristics is known to the engineers. .

degree of accuracy.[10]

Another approach to linking engineering attributes to customer perceptions is outlined by Narasimhan and Sen (1990). These researchers develop an empirical procedure to obtain the quality perceptions from users of office copiers, however, the methodology can be applied to a wide variety of situations. Using a multiple regression approach, Narasimhan and Sen relate quality perceptions to a series of engineering attributes. The resulting attribute-to- perceptions model can be used to design copiers which will be perceived to have higher copy quality. Since the costs of changing the physical feature is known, a good estimate of the cost of the improved product can be obtained.

The specification of a procedure to develop the product and service improvement programs is beyond the scope of this dissertation and will be left for future research. However, the implementation of either QFD or the Narasimhan and Sen approach appears to have the potential of developing feasible improvement programs. Both of these procedures allow for the development of programs which meet the three essential criteria of improvement programs: (i) the precise specification product (service) adjustments; (ii) an estimate of the fixed and variable costs associated with the improvement; and, (iii) an estimate of the improvement's effect on perceived product (service) quality.

3.3.4 Mapping Potential Improvements into Perceptual Space

This stage of the SDM model merges the implementation level with the customer level. Each of the potential improvements listed in the product and service improvement programs are to be mapped (in turn) into the perceptual spaces defined by the customer input.

[10]For an application of QFD to services see Orsini (1990).

For purposes of exposition, consider a service improvement program in a single market.[11] [12] Let the subscript l represent an item in the service improvement program. For each item, the implementation managers provide three pieces of information:

(i) d_l^s, an estimate of the average amount that service quality is increased in an individual's perceptual map as a result of the improvement. The actual amount would vary by individual. d_l^s focuses on the impact of a product improvement on customer perceptions. For example, if the customer is concerned about parts availability, d_l^s would define the degree to which the customer perceptions of service increase when the availability of parts is reduced from 3 days to 24 hours.

(ii) c_l^s, an estimate of the variable cost of the improvement.

(iii) F_l^s, an estimate of the fixed costs associated with the improvement.

When mapping potential improvements into perceptual space, the d_l^s estimates are required. The estimates of variable and fixed costs are used in the calculation of estimated profits and investment return (see below).

The perceptual position of an offering is defined as $\boldsymbol{\xi}_{ik} = (\xi_{ipk}, \xi_{isk})$, where ξ_{ijk} represents offering k's location on dimension j (either product, "p", or service, "s") in customer i's perceptual space. Assuming that the analysis is being undertaken for firm 1, the predicted perceptual position of firm 1's offering ($\hat{\boldsymbol{\xi}}_{i1}$) for customer i following a *service* improvement is defined as follows:

$$\hat{\boldsymbol{\xi}}_{i1} = \boldsymbol{\xi}_{i1} + d_l^s \boldsymbol{\theta}^s + \boldsymbol{\varepsilon}^s \tag{3.2}$$

[11] Multiple markets can be considered by analyzing the improvement program effects in each market. Global demand effects from improvements are obtained by summing over all markets

[12] The same analysis can be undertaken for a product improvement.

where:

$\boldsymbol{\xi}_{i1}$ = position of target offering (as measured by customer data) in customer i's perceptual space. $\boldsymbol{\xi}_{i1} = (\xi_{ip1}, \xi_{is1})$.

$\boldsymbol{\theta}^s$ = $(r_{ps}, 1)$, where r_{ps} is the correlation between the *product* and *service* dimensions.

$\boldsymbol{\varepsilon}^s$ = error. $\boldsymbol{\varepsilon}^s = (\varepsilon_p^s, \varepsilon_s^s)$

The term $\boldsymbol{\varepsilon}^s$ has been added to account for the errors associated with the mapping of an improvement into perceptual space. There are two types of error which can result from the analysis of a potential service improvement. First, the degree of improvement may be perceived to be better (worse) than expected. This is essentially an error in the estimate of the amount of offering improvement. Second, the direction of the perceptual improvement may not be precisely in the same direction as the *service* dimension.[13]

In order to account for these errors the perceptual position of a service improvement is defined by a probability distribution with a mean of $\overline{\boldsymbol{\xi}}_{i1} = \boldsymbol{\xi}_{i1} + d_l^s \boldsymbol{\theta}^s$ and a variance matrix, Σ^s. It is assumed that Σ^s is the same for all customers. The nature of the errors described above does imply a particular error distribution. For the SDM model, it is assumed that the errors have a bivariate normal distribution.[14] Managerial judgement can be used to estimate the parameters of the error distribution. Essentially this requires an estimation of σ_p^2 and σ_s^2 which are the variances along the *product* and *service* dimensions

[13]A third source of error results from individual differences in perception. This source of error has not been specifically addressed as it is assumed that d_l^s and the distribution of errors are constant across individuals.

[14]To account for the fact the larger improvements are more uncertain, it is assumed that the variance of the error distribution increases with the magnitude of the expected movement in perceptual position, d_l^s.

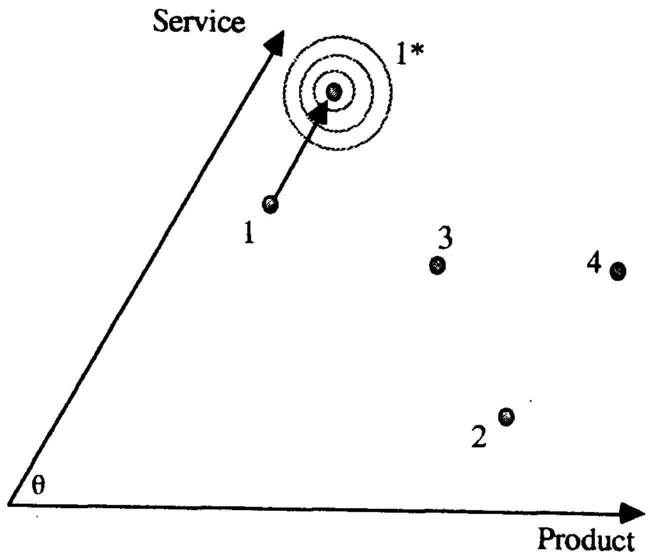


Figure 3.5: An Individual's Perceptual Map Following a Service Improvement

respectively.[15] Implementation managers may be best qualified to make these judgements as they have considered the extent of offering improvement in the development of the improvement programs.

Figure 3.5 illustrates a perceptual map following a service improvement. The elipses around firm 1's new position represent different probability levels of the improved offering's location.

[15]The covariation is calculated using estimate of the correlation between the product and service dimensions (r_{ps}).

3.3.5 Estimating Price and Share of Demand for an Improved Offering

The profitability of a product or service improvement is often dependent both on an increased demand for the offering and a higher price. Notice that demand is also a function of price (see the individual value function (3.1)). Therefore, the assessment of the value of an improvement must consider the expected price of the improved offering. The specific price charged for an offering is a local decision. That is, the price in a particular market is determined by a consideration of the customers, the competitors and the company's offering in that market.[16]

The SDM model is flexible enough to incorporate a number of pricing assumptions including optimal pricing and competitive (Nash equilibrium) pricing. Hauser and Simmie (1981) used an optimal pricing strategy while more recently, Horsky and Nelson (1989) and Choi, DeSarbo and Harker (1990) have incorporated competitive pricing into their optimal product positioning frameworks. The implementation of competitive pricing will be described here. However, an empirical application of this pricing framework is beyond the scope of the dissertation.

The competitive pricing assumption models how firms might "react" to potential improvements by the target firm. It also assures that the price the target firm charges for its improvements is in line with market conditions. The competitive pricing framework assumes that, given the current position of the offerings, all firms optimize their price levels simultaneously. It is a short term decision which does not incorporate fixed investments.

The profit for the kth firm is defined as:

$$\Pi_k = (p_k - c_k) m_k D \tag{3.3}$$

[16]It is assumed that there are sufficient barriers between markets to prevent arbitrage.

where:

c_k = the variable cost of offering k.

m_k = the market share of firm k (dependent on prices).

D = the market demand over the planning horizon (usually 1 year). Assumed to be independent of price.

A Nash price equilibrium solution occurs when no firm can improve its profits by unilaterally altering its price. In a specific market, this requires the selection of k prices which solve each firm's first order condition. The first order condition of the the kth firm is:

$$\frac{\partial \Pi_k}{\partial p_k} = \left(m_k + (p_k - c_k)\frac{\partial m_k}{\partial p_k} \right) D = 0 \tag{3.4}$$

The solution to the set of equations described by (3.4) can be determined through a numerical analysis. Readers interested in the development of a numerical procedure are directed to Hauser (1988, p. 27).

The determination of price and demand estimates for an improved offering follows a number of steps:

1. Determine the price equilibrium relating to current positions of all offerings in the market. Since the firm is able to adjust prices independent of the strategic direction decision, the price equilibrium solution to the current offering positions becomes the base case against which improvements are compared.

2. Re-evaluate the individual customer value functions considering the estimated position of the target firm's improved offering.

3. Develop the price equilibrium following the offering improvement.

4. Determination of the final demand estimate for the improved offering using the equilibrium prices. Evaluate diagnostic information.

Each of these steps will be discussed in more detail.

The first step in the price and demand assessment of an improved offering is the development of the price equilibrium relating to the current market situation. In order to complete this analysis, a variable cost estimate is required for each of the competitors' offerings. An engineering analysis should be able to provide a reasonable estimate. The price equilibrium relating to the current positions of the offerings will be used as a base case against which potential improvements will be compared. This assures that the profit results of potential improvements are not affected by inefficiencies in the current pricing structure.

In the second step, the demand for improved offerings is estimated. This requires a re-analysis of the individual value functions (as given by (3.1)) with the position for the target firm being the estimated position of the new offering (as discussed above). Without loss of generality, assume once again that the target firm is firm 1 and that a service improvement is currently under consideration. All other firms are assumed to remain in the same location in perceptual space. The value that individual place on these offerings is calculated at the equilibrium prices determined in the previous step.

The target firm, following the service improvement, has an expected perceptual position in customer i's perceptual map defined by a probability distribution with a mean of $(\overline{\xi}_{ip1}, \overline{\xi}_{is1})$ and a variance of Σ^s. When applying the value function to this estimated location, the resulting value for the target firm will be a normally distributed random variable with a mean and variance of (Glass and Stanley 1970, p. 127):

$$\overline{U}_{i1} = w_1\overline{\xi}_{ip1} + w_2\overline{\xi}_{is1} - w_3 p_1^e \tag{3.5}$$

$$\mathrm{Var} = w_1^2\sigma_p^2 + w_2^2\sigma_s^2 + 2w_1w_2\sigma_p\sigma_s\rho_{ps} \tag{3.6}$$

where

p_1^e = the equilibrium price for firm 1's offering.

ρ_{ps} = the correlation between *product* and *service* dimensions.

Figure 3.6a illustrates an individual's valuation of the offerings prior to an offering improvement by firm 1. In this scenario, each offering has a specific value: the value U_k as determined in (3.1). Using a first preference choice rule, an individual will choose the offering which has the highest value (firm 4's offering in Figure 3.6a). Figure 3.6b illustrates an individual's valuation of the offerings following an improvement in firm 1's offering. The location of all competing offerings remains unchanged. The mean valuation of firm 1's offering has shifted to a higher value and the probability distribution of the improved location is given by a normal distribution.[17] Because of the inclusion of an estimated offering location, the first preference choice rule becomes a probability of choice between two offerings. The individual will either choose the target offering or the offering with the highest value among the competitors. The probability that an individual will choose the target firm is the area under the normal distribution to the right of the highest valued competitor. In Figure 3.6b, this is the area to the right of firm 4. Since the mean and variance of the value distribution of firm 1's offering has been

[17]Since firm 1's offering is being improved, it is assumed that the probability that the new offering will have a lower value than before the improvement is arbitrarily small.

estimated, the probability that the individual will choose firm 1 can be determined. The probability that the individual will choose the competitive offering is simply 1-Pr[Firm 1's Offering]. An estimate of aggregate demand for the offerings in a particular region can be obtained by summing the probability levels across individuals.

The third step in the price and demand estimation for an improved offering is the re-establishment of the price equilibrium. Notice that the demand estimates in the above analysis did not consider the effects of changing prices. As prices for the firms change, the relative value that an individual places of the offering changes as well. For firm 1, the mean of the probability distribution increases (decreases) with a price increase (decrease). The variance of the distribution is unaffected. A numerical procedure which adjusts for these changing probabilities can be used to determine the new price equilibrium.

The final step in the analysis simply inserts the equilibrium prices into the value functions to determine the final estimate of demand for the improved offering. Following the analysis, it is important to analyze the shifts that occurred in the market as the result of offering improvement. Diagnostic information such as an analysis of the sources of increased demand and the movement in equilibrium prices should indicate which firms will be most affected by the potential improvement. This information may aid in the marketing of the improved offering.

In the previous discussion, emphasis was placed on how a single potential improvement could be analyzed with the customer data. Before adequate information is available to make the strategic direction decision, each of the items in the product and service improvement programs should be assessed in a similar manner. This "one-improvement-at-a-time" analysis allows management to assess the relative potential of an emphasis on product or service improvements. However, the analysis does not consider the interactive effects of simultaneously implementing several offering improvements. Because the

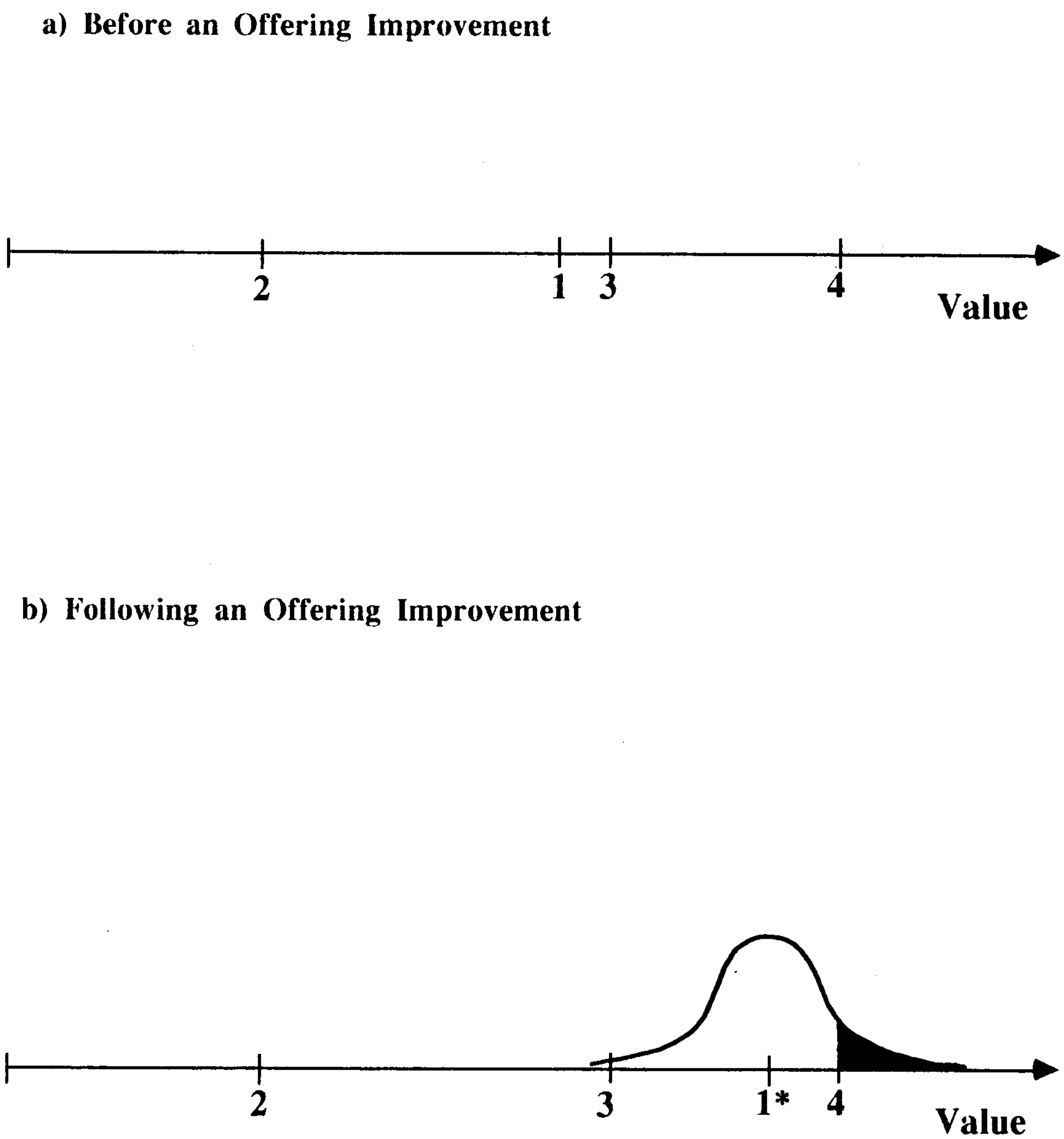


Figure 3.6: An Individual's Valuation of the Offerings

estimation of these effects is extremely difficult, they are not included in the analysis.

3.3.6 Assessing Return on Investment

In the previous section, the SDM model assessed the share of demand under competitive prices for the each item in the product and service improvement programs. These calculations were based on the notion of profit maximization. However, in order to assess the merits of an improvement, fixed costs have to be incorporated. Therefore, return on investment is used as a basis of comparison for each improvement. The ROI measure assumes that competitors will not react with offering improvements and customers are fully aware of the target firm's improvement. This situation is unlikely in reality. However, ROI does provide an effective means of comparing product and service improvements which may differ in terms of price, fixed and variable costs, and share of demand.

A two stage procedure is used to determine the ROI for a particular improvement program. First, an estimate of the incremental profitability of each improvement is determined. Second, a weighted average ROI calculation for the entire improvement program is calculated. This procedure will be described in more detail.[18]

Following the service improvement l, the profit for firm 1, Π^s (the firm subscript is omitted), can be expressed as follows:

$$\Pi_l^s = (p^e - c_l^s)m_l^s D \tag{3.7}$$

[18]Note again that this discussion relates to a single market. A second order algorithm is required to capture the multiple market effects.

where:

p^e = the equilibrium price determined in the estimation of demand stage.

c_l^s = the variable costs of the improved offering (l) as estimated during the offering improvement stage.

m_l^s = the expected share of demand of the improved offering (l) determined in the estimation of demand stage.

To determine the incremental profit resulting from the service improvement, the base case profits must be subtracted from (3.7). Base case profits are determined by inserting the equilibrium prices associated with the current positioning of the offerings (as calculated in step 1 of the analysis in the previous section) into the customer value functions. Base case profits for firm 1, Π^* (the firm subscript is omitted), can be defined as:

$$\Pi^* = (p^e - c)mD \tag{3.8}$$

where:

p^e = the equilibrium price.

c = the variable costs of the current offering.

m = the share of demand determined in the estimation of Nash equilibrium prices.

Incremental profit derived from the service improvement l is $\Delta\Pi_l^s = \Pi_l^s - \Pi^*$. Summing over all items, the total incremental profit derived from the service improvement program ($\Delta\Pi^s$) is defined as:

$$\Delta\Pi^s = \sum_l \Pi_l^s - \Pi^*$$

By incorporating the fixed cost estimates (F_l^s's), an ROI value for each item in the service improvement program (ROI_l^s) can be calculated:

$$ROI_l^s = \left(\frac{\Pi_l^s - \Pi^*}{F_l^s} \right) \times 100\% \tag{3.9}$$

Once the ROI calculations have been conducted for each item of both the product and service improvement programs, the strategic direction decision can be made.

The analysis described in this section considers only one market or region. If the SDM model is implemented over a number of markets, the equilibrium prices, market share, demand and possibly costs need to be subscripted by market. The incremental improvement in profits for each region would be summed to assess the potential profit impact of an improvement. It is at this stage that (3.9) is evaluated. As above, this procedure would be undertaken for both the product and the service improvement programs.

3.3.7 Strategic Direction Decision

The strategic direction decision follows a comparison of ROI levels across improvement programs. In the process of undertaking this comparison, there are two issues that need to be taken into consideration:

1. When implementation managers suggest items for the improvement programs, they are optimizing the best they can. However, they may not be fully aware of the competitive situation. As a result, the market outcome of these projects may not be favorable. Therefore, the inclusion of all improvement program items in an ROI comparison is not appropriate. An alternative would be compare the n best product improvements to the n best service improvements. The choice of n is subjective. It should be small enough so that only promising improvements are considered and large enough to ensure that the set of product or service improvements represents a medium term improvement program.

2. In every company, there is a limit as to the amount of money that can be invested in offering improvements. Therefore, it is necessary to ensure the improvement programs which are considered can be feasibly financed by the company. A budget constraint can be used to limit the improvements which are to be considered in the ROI comparison. If items in the product and service improvement programs are ordered from highest to lowest ROI, items can be sequentially added into the comparison such that the following constraints are satisfied:

$$\sum_{l} F_l^p \leq F \quad \text{and} \quad \sum_{l} F_l^s \leq F$$

   Note that these constraints may result in different numbers of items in the ROI comparison. However, each program would require an equal investment. In addition, the budget constraints give direction to the implementation managers in the offering improvement stage.

The issues discussed above forward two approaches to equalizing the ROI comparison across improvement programs. Choosing the best n projects ensures that only promising improvements are considered. However, affordability of the program is not considered. Including the highest ROI items such that the budget constraints are satisfied ensures that the chosen program can be feasibly financed. However, with a sufficiently high budget, F, this approach could include low ROI improvements. Given the counterbalancing strengths and weakness of these equalization rules, it is suggested that both rules be implemented simultaneously. That is, if improvements are renumbered in terms of ROI ($l = 1$ has the highest ROI), either the budget constraint or the best n constraint can limit the number of improvements which are considered in the product and service improvement comparison.

Once the appropriate product and service improvements have been selected for comparison, an overall ROI calculation can be made for the product improvements and the service improvements. This can be accomplished by summing the incremental profits for the selected items of an improvement program and divided by the sum of the fixed costs associated with those improvements. The improvement program (product or service) which yields the highest ROI in this comparison should govern the firm's choice of strategic direction. Again, it is important to note that the interactive effects of simultaneously implementing several offering improvements is not considered. Though this is a weakness, it is believed that the suggested comparison will allow management to assess the relative potential of an emphasis on product or service improvements.[19]

Assuming that items in an improvement program are ranked by ROI ($l = 1$ has the highest ROI), the strategic direction decision can be summarized by the following math program.

[19]Subjective judgements made by implementation managers can provide an estimate of interactive effects.

$$\underset{x \in (0, x^p, x^s)}{\text{Maximize}} \quad \left(\frac{\sum_l^L (\Pi_l^p - \Pi^*)}{\sum_l^L F_l^p}\right) x^p + \left(\frac{\sum_l^L (\Pi_l^s - \Pi^*)}{\sum_l^L F_l^s}\right) x^s \tag{3.10}$$

subject to (as appropriate):

$$\begin{aligned} F^p x^p + F^s x^s &\leq F && \text{(Budget Constraint)} \\ L &\leq n && \text{(Best } n \text{ Improvements)} \\ x^p + x^s &\leq 1 && \text{(Strategic Direction Choice)} \end{aligned}$$

where:

x^p = 1 if product strategic direction chosen, 0 otherwise.

x^s = 1 if service strategic direction chosen, 0 otherwise.

F^p, F^s = Fixed costs for the product and service improvement programs. $F^p = \sum_l F_l^p$, $F^s = \sum_l F_l^s$

(3.10) calls for a comparison of the expected ROI levels for the product and service improvement programs. The budget constraint and the best n improvements constraint determine which improvement items enter into the comparison. Finally, the strategic direction choice constraint ensures that only one of the two strategic directions can be chosen.

There are several features of the strategic direction decision that are worth noting. First, the decision is based on an analysis of expected outcomes. This market oriented approach considers the position of the particular firm in the markets in which it competes rather than industry trends alone. Notice that the strategic direction decision for two competitors may be different. Second, upon selection of the appropriate strategic direction, a relatively detailed plan of action is immediately available for implementation.

There should be relatively little "down" time between decision and action. Finally, the fact that implementing managers, who develop the improvement programs, are involved in the strategy formulation of the company should have a positive influence on the corporate culture of the firm. This effect can be enhanced if senior management emphasizes this participative role.

3.4 Contributions, Future Research and Summary

Contributions

The SDM model is designed to aid combined product-service firms in making offering positioning and pricing decisions. Drawing on the optimal product positioning literature, the model uses an analytical approach to the resolution of the strategic question of whether to invest in product or service improvements. A comparison of the model with more traditional optimal product positioning models illustrates the contributions of this research. A summary of this comparison is shown in Table 3.1.

The model presented in this research is fundamentally different from optimal product positioning models as it optimizes a firm's strategic direction rather than searches for the optimal new product location. This strategic focus adds a number of dimensions to the modeling problem including:

1. <u>The inclusion of several "levels" of analysis.</u> The positioning problem is analyzed from the perspective of the customer and the company. Within the company, managers at both the implementation and senior management levels combine to assess the appropriate strategic direction for the firm.

2. <u>The consideration of services.</u> Services are viewed as a critical component in the

Strategic Direction Model	**Optimal Product Positioning**
Strategic Direction	Optimal New Product Location
Physical -> Perceptual • Known Offering • Accurate Cost Estimates	Perceptual -> Physical • Optimal Perceptual Position • Lack of 1 to 1 relationship between perceptual/physical
Improvement Program	"Best Product"
ROI Over Entire Program	Share of Demand, Profit
Estimated New Offering Location Regional Differences Services	

Table 3.1: Comparison of the SDM model with Optimal Product Positioning Models

company's offering.

3. The consideration of multiple markets. Each market may differ in terms of size, number of competitors and the structure of customer perceptions and preferences. In addition, the ability to modify services at the regional level adds flexibility to the company's positioning options.

One of the primary contributions of the SDM model is the nature of its specification of the link between physical and perceptual spaces. In the offering improvement phase, the model develops a number of promising offering improvements and subsequently estimates their location in perceptual space. This approach is the reverse of optimal product positioning models which typically search for an optimal product location in perceptual space and attempt to relate this to a physical product. Although the SDM model does not find the optimal perceptual location, it does address the major criticisms of optimal product positioning models including the identification of the characteristics of the physical offering and an accurate estimate of production costs.

Finally, the SDM model contributes to the research on global marketing by providing an analytical, firm-specific approach to the development of a global product-service strategy. The model takes the view that an offering, especially its service component, need not be standardized across regions. More importantly, the model determines a company's strategy by considering the position of the firm's offering relative to competitive offerings as well as other regional market conditions.

Future Research

In this chapter, the components of the SDM model have been described in detail. However, additional research is required in a number of areas before the model can be implemented in an actual company setting. First, an approach to the development of an individual-level customer decision model needs to be developed. This research requirement is addressed in the next chapter of this dissertation.

Second, the development of improvement programs requires additional empirical research. The improvement programs are critical to the success of the model. To be of value, the product and service improvement programs must be specific enough to identify the most promising alternatives, but simple enough to be of value in a modeling procedure. In a company which is not currently involved in a quality function deployment system, a procedure similar to the one developed by Narasimhan and Sen (1990) appears to be the most promising.

Third, a numerical procedure for the development of a price equilibrium has not been developed. The critical component of this research step is the development of accurate cost assessments for the competitive offerings. The customer model developed in the next chapter can be used as synthetic data to illustrate how the price equilibrium analysis would operate.

Finally, additional research is necessary to extend the current model to the analysis of multiple regions. Conceptually, this extension in straightforward as an additional level of analysis can be accommodated by all phases of the model. The development of improvement programs would probably present the most difficulty in this extension as multiple markets would compound the number of projects which warrant consideration.

Summary

This research addresses a significant management problem: the choice of strategic direction. As the importance of services in traditional manufacturing organizations increases, research is necessary to aid managers facing new strategic trade-offs. Moreover, the issues facing these organizations are made more complex when global manufacturing requirements are to be balanced against local competitive needs. No single research project can expect to resolve such complexities, but it is believed that the research presented here is a step in that direction.

Chapter 4

An Individual Level Customer Decision Model

4.1 Introduction

Marketing researchers have developed a number of multi-attribute customer decision models designed to aid in the formulation of marketing strategy or the generation new or optimal product concepts (e.g., Shocker and Srinivasan 1974, Hauser and Simmie 1981, Hauser and Shugan 1983, Horsky and Nelson 1989). A customer decision model estimates brand preferences as a function of brands' perceptual locations and prices. The model is primarily used to estimate the effects of changes in the current market conditions. For example, the customer decision model incorporated in DEFENDER (Hauser and Shugan 1983) estimates the change in demand which results from the entry of a new product.

In this chapter, the research on customer decision models is extended by the development and implementation of an individual level model. The model combines a perceptual mapping technique (confirmatory factor analysis) with conjoint analysis to allow for individual differences in both perception and preference. The model is specifically designed for situations where the relevant attributes are characterized by infinite ideal points. That is, customers always prefer more of an attribute. Customer decision models developed by Hauser and Simmie (1981), Hauser and Shugan (1983) and Horsky and Nelson (1989) also consider *more is better* attributes.

The model is unique in a number of respects. First, confirmatory factor analysis is used to define the perceptual space. Like other factor analytic techniques, confirmatory factor analysis allows for heterogeneous perceptions through the estimation of individual factor scores. In addition, confirmatory factor analysis allows for a priori specification of number of perceptual dimensions and the measurement of their inter-correlation. Second, the model uses conjoint measurement to estimate customers' preference weightings for each of the perceptual dimensions and price. Parameters are estimated at the individual level and applied to an individual's brand perceptions to determine the individual's relative preference for each of the brands in the market. Finally, the model allows for the incorporation of price competition between brands. Because the price parameter is estimated over a range of price levels, the customer decision model is still valid as current prices are adjusted to Nash equilibrium prices.

Building on the SDM model developed in chapter 3, the customer decision model is specifically designed for markets which are characterized by the presence of product-service firms. However, its general formulation allows it to be applied in any setting. A product-service firm is defined as a company which is responsible for providing both the manufactured product and the associated services. A significant number of manufacturers of industrial and commercial products fall into this category. In the empirical study outlined later in this chapter, the customer decision model is applied in the combine harvester market of the farm equipment industry. This market provides a good example of a product-service setting. Each of the competitors in the market, like John Deere, manufacture a line of combine harvesters and market them through a network of exclusive dealerships. Customers (farmers) consider both product related attributes (e.g., *durability*) and service related attributes (e.g., *parts availability*) when making a purchase decision. Therefore, it is important to consider the entire *offering* (consisting of product and service features) in the development of the customer decision model.

In a product-service setting, it is expected that there will be significant differences in the customer perceptions of the offerings. This prediction is primarily due to the fact that there is a service component. There are two primary causes for significant differences in the customer perceptions. First, unlike "products", the offerings vary across customers due to individual experiences with service providers. In addition, in many situations (including the one analyzed in the empirical study), there are multiple service centers (of varying quality) for each of the manufacturers. This implies that there are true differences in the offerings across customers. Second, individual differences in peoples' evaluations of the offerings lead to perceptual heterogeneity even when the offerings are identical. These two causes imply that it is important to allow for differential perceptions (including alternative rankings) between customers.

The inclusion of heterogeneous preferences is typical of most customer decision models. In a product-service setting, where the offerings are often comprised of complex products which require specialized service, the measurement of preferences at the individual level is reasonable.

The remainder of this chapter is organized as follows. First, the customer decision model is developed. This is followed by a description of the features of the empirical study and a reporting of its results. The chapter concludes with a discussion of model contributions.

4.2 Model Development

4.2.1 A Framework for Multi-attribute Customer Decision Model Development

A significant amount of research has been conducted into the development of multi-attribute customer decision models. Shocker and Srinivasan (1979) outlined the major components of customer decision modeling approaches:

1. *Determination of relevant product-market(s):* A set of procedure used to define the bounds of relevant sub-markets and competitors. These bounds are often defined on usage situations.

2. *Identification of determinant attributes:* Identification of the set of attributes which are probable determinants of choice.

3. *Creation of an abstract representation of the product-market(s):* Existing brands (and possibly ideal points) are represented as locations in an abstract perceptual space.

4. *Development of models of individual behavior towards existing (and potential) brands:* A model is developed to predict the preferences (choice) for each individual among alternatives in the relevant sub-markets. The model determines how locations in perceptual spaces are valued by individuals. More recent models have incorporated price into the preference (choice) model.

5. *Evaluation of new product concepts and/or search of the perceptual space for "optimal" new product concepts:* New concepts are positioned in the perceptual space

and subjected to the model of individual behavior developed above. Recent models (e.g., Horsky and Nelson 1989, Choi, DeSarbo and Harker 1990) have allowed competitive reaction to the new product concepts in the form of price competition.

The customer decision model developed here follows general framework (Shocker and Srinivasan 1979). However, the suggested approach for the creation of the perceptual space and the parameterization of the individual decision model differs significantly from research to date. It is on these topics that much of the following discussion concentrates.

4.2.2 Perceptual Structure

The perceptual structure for the individual level customer decision model is developed through the use of confirmatory factor analysis: a specific form of factor analysis. Empirical research conducted by Hauser and Koppelman (1979) indicated that perceptual maps derived via factor analysis are superior to those developed via MDS and discriminant analysis in terms of interpretability and predictability.

When factor analysis is used in the development of a perceptual space, attribute rating data is required from a sample of customers. Urban and Hauser (1980) outline the most common procedures for the collection of this data and the development of perceptual maps. A similar procedure is adopted in the current model. Assume that N individuals evaluate (an average of) J existing brands on K attributes. Each set of brand attribute ratings is considered as a single case. Therefore an $NJ \times K$ matrix of person-brand attribute ratings is factor analyzed. The use of a data matrix in which individual responses on different brands are "stacked" on top of each other is referred to as a *Total Analysis* since both the variability between individuals and between stimuli (brands) is being factor analyzed. Srinivasan, Vanden Abeele and Butaye (1989) discuss the situations where this type of approach is most applicable and compare *Total Analysis* with *Within Analysis* (between individuals) and *Among Analysis* (between stimuli or brands). In most perceptual mapping situations, a *Total Analysis* is used as it is important to capture differences between individuals as well as between brands. This allows for the specification of individual differences in perception.

Factor analysis searches for a small number of latent variables or factors which can explain the variance in the observed set of attribute ratings. These factors become the dimensions of a perceptual map. It is assumed that customers use these latent factors in formulating judgements about the brands in the market. There are several types of factor analysis. Common factor analysis and principal components analysis (PCA) are the types most often used to develop perceptual maps (Urban and Hauser 1980). These approaches will be compared to the confirmatory factor analysis approach used for the individual level customer decision model. Readers interested in a more detailed description of factor analysis are directed to Mulaik (1972) and Rummel (1970).

Confirmatory Factor Analysis

The basic distinction between confirmatory factor analysis and other forms of factor analysis is similar to the distinction between confirmatory and exploratory research. In a confirmatory factor analysis, it is assumed that the researcher has obtained a certain amount of knowledge about the customers in the market and is, therefore, in a position to specify the latent factors and the relationship between these factors and the attributes on which they depend. This situation is typical of many markets in which perceptual maps are developed. Essentially, the researcher is confirming a structure which has been recognized in previous analyses. Statistical procedures are used to test the significance of the hypothesized relationships. This approach differs from common factor analysis and PCA. These methods of factor analysis are exploratory in nature. The main objective of an exploratory analysis is to find a simple but meaningful interpretation of survey results. Two steps are required in an exploratory analysis. First, the researcher must decide how many factors to retain to explain the variance in the data. Second the estimated factors are submitted to a linear transformation or rotation. This procedure yields new factors which can be given a more meaningful interpretation. Exploratory factor analysis does not use prior knowledge about the market under consideration and the relationships between factors and attributes cannot be tested statistically.

The confirmatory factor model, like common factor analysis, postulates that the attributes are linear functions of latent factors plus a residual term:

$$\boldsymbol{x} = \boldsymbol{\Lambda}\boldsymbol{\xi} + \boldsymbol{\delta} \tag{4.1}$$

where:

$\boldsymbol{x}$ = a vector of K observable attributes.

$\boldsymbol{\xi}$ = a vector of F latent factors. $F < K$

$\boldsymbol{\Lambda}$ = a matrix of factor loadings which specifies the relationship between the attributes and the latent factors.

$\boldsymbol{\delta}$ = measurement error. Note E($\xi\delta'$)=0 and E($\delta\xi'$)=0.

The confirmatory factor model attempts to explain the variance in the observed attribute ratings with a small number of factors. From (4.1), the variance in the attribute ratings, $\boldsymbol{\Sigma}$, can be defined as:

$$\boldsymbol{\Sigma} = \boldsymbol{x}\boldsymbol{x}' = \boldsymbol{\Lambda}\boldsymbol{\Phi}\boldsymbol{\Lambda}' + \boldsymbol{\Theta}_{\delta} \tag{4.2}$$

where:

$$\boldsymbol{\Phi} = \boldsymbol{\xi}\boldsymbol{\xi}'.$$

$$\boldsymbol{\Theta}_{\delta} = \boldsymbol{\delta}\boldsymbol{\delta}'.$$

As described thus far, the confirmatory model is virtually identical to the common factor model (prior to a rotation). The difference between the two approaches is in the specification of $\boldsymbol{\Lambda}$ and $\boldsymbol{\Phi}$. In the common factor model, once the number of factors has been selected, all elements of $\boldsymbol{\Lambda}$ and $\boldsymbol{\Phi}$ are estimated. In the confirmatory model, the number of factors (F) is set a priori as is the pattern of relationships between the F factors and the K attributes. These relationships call for the estimation of only certain parameters in $\boldsymbol{\Lambda}$. For example, a researcher might propose a two factor model for a set of six variables with the following pattern:

$$\begin{pmatrix} \mathrm{X} & 0 \\ \mathrm{X} & 0 \\ \mathrm{X} & \mathrm{X} \\ 0 & \mathrm{X} \\ 0 & \mathrm{X} \\ 0 & \mathrm{X} \end{pmatrix}$$

The columns of the above matrix relate to the latent factors while the rows relate to the observed attributes. The X's represent free parameters which are to be estimated.

All remaining elements are fixed with a value of zero. The statistical significance of the free parameter estimates and the overall goodness of fit of the model can be assessed via Maximum Likelihood. In a similar manner, the pattern of elements of $\boldsymbol{\Phi}$ can be specified. This allows for the estimation of correlated factors.

The estimated brand locations in the perceptual space are determined by the factor scores relating to an individual attributes ratings of the brands. The factor scores are estimated as a linear function of the original ratings. The parameters of this equation are called "factor score coefficients". The confirmatory model incorporates measurement error and the factor score coefficients can be estimated via OLS regression. These coefficients are standard output in computer packages like LISREL (Joreskög and Sörbom 1985).

As described above, the major distinction between confirmatory factor analysis, common factor analysis and PCA is the fact that both the latter two factor analytic techniques are exploratory in nature. Other differences, outlined in the development of the confirmatory factor model, are the measurement of correlated factors and the inclusion of measurement error. These two issues will be discussed in more detail.

One of the major advantages of the confirmatory factor model is the ability to measure (and test statistically) the correlation between perceptual dimensions. Virtually all perceptual maps created via exploratory factor analysis (as well as MDS and discriminant analysis) restrict the latent factors to being orthogonal when, in fact, it is quite likely that the "true" latent factors are correlated.[1] The factors extracted using an exploratory approach are rotationally indeterminate. That is, the factor matrix can be

[1]Although an oblique rotation of factors is possible, it is rarely, if ever, used. One of the possible explanations for this fact is the ambiguity in interpreting the output of an oblique rotation as two factor matrices, a factor pattern matrix and a factor structure matrix, are given as output along with an estimate of the correlation between factors. See Green (1978) for a discussion of oblique rotations.

rotated in an infinite number of ways which may lead to different interpretations of the data. The orthogonal rotation most often suggested, VARIMAX, maximizes the columns of the squared factor matrix. Typically, this leads to a factor matrix in which only a few attributes load highly on each dimension. Although the orthogonality constraints allows for an easy pictorial representation of the product market, it is unclear whether it offers a better understanding of the underlying perceptual structure. This can be illustrated by means of an example.

Consider a hypothetical product-market in which a factor analysis yielded two perceptual dimensions (say, *ease of use* and *power*). Figure 4.1a illustrates an individual's perceived location of 3 brands in this perceptual space. This perceptual map implies that if brand A was successful in increasing its perceived *ease of use*, it would have no effect on its perceived *power*. Now assume that the two latent constructs (*ease of use* and *power*) have an inter-correlation of 0.5. This implies that higher levels of *power* are perceived to be associated with higher levels of *ease of use*. Figure 4.1b illustrates a the perceptual map with these correlated constructs. The axes are separated by a 60° angle rather being orthogonal ($\cos(60°) = 0.5$). In this revised model of perceptual structure, an improvement of x units in brand A's perceived *ease of use* would result in an increase of $x \cos\theta = .5x$ units in brand A's perceived *power*. This secondary effect on perceived *power* is not captured in an analysis using an orthoganol factor rotation. If the goal of the development of a perceptual space is to gain insight into consumer's perceptions of the various brands, the restriction of orthoganol constructs may hide some important information. It is not hard to imagine that a high inter-factor correlation could have a significant impact in any repositioning strategy.

The treatment of measurement error (termed attribute uniqueness in the common factor model) is another feature on which the factor analytic techniques differ. Both

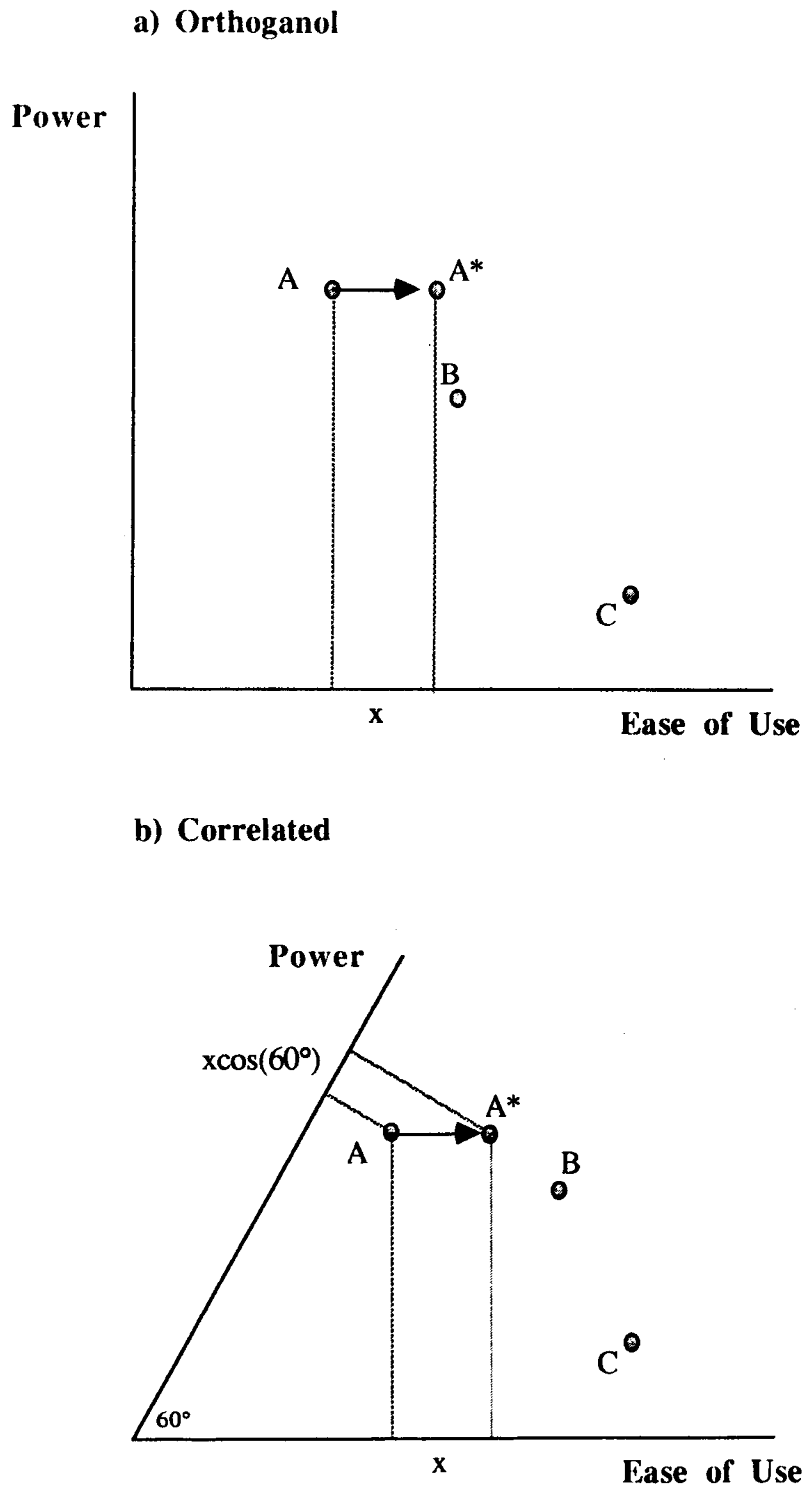


Figure 4.1: Perceptual Maps Illustrating Orthogonal Versus Correlated Factors

confirmatory and common factor analysis include measurement error whereas principal components analysis does not. Theoretically the inclusion of measurement error is desirable as it is impossible to measure a latent factor without error. However, there are implications to its inclusion. In confirmatory and common factor analysis, the objective is to replicate the covariation between attributes (off- diagonals in the correlation matrix) with a reduced number of factors. Differences in the variances (the diagonal of the correlation matrix) between the observed data and the predicted model are assumed to be measurement error. This leads to the factor indeterminacy problem. That is, it is possible to derive different sets of factor scores and measurement errors which fit the data equally as well but have very different interpretations. Steiger (1979) discusses the history of the factor indeterminacy problem. In short, proponents of the common and confirmatory factor models suggest that factor indeterminacy is not a serious problem as it rarely affects interpretations (e.g. McDonald (1974), Green 1976). These researchers prefer the more theoretically sound model formalizations.

Other researchers prefer to circumvent the indeterminacy problem through the use of principal components analysis. PCA assumes no attribute uniquenesses or measurement error (Urban and Hauser 1980). Since the results from both of these methods tend to have little or no difference in interpretation, the use of PCA seems appropriate. However, it is important to note that there exists no confirmatory factor procedure which assumes no measurement error. The use of principal components analysis for the construction of a perceptual space has been discussed extensively by Huber and Holbrook (1979) and Dillon, Frederick and Tangpanichdee (1985).

Confirmatory factor analysis, when used in situations where a base of prior knowledge about the product market is available, has a number of advantages over common factor analysis and principal components analysis. First, the model defines and tests the statistical significance of the relationships between offering attributes and latent factors. Essentially, the researcher is testing a theory about the structure of customer preferences. This gives the researcher a better understanding of the composition of the latent factors and should aid in the development of offering improvements which will have a positive impact on customer perceptions. Second, the confirmatory factor model does not suffer from the rotational indeterminacy which results from an exploratory factor model. Dillon, Frederick and Tangpanichdee (1985) suggest that the effects of rotationally indeterminacy as it relates to perceptual space construction has not been adequately studied. Finally, the confirmatory model allows for the specification of correlated factors. As discussed above, this may yield important information about the relationship between latent factors. In addition, when confirmatory factor analysis is used (as opposed to an oblique rotation), the statistical significance of the factor correlations can be assessed. In sum, confirmatory factor analysis for use in the development of perceptual maps provides an attractive alternative to exploratory factor analysis.

4.2.3 Preference Measurement

Once the perceptual structure is developed, the next task in the development of a customer decision model is the measurement of individual preferences. As was stated earlier, the customer decision model developed here is specifically designed for situations where the relevant attributes and latent constructs are characterized by infinite ideal points. Therefore, the vector model, which models utility as a weighted sum of factor or dimension levels of each alternative, is a natural choice for a model of preference. The vector model postulates that the value, U, that customer i places on k's offering is defined as follows (the customer subscript, i is excluded):

$$U_k = \sum_{j=1}^{J} w_j \xi_{jk} - w_{J+1} p_k \tag{4.3}$$

where:

ξ_{jk} = offering k's location on the factor j.

p_k = price of offering k.

$w_1, \ldots, w_{J+1}$ = parameters to be estimated.

There two points worth noting about the vector model described in (4.3). First, income effects are not included. Models based on the Lancaster tradition incorporate price by subtracting it from income. This yields a term, $Y - p_k$, which represents the amount of funds available for expenditure on all other goods. A similar formulation would also apply in the current model. However, since (4.3) is estimated at the individual level, income becomes redundant (see Ratchford 1979, p.80).[2]

Second, no interaction term is included in the value function. Though it is common in models of this type not to include interaction terms (e.g., Hauser and Shugan 1983, Horsky and Nelson 1989), the importance of interactions remains an open question (see Green and Srinivasan 1990, p.5). Interaction terms are not included in (4.3) because the correlation between the latent factors (as determined by the confirmatory factor analysis) already captures some of the interactive effect when product improvements are being evaluated. Nevertheless, the empirical study described later in this chapter includes a test of whether interaction terms add to the predictive ability of the model.

[2]Because a combine is a major purchase, income probably has some explanatory value. For example, income may be a good predictor of whether a farmer purchases a combine in the new or used market. The inclusion of this type of income effect is beyond the scope of this dissertation.

Issues Surrounding Preference Measurement Procedures in Customer Decision Models

In most customer decision models, the parameterization of the model of individual preference has proceeded by comparing customer preferences of the brands in the product-market to their location in the perceptual product space. Brand preferences are typically determined by either a ranking or rating procedure. The ranking of brands yields ordinal preferences whereas a rating of brands yields ratio-scaled preferences when an intensity measure like constant sum paired comparisons is employed (Hauser and Shugan 1980). When price is included in the customer decision model, brand preferences are determined at a specific "sticker price". These prices usually correspond to the prevailing market prices.[3]

There are several issues which are raised by this type of parameter estimation procedure. First, the reliability of the estimates is affected by the number of brands in the product-market. Each preference ranking (or rating) of a brand represents an observation to be used in the model estimation. In markets where there is a low ratio between the number of observations (brands) and the number of parameters to be estimated, the reliability of the parameter estimates is reduced. For example, Horsky and Nelson (1989) use 12 observations to estimate individual preference models with 7 to 9 parameters. The good fit of model to the data must be tempered against the low reliability of the parameter estimates. To improve this situation, the model can be estimated on segments of respondents rather than at the individual level.

[3]Actual brand choice information can be used if this information is available and can be assumed to represent the current preferences of the respondents. Hauser and Gaskin (1984) use choice information to assess the relative importance of price scaled dimensions. Rather than estimate individual preferences, the distribution of customer tastes is estimated.

Second, parameter estimates are affected by the range of brands in the product-market. In markets where there are few brands or markets where brands tend to be clustered in a few perceptual locations, the customer decision model may place too much emphasis on the differentiating features of the relatively homogeneous brands. For example, assume that three features are important in the market, but all brands are equal on the most important feature (say *Power*). When brand preferences are compared to product locations, *Power* will not be viewed as an important indicator of choice. This finding is true of the current market, but if the objective of the customer decision model is to develop new product concepts, the *Power* feature may be ignored. In a related issue, if brands tend to be clustered in a few perceptual locations, the customer decision model is estimated on observations which span only a fraction of the perceptual product space. It is unclear whether the parameter estimates would apply to new concepts which are located in an "unexplored" area of the perceptual product space.

A final measurement issue arises when price is included as a variable in the customer decision model. The objective is to estimate a price parameter which will correctly assess the price sensitivity of potential customers. In a typical procedure, all brands in the market are listed at a sticker price and respondents are asked to rank (or rate) the brands. There appears to be two major problems with this data collection method. First, the preference data collected in this manner is used to estimate a multi-factor model with price. When the information is collected, the brand is supposed to act as a proxy for the multiple factors or perceptual dimensions whereas the price component is separated. It would appear that respondents to this question would allocate too much importance to the price of brand. Second, recent optimal product positioning models (Choi, DeSarbo and Harker 1990, Horsky and Nelson 1989) as well as the model developed here, allow for the incorporation of price competition. The resulting Nash equilibrium may yield a brand-price profile which is substantially different to the one for which the preference data was collected. This raises questions about the appropriateness of the estimated model.

A Conjoint Measurement Approach to the Parameterization of the Model of Individual Behavior

In order to address the issues outlined above, the customer decision model developed in this research uses conjoint measurement to parameterize the model of individual behavior. Conjoint measurement techniques have received widespread acceptance in both academia and industry as a set of methods for measuring customer's tradeoffs between multi-attribute products and services (Wittink and Cattin 1989). Green and Srinivasan (1978, 1990) review the major developments in conjoint analysis and discuss implementation procedures.

Conjoint measurement is used to estimate the weights of the individual preference models (the w_j's in (4.3)). To do this, a series of profiles incorporating price and the the latent factors derived through the confirmatory factor analysis are developed. These profiles are, in turn, evaluated by potential customers and the resulting preference weights are estimated. In addition to design issues like the selection of experimental profiles and the profile presentation format, there are two issues which have a significant impact on the application of conjoint measurement discussed here. First, in order for the preferences developed through the conjoint measurement procedure to be valid, the customers must be considering the latent factors when evaluating the various profiles. If the labelling of the factors in the conjoint measurement task does not imply the construct developed through the confirmatory factor analysis (in the minds of the customer), it is inappropriate to use the resulting preference estimates in equation (4.3). Second, it is important that the range of levels on each of the factors used in the conjoint measurement task covers the possible range of potential perceptual locations. Satisfying this condition ensures that the parameter estimates are valid for all locations in the perceptual space. Approaches to addressing these issues are discussed below.

Labelling of Factors

The customer decision model developed in this chapter is designed to be applied in markets where the researcher has some a priori information about the structure of perceptions. In these situations, the latent factors or dimensions of the perceptual space (and thus, the factors in the conjoint measurement experiment) are hypothesized prior to data collection. Although there may be a high degree of confidence that the chosen attribute-to-factor associations are relevant in the market under consideration, the naming or labelling of these factors is arbitrary. Since it is these factor labels that are to be used in the conjoint measurement task, it is important that the selected labels capture the essence of the underlying construct. Specifically, do customers make the same attribute-to-factor associations as hypothesized in the confirmatory factor analysis when they are presented with the factor labels? One approach to assessing this issue would be to collect data from an independent sample of potential customers in the product-market. Respondents can be asked which of the determinant attributes (used in the confirmatory factor analysis) are associated with the factors as labelled in the conjoint measurement task. To be confident that the appropriate factor labels are being used, the results of these questions should identify a factor pattern identical to that which was used in the confirmatory factor analysis.

Selection of Factor Levels

Not only is it important to have a match between the factors used in the confirmatory factor analysis and the conjoint measurement task, the levels used in both analyses must match as well. This matching is is necessary because the researcher must ensure that the range of levels used in the conjoint analysis covers the possible range of potential perceptual locations on each of the factors. Note that matching is not necessary for the price factor as it is assumed to be objective rather than perceptual in nature. However, like the perceptual factors, the range of price levels used in the analysis should cover the range of possible pricing options. In the empirical study which follows, the levels for the latent factors used in each of the analyses are semantically linked. Respondents were asked to evaluate the various brands on the determinant attributes using the following 7 point scale:

Poor	-	1
		2
Fair	-	3
		4
Good	-	5
		6
Excellent	-	7

In the subsequent conjoint measurement task, the levels *Poor, Fair, Good* and *Excellent* were used in the design. The vector preference model was estimated (via regression) using a coding scheme which matched the attribute scale. In order to have an equal number of levels for each factor, the price factor was also specified at 4 levels.

4.2.4 Customer Choice Rule

The customer decision model combines the confirmatory factor model and results of the conjoint measurement task with a specific choice rule. An individual's utility or value for a particular brand is calculated by using the brand's perceptual location (factor scores) and its price as the variable levels of the vector model defined in (4.3). The weights used to parameterize this model are calculated at for each individual from the conjoint data. These utility or value levels form the basis of the customer choice rule.

It is relatively straightforward to apply either a deterministic or probabilistic choice rule to the value function defined in (4.3). The selection of a choice rule depends on the product market under investigation. Since the customer decision model developed here is designed for markets which are characterized by product-service firms, a deterministic, first choice rule is implemented. This choice rule assumes that the brand of choice is the brand which receives the highest value in equation (4.3). Gavish, Horsky and Srinkanth (1983) suggest that a deterministic choice rule is appropriate for infrequently purchased goods or durables. This description applies in most product-service markets, such as the combine harvester market used in the empirical study. Gavish, Horsky and Srinkanth argue that in these situations, customers choose with certainty after an evaluation of all alternatives. As part of the empirical study, discussions with farmers clearly identified a conscious (and ongoing) evaluation of alternatives in the combine harvester market.

4.2.5 Why Not Use Conjoint Alone

Conjoint analysis continues to grow in popularity among academicians and practitioners (Wittink and Cattin 1989). In industry, it is common practice to use the elicited attributes in a conjoint experiment and then use the resulting preferences used as input in a choice simulator (Green and Srinivasan 1990). This procedure eliminates the need for the development of a perceptual product space as the customer decision model is based on the underlying attributes. However, the choice simulator uses the researcher's subjective judgement to estimate a brand's characteristic levels. In addition, perceptual heterogeneity is ignored. These issues will be discussed in more detail.

Green and Srinivasan (1990) suggest that one of the main reasons for the popularity of conjoint analysis in industry is the availability of choice simulators. Choice simulators use the individual preference estimates obtained through the conjoint study to answer various "what if" questions about the market under consideration. The input to a choice simulator is the matrix of customers' part-worths (customers' preference intensity for each level of each attribute). To assess the current market situation, each of brands in the market is described by its levels on the important attributes. These descriptions are used as input in the choice model. Following the selection of a choice rule (max utility, logit rule, etc.,) the market shares of the brands are estimated based on analysis of the customers' part-worths.

The subjective assignment of attribute or characteristic levels to describe actual brands and new product concepts may be limiting. In many situations, at least some of the elicited attributes are latent (e.g., *durability*, *ease of use*). It is very difficult to link the levels of these attributes with the actual brands without an independent measurement of customer perceptions.[4] In addition, these perceptions will vary at the individual level while the choice simulator assumes homogeneous perceptions. The impact of using subjective judgement to describe the characteristics of brands and new product concepts

[4]An alternative may be to consider only objective, physical attributes. Agarwal and Ratchford (1980), use physical attributes in a model of car preference. They selected objective characteristics which correlated with a set of independently determined perceptual dimensions (e.g. engine displacement and passing time are related to performance). However, these researchers note that not all perceptual dimensions could be associated with objective attributes.

depends on the market under consideration. In markets where there is very little perceptual heterogeneity and/or the important attributes are objective, the use of a choice simulator can be very effective. However, when significant perceptual heterogeneity exists, the homogeneous perceptions assumption of the choice simulator may yield results which are significantly different from the "true" market response. This is due to the fact that customers may have very different opinions about the characteristic levels of the brands.

In markets which are characterized by product-service firms, the significant differences in individual perceptions eliminate the option of using of a conjoint choice simulator as a customer decision model unless homogeneous segments can be found. The methodology outlined above, which combines a perceptual mapping technique with conjoint measurement, would be more appropriate in these situations. An alternative to a conjoint choice simulator would be the development of an alternative form of choice simulator which includes both perception and preference information. This simulator, which could operate in much the same way as conjoint choice simulators, would have the added benefit of incorporating customer perceptions when "what if" analyses are undertaken. Because the customer decision model outlined above is analyzed at the individual level, the development of this type of simulator would be relatively straightforward.

4.2.6 Summary of the Customer Decision Model

This section outlines a procedure for the development of a customer decision model in situations where relevant attributes are characterized by infinite ideal points. The procedure addresses a number of the issues raised by previous modeling efforts. By combining confirmatory factor analysis with conjoint measurement, a individual level model which incorporates both heterogeneous perceptions and preferences is developed. Model advantages include the ability to statistically test the attribute-to-factor relationships, the measurement of correlated perceptual dimensions, an improved method for preference estimation and the incorporation of price in a more meaningful way. Though an empirical application of the model will follow, extensive empirical testing is required to fully assess the importance of these modeling improvements.

4.3 An Empirical Application of the Individual Level Customer Decision Model

The individual level customer decision model will be illustrated with an application to combine harvesters within the farm equipment industry. This section will provide some background on the selected product-market as well as detailed description of the study which was undertaken.

4.3.1 The North American Combine Industry

Combines are sophisticated machines (costing up to US$200,000) which are used to harvest a wide variety of crops. The combine harvester market provides a good example of a market consisting of a set of product-service firms. Both product related and service related attributes as well as price have significant impact on the customer's purchase decision. Farmers interested in purchasing a combine consider product features like durability, threshing technology and ease of monitoring the combine's operation. In addition, they consider service features like parts availability and the location of the local dealer.

The North American combine market is dominated by four manufacturers: Case-International, Duetz-Allis (Gleaner), John Deere and New Holland.[5] Each of the major combine manufacturers utilizes centralized production facilities producing combines which incorporate a standard global technology. In addition, all manufacturers operate a dealer network which markets and services that firm's entire line of farm machinery. Depending on the crop growing region, dealers typically operate in a 30-70 mile radius.

The combine market, as well as the farm equipment industry in general, has undergone substantial change in recent years. The change has been brought on by a severely depressed farm economy. In the last five years, two major combine manufacturers, White Farm Equipment and Massey Ferguson, have ceased production. Together, these manufacturers represented 25% - 30% of the inventory of combines in North America. Though independent manufacturers are attempting to revive the production of these combines (apparently because of their superior technology), the lack of an established dealer network has limited their market penetration. The depressed farm economy has also led to a dramatic reduction in the number of new combines purchased in recent years. However, forecasts for the 1990 year were encouraging as sales were expected to improve in all regions (Agri-Marketing 1990).

The North American market for combines can be divided into a number of distinct regions on the basis of crops grown. From a demand perspective, the two most important regions are the prairies/plains (primarily wheat and barley) and the midwestern states (primarily corn and soybeans). Though many of the important product and service attributes are similar for these two regions, there are some important differences. In addition, a distinction can be made between markets in Canada and the United States.

[5]There are also a number of minor manufacturers (Klaas, Belarus, Coop Implements) who together account for less than 5% of combine inventory.

The current study concentrates on the Canadian prairies. Therefore, the multiple regions component of the strategic direction model will not be tested at this time. However, it is straightforward to see how the model extends to multiple regions.

4.3.2 Data Collection Procedures

The empirical study consisted of two separate surveys of combine owners. The main survey collected the farmers' perception and preference information that was used in the model parameterization. The secondary survey was used to test whether farmers associated the determinant attributes with the latent factors as discussed in the previous chapter. The major features of the data collection phase of the research are as follows:

1. Interviews were conducted at the Canada Western Agribition in Regina, Saskatchewan. This trade show, which ran from November 24 -30, 1990, is attended by an estimated 30,000 farmers annually. The majority of these farmers own a combine.

2. With the cooperation of the Agribition, a booth was set up to conduct the interviewing. This booth was set up in a high traffic area where the majority of exhibits were dedicated to grain and oilseed production. In addition, interviewers were granted permission to approach trade show visitors who passed the booth. Using a random intercept procedure, farmers were asked to complete one of the two questionnaires. No farmer was asked to complete both questionnaires. Completion of both interviews occurred concurrently on all days of the show. This interviewing approach represented an economical means of obtaining the necessary data to test and demonstrate the proposed framework.

3. Mark Vandenbosch supervised the interview process. The primary interview was computer driven and collected on one of 4 computer systems set up at the booth. The survey was completed independently by the respondents, however, each of the major questioning sections was explained by the supervisor. This was in addition to typed instructions provided throughout the computer questionnaire. The supervisor also answered any questions the respondents may have had concerning the questionnaire and the study itself. The secondary questionnaire was collected via a personal interview with one of two hired interviewers. These interviewers, hired locally from a marketing research firm, also recruited the respondents for the computer interview.

4.3.3 Questionnaire Design

The computer questionnaire was developed using Sawtooth Software's Ci2 software package. Appendix C contains a copy of the questionnaire and Table 4.1 outlines its major sections. Each of these sections will be discussed in more detail.

Level of Analysis

Within the combine market, each of the major manufacturers markets a range of combine models to appeal to different farm sizes and conditions. Though there may be specific exceptions, the manufacturers are well matched at the model level. For example, there are three models in John Deere's Maximizer line of combines and four models in Case-International's 1600 Series (John Deere 1990, J. I. Case Canada 1990). The main differentiating feature between the models is the capacity of the combine. The basic

1	Crops Information and Combine Inventory
2	Combine Attribute Ratings
3	Ranking of Manufacturer Preferences
4	Conjoint Measurement
5	Demographics

Table 4.1: Questionnaire Outline

technology used in the combine is the same for all models of each manufacturer. Thus, the number of acres to be harvested determines what model size that farmers compare across manufacturers.

An important question is whether to consider each model of each manufacturer as competitors or to consider manufacturers as competitors. Although incorporating all models as competitors may yield some important insights into cannibalization, there are not sufficient differences between models to warrant the extra detail. None of the service attributes and only some of the product attributes would vary between different models of the same manufacturer. In addition, the manufacturers do not market the individual models separately. Therefore, analysis was conducted at the manufacturer level.

In order to ensure that respondents considered the manufacturer comparison, each respondent was asked to "consider a combine of a size which would be suited to [his] farm operation" when making inter-brand comparisons. To compliment this approach, size or capacity features were not included in the list of important attributes. This assumes that all manufacturers were able to offer choices in all desired capacity ranges. This assumption does not appear to be restrictive.

Crops Information and Combine Inventory

The first section of the questionnaire was used to familiarize respondents with the computer questionnaire format. Several multiple choice questions explored the type of farm type, crops grown in 1990 and the brand(s) of combines owned. In a representative survey, these questions would identify key background variables which may affect the purchase decision. Variables like *brand of combine owned* and *number of acres seeded* can be used to weight respondents in order to match known distributions.

Attribute Ratings

The next section consisted of a rating of the 4 major brands on important product and service attributes. Many farmers were very familiar with all manufacturers' combines. This is probably due to the fact that the combine is the largest single machinery investment of the farm. Because of this high level of awareness, respondents were asked to rate all 4 of the major manufacturers on all relevant attributes rather than only those in their individual choice set. Respondents who stated they were unfamiliar with particular brands were permitted to withhold their rating of those features and brands with which they were unfamiliar.

A total of eight attributes were included in the rating task. These attributes were selected primarily through a review of previous marketing research studies. The main source was a study in which 10 focus groups were conducted with farmers in the prairies (both Canada and U.S.A.) and the midwestern states (Deloitte, Haskins and Sells 1985). Using the Nominal Group Technique (Claxton, Ritchie and Zaichkowsky 1980), the focus groups determined which attributes were important to farmers when evaluating and choosing combines. Each group devised its own list of important attributes and the lists were subsequently compiled across groups. Attributes which were considered important at each of the prairie groups made up the preliminary attribute list for the present study. The preliminary attribute list was modified through discussions with marketing researchers who have recently conducted combine studies in western Canada. The goal was to ensure that the attributes were relevant to the specific region in which the empirical study was to take place.

The revised list of attributes went through four more modifications before the final attribute list was selected. First, an attribute relating to the harvesting capacity of the combine was removed to be consistent with the level of analysis to be addressed in the empirical study. Second, combine advertising literature was surveyed to see how well the preliminary attribute list matched the attributes stressed by the manufacturers. Third, seven dealers in Saskatchewan were contacted and asked for their input on what attributes they thought farmers used in their combine evaluation processes. This exercise resulted in only minor semantic changes to the attributes. Finally, farmers participating in the questionnaire pretest were asked how well the preliminary attribute list captured the essence of the combine evaluation task.

The final attribute list consisted of eight attributes. *Durability, Ease of Maintenance, Ease of Controlling Operation* and *Threshing Technology* were hypothesized to be associated with *Combine Quality*. *Parts Availability, Dealer Location* and *Dealer-Farmer Relations* were hypothesized to be associated with *Service Quality* (termed *Dealer Service* following discussions with farmers). The final attribute, *Combine Warranty*, was hypothesized to consist of two components. First, a review of earlier studies seemed to indicate that a "good" warranty was associated with higher *Combine Quality*. Second, the willingness of dealers to honor the warranty and perform warranty repairs was considered a service feature (see Figure 4.2).

Farmers completing the questionnaire were asked to rate Case-International, Gleaner, John Deere and New Holland combines on each of the 8 attributes using the following 7 point scale:

Poor	-	1
		2
Fair	-	3
		4
Good	-	5
		6
Excellent	-	7

Respondents rated each brand on a particular attribute before continuing. The order in which the attributes appeared was randomized for each respondent, but the brand order was not.

Manufacturer Preferences

An important component of the strategic direction model is the inclusion of price. The assessment of farmer preferences for the various manufacturer brands incorporated this feature. Both a ranking of brands "at a sticker price" and a ranking of brands at orthogonally varied prices were used to assess farmer preferences for combine brands at

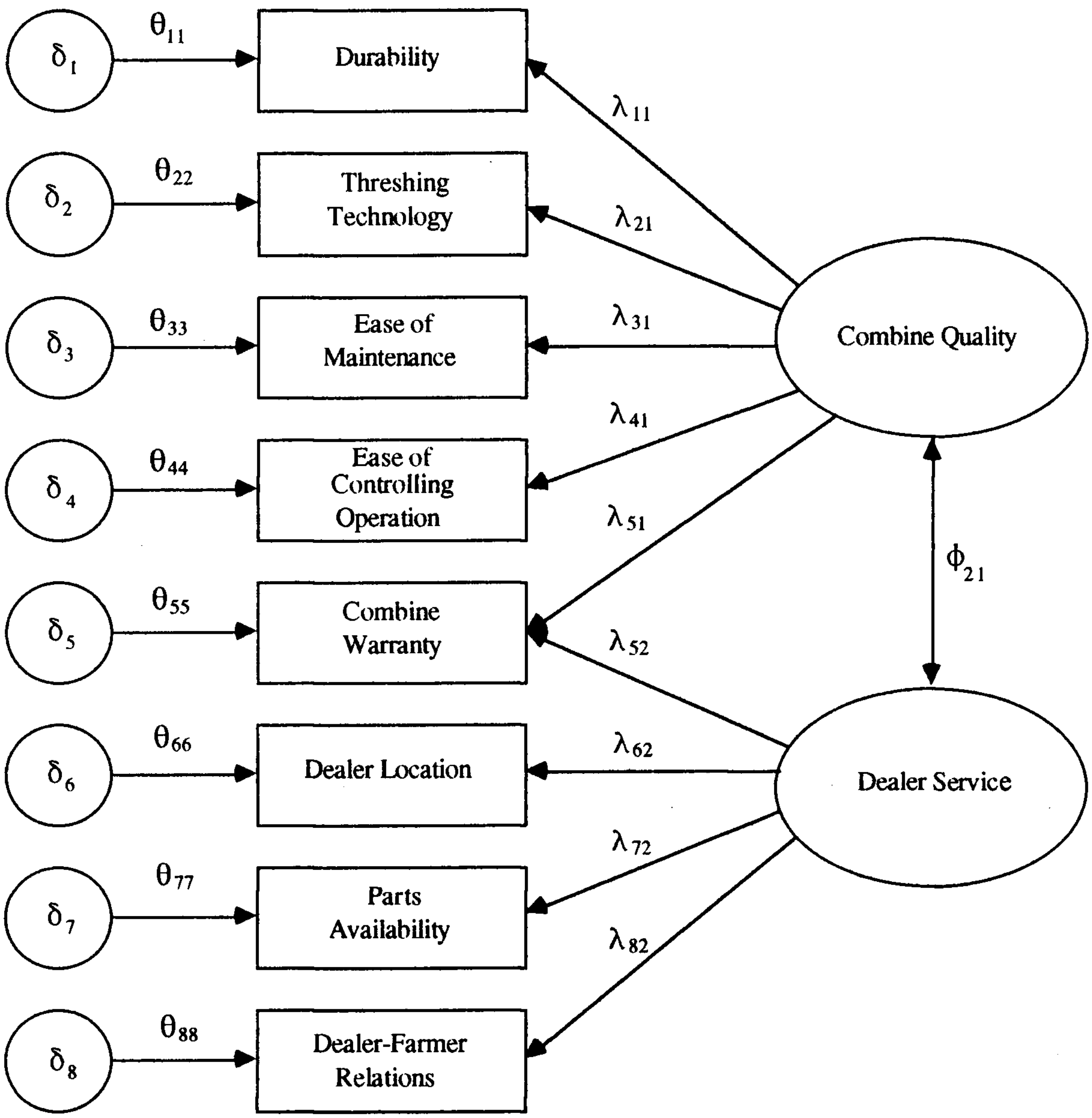


Figure 4.2: Confirmatory Factor Analysis Path Diagram

different prices.

Since the level of analysis was set at the manufacturer rather than the model level, combine prices could not be included as an actual dollar amount. This is due to the fact that there is a substantial price difference between high and low capacity combine models. Therefore, prices were expressed as relative to the average price for a combine of the desired capacity. For example, Brand A priced at 5% Above Average or Brand C priced at 5% Below Average. Both the dealers and pretest farmers were comfortable with this pricing method.

It is unclear whether the use of relative price levels is restrictive. On the one hand, actual prices are more salient to the respondent, especially when a 10% difference could mean as much as $20,000. However, a dollar figure may lead to a "sticker shock" effect which would over emphasize the importance of price. In addition, the extensive negotiations which take place between dealer and farmer on the purchase of the combine raises questions about the meaning of list prices in a brand-price comparison. On the other hand, the relative prices allowed for a comparison based on price perceptions even though the levels of relative price were chosen objectively. Additional empirical research is necessary to determine which approach would be superior in the context of the strategic direction model.

In the brand "at a sticker price" question, respondents were asked to rank their preference for the various manufacturers at specific relative prices. The relative prices were determined through discussions with 7 farm equipment dealers in Saskatchewan. Two dealers for John Deere, Case-International and New Holland were contacted as well as a Gleaner dealer. The dealers were first asked whether the various manufacturers were matched on model size. All were in agreement that this was generally the case. Second, the dealers were asked what the relative prices of the manufacturer combines for models of equal size. The majority of dealers replied that the list prices were very close together. When probed about actual selling prices, most dealers felt that John Deere combines "held their price" while Deutz-Allis combines "discounted more than the others". Financing packages and trade-ins made exact pricing comparisons difficult for the dealers.

The final prices selected for the analysis were Case International priced at Average; Duetz-Allis priced at 5% below average; John Deere priced at 10% Above Average; and, New Holland priced at Average. These exact relative prices were offered by two of the dealers. The order in which the brand "at a sticker price" combinations were shown was randomized for each respondent.

The second measure of manufacturer preferences incorporating price was derived through a ranking of 8 brand-price pairs. The brand-price combinations selected for evaluation were chosen from a brand-price trade-off table containing the four manufacturers and four price levels: 15% Below Average, 5% Below Average, 5% Above Average, and 15% Above Average. Table 4.2 illustrates the selected combinations. Each brand and each price level appeared twice in the analysis. The order in which the brand-price combinations were shown was randomized for each respondent.

Conjoint Measurement

Following the questions relating to manufacturer preferences, the respondents completed a conjoint task containing three factors: *Combine Quality, Dealer Service* and *Price*. There were four levels for each factor. The levels for *Combine Quality* and *Dealer Service* were Excellent, Good, Fair and Poor. These levels were directly related to the scale used in the attribute rating task. The levels for price were 15% Below Average, 5%

1	Case International Priced at 5% Below Average
2	Gleaner Priced at 15% Below Average
3	John Deere Priced at 5% Below Average
4	New Holland Priced at 15% Below Average
5	Case International Priced at 15% Above Average
6	Gleaner Priced at 5% Above Average
7	John Deere Priced at 5% Above Average
8	New Holland Priced at 15% Above Average

Table 4.2: Brand-Price Pairs

Below Average, 5% Above Average, and 15% Above Average. These levels matched the brand-price rating task.

Twelve profiles were developed for the task (see Table 4.3). The profiles allowed for the measurement of the main effects as well as a *Combine Quality* and *Dealer Service* interaction provided that a vector-type preference model was estimated. The hypothesized preference model called for the estimation of 4 parameters (including the constant) using the 12 data points. Although the low ratio of data points to estimated parameters ($\frac{12}{4} = 3.0$) raises some concern over the reliability of the parameters, the ratio improves on previous studies which measured both heterogeneous perceptions and preferences. For example, Horsky and Nelson (1989) estimate a model with 9 parameters (plus a constant) using 12 data points. Future empirical research should consider this parameter reliability issue. The solution is not merely collecting more data as the data requirements have to be balanced against the realities of the data collection situation.

Respondents were asked to rank the 12 profiles which were shown simultaneously on the computer screen. The order in which the profiles were displayed on the screen was randomized for respondent.

Demographics

The final questions in the computer questionnaire collected general farm information including the nature of livestock on the farm, number of years the respondent has been farming and location of the farm operation.

	Combine Quality	Dealer Service	Price
1	Excellent	Good	15% Above
2	Excellent	Fair	5% Above
3	Excellent	Poor	5% Below
4	Good	Excellent	5% Below
5	Good	Good	5% Above
6	Good	Poor	15% Below
7	Fair	Excellent	15% Below
8	Fair	Fair	15% Above
9	Fair	Poor	5% Above
10	Poor	Excellent	15% Above
11	Poor	Good	15% Below
12	Poor	Fair	5% Below

Table 4.3: Combine Profiles Used in Conjoint Analysis

4.3.4 Computer Interview Pretest

Since there are few combine owners near Vancouver, pretesting the questionnaire on a large sample of farmers was not possible. However, a limited pretest was undertaken during a trip to southwestern Ontario. Using a laptop computer, personal interviews were completed with seven farmers. The farmers, who used their combines to harvest wheat, corn and soybeans, collectively represented ownership of the four combine manufacturers. The farmers also varied in age and farm size.

While being observed, the farmers independently completed the computer questionnaire. Following this, an in-depth discussion of the questionnaire and the evaluation of combine harvesters was undertaken. Minor changes were made to the questionnaire as a result of the pretest interviews.

4.3.5 Secondary Questionnaire

In addition to the computer questionnaire, a short personal interview was conducted with a separate sample of farmers at the Canada Western Agribition. A copy of the questionnaire is in Appendix D. The main purpose of this questionnaire was to confirm the relationship between the factor labels used in the conjoint analysis section and the attributes used in the attribute rating task.

Following a series of demographic questions (which were identical for both questionnaires), combine owners were asked whether a particular attribute represented *Combine Quality* or represented *Dealer Service.* Specifically, respondents were shown the list of combine attributes and asked: "Please read the following list of combine features. In your opinion, which features represent Combine Quality and which features represent

Dealer Service?". Assuming that the secondary interview sample is similar to the computer interview sample, it is hypothesized that the summary tabulations in the secondary questionnaire would yield a pattern of attribute-factor associations equal to the factor pattern resulting from a factor analysis of the attribute ratings in the computer interview.

4.4 Results of the Empirical Study

4.4.1 Sample

During 7 days of interviewing at the Canada Western Agribition, a total of 322 combine owners completed the computer questionnaire. Of this number, 4 interviews were incomplete. Only eleven percent of the combine owners who were asked to participate in the study refused. The high response rate was probably due to farmer interest in the topic (combine harvesters) and the fact that the questionnaire was computer driven. For many respondents, this was their first interaction with personal computers. An average of 17 minutes was required to complete the questionnaire.

The 318 useable interviews were further screened to determine the ultimate sample size to be used in model estimation. Three screens were used in this process. First, 6 interviews were dropped from the sample because they were completed by farmers who lived outside of the Canadian prairies (Manitoba, Saskatchewan, Alberta). Second, 32 respondents were removed from the sample because they gave don't know responses for some of the brand attribute ratings. Since it was decided at the outset to include the four major brands as the evoked set, it was felt that the results would be skewed by uninformed respondents.

The final screening procedure considered the consistency in which the respondents answered the questionnaire. Two sections of the questionnaire, the ranking of the 8 brand-price combinations and the conjoint task, contained combinations or profiles which were logically dominated by other choices. For example, in the ranking of brand-price combinations, two of the combinations were: *John Deere Priced at 5% Below Average* and *John Deere Priced at 5% Above Average.* Since all respondents were informed that the same combine was represented at two different prices, the lower priced combination should be preferred by everyone. The logic screen counted the number of inconsistencies for each respondent with the goal of eliminating those respondents who exhibited a relatively high number of logic errors. It was assumed that these respondents did not comprehend the tasks or were simply answering at random. A maximum of four logic errors were possible in the brand-price ranking task and 18 errors in the conjoint task. Respondents with a high number of errors tended to make errors in both task. Respondents who made 4 or more logic errors in the conjoint task were removed from the sample. This decision rule also eliminated all respondents who made more than one logic error in the brand- price ranking task. The 14 respondents affected by this screen represented less than 5 percent of the total sample.

The three screens reduced the 318 completed interviews to a final sample size of 266 respondents.

Sample Demographics

The demographics of the sample are summarized in Table 4.4. Forty-eight percent of the respondents operated farms with both crops and livestock. A wide variation in farm size was exhibited across respondents. Twenty-six percent of the farmers seeded over 1600 acres while the size ranges 320-640 acres, 641-960 acres, 961-1280 and 1281-1600 each accounted for about 17% of the sample.

Wheat was grown by 96% of the sample respondents. Barley was grown by 51% of the farmers surveyed while 36% grew canola and 16% grew flax. The dominance of the wheat crop was a function of the regional location of the farmers interviewed. This, in turn, was the due to the fact that the Agribition was held in Regina in southern Saskatchewan: a predominantly wheat growing region. Ninety percent of the respondents were from Saskatchewan while 58% had farms located in southern half of the province.

Compared with 1986 census information, the respondents tended to operated larger farms. This result was expected as larger farmers tend to attend trade shows. In addition, these farmers are more likely to purchase a combine. Farmers seeded an average of 777 acres of wheat in 1990 compared to a farm average of 350 acres reported in the census. Respondents who reported growing the specific crops seeded an average of 264 acres of barley (census - 162 acres), 216 acres of canola (census - 178 acres), and 233 acres of flax (census - 133 acres).

Farmers who completed the survey had a wide range of experience. Twenty-three percent of the farmers had been farming for 10 years or less. A total of 44% of the farmers had been farming for between 11 and 20 years while 22% had farmed between 21 and 30 years and 11% had over 30 years of experience.

Combine Inventory

Twenty-six percent of the sample owned more than one combine. Table 4.5 outlines the inventory of combines among the farmers interviewed. Case-International (26%), John Deere (25%) and Massey Ferguson (22%) were the dominant combine brands. Gleaner (9%), New Holland (8%) and White (6%) rounded out the inventory shares of the major

	Primary Sample	Secondary Sample
	(pct)	(pct)
Region:		
Manitoba	5.6	7.3
Northeast Saskatchewan	14.3	12.7
Northwest Saskatchewan	16.2	11.5
Southeast Saskatchewan	44.7	43.7
Southwest Saskatchewan	14.7	20.5
Alberta	4.5	3.4
Other	–	0.9
Farm Type:		
Crops Only	51.9	44.3
Both Crops and Livestock	48.1	55.7
Acres Seeded in 1990:		
320 acres or less	4.9	11.2
321 - 640 acres	15.8	24.4
641 - 960 acres	17.3	18.0
961 - 1280 acres	18.4	17.8
1281 - 1600 acres	17.3	11.2
Over 1600 acres	26.3	17.3
Crops Grown in 1990:		
Wheat	96.2	95.9
Barley	51.5	55.6
Canola	35.7	29.5
Flax	16.2	18.5
Farming Experience:		
5 years or less	7.5	6.6
6 - 10 years	15.4	13.7
11 - 20 years	43.6	36.1
21 - 30 years	22.2	24.1
31 - 40 years	8.6	13.7
Over 40 years	2.6	5.9
Base:	266	410

Table 4.4: Demographics of Primary and Secondary Samples

Manufacturer	Share of Combines (pct)	Share of Farmers (pct)
Case-International	25.5	28.9
John Deere	24.9	27.1
Massey Ferguson	22.0	24.1
Gleaner	8.5	9.8
New Holland	8.2	9.0
White	6.2	7.1
Other	4.7	5.3
Base:	341	266

Table 4.5: Combine Inventory

combine manufacturers. These inventory percentages were confirmed to be close to recent marketing research estimates.

4.4.2 Results of the Secondary Survey

The secondary survey was completed by 500 farmers attending the Canada Western Agribition. Eighty-two percent of these farmers owned a combine (410) and completed the section which related the the brand attributes to the latent factors. The demographics of this sample was similar to the farmers who completed the computer survey. Table 4.4 provides a demographic comparison. No farmers completed both interviews.

	Combine Quality	**Dealer Service**
	(pct of resp.)	(pct of resp.)
Durability	**94.9**	5.1
Threshing Technology	**93.7**	6.3
Ease of Maintenance	**87.3**	12.7
Ease of Controlling Operation	**92.7**	7.3
Combine Waranty	**38.3**	**61.7**
Dealer Location	4.4	**95.6**
Parts Availability	7.6	**92.4**
Dealer-Farmer Relations	12.2	**87.8**

Table 4.6: Attribute-Factor Associations in the Secondary Survey

The attribute-factor associations provided by the farmers was similar to the hypothesized factor pattern (see Table 4.6). An overwhelming majority of farmers associated *Durability* (95% of respondents), *Ease of Maintenance* (87%), *Ease of Controlling Operation* (93%) and *Threshing Technology* (94%) with *Combine Quality*. In addition, *Parts Availability* (93%), *Dealer Location* (96%) and *Dealer-Farmer Relations* (88%) were strongly associated with *Dealer Service*.

The Combine Warranty attribute was not as strongly associated with one of the two factors. Sixty- two percent of the respondents associated the *Combine Warranty* with *Dealer Service* while 38% related the attribute to *Combine Quality*. It is apparent that the dual association which was discussed in the previous chapter does apply. Perhaps a better understanding of the nature of the *Combine Warranty* attribute would have been obtained if respondents were asked why they made their chosen factor association.

From these results, it is apparent that the factor labels *Combine Quality* and *Dealer Service* are good choices for the conjoint measurement task.

4.4.3 Creation of Perceptual Space

The perceptual space for the combine harvesters in the Canadian prairies was developed via confirmatory factor analysis. Using the terminology forwarded by Srinivasan, Vanden Abeele and Butaye (1989), a *Total Analysis* was performed. This type of analysis factor analyzes an $NJ \times K$ matrix where each row is person n's rating of the jth brand on the K attributes.[6] As a basis of comparison, the data were also submitted to a common (maximum likelihood) factor analysis and a principal components analysis.

Preprocessing Transformations

Several researchers have recommended preprocessing transformations of the raw attribute ratings data to eliminate response tendency effects (Hauser and Koppelman 1979, Huber and Holbrook 1979, Srinivasan, Vanden Abeele and Butaye 1989). Dillon, Frederick and Tangpanichdee (1985) review the effects of various preprocessing transformations. The main argument for retaining the raw data is that no assumptions are made as to the manner in which respondents completed the questions. However, because of the

[6]Note that this type of matrix contains rows which are not independent (4 brand evaluations per respondent). This issue has been recognized by many researchers (see Dillon, Frederick and Tangpanichdee 1985), but the methodology has remained the "standard" in the development of perceptual maps. A preprocessing transformation (see below) can partially address this issue.

three mode nature of the data (attribute $\times$ brand $\times$ respondent), analysis of the raw data is inappropriate because the the variance in the attribute ratings for respondents is confounded with the variance of each brand on an attribute for each respondent (Dillon et al 1985, p. 57). To correct this problem, Dillon et al suggest a transformation in which each attribute is standardized across brands for each respondent. That is, the first attribute for the first respondent is standardized over the K brands. Then, the second attribute for the first respondent is standardized over the K brands, and so on for all attributes and for all respondents.

The objective of this transformation approach is to bring out the within-respondent variance on the attributes over brands for each respondent and to allow for comparisons across brands. The standardizations within each respondent remove the variance on attributes due to individual level effects. The remaining variance illustrates the interrelationships between changes in attributes over the brands generalized across the respondents (Dillon et al 1985, p. 58). Dillon et al suggest that this is a reasonable approach to collapsing three mode data into a two-way matrix.

The results presented below are computed following the preprocessing standardization suggested by Dillon et al (1985). A parallel analysis using the raw data showed only minor differences between the two data sets. Table 4.7a and 4.7b contain the correlation matrices for the eight attributes prior to and following the preprocessing transformation respectively.

a. Correlation Matrix Using Raw Data

	Dur.	T.T.	E.O.M.	E.C.O.	C.W.	D.L.	P.A.	D.F.R.
Durability	1.00							
Threshing Technology	0.50	1.00						
Ease of Maintenance	0.57	0.50	1.00					
Ease of Controlling Operation	0.57	0.50	0.56	1.00				
Combine Waranty	0.51	0.43	0.47	0.49	1.00			
Dealer Location	0.41	0.27	0.34	0.36	0.33	1.00		
Parts Availability	0.52	0.35	0.47	0.47	0.44	0.54	1.00	
Dealer-Farmer Relations	0.49	0.34	0.46	0.45	0.47	0.49	0.59	1.00

b. Correlation Matrix Following the Preprocessing Transformation

	Dur.	T.T.	E.O.M.	E.C.O.	C.W.	D.L.	P.A.	D.F.R.
Durability	1.00							
Threshing Technology	0.41	1.00						
Ease of Maintenance	0.56	0.47	1.00					
Ease of Controlling Operation	0.54	0.47	0.51	1.00				
Combine Waranty	0.44	0.37	0.40	0.41	1.00			
Dealer Location	0.38	0.21	0.33	0.37	0.31	1.00		
Parts Availability	0.50	0.31	0.45	0.47	0.44	0.58	1.00	
Dealer-Farmer Relations	0.48	0.32	0.46	0.45	0.46	0.54	0.58	1.00

Table 4.7: Combine Attribute Correlation Matrix

Perceptual Structure

For comparison purposes, three different approaches were use to develop the perceptual structure: confirmatory factor analysis, common factor analysis and principal components analysis. Within each of these methods, a number of variations were analyzed to check the appropriateness of various models.

The confirmatory factor analysis was performed using LISREL VI (Joreskög and Sörbom 1985). Three different models were estimated. The first model, CFA1 describes the hypothesized factor structure. In CFA1, the *Combine Warranty* attribute was associated with both *Combine Quality* and *Dealer Service*. The path diagram for this model is shown in Figure 4.2. The second model, CFA2, removes the *Combine Warranty - Dealer Service* association. This model was analyzed to match the results of the common factor model (see discussion below). The final model, CFA3, was a single factor model in which all attributes were associated with a single latent variable.

The CFA1 model fit the data extremely well. The chi-square statistic was significant ($\chi^2_{18} = 90.85, p < 0.001$). However, this can be partially attributed to the large sample size. The adjusted goodness of fit index (AGFI) was 0.959 and the root mean square residual (RMR) was 0.027. Typically, an AGFI of greater than 0.9 and and RMR of less than 0.05 indicate a good model fit. See Bollen (1989, p.257-281) for a discussion of procedures for the assessment of model fit. In addition all parameter values were significant at the $p < 0.01$ level. What this indicated was that the CFA1 model did a very good job at measuring the covariation between attributes (off diagonal elements of the correlation matrix). The squared multiple correlations of the attributes show how well the within attribute variation is captured. The average squared multiple correlation is 0.505 indicating a reasonable fit. The CFA1 model estimated a significant correlation of .77 between the *Combine Quality* and *Dealer Service* factors. Table 4.8 summarizes these results.

The CFA2 model, which only removed one path, also fit the data very well. This model also had a significant chi-square statistic ($\chi^2_{19} = 109.05, p < 0.001$). The reduced model had an AGFI of 0.950 and an RMR of 0.031. The parameter estimates and squared multiple correlations for the attributes are also found in Table 4.8.

Since the CFA1 and CFA2 models are nested, a sequential chi-square test can be used to assess which model provides a better fit. This test indicated that the CFA1 model provided a significantly better fit of the data ($\chi^2_1 = 18.2, p < 0.001$). Therefore, the CFA1 model will be used in further analyses.

The third confirmatory factor analysis model, CFA3, estimated a single factor model. This model did not fit as well as the full model. The results of the main tests of fit were: $\chi^2_{20} = 308.7$, $p < 0.001$; AGFI=.817; RMR=.056. These results suggest that the CFA1 model provides a better description of the underlying factor structure.

The results of the confirmatory factor analysis were compared with common factor analysis and principal components analysis. Using the eigenvalue ≥ 1 rule, the principal components and common factor analyses yielded a two factor solution. The first two eigenvalues were 4.08 and 1.00 respectively explaining 64% of the common variance. A scree plot (Figure 4.3) also suggested a two factor solution. The average communality in the common factor analysis was 0.503. This is very close the average squared multiple correlations in the CFA1 model (0.505).

The two factor solution, using a varimax rotation yielded a factor pattern in which *Durability*, *Ease of Maintenance*, *Ease of Controlling Operation*, *Threshing Technology*, and *Combine Warranty* had high loadings on the first factor (named *Combine Quality*) and *Dealer Location*, *Parts Availability* and *Dealer-Farmer Relations* had high loadings

	CFA1			CFA2		
	Parameter Value	T-Value	Squared Mult. R*	Parameter Value	T-Value	Squared Mult. R*
Combine Quality Indicators						
Durability	0.72	26.81	0.57	0.72	26.82	0.57
Threshing Technology	0.56	19.58	0.35	0.56	19.44	0.34
Ease of Maintenance	0.69	25.62	0.53	0.69	25.42	0.52
Ease of Controlling Operation	0.67	25.46	0.53	0.67	25.38	0.52
Combine Warranty	0.32	6.80	0.36	0.51	20.07	0.36
Dealer Service Indicators						
Combine Warranty	0.21	4.40	0.36	---	---	---
Dealer Location	0.63	23.55	0.47	0.63	23.65	0.48
Parts Availability	0.77	28.74	0.64	0.77	28.77	0.65
Dealer Farmer Relations	0.72	27.03	0.59	0.72	26.82	0.58
Errors						
$\theta(1, 1)$	0.39	17.13		0.40	17.54	
$\theta(2, 2)$	0.59	17.98		0.59	20.88	
$\theta(3, 3)$	0.42	20.71		0.43	18.43	
$\theta(4, 4)$	0.40	21.36		0.41	18.45	
$\theta(5, 5)$	0.46	18.09		0.45	20.69	
$\theta(6, 6)$	0.44	18.93		0.43	18.81	
$\theta(7, 7)$	0.33	14.64		0.33	14.46	
$\theta(8, 8)$	0.37	16.43		0.37	16.51	
Factor Correlations						
Combine Qual. - Dealer Serv.	0.77	36.46		0.79	40.02	
Analysis of Model Fit						
chi-square statistic	chi-square(18) = 90.85 p < 0.001			chi-square(19) = 109.05 p < 0.001		
Adjusted Goodness of Fit Index	0.959			0.95		
Root Mean Square Residual	0.027			0.031		
Model Comparison						
CFA1 vs. CFA2	chi-square(1) = 18.2, p < 0.001					

*Squared Mult R = Squared Multiple Correlation
Note: All parameters significant at the p=0.001 level

Table 4.8: Confirmatory Factor Analysis Results

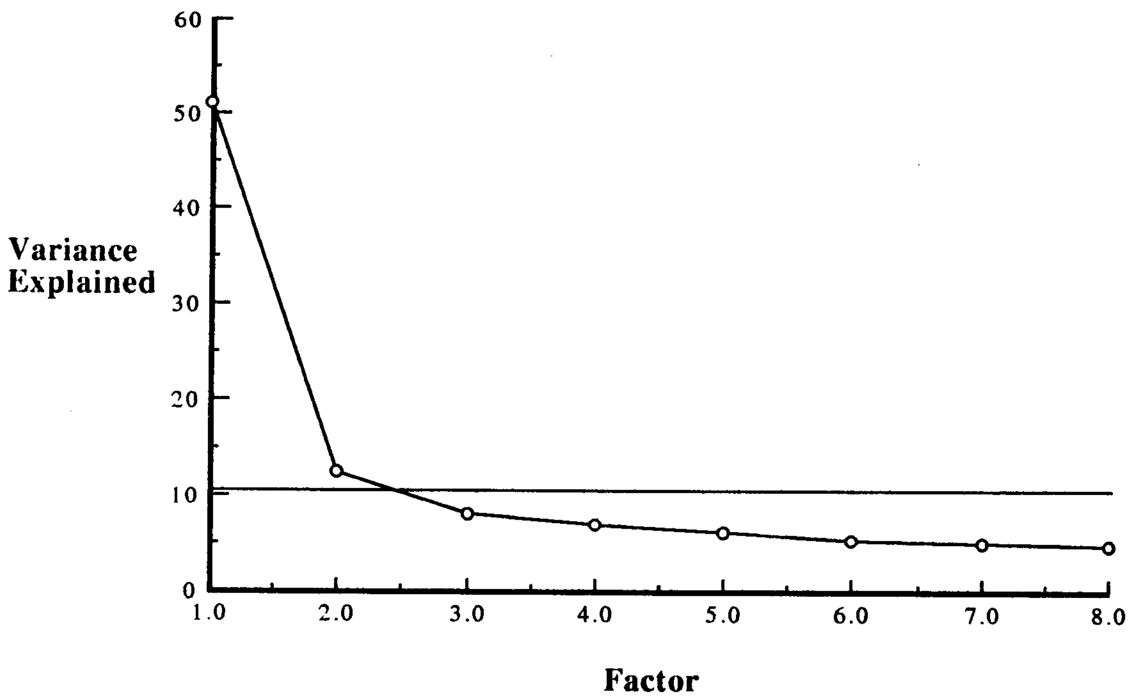


Figure 4.3: Scree Plot of the Variance Explained by Common Factors and Principal Components

	Common Factor Analysis		Principal Components	
	Combine Quality	Dealer Service	Combine Quality	Dealer Service
Durability	**0.65**	0.42	**0.63**	0.39
Threshing Technology	**0.82**	0.01	**0.64**	0.13
Ease of Maintenance	**0.73**	0.29	**0.67**	0.30
Ease of Controlling Operation	**0.70**	0.34	**0.63**	0.35
Combine Waranty	**0.54**	0.39	**0.47**	0.37
Dealer Location	0.10	**0.85**	0.18	**0.72**
Parts Availability	0.32	**0.78**	0.35	**0.72**
Dealer-Farmer Relations	0.35	**0.74**	0.38	**0.64**

Table 4.9: Loadings for Common Factor and Principal Components Analyses

on the second factor (named *Dealer Service*) (See Table 4.9). The high loading of the *Combine Warranty* attribute on *Combine Quality* is contrary to what was expected given the results of the secondary interview.

Both the principal components and confirmatory factor analyses suggest the two factor model provides a reasonable fit the the data. The three factor and the one factor solutions for both analyses were also computed. These analyses did not improve the interpretability of the data.

In general, the results of the three types of factor analysis were similar. All three methods suggested a two factor solution with agreement on virtually all attribute factor associations. For reasons described in section 4.2.2, the best confirmatory factor model, CFA1, will be used in the development of the customer decision model. The statistical results for this model suggested a strong correlation between *Combine Quality* and *Dealer Service* as well as an association between *Combine Warranty* and both latent factors.

Perceptual Map and Offering Positions

The CFA1 model estimated that the correlation between the two latent factors (*Combine Quality* and *Dealer Service*) is 0.77. This translates to a 39° angle between the axes of the perceptual map. Offering locations are determined by multiplying the original attribute ratings (following the preprocessing transformation) by the factor score coefficients (given as output in LISREL). The factor score coefficients are for the CFA1 model are shown in Table 4.10. Figure 4.4a shows the perceptual map for one respondent while Figure 4.4b shows the average perceptual map. The two axes are joined at -4. This is done for illustrative purposes as it shows all manufacturers positioned between the two axes.

The positions of the manufacturers varied substantially between respondents (see Table 4.11). The standard deviation of the manufacturer positions were relatively large (.64 to .84) in comparison to the range of factor scores used to develop the perceptual maps (4.34). This large variation in respondent perceptions was expected given the nature of the product-market (see section 4.1).

Summary

In summary, there are several points worth noting. First, the hypothesized model CFA1, provided a good fit of the survey data. All attribute-factor relationships were significant

Attribute	Combine Quality	Dealer Service
Durability	0.290	0.076
Threshing Technology	0.151	0.040
Ease of Maintenance	0.259	0.068
Ease of Controlling Operation	0.263	0.069
Combine Warranty	0.130	0.103
Dealer Location	0.056	0.231
Parts Availability	0.096	0.376
Dealer Farmer Relations	0.081	0.315

Table 4.10: Factor Score Coefficients From CFA1

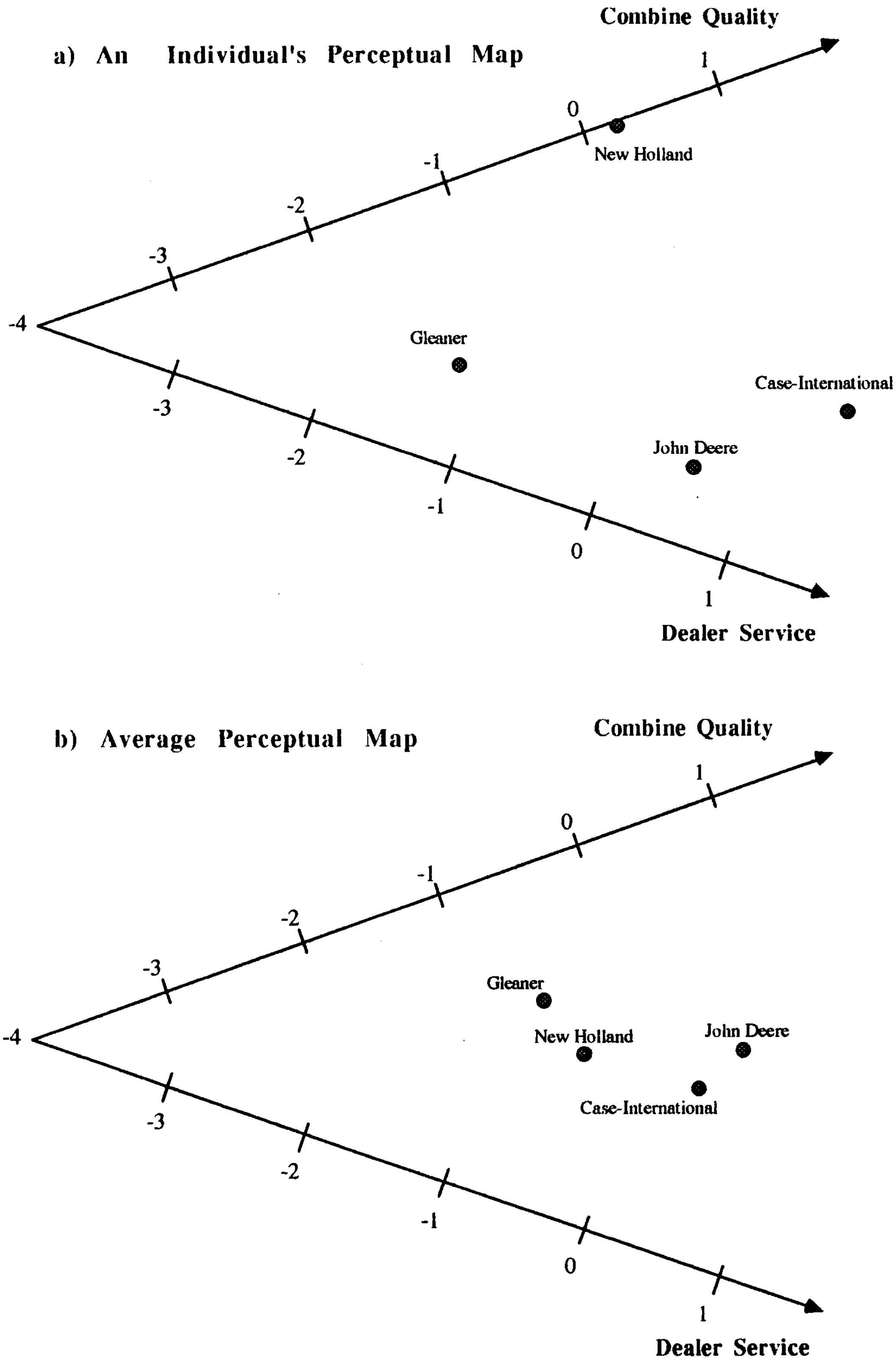


Figure 4.4: Perceptual Maps

	Case-International		Gleaner		John Deere		New Holland	
	CQ	DS	CQ	DS	CQ	DS	CQ	DS
Mean Location	0.26	0.41	-0.52	-0.78	0.67	0.74	-0.41	-0.37
Standard Deviation	0.73	0.64	0.84	0.73	0.79	0.66	0.75	0.73
Highest Score	2.10	1.89	1.89	1.75	2.15	2.01	2.09	1.78
Lowest Score	-1.70	-1.95	-2.19	-2.15	-1.31	-1.09	-2.01	-1.85
Range	3.80	3.84	4.08	3.90	3.46	3.10	4.10	3.63

Table 4.11: Mean and Standard Deviation of Manufacturer Positions

at the $p < 0.01$ level. Secondly, a significant correlation between latent factors was found indicating that the incorporation of correlated dimensions in perceptual space is important. Finally, respondents varied significantly in their perceptual locations of the manufacturers. This suggests that the individual level approach to the development of the customer decision model is warranted.

4.4.4 Preference Measurement

A conjoint measurement task was undertaken to assess individual preferences for various combine profiles. Respondents were asked to rank 12 combine profiles (see Table 4.3). Each profile provided a *Combine Quality* rating, a *Dealer Service* rating, and a price. A vector model of preference was assumed (see (4.3)):

$$U = \beta_0 + \beta_1 CQ + \beta_2 DS + \beta_3 Price \tag{4.4}$$

The conjoint model was estimated using OLS regression with the dependent variable being the reverse ranking of profiles. That is, the most preferred profile was given a value of "12" while the least preferred profile was given a value of "1". Wittink and Cattin (1981) report that there is very little difference in the predictive validity of estimation techniques and that metric procedures, like OLS, compare favorably with nonmetric approaches when attribute weights do not exhibit a lexicographic structure.

The levels for *Combine Quality* and *Dealer Service* were Excellent, Good, Fair and Poor. These levels were directly related to the scale used in the attribute rating task. The levels for price were 15% Below Average, 5% Below Average, 5% Above Average, and 15% Above Average. In estimating (4.4), the prices can be coded in any form (percentages, levels, etc.) which incorporates the differences between levels. More care must be taken in the coding of the latent factors. The conjoint measurement task allows for an estimation of the relative importance of the factors which form an individual's preference for a set of objects. However, in the context of the customer decision model, these importance parameters are only useful when they are estimated in the same units as the product positions in perceptual space. Because the customer decision model incorporates both preferences and perceptions on the latent factors, the same units must be used in the measurement of each. If this matching of units is achieved, the relative importance of price in an individual's preference function is adequately represented.[7]

[7]For example, the relative importance of the factors in a conjoint analysis would be unchanged if the the latent factors were coded with a range of (10,10) or (-100,100). The only difference would be the scaling of the parameters. Now assume that the product positions (estimated through the confirmatory

For the current analysis, the data which were used in the construction of the perceptual space was standardized in a manner in which each of the attributes had a mean of zero and a standard deviation of one at the individual level. Since factor scores are simply a linear transformation of the attribute levels, the manufacturer positions derived from this analysis also have $\mu = 0$ and $\sigma = 1$ at the individual level.[8] To match the units used in the perceptual space construction, the levels of the latent factors in the conjoint analysis were coded with $\mu = 0$ and $\sigma = 1$.

Assessment of the Importance of a *Combine Quality-Dealer Service* Interaction

As was outlined in section 4.4.3, there was a significant correlation between *Combine Quality* and *Dealer Service*. An important issue in the development of the preference model is the assessment of whether or not this correlation yields an important interaction term in the preference function. In order to test this issue, the predictive validity of the preference model defined in (4.3) with a *Combine Quality-Dealer Service* interaction term (shown as (4.4)) was compared to (4.3). Predictive validity, operationalized by the estimated mean squared error of prediction, is an appropriate comparison criterion as the main purpose of the customer decision model is to *predict* the effect of product or service improvements to the target offering.

Two conjoint models were estimated at the individual level. The general model included the *Combine Quality-Dealer Service* interaction while the reduced model did not.

factor analysis) had a possible range of (-10,10). When the preference parameters are combined with the perceptual positions of the products (to estimate value for a particular product), the importance of the price in model estimates would be dramatically different for the two codings of the latent factors in the conjoint analysis.

[8]The manufacturer positions for all respondents will have $\mu = 0$, but not all positions have $\sigma = 1$. This is because respondents sometimes rated all brands equally on a particular attribute. Therefore, for these attributes the across brand variation (within a respondent) will have $\mu = 0$ and $\sigma = 0$.

The two models were compared in terms of their predictive validity using the procedure developed by Hagerty and Srinivasan (1991). The procedure estimates the mean squared error of prediction for each model with the following equation.

$$E S\widehat{M}EP_R = (R_G^2 - R_R^2) + (1 - R_G^2)(1 - \frac{k}{n}) \tag{4.5}$$

where:

$E S\widehat{M}EP_R$ = estimated mean squared error of prediction for the reduced model.

R_G^2 = adjusted R^2 for the general model.

R_R^2 = adjusted R^2 for the reduced model.

k = the number of parameters estimated in the reduced model.

n = the number of profiles used in estimation.

The model which has the lowest $E S\widehat{M}EP$ should have the highest predictive validity (Green and Srinivasan 1990).

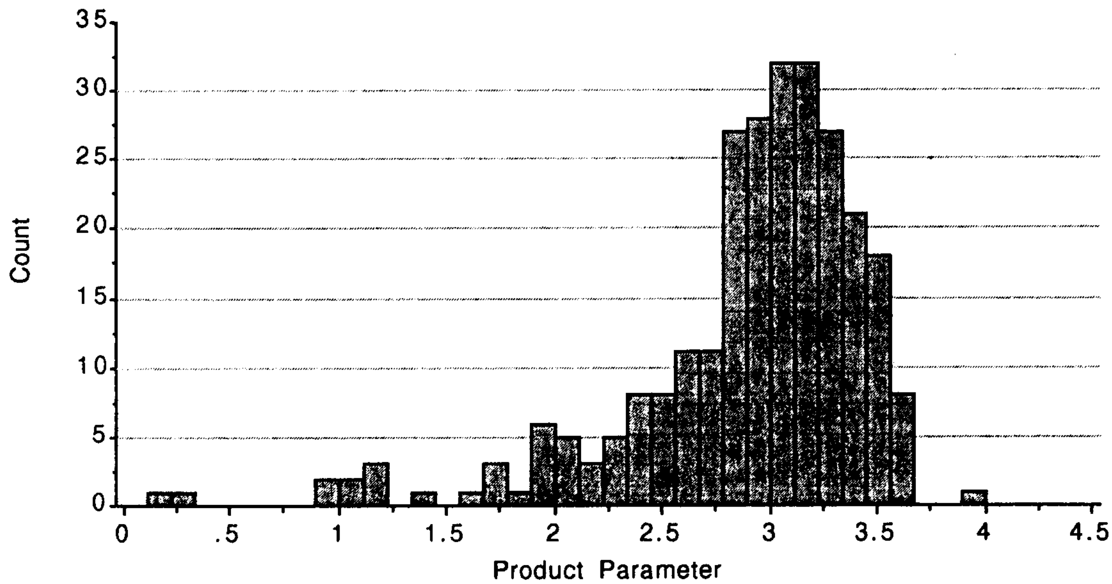
The results of the model comparison indicated that on average, the reduced model, with no interaction term, had the lowest $E S\widehat{M}EP$. At the individual level, 64% of respondents had a lower $E S\widehat{M}EP$ with the reduced model. For the current empirical study, the model which had the lowest, population-wide $E S\widehat{M}EP$ was selected. Therefore, the reduced model was selected as the preference model. This model is the same as the vector model described in (4.3).[9]

As has been discussed by other researchers (e.g. Srinivasan and Shocker 1973), the estimation of preference models via OLS regression may yield inappropriate parameter estimates, like a positive price parameter, which are difficult to interpret. To eliminate this problem, inequality constrained linear regression was performed. Using the procedure described by Geweke (1986), the models for individuals with inappropriate parameter values were re-estimated while constraining *Combine Quality* and *Dealer Service* to be greater than or equal to zero and *Price* to be less than or equal to zero. This estimation is relatively straightforward in SHAZAM (White, Haun, Horsman and Wong 1988).[10]

The average R^2 for the preference model, (4.3), was 0.79. The *Combine Quality* factor was, on average, about twice as important as *Dealer Service* in the customer's value functions. The mean value of the product parameter was 2.90 as compared to 1.36 for the service parameter. When *Price* is scaled to the same units as the latent factors, the mean value of the price parameter was 0.93. The relative sizes of these parameter values coincided with informal discussions with farmers following the interviews. However, the low value of the price parameter may have been a function of the form in which price was incorporated into the analysis and the range of price levels included. Figures 4.5-4.7 show the distributions for the three parameters. It is important to note that although averages give some insight into the relative importance of the various factors, all analysis was undertaken at the individual level.

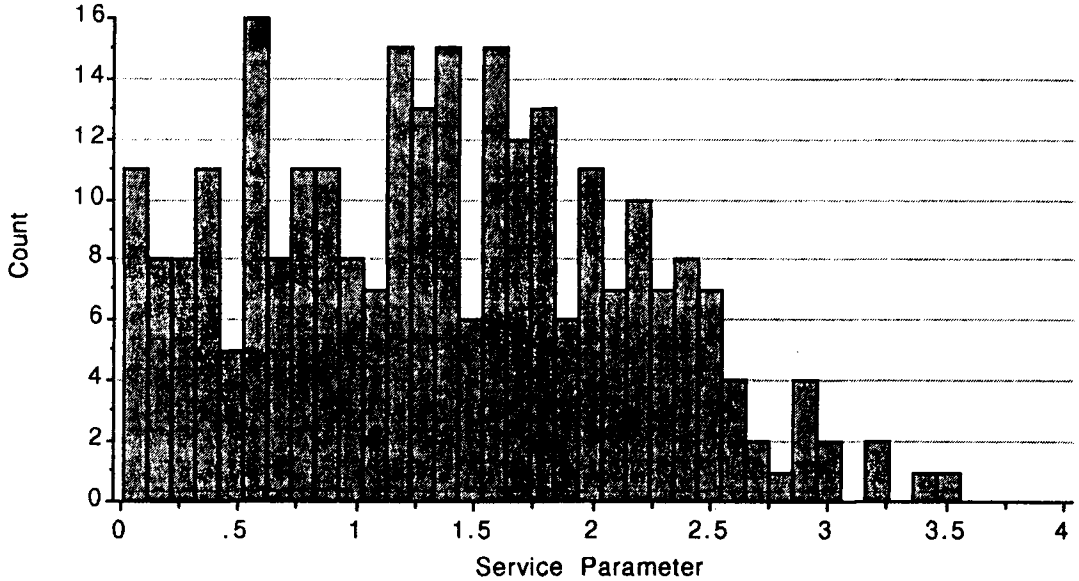
[9] An alternative option would be to individualize the preference model on the basis of the $\widehat{ESMEP}$ results. That is 64% of the respondents would use the reduced model as a model of preference and 36% would use the general model. If it is assumed that the sample represents the population of farmers, then this approach would be reasonable as it can be assumed that a different segments of the population have different preference models.

[10] A total of 35 parameters (4% of the estimated parameters excluding the constant) from 26 respondents had the inappropriate sign and were re-estimated using the constrained regression procedure.



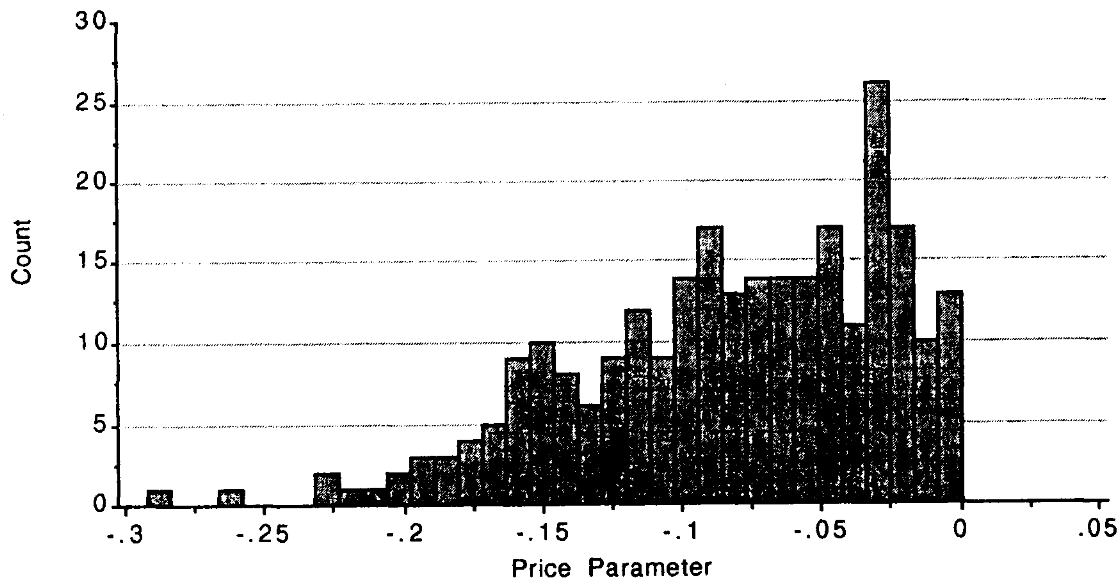
Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
2.898	.579	.036	.336	19.99	266

Figure 4.5: Distribution of *Product* Parameter Values



Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
1.355	.787	.048	.619	58.063	266

Figure 4.6: Distribution of *Service* Parameter Values



Mean:	Std. Dev.:	Std. Error:	Variance:	Coef. Var.:	Count:
-.083	.056	.003	.003	-67.476	266

Figure 4.7: Distribution of *Price* Parameter Values

4.4.5 Estimation of Preferences for Brands

The customer decision model is developed by combining individual value functions estimated in the conjoint measurement task with manufacturer locations in the perceptual space and relative price. A deterministic choice rule is used. Therefore, the model predicts that a respondent will choose the brand which maximizes (4.3).

The best measure of the predictive validity of the model would be a comparison of actual choice data to model predictions. However, given the nature of the product-market and the available sample, this was not possible in the context of the current study. A test of how well the customer decision model predicted choice can be obtained by comparing the farmers' brand "at a sticker price" rankings and ranking of brand-price pairs to the model predictions. The individual perceptions and preferences used in the customer decision model were collected independent of these ranking tasks.

Model vs. Brand "at a Sticker Price" Rankings

In the survey, respondents were asked to rank their preference for the four brands at a specific price. The respondents' first choices were compared to the model prediction using the kappa statistic (Cohen 1960).

The kappa statistic is an overall measure of agreement between two tests and is useful for measuring agreement in the absence of a standard. It compares the observed proportion of respondents in which the first choice and model prediction agree with the proportion which would be expected to agree by chance. It is normalized to have values between 1 and $-p/(1-p)$, where p is the proportion of respondents that would be expected to agree by chance. Using the notation in Table 4.12, the kappa statistic is defined as $\kappa = (a+d-p)/(1-p)$, where $p = (a+b)(a+c)+(c+d)(b+d)$. Landis and Koch (1977)

		First Choice Preferences	
		Brand A	Brand B
Model Predictions	Brand A	**a**	**b**
	Brand B	**c**	**d**

Table 4.12: A Two-Way Table that Serves as a Basis for Defining Agreement Measures

provide the following benchmarks for interpreting kappa: $\kappa \leq 0$ corresponds to "poor" agreement; $0 < \kappa \leq 0.20$ is "slight" agreement; $0.20 < \kappa \leq 0.40$ is fair agreement; $0.40 < \kappa \leq 0.60$ is "moderate" agreement; $0.60 < \kappa \leq 0.80$ is "substantial" agreement; and $0.80 < \kappa \leq 1.00$ is "almost perfect" agreement. Calculations of confidence intervals are based on standard errors derived from approximations to its variance (Bishop, Feinberg and Holland 1975).

Table 4.13 presents the two-way table comparing the respondents' first choices with the model predictions. Overall, the model yielded good predictions. There was 71% agreement between first choices and model predictions. The kappa statistic of 0.57 indicated a moderate to substantial agreement between first choices and model predictions. A standard deviation of .041 yielded a 95% confidence interval on kappa of (.494, .654). The model predicted the preferences of the smaller share brands (Gleaner, New Holland) quite well. The largest source of "error" in model predictions was between Case-International and John Deere. Specifically, the model predicted a John Deere preference for 26 respondents (9.8%) who stated a preference for Case- International.

The model also performed well in predicting the brand "at a sicker price" rankings for all 4 brands. The model predictions exactly matched the respondents rankings 36% of the time while a further 39% of the respondents had the reversed order on 1 pair of brands (Table 4.14). The fact that later choices in the ranking task are dependent on earlier choices eliminated the option of using a nested kappa statistic as a measure of agreement.

Probably of more importance to managers is a comparison of first choice preferences to model predictions at the aggregate level. The model predicted John Deere to have the highest share of preference (43%, first choice preference=34%) while more respondents stated that they preferred Case-International (40%, model=34%). The average deviation between the predicted shares and the stated first choice shares was 5.7%.

In an attempt to get a better understanding of the relationship between model predictions, stated preferences and actual choice, an analysis was undertaken with the 187 respondents who owned at least one of the 4 brands in the study. Inventory is used as a proxy for choice. However, it is recognized that the use of inventory data concentrates on past choices and is an imperfect substitute for recent choice data. Tables 4.15 - 4.17 contain the two-way tables comparing first choice preferences to model predictions, inventory to first choice preferences, and inventory to model predictions respectively. The kappa statistics for these comparisons indicated substantial agreement between first choice preferences, model predictions and inventory (κ ranged from 0.62 to 0.66). The kappa statistic for the first choice preference vs. model predictions ($\kappa = 0.62$) was only a slight improvement over the kappa statistic for the entire sample. This indicates that ownership of one of the four brands did not have a significant impact on the model's

		First Choice Preferences				
		Case-International	Gleaner	John Deere	New Holland	**Total**
Model Predictions	Case-International	70 26.3%	7 2.6%	9 3.4%	3 1.1%	**89** **33.5%**
	Gleaner	5 1.9%	26 9.8%	2 0.8%	0 --	**33** **12.4%**
	John Deere	26 9.8%	8 3.0%	76 28.6%	4 1.5%	**114** **42.9%**
	New Holland	6 2.3%	4 1.5%	4 1.5%	16 26.3%	**30** **11.3%**
	Total	**107** **40.2%**	**45** **16.9%**	**91** **34.2%**	**23** **8.7%**	**266** **100%**

Percentage Agreement = 70.7%	kappa statistic = 0.57	95% CI on kappa statistic = (0.494, 0.654)

Brand Prices: Case-International » Average; Gleaner » 5% Below Average; John Deere » 10% Above Average; New Holland » Average.

Table 4.13: Two-Way Table Comparing First Choice Preferences with Model Predictions

Number of Agreements	Percent	Cumulative Percent
Four (Complete Agreement)	36.1	36.1
Two	39.1	75.2
One	14.7	89.9
Zero (No Agreement)	10.2	100.0

* Note: It is impossible to agree on 3 of 4 rankings. Agreement on 2 of 4 rankings implies that Rank Order Preferences and Model Predictions disagreed on the order of 2 brands.

Table 4.14: Extent of Agreement Between Rank Order Preferences and Model Predictions

ability to match respondents' preferences.[11]

On an aggregate level, the shares of first preference, model predictions and inventory were very similar (Table 4.18). The average deviation between these inventory shares and the stated first choice preferences was 3.2%. The average deviation between the inventory shares and the shares predicted by the model was 2.1%. Unfortunately, the age of the inventory was not asked so a separate analysis with recent purchasers could not be undertaken. Nevertheless, it appears that there is some consistency between the model predictions, stated preference and actual choice.

Model vs. Brand-Price Pairs Rankings

The respondents were asked to rank 8 brand-pairs comprised of each manufacturer listed at 2 separate prices. The farmers were instructed to consider a combine of a size suited to their farm operation and that this same size was listed at two different prices. This question was more difficult to complete than the brand "at a sticker price" ranking and resulted in 6% of the respondents committing an "error" by choosing the higher priced brand over the lower priced one. To simplify the task, respondents may have resorted to patternized responses similar to those encountered in tradeoff analysis (Johnson 1974). These potential data problems should reduce the predictive validity of the customer decision model.

The customer decision model was compared to the respondents' stated first choice in the brand- price ranking. All respondents chose a low priced brand as their first choice.

[11]The kappa statistics for the inventory to first choice preferences ($\kappa = 0.66$) and inventory to model predictions ($\kappa = 0.65$) illustrate that first choice preferences and model predictions do equally as well in predicting inventory (choice). The lower than expected levels of agreement (76%-77%) are probably the result of changes in product offerings and/or changes in offering perceptions since the inventory was purchased.

Model Predictions		First Choice Preferences				
		Case-International	Gleaner	John Deere	New Holland	Total
	Case-International	47 25.1%	5 2.7%	9 4.8%	2 1.1%	**63 33.7%**
	Gleaner	4 2.1%	20 10.7%	0 --	0 --	**24 12.8%**
	John Deere	17 9.1%	4 2.1%	58 31.0%	1 0.5%	**80 42.8%**
	New Holland	3 1.6%	3 1.6%	1 0.5%	13 7.0%	**20 10.7%**
	Total	**71 38.0%**	**45 16.9%**	**68 36.4%**	**16 8.6%**	**187 100%**

Percentage Agreement = 73.8%	kappa statistic = 0.62	95% CI on kappa statistic = (0.540, 0.695)

Brand Prices: Case-International » Average; Gleaner » 5% Below Average;
John Deere » 10% Above Average; New Holland » Average.

Table 4.15: Two-Way Table Comparing First Choice Preferences with Model Predictions Using Respondents Who Own One of the Four Survey Brands

		Combine Inventory				
		Case-International	Gleaner	John Deere	New Holland	**Total**
Model Predictions	Case-International	57 30.5%	3 1.6%	9 4.8%	2 1.1%	**71** **38.0%**
	Gleaner	5 2.7%	20 10.7%	5 2.7%	3 1.6%	**33** **17.7%**
	John Deere	10 5.4%	1 0.5%	53 28.3%	3 1.6%	**67** **35.8%**
	New Holland	2 1.1%	1 0.5%	1 0.5%	12 6.4%	**16** **8.6%**
	Total	**74** **39.6%**	**25** **13.4%**	**68** **36.4%**	**20** **10.7%**	**187** **100%**

Percentage Agreement = 75.9%	kappa statistic = 0.65	95% CI on kappa statistic = (0.574, 0.725)

Brand Prices: Case-International » Average; Gleaner » 5% Below Average; John Deere » 10% Above Average; New Holland » Average.

Note: **12 respondents (6.4%) owned combines of 2 different brands. Agreement occurs when the model predicts one of these brands.**

Table 4.16: Two-Way Table Comparing Combine Inventory with Model Predictions Using Respondents Who Own One of the Four Survey Brands

		Combine Inventory				
		Case-International	Gleaner	John Deere	New Holland	Total
First Choice Preferences	Case-International	52 27.8%	3 1.6%	6 3.2%	3 1.6%	**64** **34.2%**
	Gleaner	3 1.6%	19 10.2%	0 --	1 0.5%	**23** **12.3%**
	John Deere	14 7.5%	2 1.1%	59 31.6%	5 2.7%	**80** **42.8%**
	New Holland	3 1.6%	1 0.5%	3 1.6%	13 7.0%	**20** **10.7%**
	Total	**72** **38.5%**	**25** **13.4%**	**68** **36.4%**	**22** **11.8%**	**187** **100%**

Percentage Agreement = 76.5%	kappa statistic = 0.66	95% CI on kappa statistic = (0.581, 0.731)

Brand Prices: Case-International » Average; Gleaner » 5% Below Average;
John Deere » 10% Above Average; New Holland » Average.

Note: 12 respondents (6.4%) owned combines of 2 different brands. Agreement occurs when the model predicts one of these brands.

Table 4.17: Two-Way Table Comparing Combine Inventory with First Choice Preferences Using Respondents Who Own One of the Four Survey Brands

Manufacturer	Model Predictions	First Choice Preferences	Sample Inventory*
	(pct)	(pct)	(pct)
Case-International	33.7	38.0	38.0
Gleaner	12.8	16.9	12.7
John Deere	42.8	36.4	37.1
New Holland	10.7	8.6	12.2

*Note: Inventory shares reflect ownership of multiple combines.

Table 4.18: Aggregate Level Model Predictions Versus First Choice Preferences and Sample Inventory Using Respondents Who Own One of the Four Survey Brands

By design, the model also predicted a low priced brand for all respondents. The model predicted 66% of the respondents' first choices (Table 4.19). The kappa statistic of 0.50 indicated a moderate level of agreement between first choices and model predictions. A standard deviation of .044 yielded a 95% confidence interval on kappa of (.414, 584). As was the case in the brand "at a sticker price" analysis, the model predicts choice at a reasonable level. In addition, the aggregate level predicted shares were within 6% of the stated first choice shares. The average deviation was 4.2%. The lower kappa statistic can be attributed to a more difficult rating task and a different distribution of prices between the brands.

Price Responsiveness of the Customer Decision Model

An interesting aspect of the brand-price rankings is that it is possible to see how responsive the model was to price changes. Among the 8 brand-price pairs, each of the 4

		First Choice Preferences				
		Case-International	Gleaner	John Deere	New Holland	Total
Model Predictions	Case-International	44 16.5%	9 3.4%	10 3.8%	6 2.3%	**69** **25.9%**
	Gleaner	2 0.75%	25 9.4%	4 1.5%	2 0.75%	**33** **12.4%**
	John Deere	26 9.8%	5 1.9%	92 34.6%	6 2.3%	**129** **48.5%**
	New Holland	8 3.0%	7 2.6%	6 2.3%	14 5.3%	**35** **13.2%**
	Total	**80** **30.1%**	**46** **17.3%**	**112** **42.1%**	**28** **10.5%**	**266** **100%**

Percentage Agreement = 65.8%	kappa statistic = 0.50	95% CI on kappa statistic = (0.414, 0.584)

Brand Prices: Case-International » 5% Below Average; Gleaner » 15% Below Average; John Deere » 5% Below Average; New Holland » 15% Below Average.

Note: Of the 8 brand-price pairs, one of the 4 low-priced pairs was always selected by respondents and predicted by the model.

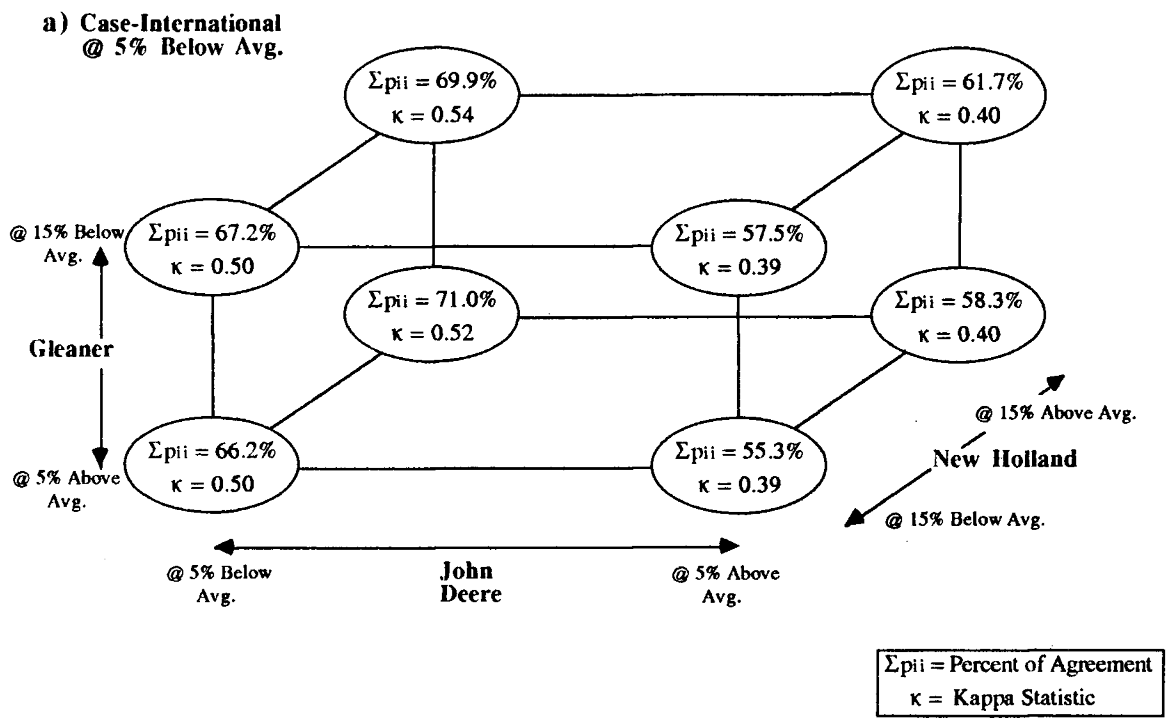
Table 4.19: Two-Way Table Comparing First Choice Preferences with Model Predictions Using the Brand-Price Pairs Information

brands was listed at two different prices. A total of 16 brand-price combinations of the 4 brands can be derived from this list. For each of the 16 combinations, the percentage of agreement between first choice preferences and model predictions and the kappa statistic were calculated. These results are illustrated in Figure 4.8. The mean level of agreement for 16 combinations was 62.7%. The average kappa statistic was 0.41. Overall, the model performed well despite large variations in price.[12]

The model was not as responsive to price changes as were respondents when making ranking decisions. This can be illustrated through an analysis of the two major brands: Case-International and John Deere. Using the information from the brand "at a sticker price" rankings and the ranking of brand-price pairs, first choice preferences were compared to model predictions at different price levels. Figure 4.9 illustrates the results of these comparisons. When John Deere was priced equal to or above Case-International, a greater proportion of respondents preferred Case-International than predicted by the model. When John Deere was priced less than Case- International, this trend was reversed and a greater proportion of respondents preferred John Deere than predicted by the model. Using the Cochran Q test (Seigel 1956), the net change in John Deere preferences between stated preferences and model predictions was found to be significant ($\chi^2_3 = 192.87, p < 0.0001$).[13] Given the nature of the empirical study, it is impossible to determine whether the model was less price- responsive than necessary or that the wide variation in preference levels was due to respondents over-emphasizing the price

[12]The kappa statistic deteriorated more than the percentage agreement because of the dominance of John Deere in many of the combinations. This increased the likelihood of "chance" agreements. In 4 of the 16 combinations, John Deere was priced at 20% below Case- International, its largest competitor. This is a 30% price change as compared to the brand "at a sticker price" ranking.

[13]The data used in Cochran's Q was calculated as follows. At each price level, the model prediction of the number of respondents preferring John Deere was subtracted from the number of respondents who stated that they preferred John Deere. To eliminate negative values, a constant was added to each of the subtraction results.



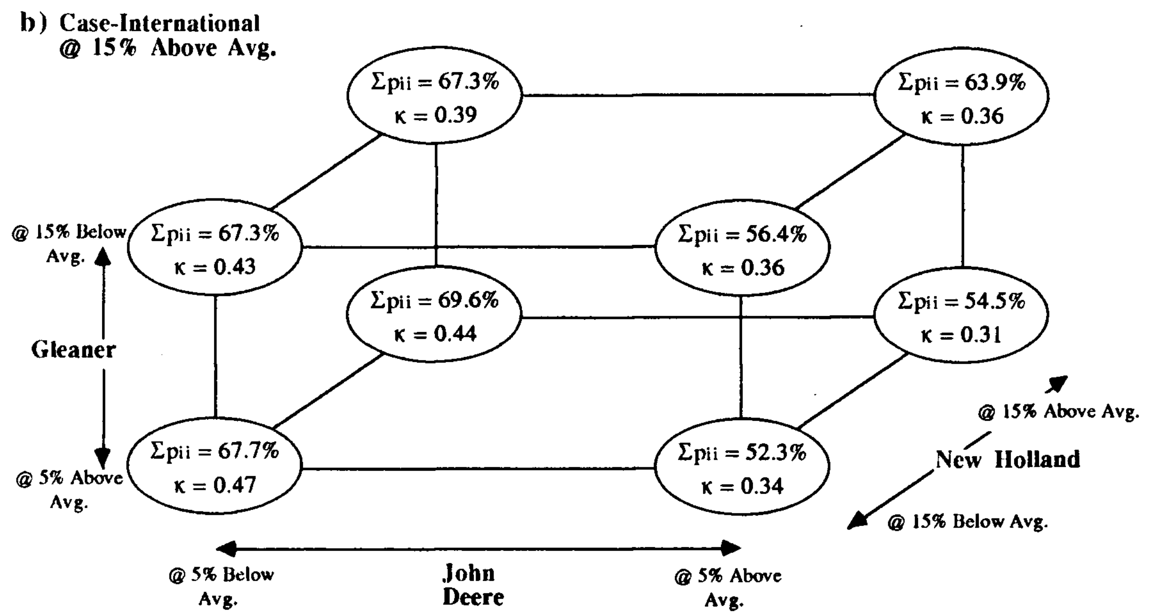


Figure 4.8: Level of Agreement Between First Choice Preferences and Model Predictions for Alternative Pricings of Combine Brands

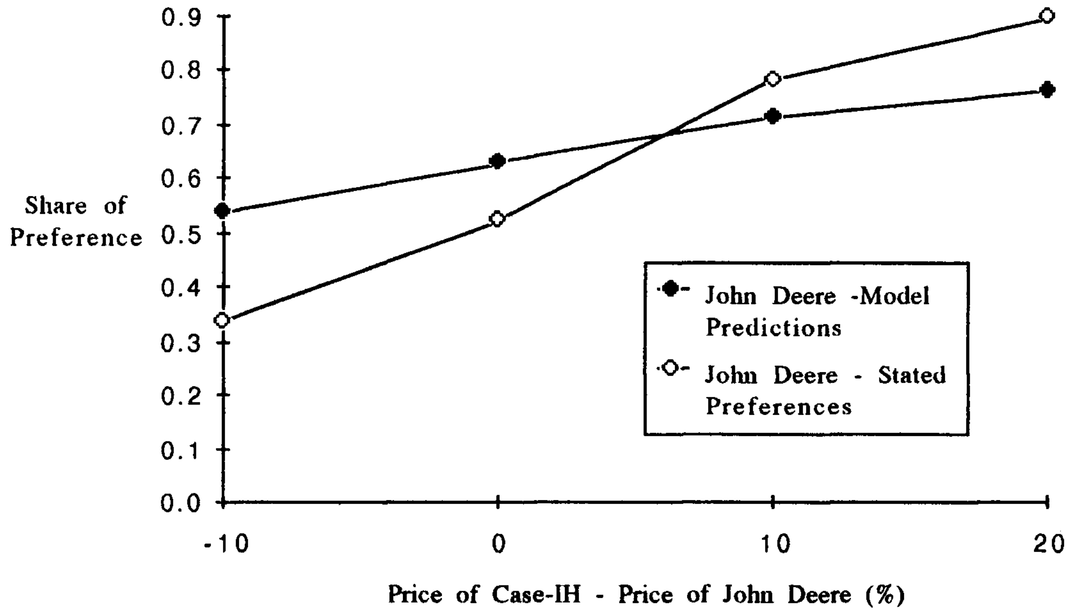


Figure 4.9: John Deere's Share of Preference at Various Prices. Share of Preference Specific to the John Deere Versus Case-IH Comparison.

component of the combines. More research is necessary to better understand this issue.

Summary of Model Performance

The data collected in the study allowed for a number of tests of model performance. At the individual level, the model had relatively high levels of agreement with the respondents' stated choices. These levels of agreement were significantly higher than what would be expected by chance. At the aggregate level, the model provided very good predictions even when the price differences between manufacturers varied substantially. In addition the model predictions compared favorably with the within sample share of inventory. It is evident that the proposed customer decision model does capture the essence of underlying perceptions and preferences in the western Canada combine harvester market.

4.5 Contributions and Conclusions

This chapter develops and tests an individual level customer decision model. Methodologically, the model extends the research on customer decision models in a number of ways. First, the analysis is conducted at the individual level. Although the perceptual space is shared by all respondents (in a particular region), the specific perceptual locations of the offerings and the preference function are unique to the individual. This level of analysis is appropriate in situations where there is a large degree of heterogeneity in both perceptions and preferences. Markets characterized by product-service firms fall into this category. The individual level modelling approach also allows for the development of a customer decision model simulator similar to choice simulators available on commercial conjoint packages. Green and Srinivasan (1990) suggest that the availability of choice simulators is one of the main reasons for the popularity of conjoint analysis in industry.

Second, the use of a confirmatory analysis in the development of the perceptual space represents an advance in perceptual mapping research. In most perceptual mapping situations, a significant amount of information is known about the market under consideration prior to data collection. Confirmatory factor analysis takes advantage of this known information to develop a model which can be tested statistically. In addition, the structure allows for the estimation of correlated perceptual dimensions while eliminating the rotational indeterminacy of common factor analysis and principal components analysis. In the empirical study, the use of confirmatory factor analysis statistically confirmed hypothesized factor pattern as well as the importance of the correlation between perceptual dimensions.

Third, the model uses conjoint measurement to estimate customers' preference weightings for each of the perceptual dimensions and price. Despite the fact that the use of conjoint measurement in the development of customer decision models was suggested over a decade ago by Shocker and Srinivasan (1979), it is believed the customer decision model presented here is the first to incorporate this form of preference measurement. A vector preference model, rather than the traditional part-worth model, is used. The vector model simplifies the data collection procedure and increases the reliability of parameter estimates.

Finally, the customer decision model improves on past procedures in the way it incorporates price. The price parameter is estimated in the conjoint measurement task in which price and other perceptual dimensions are factors. This improves on earlier preference measurement approaches, like the brand "at a sticker price" ranking or rating tasks, which tend to place more importance on the price factor relative to other dimensions of the offering. In addition, because the price parameter is estimated over a range of price levels, the customer decision model is still valid as current prices are adjusted to incorporate price competition between brands.

The customer decision model developed in this research should be of interest to marketing researchers and practitioners. The model provides an intuitive, easy to understand interpretation of the preference decisions made by customers in the market. Although, data analysis procedures are "state of the art", the model builds on well known research tools like perceptual mapping and conjoint analysis. Furthermore, the potential for the development of a choice simulator is appealing. Application of the model should not pose any substantial difficulties. The methodology uses standard data collection techniques. In addition, given that popular statistics packages are making confirmatory factor analysis packages available (e.g. SPSS with LISREL, SYSTAT with EZPATH), the data analysis procedures are relatively straightforward.

Customer decision models estimate brand preferences as a function of brands' perceptual positions and prices. As was illustrated by the empirical study, the customer decision model developed in this research does a good job in predicting the respondents' first choice preferences in the western Canada combine harvester market. Although this represents only one implementation,[14] the model's general structure should allow for its application in a wide range of settings.

[14]Chapter 5 includes a discussion of model limitations and future research.

Chapter 5

Conclusions and Contributions, Limitations and Future Research

In this dissertation, three essays concerned with positioning issues in product-service firms were developed. Though linked with the common theme, the essays differ in terms of the specific issues that are addressed. As such, no overriding conclusions or summary is offered. Instead, the purpose of this chapter is to summarize each of the essays in turn. For each essays, three aspects are discussed. First, the conclusions and contributions of the research are highlighted. This is followed by a discussion of limitations and of relevant future research.

5.1 Price and Positioning Competition in a Two-Dimensional Market

5.1.1 Conclusions and Contributions

In chapter 2, three models were developed to study the competitive implications of various product differentiation assumptions in markets characterized by multiple dimensions. The one-dimensional horizontal and vertical models were extended to two dimensions. In addition, a two-dimensional mixed vertical-horizontal model was developed. Each model was analyzed using a two-stage game theoretic analysis in which two firms compete first on product positions and then on price. Closed form equilibrium solutions were obtained for each stage in which competitors are unrestricted in their choices of price or product positions in the defined market.

The research yielded a number of interesting findings. Perhaps the most significant finding was that, in equilibrium, there is a prevalence of *MaxMin* product differentiation. That is, the two firms tend to choose positions which will represent maximum differentiation on one dimension and minimum differentiation on the other dimension. This solution implies that the maximum differentiation solutions found in one-dimensional models (d'Aspremont et al 1979, Shaked and Sutton 1982) do not extend to two dimensions. Maximum differentiation on one of the two dimensions appears to be sufficient to lessen the price competition between firms. Although most equilibria exhibited *MaxMin* product differentiation, it was found that in the two-dimensional vertical differentiation model, under certain conditions, maximum product differentiation does occur. Furthermore, there are conditions in which the firms differentiate on both dimensions, but not fully. This latter finding appears to illustrate that there are limits to the strategic effect (the desire to reduce price competition) which leads to maximum differentiation in the one-dimensional case. Finally, the price equilibria for the three models share a generalized form with some parameter values depending on the product differentiation assumptions used. This finding, combined with the *MaxMin* product differentiation result, illustrates that there are similarities in the market reactions to products based on either vertical or horizontal differentiation assumptions.

The results of the equilibrium analysis provide several contributions to the literature on product and price competition. First, the models extend the one-dimensional product differentiation models to two dimensions. Second, the models found product equilibria in situations where the competitors are allowed to choose a position on both characteristics. Earlier models which considered markets characterized by multiple dimensions (e.g., Choi, DeSarbo and Harker 1990, Kumar and Sudharshan 1988, Hauser 1988) have either analyzed the price equilibrium alone or have simplified the product equilibrium by considering only one dimension. For example, Hauser (1988) analyzes a two- dimensional market in which products must lie on a quarter circle inscribed in the positive quadrant. This restriction implies that the choice of positions can be represented by a single dimension: an angle between 0° and 90°. Finally, because three alternative models are analyzed (two- dimensional vertical, two-dimensional horizontal and mixed), comparisons across differentiation assumptions are facilitated.

5.1.2 Limitations

The results of the economic models should be viewed in light of the models' limitations. These limitations, most of which concern the assumptions of the models, are discussed below:

1. An important limitation of the economic models is the assumption of equal marginal costs regardless of position. This limitation affects the vertical characteristics to a greater degree than the horizontal characteristics because a higher value on a vertical characteristic implies a higher quality level. It would be expected that high quality products would cost more than low cost products. The one-dimensional vertical differentiation model developed by Moorthy (1988) incorporates a variable cost component. Moorthy's equilibrium analysis shows that firms choose products which are differentiated (though not maximally). In addition, the firms choose not to provide offerings which appeal to the entire market (not all consumers purchase). An extension of his model to two dimensions would be of value. The constant cost assumption is of less concern when dealing with horizontal characteristics because these characteristics emphasize variety rather than quality differences. There is no reason to expect varieties to differ systematically in terms of cost.

2. The results in the economic models are also affected by the choice of equilibrium solution concept. The economic models searched for perfect Nash equilibrium solutions. Although this is the most common solution concept used in models of this type, it is important to note the implications of this choice. It appears that the findings of the models are affected by the Nash price game in the second stage. A Nash equilibrium assumes non-cooperative behavior on the part of the firms. The strong price competition which results gives the firms a strong motivation to differentiate. This can be contrasted with a Cournot equilibrium (where firms choose quantities rather than prices) which tends to lessen the price competition aspect. The Cournot equilibrium may result in less product differentiation.

3. Though not necessarily limitations, there are several assumptions which affect the equilibrium solutions. First, the choice of orthoganol product dimensions and the consumer utility functions does not consider interactions between the two product dimensions. The development of equilibrium solutions would be very difficult, if not impossible, if interactions were included. Second, the assumption of a uniform distribution of taste parameters may be limiting. The indifference line analysis procedure used in chapter 2 can readily accommodate non-uniform distributions on the taste parameters. However, numerical procedures would be required to search for the equilibrium solutions. Third, the issue of whether firms produce products which serve the entire market cannot be addressed as it was assumed that all consumers must buy. Relaxing this assumption in future research may be useful. Finally, there is a limitation concerning the generalizability of the model results. The models analyze a restricted setting in which there are only two competitors in a market where the products are described on two dimensions. Although analysis

of these models represent an extension to the current literature, few "real world" situations match the restricted model setting.

5.1.3 Future Research

The economic models analyzed in chapter 2 represent a starting point for the many avenues of future research. These areas, which are not listed in order of importance, are described below:

1. The economic models suggest that, if an equilibrium exists, it is likely to exhibit *MaxMin* product differentiation. An interesting research project would be to test whether this phenomenon occurs in a "real world" setting. An empirical analysis of a particular market would represent a significant contribution. There have been few empirical tests of the implications of economic models. This is probably due to the fact that finding situations which match model conditions is extremely difficult. A possible approach to determining whether a particular market tends towards a *MaxMin* product equilibrium would be a historical analysis of product characteristics and prices. However, finding an appropriate market and determining the range of possible product characteristics could represent difficult problems.

2. As discussed in the limitations section, the constant marginal cost assumption is restrictive, especially for vertical product dimensions. The development of a model which considered costs of alternative locations would be a contribution. In this regard, an extension of Moorthy's (1988) model to two dimensions appears to be the most promising approach. In Moorthy's model, the variable cost of a particular location on a vertical dimension, s, is defined as ωs^2. This implies that costs

increase (at an increasing rate) as quality (the value of s) increases. It would be interesting to determine if the equilibrium outcomes of a two-dimensional vertical model incorporating costs in this fashion parallels the results of Moorthy's (1988) one-dimensional model. Moorthy's equilibrium analysis shows that firms choose products which are differentiated, but not maximally.

3. As was outlined in the literature review, the horizontal model is very sensitive to the choice of the distance function (Economides 1986a). The two-dimensional horizontal differentiation model described here uses a quadratic distance function and is a direct extension of the one-dimensional model analyzed by d'Aspremont et al (1979). The quadratic distance function was chosen to conform with ideal point models which are common in the marketing literature (e. g. Gavish, Horsky and Srikanth 1983; Choi, DeSarbo and Harker 1990, Green and Srinivasan 1978). An interesting extension to the two- dimensional horizontal model would be the analysis of a model which uses a linear distance function. A linear function would be a direct extension to Hotelling's (1929) original model and be comparable to the two-dimensional vertical model. Economides (1986b) analyzes the price equilibrium, but does not address the product equilibrium, in a two-dimensional "Hotelling" model.

4. The model structure used in the analysis of the two-dimensional models can be readily expanded to analyze situations in which there are several competitors or several product dimensions. The indifference line approach used in the chapter 2 models extends easily to accommodate either additional competitors or product dimensions. However, the added complexities would probably require that the price equilibrium be established through numerical procedures. The equilibrium implications of including several competitors or several dimensions is unknown a priori.

Important research questions include: Does the *MaxMin* product equilibrium hold when there are three dimensions and two competitors? n dimensions? Does the *MaxMin* product equilibrium result hold when there are three competitors and two dimensions?

5.2 Setting the Strategic Direction in a Product-Service Firm

5.2.1 Conclusions and Contributions

The SDM model is designed to aid combined product-service firms in making offering positioning and pricing decisions. Drawing on the optimal product positioning literature, the model uses an analytical approach to the resolution of the strategic question of whether to invest in product or service improvements.

The SDM model is fundamentally different from optimal product positioning models. The SDM model optimizes a firm's strategic direction whereas optimal product positioning models search for an optimal new product location. This strategic focus adds a number of dimensions to the modeling problem. First, the SDM analyzes the positioning problem is analyzed from the perspective of the customer and the company. Within the company, managers at both the implementation and senior management levels combine to assess the appropriate strategic direction for the firm. Second, the SDM model views services as a critical component in the company's offering. As technological product differences are reduced, firms must look to services to obtain competitive advantage. Finally, the SDM model allows for the consideration of competing in multiple markets. Each of these markets may differ in terms of size, number of competitors and the structure of customer perceptions and preferences. In addition, the ability to modify services at the regional level adds flexibility to the company's positioning options.

One of the primary contributions of the SDM model is the nature of its specification of the link between physical and perceptual spaces. In the offering improvement phase, the model develops a number of promising offering improvements and subsequently estimates their location in perceptual space. This approach is the reverse of optimal product positioning models which typically search for an optimal product location in perceptual space and attempt to relate this to a physical product. Although the SDM model does not find the optimal perceptual location, it does address the major criticisms of optimal product positioning models including the identification of the characteristics of the physical offering and an accurate estimate of production costs.

The SDM model also contributes to the research on global marketing by providing an analytical, firm-specific approach to the development of a global product-service strategy. The model takes the view that an offering, especially its service component, need not be standardized across regions. More importantly, the model determines a company's strategy by considering the position of the firm's offering relative to competitive offerings as well as other regional market conditions.

5.2.2 Limitations

The SDM model represents an initial step in the development of an analytical procedure to aid a product-service firm in setting an appropriate strategic direction. In its current stage of development, there are a number of limitations to the SDM model. These limitations are outlined below:

1. Because of cross-offering synergies which can be realized in both production and the delivery of services, the strategic direction decision should be a company-wide

decision. However, the SDM model developed in chapter 3 assumes that there is only one offering for the firm. Since most product-service firms market a range of offerings, the development of a model which considers multiple offerings is necessary.

2. A significant limitation of the SDM model is the static nature of the analysis. The model determines the optimal strategic direction by comparing what the customer wants with what the firm is capable of offering at a particular point in time. The SDM model does not consider dynamic issues like changing customer preferences and the potential for significant technological breakthroughs. When analyzing the improvement programs, the SDM model does not consider the time required to develop the improvements, the rate at which improvements are accepted by customers and the offering-based actions or reactions of competitors. Model improvements in these areas would represent a significant contribution.

3. The SDM model requires information from a wide variety of sources. These include customers as well as managers in marketing, production and research and development. If multiple regions are considered, information from both customers and managers in each regions is required. Co-ordination of these information sources represents a significant task which requires a strong commitment from all levels of the organization. In addition, controlling for agency effects (the tendency for managers to act in their own best interest) would be difficult.

5.2.3 Future Research

The objective the chapter 3 was to describe the components of the SDM in detail. Additional research is required in a number of areas before the model can be implemented in an actual company setting. These areas are outlined below.

1. An approach to the development of an individual-level customer decision model needs to be developed. This research requirement was addressed in the chapter 4.

2. The development of improvement programs requires additional empirical research. The improvement programs are critical to the success of the model. To be of value, the product and service improvement programs must be specific enough to identify the most promising alternatives, but simple enough to be of value in a modeling procedure. In a company which is not currently involved in a quality function deployment system, a procedure similar to the one developed by Narasimhan and Sen (1990) appears to be the most promising.

3. A numerical procedure for the development of a price equilibrium has not been developed. The critical component of this research step is the development of accurate cost assessments for the competitive offerings. The customer model developed in the chapter 4 can be used as synthetic data to illustrate how the price equilibrium analysis would operate.

4. Finally, additional research is necessary to extend the current model to the analysis of multiple regions. Conceptually, this extension in straightforward as an additional level of analysis can be accommodated by all phases of the model. The development of improvement programs would probably present the most difficulty in this extension as multiple markets would compound the number of projects which warrant consideration.

Once the research outlined above has been completed, an obvious extension would be to apply the SDM model in an actual situation. The empirical application should include both improvement programs and the customer decision model. In this regard, an extension of the combine harvester example to incorporate improvements may be possible.

In addition to completing the research necessary to implement the SDM model, research is necessary to address the issues raised in the limitations section. The SDM model, at its current stage of development, is concerned with determining the optimal strategic direction for a one offering firm. However, most product-service firms market a range of offerings. Because of the potential for product-based or service-based synergies, the strategic direction decision should incorporate this added complexity. Therefore, a more comprehensive model needs to be developed.

Finally, research aimed at incorporating time dynamics into the analysis is needed. The static analysis issue has always been a concern in positioning research and resolving the associated modeling problems has proven to be difficult. In the SDM model, initial efforts to incorporate time dynamics into the analysis should occur in the ROI analysis phase. Here, assumptions can be made regarding the rate of improvement acceptance by customers and the length of time until competitors react to these improvements. These modifications would require a net present value analysis in the assessment of the impact of potential improvements.

5.3 An Individual Level Customer Decision Model

5.3.1 Conclusions and Contributions

Chapter 4 develops and tests an individual level customer decision model. Methodologically, the model extends the research on customer decision models in a number of ways.

First, the analysis is conducted at the individual level. Although the perceptual space is shared by all respondents (in a particular region), the specific perceptual locations of the offerings and the preference function are unique to the individual. This level of analysis is appropriate in situations where there is a large degree of heterogeneity in both perceptions and preferences. Markets characterized by product-service firms fall into this category. The individual level modelling approach also allows for the development of a customer decision model simulator similar to choice simulators available on commercial conjoint packages. Green and Srinivasan (1990) suggest that the availability of choice simulators is one of the main reasons for the popularity of conjoint analysis in industry.

Second, the use of a confirmatory analysis in the development of the perceptual space represents an advance in perceptual mapping research. In most perceptual mapping situations, a significant amount of information is known about the market under consideration prior to data collection. Confirmatory factor analysis takes advantage of this known information to develop a model which can be tested statistically. In addition, the structure allows for the estimation of correlated perceptual dimensions while eliminating the rotational indeterminacy of common factor analysis and principal components analysis. In the empirical study, the use of confirmatory factor analysis statistically confirmed hypothesized factor pattern as well as the importance of the correlation between perceptual dimensions.

Third, the model uses conjoint measurement to estimate customers' preference weightings for each of the perceptual dimensions and price. Despite the fact that the use of conjoint measurement in the development of customer decision models was suggested over a decade ago by Shocker and Srinivasan (1979), customer decision models have not incorporated this form of preference measurement. A vector preference model, rather than the traditional part-worth model, is used. The vector model simplifies the data collection procedure and increases the reliability of parameter estimates.

Finally, the customer decision model improves on past procedures in the way it incorporates price. The price parameter is estimated in the conjoint measurement task in which price and other perceptual dimensions are factors. This improves on earlier preference measurement approaches, like the brand "at a sticker price" ranking or rating tasks, which inadvertently tend to place more relatively more emphasis on the price dimension as compared to other dimensions of the offering. In addition, because the price parameter is estimated over a range of price levels, the customer decision model is still valid as current prices are adjusted to incorporate price competition between brands.

The customer decision model developed in this research should be of interest to marketing researchers and practitioners. Building on well known research tools like perceptual mapping and conjoint analysis, the model provides an intuitive, easy to understand interpretation of the preference decisions made by customers in the market. In addition, the potential for the development of a choice simulator is appealing. Application of the model should not pose any substantial difficulties. The methodology uses standard data collection techniques. In addition, given that popular statistics packages are making confirmatory factor analysis packages available (e.g. SPSS with LISREL, SYSTAT with EZPATH), the data analysis procedures are relatively straightforward.

5.3.2 Limitations

There are a number of limitations which impact the individual level customer decision model and the empirical results outlined in chapter 4. These limitations are discussed below:

1. The empirical application of the customer decision model yielded good predictive results in the combine harvester market. However, this represents only one limited application. To better determine the strengths and weaknesses of the model, several additional applications need to be undertaken. These applications should study a wide range of situations and compare the individual level model performance with more aggregate level models.

2. The use of respondents' stated preferences as a proxy for choice information is limiting. It is unclear whether these responses provide an accurate representation of how customers would respond in a choice situation. Access to timely choice information is preferred, but difficult to obtain in many situations. Even if choice information were available, the problem of obtaining an accurate representation of customer choice does not disappear since there exists the problem of respondents using post-hoc reasoning.

3. There are some specific aspects of the empirical study which affected model performance. First, by having respondents rate all four combine brands, it was assumed that all brand were in each respondents choice set. Of all types of farm equipment, the combine harvester is the most likely to receive the most prepurchase consideration. However, since some farmers choose the same brand for all of their farm equipment needs, the inclusion of choice sets in the model would be of value. Second, the preference parameters measured through the conjoint analysis have a relatively low level of reliability. For each respondent, three parameters (and a constant) were estimated from an evaluation of 12 profiles. In future studies, if no interactions are assumed, fractional factorial designs should be used in this phase of the analysis. Finally, the use of relative prices instead of actual prices may be

limiting. Though both farmers and combine dealers felt comfortable using the relative price scales, the effect that this choice had on the importance of the price parameter is unknown.

5.3.3 Future Research

The development and application of the customer decision model provides several opportunities for future research:

1. The application of the customer decision model in other settings should be one of the main priorities of future research. These studies could be used to determine the applicability of the model in diverse situations including non product-service settings. Several adjustments to the specific customer decision model can be made. These adjustments are primarily in response to limitation 3 above. A more in-depth conjoint measurement procedure and a review of how prices are incorporated should be a priority. Future research may also want to consider choice sets issues.

2. One of the key aspects of the customer decision model is the use of perceptual factors in the conjoint measurement phase. This allows for the parameterization of a preference model based on perceptions. In this procedure, it is important that the labels used in the conjoint measurement task imply the relevant attributes in the minds of the respondent. The current application used a secondary survey to check the attribute- factor associations. However, more research is necessary to determine better ways of ensuring that the appropriate factors are used in the preference measurement procedure.

3. The customer decision model outlined in chapter 4 considers both heterogeneous preferences and perceptions in developing a model of choice. The individual nature of the data allows for the development of a simulator similar to the choice simulators which are available with commercial conjoint programs. The data available through the customer decision model is potentially richer than the data derived from a conjoint study as the individual's perceptions of existing offerings is also included. Given the popularity of these simulators, development of a system would be of benefit to practitioners.

In Conclusion

This dissertation has concentrated on positioning in product-service firms. To date, research in this area has been limited. However, as firms search for new ways of creating and maintaining competitive advantage, issues relating to product-service firms will increase in importance. It is believed that the research developed in this dissertation contributes to our understanding of some of these issues.

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Appendix A

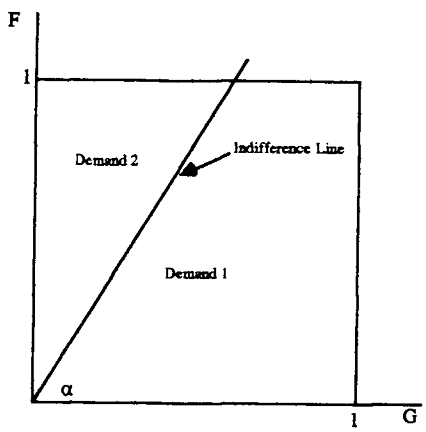
Price Equilibrium Analysis

This appendix provides the mathematical details of the price equilibria discussed in the text (section 2.4). First, the asymmetric characteristics case will be analyzed with characteristic x dominance being presented before characteristic y dominance. Second, the dominated characteristics case will be presented. In some instances, second order conditions are calculated to show that they are satisfied. In all other instances, they are analyzed by inspection.

A.1 Asymmetric Characteristics

Case 1: Characteristic x Dominance

Characteristic x dominance implies that $k(a_1 - a_2) \geq (b_2 - b_1)$. In terms of the angle of competition this implies that $\alpha \geq 45°$. This situation is depicted in the following graph.



Within characteristic x dominance, there are three regions in which a price equilibrium may occur R_x^1, R_x^2 and R_x^3. The demand for firm 1 in these regions is developed in section 2.4.1 of the text and are defined by equations (2.13), (2.15) and (2.17) respectively. These equations are listed below:

$$D_1^1 = \frac{1}{2}\left(\frac{\hat{p}_2 - p_1 + j + mk\boldsymbol{a}}{m\boldsymbol{b}}\right)^2 \cot\alpha \tag{A.1}$$

$$D_1^2 = \frac{1}{2}\cot\alpha + \left(1 + \frac{\hat{p}_2 - p_1 + j}{mk\boldsymbol{a} - m\boldsymbol{b}}\right)(1 - \cot\alpha)$$

$$D_1^3 = 1 - \frac{1}{2}\cot\alpha + \frac{1}{2}\left(\frac{\hat{p}_2 - p_1 + j}{m\boldsymbol{b}}\right)^2 \cot\alpha$$

The demand for firm 2 in these regions is simply $1 - \text{Demand}_1$.

Since marginal costs are assumed to be zero regardless of position, the profit function for firm i ($i = 1, 2$) is defined as $\Pi_i(p_i, p_j) = p_i D_i(p_i, p_j)$ for $i \neq j$. A noncooperative price equilibrium is a pair of prices (p_i^*, p_j^*) such that:

$$\Pi_i(p_i^*, p_j^*) \geq \Pi_i(p_i, p_j^*), \qquad \forall \quad p_i \geq 0;\ i, j = 1, 2\ ;\ \text{and, } i \neq j$$

The price equilibrium analysis will begin with R_x^2.

A.1.1 Price Equilibrium in R_x^2

Consider firm 1:

$$
\begin{aligned}
\Pi_1 &= p_1 D_1^2 \\
&= p_1 \left(\frac{1}{2}\cot\alpha + \left(1 + \frac{p_2 - p_1 + j}{m k \boldsymbol{a} - m \boldsymbol{b}}\right)(1 - \cot\alpha) \right)
\end{aligned}
$$

The first order condition of this profit function is:

$$
\frac{\partial \Pi_1}{\partial p_1} = \frac{1}{2}\cot\alpha + (1 - \cot\alpha) + (p_2 - p_1 + j)\left(\frac{1 - \cot\alpha}{m k \boldsymbol{a} - m \boldsymbol{b}}\right) - p_1\left(\frac{1 - \cot\alpha}{m k \boldsymbol{a} - m \boldsymbol{b}}\right) = 0
$$

Isolating p_1 yields:

$$
p_1 = \frac{1}{4}\left(\frac{1 - \cot\alpha}{m k \boldsymbol{a} - m \boldsymbol{b}}\right)\cot\alpha + \frac{1}{2}(m k \boldsymbol{a} - m \boldsymbol{b} + p_2 + j) \tag{A.2}
$$

Now consider firm 2 and conduct a similar analysis.

$$
\begin{aligned}
\Pi_2 &= p_2(1 - D_1^2) \\
&= p_2 \left(1 - \frac{1}{2}\cot\alpha - \left(1 + \frac{p_2 - p_1 + j}{m k \boldsymbol{a} - m \boldsymbol{b}}\right)(1 - \cot\alpha) \right)
\end{aligned}
$$

$$
\frac{\partial \Pi_2}{\partial p_2} = \frac{1}{2}\cot\alpha - (p_2 - p_1 + j)\left(\frac{1 - \cot\alpha}{m k \boldsymbol{a} - m \boldsymbol{b}}\right) - p_2\left(\frac{1 - \cot\alpha}{m k \boldsymbol{a} - m \boldsymbol{b}}\right) = 0
$$

$$
p_2 = \frac{1}{4}\left(\frac{1 - \cot\alpha}{m k \boldsymbol{a} - m \boldsymbol{b}}\right)\cot\alpha + \frac{1}{2}(p_1 - j) \tag{A.3}
$$

Solving for p_1 and p_2 in (A.2) and (A.3) yields (note that $\cot\alpha = \frac{\boldsymbol{b}}{k\boldsymbol{a}}$):

$$p_1^* = \frac{\frac{3}{2}\left(\frac{mk\boldsymbol{a}-m\boldsymbol{b}}{1-\cot\alpha}\right)\cot\alpha + 2(mk\boldsymbol{a}-m\boldsymbol{b})+j}{3} = \frac{4mk\boldsymbol{a}-m\boldsymbol{b}+2j}{6} \tag{A.4}$$

$$p_2^* = \frac{\frac{3}{2}\left(\frac{mk\boldsymbol{a}-m\boldsymbol{b}}{1-\cot\alpha}\right)\cot\alpha + mk\boldsymbol{a}-m\boldsymbol{b}-j}{3} = \frac{2mk\boldsymbol{a}+m\boldsymbol{b}-2j}{6} \tag{A.5}$$

These equilibrium prices are shown in equations (2.18) and (2.19) in section 2.4.1 of the text. In the text, these equations are followed by a discussion of the conditions which are necessary for this equilibrium to be valid. When the equilibrium is valid, the profits for the firms are obtained by multiplying the equilibrium prices by the demand equations. Substituting the equilibrium prices and $\cot\alpha = \frac{\boldsymbol{b}}{k\boldsymbol{a}}$ into the demand equations D_1^2 and D_2^2 yields:

$$D_1^2 = \frac{4mk\boldsymbol{a}-m\boldsymbol{b}+2j}{6mk\boldsymbol{a}}$$

$$D_2^2 = 1 - D_1^2 = \frac{2mk\boldsymbol{a}+m\boldsymbol{b}-2j}{6mk\boldsymbol{a}}$$

Profits for the firms when this equilibrium holds are:

$$\Pi_1^* = p_1^* D_1^2 = \frac{(4mk\boldsymbol{a}-m\boldsymbol{b}+2j)^2}{36mk\boldsymbol{a}} \tag{A.6}$$

$$
\begin{aligned}
\Pi_2^* &= p_2^* D_2^2 \\
&= \frac{(2mk\boldsymbol{a} - m\boldsymbol{b} - 2j)^2}{36mk\boldsymbol{a}}
\end{aligned}
\tag{A.7}
$$

A.1.2 Price Equilibrium in R_x^1

Consider firm 1. Demand is given by (2.13) in the text (section 2.4.1) and (A.1) above. Profits in this region for firm 1 are:

$$
\begin{aligned}
\Pi_1 &= p_1 D_1^1 \\
&= p_1 \left(\frac{1}{2} \left(\frac{p_2 - p_1 - j + mk\boldsymbol{a}}{m\boldsymbol{b}} \right)^2 \cot\alpha \right)
\end{aligned}
$$

The first order condition for profit maximization is:

$$
\begin{aligned}
\tfrac{\partial \pi_1}{\partial p_1} = \;& (p_2 - p_1 + j + mk\boldsymbol{a})^2 \left(\frac{\frac{1}{2}\cot\alpha}{(m\boldsymbol{b})^2} \right) + \\
& p_1 \left(\frac{\frac{1}{2}\cot\alpha}{(m\boldsymbol{b})^2} \right) (2p_1 - 2p_2 - 2j - 2mk\boldsymbol{a}) = 0
\end{aligned}
$$

Expanding this equation yields,

$$
\begin{aligned}
& 3p_1^2 - p_1(4p_2 + 4j + 4mk\boldsymbol{a}) + p_2^2 + j^2 + (mk\boldsymbol{a})^2 \\
& + p_2 j + 2p_2 mk\boldsymbol{a} + 2jmk\boldsymbol{a} = 0
\end{aligned}
\tag{A.8}
$$

(A.8) is a quadratic equation of the form $fp_1^2 + gp_1 + h = 0$. This can be solved using the quadratic formula:

$$p_1 = \frac{-g \pm \sqrt{g^2 - 4fh}}{2f}$$

The two roots to (A.8) are:

$$p_1 = p_2 + j + mk\boldsymbol{a} \tag{A.9}$$

$$p_1 = \frac{p_2 + j + mk\boldsymbol{a}}{3} \tag{A.10}$$

In (A.9), $p_1 = p_1^u$, the price at which demand for firm 1 is equal to zero (see section 2.4.1 of text). (A.10) maximizes profit and is used in the analysis below.

Now consider firm 2. The profit function and associated first order condition are:

$$\begin{aligned}
\Pi_2 &= p_2(1 - D_1^1) \\
&= p_2\left(1 - \left(\frac{1}{2}\cot\alpha\right)\left(\frac{p_2 - p_1 + j + mk\boldsymbol{a}}{m\boldsymbol{b}}\right)^2\right)
\end{aligned}$$

$$\begin{aligned}
\frac{\partial \Pi_2}{\partial p_2} = &\left(1 - \left(\frac{1}{2}\cot\alpha\right)\left(\frac{p_2 - p_1 + j + mk\boldsymbol{a}}{m\boldsymbol{b}}\right)^2\right) \\
&+p_2\left(\frac{-\frac{1}{2}\cot\alpha}{(m\boldsymbol{b})^2}\right)(2p_2 - 2p_1 + 2j + 2mk\boldsymbol{a}) = 0
\end{aligned}$$

Multiplying by $\left(\frac{-(m\boldsymbol{b})^2}{\frac{1}{2}\cot\alpha}\right)$ and expanding yields:

$$3p_2^2 + p_2(4j + 4mk\boldsymbol{a} - 4p_1) + j^2 + (mk\boldsymbol{a})^2 + p_1^2 + 2jmk\boldsymbol{a}$$
$$-2p_1 j - 2p_1 mk\boldsymbol{a} - \frac{2(m\boldsymbol{b})^2}{\cot\alpha} = 0$$

Subbing the equality for p_1 from (A.10) into the above equation yields (recall that $\cot\alpha = \frac{\boldsymbol{b}}{k\boldsymbol{a}}$):

$$4p_2^2 + p_2(5j + 5mk\boldsymbol{a}) + (j + mk\boldsymbol{a})^2 - \frac{9}{2}m^2 k\boldsymbol{ab} = 0$$

This equation is quadratic in p_2 and can be solved using the quadratic formula. The larger of the two roots maximizes Π_2 ($\frac{\partial^2 \pi_2}{\partial p_2^2} \leq 0$). Solving for this root and substituting this value of p_2 into (A.10) yields the following price equilibrium:

$$p_1^* = \frac{j + mk\boldsymbol{a} + \sqrt{(j + mk\boldsymbol{a})^2 + 8m^2 k\boldsymbol{ab}}}{8} \tag{A.11}$$

$$p_2^* = \frac{-5j - 5mk\boldsymbol{a} + 3\sqrt{(j + mk\boldsymbol{a})^2 + 8m^2 k\boldsymbol{ab}}}{8} \tag{A.12}$$

These equilibrium prices are shown in equations (2.23) and (2.24) in section 2.4.1 of the text. In the text, these equations are followed by a discussion of the conditions which are necessary for this equilibrium to be valid. When the equilibrium is valid, the profits for the firms are obtained by multiplying the equilibrium prices by the demand equations. Substituting the equilibrium prices and $\cot\alpha = \frac{\boldsymbol{b}}{k\boldsymbol{a}}$ into the demand equations D_1^2 and D_2^2 yields:

$$D_1^1 = \frac{\left(j + mk\boldsymbol{a} + \sqrt{(j + mk\boldsymbol{a})^2 + 8m^2k\boldsymbol{ab}}\right)^2}{32m^2k\boldsymbol{ab}}$$

$$\begin{aligned} D_2^1 &= 1 - D_1^1 \\ &= \frac{(32m^2k\boldsymbol{ab}) - \left(j + mk\boldsymbol{a} + \sqrt{(j + mk\boldsymbol{a})^2 + 8m^2k\boldsymbol{ab}}\right)^2}{32m^2k\boldsymbol{ab}} \end{aligned}$$

The profit for firm 1 is:

$$\begin{aligned} \Pi_1^\star &= p_1^\star D_1^1 \\ &= \frac{\left(j + mk\boldsymbol{a} + \sqrt{(j + mk\boldsymbol{a})^2 + 8m^2k\boldsymbol{ab}}\right)^3}{256m^2k\boldsymbol{ab}} \end{aligned} \tag{A.13}$$

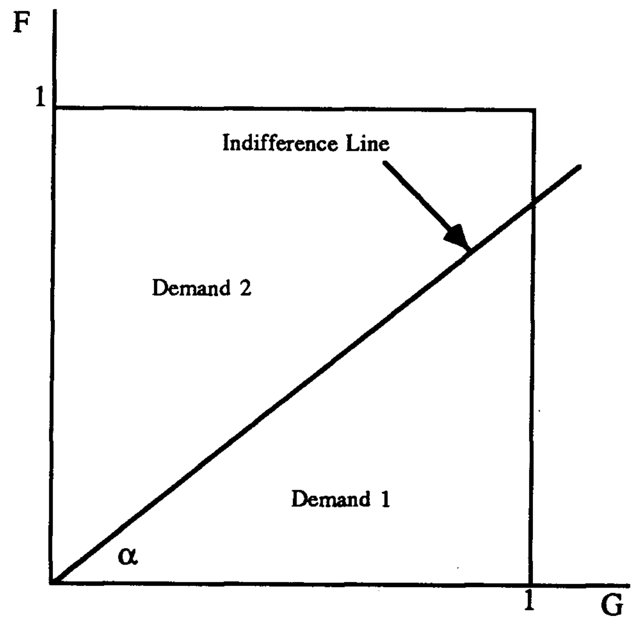
The profit for firm 2, as can be seen from the equation for D_2^1, is a complex equation. As is shown in the product equilibrium sections of the text (section 2.5.3, Appendix B), it is not required for the determination of the product equilibrium.

A.1.3 Price Equilibrium in R_x^3

The price equilibrium in R_x^3 is a complex quadratic function of price. The exact solution has not been calculated as it is not required for the product equilibrium (see sections 2.5.1, 2.6.1, 2.7.1 of the text).

A.2 Case 2: Characteristics y Dominance

When characteristic y dominance holds, $\alpha \leq 45°$. This implies that $k(a_1 - a_2) \leq (b_2 - b_1)$. The same price equations hold (equations 2.8-2.11 in the text) but now $p_1^u > p_1^n \gtrsim p_1^m > p_1^l$ since as firm 1 decreases its price from p_1^u (given p_2), the indifference line passes through the origin before it passes through point (1, 1). This situation is depicted in the following graph.



Using the same procedure as outlined under characteristic x dominance, demand in each of the regions can be defined as a function of prices and α. There are three regions in which a price equilibrium may occur, R_y^1, R_y^2 and R_y^3. The demand for firm 1 in these regions is developed in section 2.4.2 of the text and defined by equations (2.26), (2.27) and (2.28) respectively. These equations are listed below:

$$D_1^1 = \frac{1}{2}\left(1 + \frac{\hat{p}_2 - p_1 + j}{mk\boldsymbol{a}}\right)^2 \tan\alpha \tag{A.14}$$

$$D_1^2 = \frac{1}{2}\tan\alpha + \left(\frac{\hat{p}_2 - p_1 + j}{m\boldsymbol{b} - mk\boldsymbol{a}}\right)(1 - \tan\alpha)$$

$$D_1^3 = 1 - \frac{1}{2}\tan\alpha + \frac{1}{2}\left(\frac{\hat{p}_2 - p_1 + j + m\boldsymbol{b} + mk\boldsymbol{a}}{mk\boldsymbol{a}}\right)^2 \tan\alpha$$

A.2.1 Price Equilibrium in R_y^2

Consider firm 1. Profits for this firm in R_y^2 are:

$$\begin{aligned}
\Pi_1 &= p_1 D_1^2 \\
&= p_1\left(\frac{1}{2}\tan\alpha + \left(\frac{p_2 - p_1 + j}{m\boldsymbol{b} - mk\boldsymbol{a}}\right)(1 - \tan\alpha)\right)
\end{aligned}$$

The derivative of this profit function with respect to p_1 is:

$$\frac{\partial \Pi_1}{\partial p_1} = \frac{1}{2}\tan\alpha + (p_2 - p_1 + j)\frac{1 - \tan\alpha}{m\boldsymbol{b} - mk\boldsymbol{a}} - p_1\frac{1 - \tan\alpha}{m\boldsymbol{b} - mk\boldsymbol{a}} = 0$$

Isolating for p_1 yields:

$$p_1 = \frac{1}{4}\left(\frac{m\boldsymbol{b} - mk\boldsymbol{a}}{1 - \tan\alpha}\right)\tan\alpha + \frac{1}{2}(p_2 + j) \tag{A.15}$$

Now consider firm 2 and perform a similar analysis.

$$
\begin{aligned}
\Pi_2 &= p_2(1 - D_1^2) \\
&= p_2\left(1 - \frac{1}{2}\tan\alpha - \left(\frac{p_2 - p_1 + j}{m\boldsymbol{b} - mk\boldsymbol{a}}\right)(1 - \tan\alpha)\right)
\end{aligned}
$$

$$
\frac{\partial \Pi_2}{\partial p_2} = \frac{1}{2}\tan\alpha + 1 - \tan\alpha - (p_2 - p_1 + j)\frac{1 - \tan\alpha}{m\boldsymbol{b} - mk\boldsymbol{a}} - (p_2 - c_2)\frac{1 - \tan\alpha}{m\boldsymbol{b} - mk\boldsymbol{a}} = 0
$$

$$
p_2 = \frac{1}{4}\left(\frac{m\boldsymbol{b} - mk\boldsymbol{a}}{1 - \tan\alpha}\right)\tan\alpha + \frac{1}{2}(p_1 + m\boldsymbol{b} - mk\boldsymbol{a} - j) \tag{A.16}
$$

Solving for p_1 and p_2 in (A.15) and (A.16) yields the following price equilibrium (note that $\tan\alpha = \frac{mk\boldsymbol{a}}{m\boldsymbol{b}}$):

$$
\begin{aligned}
p_1^{**} &= \frac{\frac{3}{2}\left(\frac{m\boldsymbol{b} - mk\boldsymbol{a}}{1 - \tan\alpha}\right)\tan\alpha + m\boldsymbol{b} - mk\boldsymbol{a} + j}{3} \\
&= \frac{2m\boldsymbol{b} + mk\boldsymbol{a} + 2j}{6}
\end{aligned} \tag{A.17}
$$

$$
\begin{aligned}
p_2^{**} &= \frac{\frac{3}{2}\left(\frac{m\boldsymbol{b} - mk\boldsymbol{a}}{1 - \tan\alpha}\right)\tan\alpha + 2(m\boldsymbol{b} - mk\boldsymbol{a}) - j}{3} \\
&= \frac{4m\boldsymbol{b} - mk\boldsymbol{a} + 2j}{6}
\end{aligned} \tag{A.18}
$$

These equilibrium prices are shown in equations (2.29) and (2.30) in section 2.4.2 of the text. In the text, these equations are followed by a discussion of the conditions which are necessary for this equilibrium to be valid. When the equilibrium is valid, the profits for the firms are obtained by multiplying the equilibrium prices by the demand equations. Substituting the equilibrium prices and $\cot\alpha = \frac{\boldsymbol{b}}{k\boldsymbol{a}}$ into the demand equations D_1^2 and D_2^2 yields:

$$D_1^2 = \frac{2m\boldsymbol{b} + mk\boldsymbol{a} + 2j}{6m\boldsymbol{b}}$$

$$\begin{aligned} D_2^2 &= 1 - D_1^2 \\ &= \frac{4m\boldsymbol{b} - mk\boldsymbol{a} - 2j}{6mk\boldsymbol{b}} \end{aligned}$$

Profits for the firms when this equilibrium holds are:

$$\begin{aligned} \Pi_1^{**} &= p_1^{**} D_1^2 \\ &= \frac{(2m\boldsymbol{a} + m\boldsymbol{a} + 2j)^2}{36mk\boldsymbol{b}} \end{aligned} \tag{A.19}$$

$$\begin{aligned} \Pi_2^{**} &= p_2^{**} D_2^2 \\ &= \frac{(4m\boldsymbol{a} + mk\boldsymbol{a} - 2j)^2}{36m\boldsymbol{b}} \end{aligned} \tag{A.20}$$

A.2.2 Price Equilibrium in R_y^1

Using the fact that $\tan\alpha = \frac{mka}{mb}$ and that $\cot\alpha = \frac{1}{\tan\alpha}$, it can be shown that the demand for firm 1 in R_y^1 (defined by (2.26) in the text and (A.14) above) is equal to the demand for firm 1 in R_x^1 (defined by (2.13) and (A.1) above). Therefore, the demands for firm 2 in both of these regions are equal as well. Since profits are defined as $p_i D_i^1$, The price equilibrium in R_y^1 is identical to the price equilibrium in R_x^1. This equilibrium is defined by (2.23) and (2.24) in the text and (A.11) and (A.12) above. See section 2.4.2 for a discussion of the feasible region for this equilibrium.

A.2.3 Price Equilibrium in R_y^3

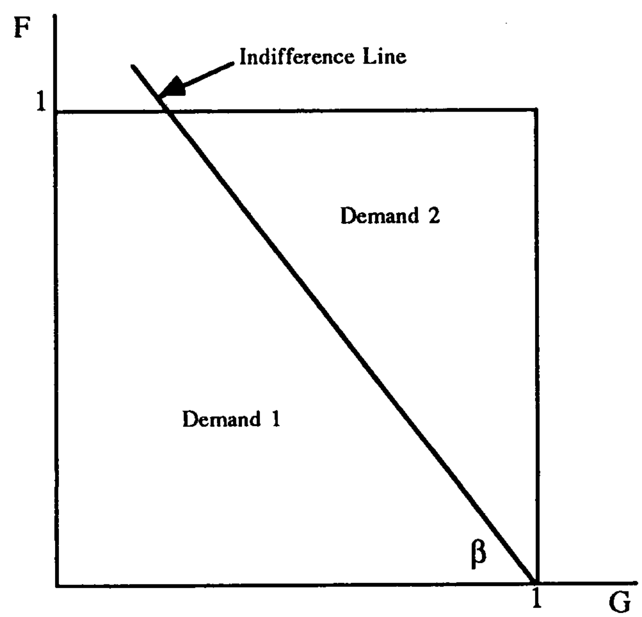
The price equilibrium in R_y^3 is a complex quadratic function of price. The exact solution has not been calculated as it is not required for the product equilibrium (see sections 2.5.1, 2.6.1, 2.7.1 of the text).

A.3 Dominated Characteristics

The two-dimensional horizontal differentiation model and the mixed model can always be set up to conform with asymmetric characteristics competition. However, the two-dimensional vertical differentiation model allows for dominated characteristics competition. As the generalized price equilibrium analysis assumes asymmetric characteristics competition, the dominated characteristics case for the vertical model must be analyzed separately. This section will outline the demand analysis and price equilibria for both characteristic x dominance and characteristic y dominance for the dominated characteristics case of the vertical model.

Case 1: Characteristic x Dominance

The dominated characteristics case is analyzed in much the same way as the asymmetric characteristics case. The general form of the indifference line (equation (2.7) in the text) applies as do the key price levels (equations 2.8-2.11 in the text). Since the dominated characteristics analysis is only required for the vertical model, the parameters $k = 1$, $m = 1$ and $j = 0$ are substituted into these equations. The modified form of these equations is shown in equations (2.31)- (2.35) in section 2.4.3. Without loss of generality, it is assumed that firm 2's product is dominant. That is, $a_2 \geq a_1$ and $b_2 \geq b_1$. This implies that $\boldsymbol{a} = (a_1 - a_2) \leq 0$ and slope of the indifference curve is negative. Under characteristic x dominance, $90° \leq \alpha \leq 135°$. Alternatively, the angle of competition can be described by an angle $\beta \geq 45°$ where $\beta = 180° - \alpha$. This implies that $-(a_1 - a_2) \geq (b_2 - b_1)$. Under these conditions, the ordering of the price equations is $p_1^m < p_1^u \leq p_1^l < p_1^n$. This situation is depicted in the following graph.



Like the asymmetric characteristics case, there are three regions in which a price equilibrium may be found, ${}_dR_x^1$, ${}_dR_x^2$ and ${}_dR_x^3$. Using the same procedure as described in section 2.4.1 of the text, the demand equations for these three regions can be defined. These equations are listed below.

$$D_1^1 = \frac{1}{2}\left(\frac{p_2 - p_1}{b}\right)^2 \cot\beta \tag{A.21}$$

$$D_1^2 = \frac{1}{2}\cot\beta + \left(\frac{p_2 - p_1 - b}{-a - b}\right)(1 - \cot\beta)$$

$$D_1^3 = 1 - \frac{1}{2}\cot\beta + \frac{1}{2}\left(\frac{p_2 - p_1 + a}{b}\right)^2 \cot\beta$$

The demand for firm 2 in these regions is simply $1 - \text{Demand}_1$.

Since marginal costs are assumed to be zero regardless of position, the profit function for firm i ($i = 1, 2$) is defined as $\Pi_i(p_i, p_j) = p_i D_i(p_i, p_j)$ for $i \neq j$.

A.3.1 Price Equilibrium in ${}_dR_x^2$

Consider firm 1. Profit in ${}_dR_x^2$ is defined as:

$$\begin{aligned}
\Pi_1 &= p_1 D_1^2 \\
&= p_1\left(\frac{1}{2}\cot\beta + \left(\frac{p_2 - p_1 - b}{-a - b}\right)(1 - \cot\beta)\right)
\end{aligned}$$

The first order condition for profit maximization is:

$$\frac{\partial \Pi_1}{\partial p_1} = \frac{1}{2}\cot\beta + \left(\frac{p_2 - p_1 - \boldsymbol{b}}{-\boldsymbol{a} - \boldsymbol{b}}\right)(1 - \cot\beta) - p_1\left(\frac{1 - \cot\beta}{-\boldsymbol{a} - \boldsymbol{b}}\right)$$

Isolating p_1 in the above equation yields:

$$p_1 = \frac{1}{4}\left(\frac{-\boldsymbol{a} - \boldsymbol{b}}{1 - \cot\beta}\right)\cot\beta + \frac{1}{2}(p_2 - \boldsymbol{b}) \tag{A.22}$$

Now consider firm 2 and conduct a similar analysis.

$$\begin{aligned}
\Pi_2 &= p_2(1 - D_1^2) \\
&= p_2\left(1 - \frac{1}{2}\cot\beta - \left(\frac{p_2 - p_1 - \boldsymbol{b}}{-\boldsymbol{a} - \boldsymbol{b}}\right)(1 - \cot\beta)\right)
\end{aligned}$$

Differentiating with respect to p_2 yields:

$$\frac{\partial \Pi_2}{\partial p_2} = \left(1 - \frac{1}{2}\cot\beta - \left(\frac{p_2 - p_1 - \boldsymbol{b}}{-\boldsymbol{a} - \boldsymbol{b}}\right)(1 - \cot\beta)\right) - p_2\left(\frac{1 - \cot\beta}{-\boldsymbol{a} - \boldsymbol{b}}\right)$$

Isolating p_2 in this first order condition results in:

$$p_2 = \frac{1}{4}\left(\frac{-\boldsymbol{a} - \boldsymbol{b}}{1 - \cot\beta}\right)\cot\beta + \frac{1}{2}(p_1 - \boldsymbol{a}) \tag{A.23}$$

Solving for p_1 and p_2 in (A.22) and (A.23) yields the following price equilibrium:

$$\begin{aligned}
p_1^{***} &= \frac{\frac{3}{2}\left(\frac{-\boldsymbol{a}-\boldsymbol{b}}{1-\cot\beta}\right)\cot\beta - 2\boldsymbol{b} - \boldsymbol{a}}{3} \\
&= \frac{-2\boldsymbol{a} - \boldsymbol{b}}{6}
\end{aligned} \tag{A.24}$$

$$\begin{aligned} p_2^{***} &= \frac{\frac{3}{2}\left(\frac{-\boldsymbol{a}-\boldsymbol{b}}{1-\cot\beta}\right)\cot\beta - \boldsymbol{b} - 2\boldsymbol{a}}{3} \\ &= \frac{-4\boldsymbol{a}-\boldsymbol{b}}{6} \end{aligned} \tag{A.25}$$

These equilibrium prices are shown in equations (2.36) and (2.37) in section 2.4.3 of the text. In the text, these equations are followed by a discussion of the conditions which are necessary for this equilibrium to be valid. When the equilibrium is valid, the profits for the firms are obtained by multiplying the equilibrium prices by the demand equations. Substituting the equilibrium prices and $\cot\beta = \frac{\boldsymbol{b}}{-\boldsymbol{a}}$ into the demand equations D_1^2 and D_2^2 yields:

$$D_1^2 = \frac{-2\boldsymbol{a}-\boldsymbol{b}}{-6\boldsymbol{a}}$$

$$\begin{aligned} D_2^2 &= 1 - D_1^2 \\ &= \frac{-2\boldsymbol{a}-\boldsymbol{b}}{-6\boldsymbol{a}} \end{aligned}$$

Profits for the firms when this equilibrium holds are:

$$\begin{aligned} \Pi_1^{***} &= p_1^{***} D_1^2 \\ &= \frac{(-2\boldsymbol{a}-\boldsymbol{b})^2}{-36\boldsymbol{a}} \end{aligned} \tag{A.26}$$

$$\Pi_2^{***} = p_2^{***} D_2^2$$

$$= \frac{(-4\boldsymbol{a} - \boldsymbol{b})^2}{-36\boldsymbol{a}} \tag{A.27}$$

These profit levels are shown in equations (2.46) and (2.47) in section 2.5.2 of the text.

A.3.2 Price Equilibrium in ${}_dR_x^1$

Consider firm 1. Demand is given by (A.21) above. Profits in this region for firm 1 are:

$$\begin{aligned} \Pi_1 &= p_1 D_1^1 \\ &= p_1 \left(\frac{1}{2}\cot\beta\left(\frac{p_2 - p_1}{\boldsymbol{b}}\right)^2\right) \end{aligned}$$

Differentiating with respect to p_1 yields:

$$\frac{\partial \Pi_1}{\partial \Pi_1} = \frac{1}{2}\cot\beta\left(\frac{p_2 - p_1}{\boldsymbol{b}}\right)^2 + p_1\left(\frac{1}{2}\cot\beta\right)\left(\frac{2p_1 - 2p_2}{b^2}\right) = 0$$

This reduces to:

$$3p_1^2 - 4p_1p_2 + p_2^2 = 0 \tag{A.28}$$

Using the quadratic formula, the two roots of (A.28) are:

$$p_1 = p_2$$

and

$$p_1 = \frac{p_2}{3} \tag{A.29}$$

Since $D_1 = 0$ at $p_1 = p_2$, the second root is chosen in this region.

Now consider firm 2. Profits in this region are:

$$\begin{aligned} \Pi_2 &= p_2(1 - D_1^1) \\ &= p_2\left(1 - \frac{1}{2}\cot\beta\left(\frac{p_2 - p_1}{\boldsymbol{b}}\right)^2\right) \end{aligned}$$

Differentiating the profit function with respect to p_2 yields:

$$\frac{\partial \Pi_2}{\partial \Pi_2} = (1 - (p_2 - p_1)^2)\frac{\frac{1}{2}\cot\beta}{b^2} - p_2(2p_2 - 2p_1)\frac{\frac{1}{2}\cot\beta}{b^2} = 0$$

Multiplying the first order condition by $-\frac{\boldsymbol{b}^2}{\frac{1}{2}\cot\beta}$ and substituting $\cot\beta = \frac{\boldsymbol{b}}{-\boldsymbol{a}}$ yields

$$3p_2^2 - 4p_2p_1 + p_1^2 + 2\boldsymbol{ab} = 0 \tag{A.30}$$

Substituting (A.29) into (A.30) yields

$$8p_2^2 + 9\boldsymbol{ab} = 0 \tag{A.31}$$

Solving for p_2 in (A.31 and substituting this value into (A.29) yields the following price equilibrium:

$$p_1^{***} = \frac{\sqrt{-8\boldsymbol{ab}}}{8} \tag{A.32}$$

$$p_2^{***} = \frac{3\sqrt{-8\boldsymbol{ab}}}{8} \tag{A.33}$$

These equilibrium prices are shown in equations (2.38) and (2.39) in section 2.4.3 of the text. In the text, these equations are followed by a discussion of the conditions which are necessary for this equilibrium to be valid. When the equilibrium is valid, the profits for the firms are obtained by multiplying the equilibrium prices by the demand equations. Substituting the equilibrium prices and $\cot\beta = \frac{b}{-a}$ into the demand equations D_1^2 and D_2^2 yields:

$$D_1^1 = \frac{1}{2}\left(\frac{p_2^{***} - p_1^{***}}{b}\right)^2 \cot\beta = \frac{1}{4}$$

$$D_2^1 = 1 - D_1^1 = \frac{3}{4}$$

Multiplying these demands by the equilibrium prices ((2.38) and(2.39) in the text and (A.32) and (A.33) above) yields the following equilibrium profits:

$$\begin{aligned} \Pi_1^{***} &= p_1^{***} D_1^1 \\ &= \frac{\sqrt{-8ab}}{32} \end{aligned} \tag{A.34}$$

$$\begin{aligned} \Pi_2^{***} &= p_2^{***} D_2^1 \\ &= \frac{9\sqrt{-8ab}}{32} \end{aligned} \tag{A.35}$$

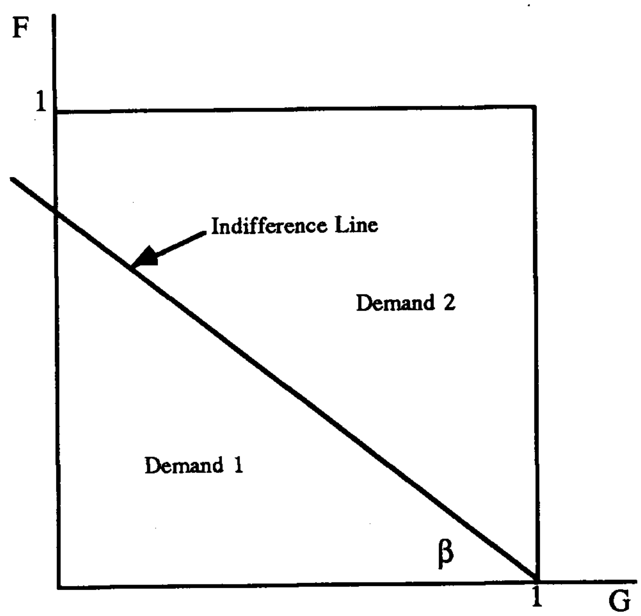
These profits are shown in equations (2.48) and (2.49) in section 2.5.2 of the text.

A.3.3 Price Equilibrium in R_x^3

The price equilibrium in ${}_dR_x^3$ is a complex quadratic function of price. The exact solution has not been calculated as it is not required for the product equilibrium (see sections 2.5.2 of the text).

A.4 Case 2: Characteristics y Dominance

When characteristic y dominance holds, $\beta \leq 45°$. This implies that $-(a_1 - a_2) \leq (b_2 - b_1)$. The same price equations hold (equations 2.8-2.11 in the text) but now $p_1^n > p_1^u \geq p_1^l > p_1^m$ since as firm 1 decreases its price from p_1^n (given p_2), the indifference line passes through point (1,0) before it passes through point (0, 1). This situation is depicted in the following graph.



Using the same procedure as outlined in section 2.4.1 of the text, demand in each of the regions can be defined as a function of prices and β. There are three regions in which a price equilibrium may occur, ${}_dR_y^1$, ${}_dR_y^2$ and ${}_dR_y^3$. The demand for firm 1 in these regions is:

$$D_1^1 = \frac{1}{2}\left(\frac{\dot{p}_2 - p_1}{-\boldsymbol{a}}\right)^2 \tan\beta \tag{A.36}$$

$$D_1^2 = \frac{1}{2}\tan\beta + \left(\frac{\dot{p}_2 - p_1 + a}{\boldsymbol{b}+\boldsymbol{a}}\right)(1 - tan\beta)$$

$$D_1^3 = 1 - \frac{1}{2}\tan\beta + \frac{1}{2}\left(\frac{\dot{p}_2 - p_1 - \boldsymbol{a}}{-\boldsymbol{a}}\right)^2 \tan\beta$$

A.4.1 Price Equilibrium in ${}_dR_y^2$

Consider firm 1. Profit in ${}_dR_y^2$ is defined as:

$$\begin{aligned} \Pi_1 &= p_1 D_1^2 \\ &= \left(\frac{1}{2}\tan\beta + \left(\frac{p_2 - p_1 + \boldsymbol{a}}{\boldsymbol{b}+\boldsymbol{a}}\right)(1 - \tan\beta)\right) \end{aligned}$$

The derivative of this profit function with respect to p_1 is:

$$\frac{\partial \Pi_1}{\partial p_1} = \left(\frac{1}{2}\tan\beta + \left(\frac{p_2 - p_1 + \boldsymbol{a}}{\boldsymbol{b}+\boldsymbol{a}}\right)(1 - \tan\beta)\right) - p_1\left(\frac{1 - \tan\beta}{\boldsymbol{b}+\boldsymbol{a}}\right) = 0$$

Isolating p_1 in this first order condition yields:

$$p_1 = \frac{1}{4}\left(\frac{\boldsymbol{b}+\boldsymbol{a}}{1 - \tan\beta}\right)\tan\beta + \frac{1}{2}(p_2 + \boldsymbol{a}) \tag{A.37}$$

Now consider firm 2 and conduct a similar analysis.

$$\begin{aligned}\Pi_1 &= p_1 D_1^2 \\ &= p_2\left(1 - \frac{1}{2}\tan\beta - \left(\frac{p_2 - p_1 + \boldsymbol{a}}{\boldsymbol{b} + \boldsymbol{a}}\right) 1 - \tan\beta)\right)\end{aligned}$$

After differentiation, p_2 can be expressed as:

$$p_2 = \frac{1}{4}\left(\frac{\boldsymbol{b}+\boldsymbol{a}}{1-\tan\beta}\right)\tan\beta + \frac{1}{2}(p_1 + \boldsymbol{b}) \tag{A.38}$$

Solving for p_1 and p_2 in (A.37) and (A.38) results in the following price equilibrium (note that $\tan\beta = \frac{-\boldsymbol{a}}{\boldsymbol{b}}$:

$$\begin{aligned}p_1^{****} &= \frac{\frac{3}{2}\left(\frac{\boldsymbol{b}+\boldsymbol{a}}{1-\tan\beta}\right)\tan\beta + 2\boldsymbol{a} + \boldsymbol{b}}{3} \\ &= \frac{2\boldsymbol{b}+\boldsymbol{a}}{6} \end{aligned} \tag{A.39}$$

$$\begin{aligned}p_2^{****} &= \frac{\frac{3}{2}\left(\frac{\boldsymbol{b}+\boldsymbol{a}}{1-\tan\beta}\right)\tan\beta + \boldsymbol{a} + 2\boldsymbol{b}}{3} \\ &= \frac{4\boldsymbol{b}-\boldsymbol{a}}{6} \end{aligned} \tag{A.40}$$

These equilibrium prices are shown in equations (2.40) and (2.41) in section 2.4.3 of the text. In the text, these equations are followed by a discussion of the conditions which are necessary for this equilibrium to be valid. When the equilibrium is valid, the profits for the firms are obtained by multiplying the equilibrium prices by the demand equations. Substituting the equilibrium prices and $\tan\beta = \frac{-\boldsymbol{a}}{\boldsymbol{b}}$ into the demand equations D_1^2 and D_2^2 yields:

$$D_1^2 = \frac{2\boldsymbol{b} + \boldsymbol{a}}{6\boldsymbol{b}}$$

$$\begin{aligned} D_2^2 &= 1 - D_1^2 \\ &= \frac{4\boldsymbol{b} - \boldsymbol{a}}{6\boldsymbol{b}} \end{aligned}$$

Profits for the firms when this equilibrium holds are:

$$\begin{aligned} \Pi_1^{****} &= p_1^{****} D_1^2 \\ &= \frac{(2\boldsymbol{b} + \boldsymbol{a})^2}{36\boldsymbol{b}} \end{aligned} \tag{A.41}$$

$$\begin{aligned} \Pi_2^{****} &= p_2^{****} D_2^2 \\ &= \frac{(4\boldsymbol{b} - \boldsymbol{a})^2}{36\boldsymbol{b}} \end{aligned} \tag{A.42}$$

The profits are shown in equations (2.50) and (2.51) in section 2.5.2 of the text.

A.4.2 Price Equilibrium in R_y^1

Using the fact that $\tan\beta = \frac{-\boldsymbol{a}}{\boldsymbol{b}}$ and that $\cot\beta = \frac{1}{\tan\beta}$, it can be shown that the demand for firm 1 in ${}_dR_y^1$ (defined by (A.36) above) is equal to the demand for firm 1 in ${}_dR_x^1$

(defined by (A.21) above). Therefore, the demands for firm 2 in both of these regions are equal as well. Since profits are defined as $p_i D_i^1$, The price equilibrium in ${}_dR_y^1$ is identical to the price equilibrium in ${}_dR_x^1$. This equilibrium is defined by (2.38) and (2.39) in the text and (A.32) and (A.33) above. See section 2.4.3 for a discussion of the feasible region for this equilibrium.

A.4.3 Price Equilibrium in R_y^3

The price equilibrium in ${}_dR_y^3$ is a complex quadratic function of price. The exact solution has not been calculated as it is not required for the product equilibrium (see section 2.5.2 of the text).

Appendix B

Proof of Lemma

Lemma: Given any (a_i, b_i), there exists no best response in the interior of R_x^1 or R_y^1 for firm $j \neq i$.

Proof:

I. As shown in section 2.4.2 of the text, the demands and equilibrium prices for the two firms are identical in R_x^1 or R_y^1. In this section, consider firm 1. The equilibrium prices for the two firms are given by (2.23) and (2.24) in the text while the demand and profit for firm 1 are given in Appendix A (equation (A.13)). Substituting the parameter values for the mixed model $(m = 1, k = 2)$ into these equations yields:

$$\begin{aligned}
p_1^* &= \frac{j + 2\boldsymbol{a} + \sqrt{(j + 2\boldsymbol{a})^2 + 16\boldsymbol{ab}}}{8} \\
p_2^* &= \frac{-5j - 10\boldsymbol{a} + 3\sqrt{(j + 2\boldsymbol{a})^2 + 16\boldsymbol{ab}}}{8} \\
D_1^1 &= \frac{\left(j + 2\boldsymbol{a} + \sqrt{(j + 2\boldsymbol{a})^2 + 16\boldsymbol{ab}}\right)^2}{64\boldsymbol{ab}} \\
\Pi_1^* &= \frac{\left(j + 2\boldsymbol{a} + \sqrt{(j + 2\boldsymbol{a})^2 + 16\boldsymbol{ab}}\right)^3}{512\boldsymbol{ab}}
\end{aligned} \tag{B.1}$$

The first part of the lemma will be proven by showing that there is no best response for firm 1 with respect to the vertical characteristic (b_1) in the interior of R_x^1 or R_y^1.

$$\begin{aligned} \text{Let } F &= \sqrt{(j+2\boldsymbol{a})^2 + 16\boldsymbol{ab}} \\ \text{Therefore, } \tfrac{\partial F}{\partial b_1} &= \frac{-8\boldsymbol{a}}{F} \end{aligned}$$

Differentiating the profit function with respect to b_1 yields:

$$\frac{\partial \Pi_1^*}{\partial b_1} = \left(\frac{(j+2\boldsymbol{a}+F)^2}{512b^2}\right)\left(j+2\boldsymbol{a}+F-\frac{24\boldsymbol{ab}}{F}\right) \tag{B.2}$$

Notice that the first term of the (B.2) is always positive. Therefore, to determine the sign of the derivative, an analysis of the second term is necessary. In R_x^1 and R_y^1, (B_M) is violated so $b_1 \neq b_2$ ((B_M) is defined in 2.7 of the text). Therefore, for there to be a best response in R_x^1 or R_y^1, it must be true that

$$j+2\boldsymbol{a}+F-\frac{24\boldsymbol{ab}}{F} = 0$$

Multiplying the above equation by F and rearranging terms yields:

$$(j+2\boldsymbol{a})F = 8\boldsymbol{ab} - (j+2\boldsymbol{a})^2$$

By squaring both sides and rearranging terms:

$$(j + 2\boldsymbol{a})^2 = 2\boldsymbol{ab} \tag{B.3}$$

As condition (B_M) is violated, $2\boldsymbol{b} > 4\boldsymbol{a} + j$. Substitution of this inequality into (B.3) yields:

$$\begin{aligned} j^2 + 4\boldsymbol{a}j + 4\boldsymbol{a}^2 &> 4\boldsymbol{a}^2 + \boldsymbol{a}j \\ j(j + 3\boldsymbol{a}) &> 0 \end{aligned} \tag{B.4}$$

Since $j = (a_2^2 - a_1^2) < 0$, for (B.4) to be true, $j + 3\boldsymbol{a} = (a_2^2 - a_1^2) + 3(a_1 - a_2) < 0$. This implies that $3 - (a_1 + a_2) < 0$ which is a contradiction. Therefore $\frac{\partial \Pi_1^*}{\partial b_1} = 0$ does not exist in R_x^1 or R_y^1.

II. Now consider firm 2. From (B.1) and substituting F:

$$p_2^* = \frac{-5_j - 10\boldsymbol{a} + 3F}{8}$$

Differentiating p_2^* with respect to b_2 yields:

$$\frac{\partial p_2^*}{\partial b_2} = \frac{3}{8}\left(\frac{8\boldsymbol{a}}{F}\right) > 0 \tag{B.5}$$

The demand for firm 2 in this region is:

$$\begin{aligned} D_2^1 &= 1 - D_1^1 \\ &= 1 - \left(\frac{(j + 2\boldsymbol{a} + F)^2}{64\boldsymbol{ab}}\right) \end{aligned}$$

Differentiating D_2^1 with respect to b_2 yields:

$$\frac{\partial D_2^1}{\partial b_2} = -\left(\frac{(j + 2\boldsymbol{a} + F)}{64\boldsymbol{a}b^2}\right)\left(\frac{16\boldsymbol{ab}}{F} - (j + 2\boldsymbol{a} + F)\right)$$

The first term of the derivative is positive. Therefore, for $\frac{\partial D_2^1}{\partial b_2} > 0$, it must be true that

$$j + 2\boldsymbol{a} + F > \frac{16\boldsymbol{ab}}{F}$$

Multiplying this equation by F and rearranging terms yields:

$$(j + 2\boldsymbol{a})(F + (j + 2\boldsymbol{a})) > 0$$

Since $(j + 2\boldsymbol{a}) = \boldsymbol{a}(2 - (a_1 + a_2))$ and F are both greater than zero, $\frac{\partial D_2^1}{\partial b_2} > 0$. Combining this with the fact that $\frac{\partial p_2^*}{\partial b_2} > 0$ ((B.5) above) ensures that $\frac{\partial \Pi^*}{\partial b_2} = 0$ cannot hold in the interior of R_x^1 or R_y^2.

III. Since there does not exist a best reply for either firm in R_x^1 or R_y^2, the proof of the lemma is complete.

Appendix C

Computer-Driven Questionnaire

COMBINE OWNER SURVEY

This survey is being conducted as part of Mark Vandenbosch's doctoral dissertation in marketing at the University of British Columbia and is being conducted under the supervision of Professor Charles B. Weinberg (tel. 604-224-8327). The purpose of the survey is to assess farmer's attitudes and preferences toward combine brands and product profiles. The information will be used to test a theoretical model which uses customer input to guide product improvement decisions. The survey is not being sponsored by a farm equipment manufacturer nor will any company have access to your responses.

The completion of the following 15 minute questionnaire is the extent of your involvement in the study. We are not asking for your name so as to assure the confidentiality of your responses. You may choose to withdraw from the study at any time. Your consent to participate is assumed if you complete the questionnaire.

(Press any key to continue)

1

Combine Owner Survey

Mark Vandenbosch
University of British Columbia

Press any key to continue.

2

Does your farm consist of:

1. Crops only
2. Livestock only
3. Both Crops and Livestock

Press the correct number.

3

How many acres of land did
you seed this past year (1990)?

1. 320 acres or less
2. 321 - 640 acres
3. 641 - 960 acres
4. 960 - 1280 acres
5. 1281 - 1600 acres
6. Over 1600 acres

Press the correct number.

4

How many acres of WHEAT did you
grow this past year (1990)?

1. Did not grow WHEAT
2. 1 - 320 acres
3. 321 - 640 acres
4. 641 - 960 acres
5. 960 - 1280 acres
6. Over 1280 acres

Press the correct number.

5

How many acres of BARLEY did you
grow this past year (1990)?

1. Did not grow BARLEY
2. 1 - 160 acres
3. 161 - 320 acres
4. 321 - 640 acres
5. 641 - 960 acres
6. 961 - 1280 acres
7. Over 1280 acres

Press the correct number.

6

How many acres of CANOLA did you
grow this past year (1990)?

1. Did not grow CANOLA
2. 1 - 100 acres
3. 101 - 200 acres
4. 201 - 300 acres
5. 301 - 400 acres
6. 401 - 500
7. Over 500 acres

Press the correct number.

7

How many acres of FLAX did you
grow this past year (1990)?

1. Did not grow FLAX
2. 1 - 100 acres
3. 101 - 200 acres
4. 201 - 300 acres
5. 301 - 400 acres
6. 401 - 500
7. Over 500 acres

Press the correct number.

9

Do you own a combine?

1. Yes
2. No

Press the correct number.

10

How many combines do you own?

1. 1 combine
2. 2 combines
3. 3 combines
4. 4 or more combines

Press the correct number.

11

What brand is Combine 1?

1. Allis Chalmers
2. Case-International
3. Gleaner (Duetz-Allis)
4. International Harvester
5. John Deere
6. Massey Ferguson
7. New Holland
8. White
9. Other

Press the correct number.

12

What brand is Combine 2?

1. Allis Chalmers
2. Case-International
3. Gleaner (Duetz-Allis)
4. International Harvester
5. John Deere
6. Massey Ferguson
7. New Holland
8. White
9. Other

Press the correct number.

13

What brand is Combine 3?

1. Allis Chalmers
2. Case-International
3. Gleaner (Duetz-Allis)
4. International Harvester
5. John Deere
6. Massey Ferguson
7. New Holland
8. White
9. Other

Press the correct number.

14

What brand is Combine 4?

1. Allis Chalmers
2. Case-International
3. Gleaner (Duetz-Allis)
4. International Harvester
5. John Deere
6. Massey Ferguson
7. New Holland
8. White
9. Other

Press the correct number.

15

What brand of combine do you own?

1. Allis Chalmers
2. Case-International
3. Gleaner (Duetz-Allis)
4. International Harvester
5. John Deere
6. Massey Ferguson
7. New Holland
8. White
9. Other

16

Imagine that you are considering the purchase of a new combine of a size which is suited to your farm operation.

You will be asked to evaluate manufacturers of new combines on a number of different features. Even though you may not be that familiar with the various manufacturers and combines, please answer the questions as best you can. I am only interested in your opinions.

Press any key to continue.

17

The combine manufacturers that you will be asked to evaluate are:

Case-International
Gleaner (Duetz-Allis)
John Deere
New Holland

The features that you will be using in the evaluation are:

Durability
Threshing Technology
Ease of Maintenance
Harvesting Capacity
Combine Warranty
Ease of Controlling Operation
Dealer Location
Parts Availability
Dealer-Farmer Relations

Press any key to continue.

30

Using the scale on the right,
how would you rate each of the
manufacturer's combines on ...

COMBINE WARRANTY

Case-International
Gleaner (Duetz-Allis)
John Deere
New Holland

Press a number, then press Enter

Poor --- 1
2
Fair --- 3
4
Good --- 5
6
Excellent --- 7

38

Using the scale on the right,
how would you rate each of the
combine manufacturers on ...

DEALER LOCATION?

Case-International
Gleaner (Duetz-Allis)
John Deere
New Holland

Press a number, then press Enter

Poor --- 1
2
Fair --- 3
4
Good --- 5
6
Excellent --- 7

```
26
          Using the scale on the right,
          how would you rate each of the
          manufacturer's combines on ...

              THRESHING TECHNOLOGY?                            Poor   --- 1
                                                                       |
                                                                      -+- 2
                                                                       |
                 Case-International      Press a               Fair   -+- 3
                                         number,                       |
              Gleaner (Duetz-Allis)      then                         -+- 4
                                         press                         |
                         John Deere      Enter                 Good   -+- 5
                                                                       |
                        New Holland                                   -+- 6
                                                                       |
                                                          Excellent   --- 7
```

```
46
          Using the scale on the right,
          how would you rate each of the
          combine manufacturers on ...

             DEALER-FARMER RELATIONS?                          Poor   --- 1
                                                                       |
                                                                      -+- 2
                                                                       |
                 Case-International      Press a               Fair   -+- 3
                                         number,                       |
              Gleaner (Duetz-Allis)      then                         -+- 4
                                         press                         |
                         John Deere      Enter                 Good   -+- 5
                                                                       |
                        New Holland                                   -+- 6
                                                                       |
                                                          Excellent   --- 7
```

```
34
        Using the scale on the right,
        how would you rate each of the
        manufacturer's combines on ...

         EASE OF CONTROLLING OPERATION                        Poor  --- 1
        (adjustment, monitors, visibility)?                          |
                                                                    -+- 2
                                                                     |
               Case-International      Press a                Fair  -+- 3
                                       number,                       |
            Gleaner (Duetz-Allis)      then                         -+- 4
                                       press                         |
                       John Deere      Enter                  Good  -+- 5
                                                                     |
                       New Holland                                  -+- 6
                                                                     |
                                                         Excellent  --- 7


18
        Using the scale on the right,
        how would you rate each of the
        manufacturer's combines on ...

                 DURABILITY?                                  Poor  --- 1
                                                                     |
                                                                    -+- 2
                                                                     |
               Case-International      Press a                Fair  -+- 3
                                       number,                       |
            Gleaner (Duetz-Allis)      then                         -+- 4
                                       press                         |
                       John Deere      Enter                  Good  -+- 5
                                                                     |
                       New Holland                                  -+- 6
                                                                     |
                                                         Excellent  --- 7
```

```
22
        Using the scale on the right,
        how would you rate each of the
        manufacturer's combines on ...

             EASE OF MAINTENANCE                          Poor  --- 1
              (SERVICEABILITY)?                                  |
                                                                -+- 2
                                                                 |
               Case-International      Press a            Fair  -+- 3
                                       number,                   |
            Gleaner (Duetz-Allis)      then                     -+- 4
                                       press                     |
                       John Deere      Enter              Good  -+- 5
                                                                 |
                      New Holland                               -+- 6
                                                                 |
                                                     Excellent  --- 7
```

```
42
        Using the scale on the right,
        how would you rate each of the
        combine manufacturers on ...

             PARTS AVAILABILITY?                          Poor  --- 1
                                                                 |
                                                                -+- 2
                                                                 |
               Case-International      Press a            Fair  -+- 3
                                       number,                   |
            Gleaner (Duetz-Allis)      then                     -+- 4
                                       press                     |
                       John Deere      Enter              Good  -+- 5
                                                                 |
                      New Holland                               -+- 6
                                                                 |
                                                     Excellent  --- 7
```

50

How FAMILIAR are you with each
of the manufacturers' combines
and dealers?

(Use the scale on the right)

		Not Familiar --- 1
		2
Case-International	Press a number, then press Enter	3
Gleaner (Duetz-Allis)		4
John Deere		5
New Holland		6
		Familiar --- 7

54

The next question asks you to rank your preference for the four manufacturers' combines while considering the relative prices of the combines.

Press any key to continue.

55

Imagine that each manufacturer was offering its combines at the relative price levels shown below.

Considering all of the features that are important to you, which of the following options do you MOST prefer?

(Press your preferred number.)

	Manufacturer		Price
1 >	CASE-INTERNATIONAL	at	Average
2 >	NEW HOLLAND	at	Average
3 >	JOHN DEERE	at	10% ABOVE Average
4 >	GLEANER (DUETZ-ALLIS)	at	5% below Average

59

This question is similar to the previous one except that now you are asked to rank your preference for 8 combines. Take a minute to review all of the manufacturer and price options.

Considering all of the features which are important to you, which of the following options do you MOST prefer?

(Press your preferred number)

	Manufacturer		Price
1 >	CASE-INTERNATIONAL	at	15% ABOVE Average
2 >	CASE-INTERNATIONAL	at	5% below Average
3 >	NEW HOLLAND	at	15% below Average
4 >	JOHN DEERE	at	5% ABOVE Average
5 >	GLEANER (DUETZ-ALLIS)	at	5% ABOVE Average
6 >	JOHN DEERE	at	5% below Average
7 >	GLEANER (DUETZ-ALLIS)	at	15% below Average
8 >	NEW HOLLAND	at	15% ABOVE Average

67

Next, you will be asked to rank your preference for 12 different combine descriptions. Each description consists of a Combine Quality Rating, a Dealer Service Rating and a Price Level. Two combine descriptions are shown below (Combines A or B). If these descriptions represented actual combines, which one would you MOST prefer?

(Press your preferred letter.)

	COMBINE QUALITY	DEALER SERVICE	RELATIVE PRICE
A >	Good	Excellent	5% below
B >	Excellent	Poor	5% ABOVE

68 Take a minute to review all 12 combine descriptions. Which of the combines do you MOST prefer? (Press your preferred letter.)

	Combine Quality	Dealer Service	Relative Price		Combine Quality	Dealer Service	Relative Price
A >	Good	Good	5% ABOVE	G >	Good	Poor	15% below
B >	Excellent	Good	15% ABOVE	H >	Excellent	Poor	5% below
C >	Good	Excellent	5% below	I >	Excellent	Fair	5% ABOVE
D >	Poor	Excellent	15% ABOVE	J >	Poor	Fair	5% below
E >	Fair	Poor	5% ABOVE	K >	Poor	Good	15% below
F >	Fair	Excellent	15% below	L >	Fair	Fair	15% ABOVE

80

Please evaluate your preference for
4 more combine descriptions.

Which of the following combines do you MOST prefer?

(Press your preferred letter.)

	------------FEATURES------------		
	Combine Quality	Dealer Service	Relative Price
A >	Excellent	Poor	5% below
B >	Poor	Excellent	15% ABOVE
C >	Good	Fair	5% ABOVE
D >	Fair	Good	15% below

84

This is the last section.

There are just a few questions about your farm operation.

Press any key to continue.

85

Do you have any

BEEF CATTLE

on your farm?

1. Yes
2. No

Press the correct number.

86

On Average, how many BEEF COWS
do you have on your farm?

1. No BEEF COWS
2. 1 - 50 cows
3. 51 - 100 cows
4. 101 - 200 cows
5. 201 - 300 cows
6. Over 300 cows

Press the correct number.

87

On Average, how many FEEDLOT CATTLE
do you have on your farm?

1. No FEEDLOT CATTLE
2. 1 - 250 head
3. 251 - 500 head
4. 501 - 1000 head
5. 1000 - 2500 head
6. 2501 - 5000 head
7. Over 5000 head

Press the correct number.

88

Do you have any

DAIRY COWS

on your farm?

1. Yes
2. No

Press the correct number.

89

On Average, how many DAIRY COWS
do you have on your farm?

1. 30 cows or less
2. 31 - 50 cows
3. 51 - 70 cows
4. 71 - 90 cows
5. Over 90 cows

Press the correct number.

90

Do you have any

SWINE

on your farm?

1. Yes
2. No

Press the correct number.

91

On Average, how many SOWS
do you have on your farm?

1. No SOWS
2. 1 - 25 sows
3. 26 - 75 sows
4. 76 - 125 sows
5. 126 - 200 sows
6. Over 200 sows

Press the correct number.

92

On Average, how many FEEDER HOGS
do you have on your farm?

1. No FEEDER HOGS
2. 1 - 150 hogs
3. 151 - 300 hogs
4. 301 - 450 hogs
5. 451 - 600 hogs
6. 601 - 750 hogs
7. Over 750 hogs

Press the correct number.

93

Do you have any

POULTRY

on your farm?

1. Yes
2. No

Press the correct number.

94

On Average, how many LAYERS
do you have on your farm?

1. No LAYERS
2. 1 - 5000 birds
3. 5001 - 10000 birds
4. 10001 - 15000 birds
5. 15001 - 30000 birds
6. Over 30000 birds

Press the correct number.

95

On Average, how many BROILERS
do you have on your farm?

1. No BROILERS
2. 1 - 5000 birds
3. 5001 - 10000 birds
4. 10001 - 15000 birds
5. 15001 - 30000 birds
6. Over 30000 birds

Press the correct number.

96

How many years have you been farming?

1. 5 years or less
2. 6 - 10 years
3. 11 - 20 years
4. 21 - 30 years
5. 31 - 40 years
6. Over 40 years

Press the correct number.

97

In what province or state is
your farm located?

1. Manitoba
2. Saskatchewan
3. Alberta
4. Montana
5. North Dakota
6. South Dakota
7. Minnesota
8. Elsewhere in Canada
9. Elsewhere in the U.S.A.

Press the correct number.

98

Please type the name of the town
which is the closest to your farm?

Type the town name,
then Press Enter.

99

Thank you very much for
your cooperation.

Your input into this student
research project is very much
appreciated.

Appendix D

Secondary Questionnaire

Trade Show Visitor Information

1. Does your farm consist of:

   Crops only..1
   Livestock only.................................2 (Skip to Q.4)
   Both Crops and Livestock...........3

2. How many acres did you seed this past year?

   320 acres or less 1
   321 - 640 acres.............................2
   641 - 960 acres.............................3
   961 - 1280 acres 4
   1281 - 1600 acres.........................5
   Over 1600 acres.............................6

3. How many acres of the following crops did you grow this past year?

	Acres	or	Quarter Sections
Wheat........................	_____		______
Barley........................	_____		______
Canola........................	_____		______
Flax............................	_____		______

(If you have only crops on your farm, skip to Question 5.)

4. How many of the following types of livestock do you currently have on you farm?

	Number		Number
Beef:		**Swine:**	
Cows..................	_______	Sows..................	_______
Feedlot Cattle	______	Feeder Hogs.....	_______
Dairy:		**Poultry:**	
Cows..................	_______	Layers................	_______
		Broilers............	_______

5. How many years have you been farming?

5 years or less	1
6 - 10 years	2
11 - 20 years	3
21 - 30 years	4
31 - 40 years	5
Over 40 years	6

6. What is the name of the town which is closest to your farm?

Town: ____________________

Province/State: ____________________

7. Do you own a combine?

Yes..........1
No............2 (Skip to end)

8. Please read the following list of combine features. In your opinion, which features represent Combine Quality and which features represent Dealer Service?

FEATURES	Combine Quality	Dealer Service
Ease of Maintenance	1	2
Dealer-Farmer Relations	1	2
Ease of Controlling Operation	1	2
Combine Warranty	1	2
Parts Availability	1	2
Durability	1	2
Dealer Location	1	2
Threshing Technology	1	2

Thank you very much for your cooperation.