PRODUCT VARIETY: AN INVESTIGATION INTO ITS REVENUE, COST, AND PROFIT

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ABSTRACT

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This research investigates how consumer's perceptions about product variety influence product line performance. The research employs a computer simulation based on an appliance manufacturer's supply chain to extend consumer behavior research. The simulation models the demand increase, demand variance, and cannibalization associated with preference attributes and quality attributes. Product line performance is analyzed in terms of revenue, cost, profit, service-level and market share.

Results from the simulation experiments indicate that preference attributes and quality attributes perform different strategic functions. Preference attributes, features related solely to consumer's tastes, increase revenue and market share, but do not increase profit. Quality attributes that create a perceived product line hierarchy increase revenue, costs, profits, and market share. Quality attributes that fail to create a perceived hierarchy reduce revenue, costs, profits, and market share.

Managerial implications and strategies for each type of attribute are provided. Limitations and suggestions for future research are discussed.

This work is dedicated to **Mary Elizabeth Webb**, my very best friend.

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CHAPTER I: INTRODUCTION

1.0 Introduction

This research investigates how product variety affects firm profitability. The research expands current theory regarding product variety into a more comprehensive theory. The study then conducts critical tests to examine this theory.

This first chapter motivates the study of product variety and progresses as follows. First, it provides necessary background information to inspire the need for product variety research. Second, it defines the study's objectives. Finally, it describes the study's potential contributions and the dissertation's organization.

1.1 Background

Product variety creates both problems and opportunities for firms (Frizelle and Woodcock 1995; Vachon and Klassen 2002; Perona and Miragliotti 2004; Blecker, Kersten, and Meyer 2005). Customers prefer broad product lines and therefore marketing managers are rewarded with greater revenue when they increase product variety. However, this increased product variety may also increase costs and reduce profits (Deloitte, Touche and Tohmatsu 2003). Supply chain managers, on the other hand, prefer decreased product variety to increase efficiency. However, this increased efficiency may also reduce revenues and again reduce profits. Unfortunately, firms face this product variety conflict between supply chain managers and marketers with limited predictive ability.

1.1.1 Product variety defined

In order to understand product variety decision-making, it is first necessary to define the phenomena (Wacker 2004). This thesis identifies two elements concerning product variety:

product line breadth and attribute value. Product variegation and differentiation are the desired outcomes that managers expect from these product variety decisions (Lancaster 1990). To set the stage for future discussion, the research defines each term as follows:

- **Product line breadth** refers to the stock-keeping units (SKUs) within a brand category (Gourville and Soman 2005). For instance, a product packaged in two sizes has greater breadth than a product packaged in a single size.
- **Product attribute value** refers to the perceived worth of an individual feature of a product. For instance, Closs, Jacobs, Swink and Webb (2008) found that an automobile manufacturer differentiated only car features that customers felt strongly added to the appeal of the car. Therefore, the car company added only positive attribute value to the car model.
- **Variegation** refers to an attribute distinguishing one product from another within a product line (Ramdas 2003). For example, a liquid detergent manufacturer that has a lemon scented and a plain scented soap distinguishes between products within its product line by fragrance.
- **Differentiation** relates to how a product separates itself from market competitors (Ramdas 2003). For instance, the iPod's simplicity in downloading songs differentiates it from competitors' personal digital recording devices.

1.1.2 The great operating divide

Now that product variety is understood, the logical starting point for understanding the product variety conflict is internal integration. Internal integration is a firm's ability to act as a single unified entity (Jespersen and Skjott-Larsen 2006: page 28) pursuing common goals

(Bowersox, Closs, and Cooper 2007). This cohesive effort gives firms a strategic advantage over less coordinated firms by creating synergy in place of competition.

However, research suggests that internal integration is very difficult to achieve. Within a firm, the differing objectives, conflicting incentives, and hard-to-obtain information drive conflicting behaviors (Narayanan and Raman 2004). As a result, the firm often acts as an uncoordinated organization pursuing divergent goals. Bowersox, Closs, and Stank (2000) call this lack of internal integration the "great operating divide." In this divide, upstream focused managers must fight the downstream focused managers for resources, information, and rewards. Furthermore, managers interviewed by Fawcett and Magnan (2002) report that the divide's intensity creates personal conflict between managers. This in turn creates a vicious cycle of increasing competition. The real problem is that each business function understands their responsibilities very well, but they do not understand the total value of coordination (Fawcett and Magnan 2002). The end result is that managers don't want to feel like their side "lost the battle."

1.1.3 The supply chain manager's perspective

The supply chain manager has a unique perspective in this battle. The firm's operationally focused functions seek efficiency and cost savings. These functions strive to maintain a swift even flow of information and inventory (Schmenner and Swink 1998). They accomplish this swift even flow by establishing consistent and predictable demand and supply patterns (Whipple and Frankel 2004).

As a result of their frame of reference, supply chain managers recognize that product variety negatively impacts operations. For example, the Bain Group recently reported that 70 percent of 900 global executives reported that excessive variety increased cost and reduced profit (Gottfredson and Aspinall 2005). Press articles have declared that companies such as Motorola

and Boeing Aircraft (Handfield 2004a; Handfield 2004b; UGS 2004) have introduced complexity reduction initiatives to combat variety's negative effects. In addition, Closs, Jacobs, Swink and Webb (2008) describe tactics that six firms use to overcome strategic, variety related problems. Supply chain managers generally recognize product variety as a problem.

1.1.3.1 Variety creates inefficiency

Managers recognize that product variety is not just a general problem; it also causes specific negative results. Product variety creates inefficient supply chains (Hoole 2005, George and Wilson 2004). Hoole (2005) demonstrates that firms with greater variety performed less efficiently than peers. George and Wilson (2004) suggest that high variability reduces the value added time that products spend in supply chain processes. Additionally, Vachon and Klassen (2002) argue that firms with more complex product portfolios exhibit less certain and less efficient delivery. The result is that product variety reduces economies of scale and reduces supply chain efficiency.

1.1.3.2 Variety reduces flexibility

Reduced flexibility is a second specific effect that supply chain managers recognize with increased product variety. Hoole (2005) suggests that the reduced reliability accompanying product variety results in less strategic flexibility. For example, a firm with more variety doesn't reliably know when its manufacturing processes may conclude (Sivadasan, Efstathiou, Calinescu, and Huaccho 2004). This situation constrains a firm's ability to quickly change its production schedules or adjust lot sizes (Slack 1997). A greater product variety creates a less flexible supply chain.

1.1.3.3 Variety increases performance variability

The most critical variety related problem, however, is performance variability. Frizelle and Woodcock (1995) conclude that more complex products have highly variable schedule outcomes. Vachon and Klassen (2002) specifically demonstrate that product variety negatively affects delivery reliability. Additionally, when researchers needed to find a proxy measure for the complexity caused by product variety, they uniformly chose schedule variability measures (Calinescu, Efstathiou, Schim, and Bermejo 1998; McCarthy, Rakotobe-Joel, and Frizelle 2000; Sivadasan, Efstathiou, Frizelle, Shirazi, and Calinescu 2002; Sivadasan, Efstathiou, Calinescu, and Huatuco 2006; Wu, Frizelle, and Efstathou 2007). All of these negative consequences suggest that companies would avoid product variety.

1.1.4 The marketer's perspective

Paradoxically, firms frequently and purposefully increase variety. Diverse customers and their need for innovative attributes create a rugged competitive landscape that demands varied products. Marketing managers, therefore, demand SKU proliferation, and endless product features. The result is marketers are forced to increase product variety to meet the needs of the marketplace.

1.1.4.1 Variety satisfies customers

From a marketer's perspective, firms offer product variety to meet customers' needs. Marketers assume that a product's attributes determine the probability of a customer buying their product (Hoch, Bradlow, and Wansink 1999). Marketers implement a SKU expansion strategy to increase revenues because it allows customers to match their unique preferences to specific product attributes (Lancaster 1990, Rosen 1974). Additionally, marketing managers recognize that they must match or surpass competitors' differentiated products in order to stay competitive.

A marketer without product variety rivaling their competitor's product variety loses sales. Customers also frequently vary same product category purchases to satisfy variety-seeking needs (Kahn 1995). When a firm's product variety strategy succeeds, each customer finds exactly the attributes they desire within a firm's product assortment (Kahn 1998). Consequently, a high variety strategy creates higher revenues, greater market share and greater customer satisfaction.

1.1.4.2 SKU proliferation strategy

The drive to match product attributes with personal preferences has created SKU proliferation (Hoole 2005). For instance, AT Kearney reports more than 500 shampoo varieties at Wal-Mart, 85 different 30-inch televisions at Circuit City, 80 pen varieties at Office Depot and 15 same-brand toothpaste versions at the local drugstore (Byrne 2007). SKU proliferation allows marketers to capture greater demand by appealing to diverse customer desires (Thompson, Hamilton, and Rust 2005). SKU proliferation also creates a strategic advantage by increasing retail shelf space and increasing a customer's exposure to the brand (Chiang and Wilcox 1997). As a result, marketers seek SKU proliferation to satisfy more customers, increase market share, and generate greater demand.

1.1.4.3 Competition creates variety

Marketers must also vary products due to today's intense competition. Tang and Yam (1996) suggest a correlation between the level of market competition and the level of product variety. Marketers engaging in highly competitive industries must either differentiate their products from competitors or lose market share. For instance, Brynjolfsson, Hu and Smith (2003) demonstrate that the highly competitive nature of e-business shifted on-line book sales from cost differentiation strategies to product variety strategies. In order to compete in highly competitive markets, firms must have significant product variety.

1.1.4.4 Customer "variety seeking" drives product variety

Finally, marketers find that customers frequently alter purchases for same category items simply to fill a need for variety (Gourville and Soman 2005). As a result, a candy firm offering 20 different chocolates better meets the needs of the candy customer than a firm with 3 chocolates (Kahn 1995). Firms that invest in greater product variety are better able to accommodate variety-seeking behavior. Consequently, marketers can increase demand through product variety.

1.1.5 Product variety complicates demand

It seems apparent that product variety increases demand while simultaneously increasing costs. However, recent research suggests that product variety does not always increase demand (Rust, Thompson, and Hamilton 2006). Some industry specific examples show that firms may add unnecessary product variety that reduces demand (Jacobs 2008; Boatwright and Nunes 2001; Quelch and Kenny 1994). For instance, Boatwright and Nunes (2001) found that when an online grocer rationalized its low producing SKUs, total demand increased 11 percent. Additionally, Jacobs (2008) found that a computer server's total demand dropped when a certain number of features were added. Gourville and Soman (2005) offer an explanation for this reduced demand. They suggest that customers are averse to exerting too much cognitive effort and dislike high potential for buyers regret. As a result, customers confronted with two brands frequently simplify their choice by selecting from a brand with a limited product line.

This suggests that product variety has an ideal level specific to products and industries. If a firm goes past this point, they either reduce their total demand (Gourville and Soman 2005) or they increase costs beyond a profitable level (Closs, Jacobs, Swink, and Webb 2008).

Therefore, supply chain managers and marketers must find this ideal level in order to balance revenues with costs.

1.1.6 Performance

This research project focuses on profitability as its main performance measure. Profitability is used because it acts as the final arbitrator between variety generated costs and revenues. Another measure used to judge variety's effect on costs and revenues is the relative length of the product portfolio that is profitable. Lancaster (1990) suggests that a product line should cease adding variants when the variable costs equal the variable revenues of the product. When the product line is broad, this suggests greater market share as more customers find exactly the product they desire. When the product line is lean, this suggests greater cost efficiency. A final measure used to judge variety's on performance is market share. Even when products are not profitable, firms might increase product variety strategies to protect or win market share.

1.2 Research objectives and questions

This research seeks to contribute to product variety decision-making in three ways. First, the research attempts to discover some general decision rules about the profitable length of SKU breadth in the product variety decision. Those managing variety from the demand side and those managing variety from the supply side can then have some coordinating guidance (Hoch, Bradlow, and Wansink 1999). Second, managers need prescriptive advice regarding product variety. The variety literature inadequately explains and predicts product variety's costs and value. Therefore, managers do not have research elucidating the trade-offs between servicing fickle customers and bearing the associated supply chain costs. Understanding the cost and revenue trade-offs created by product variety can assist supply chain and marketing managers in

pursuing common goals. Finally, this research evaluates the effect that product variety strategies create. Specifically, the research seeks to understand how increased variability and cannibalization caused by an attribute's value influences performance. Additionally, the research seeks to understand how demand changes caused by product variety influence performance. In both of these situations, the emphasis of the research is how these variables influence a firm's ability to create profitability within product variety.

1.2.1 Research objectives

The research has three objectives. Each objective is motivated by the need to understand the cost and revenue trade-off inherent to product variety. The objectives are:

1. To develop decision making rules regarding product variety ideal points.
2. To identify product variety cost and revenue trade-offs to align decision making between marketing and operations managers.
3. To examine the relationships between the effects of product variety and performance.

1.2.2 Research questions

The objectives lead to five research questions:

1. How does SKU breadth influence demand and consequently performance?
2. How does SKU breadth influence demand variance and consequently performance?
3. How does attribute value influence demand and consequently performance?
4. How does attribute value influence demand variance and consequently performance?
5. How does the interaction of attribute value and SKU breadth influence performance?

1.3 Research methods

Simulation is selected for this research because the questions asked concern how changes affect an extended, interdependent system. Simulation is a powerful experimental tool that can

analyze systems that are difficult to experiment upon in the real world (Law and Kelton 2000). Simulation is ideal in this situation because it allows experimentation by altering key decision variables and investigating the system's reactions to these changes (Nair and Closs 2006). Simulation allows the research to create relationships between SKU breadth and demand, and attribute value in order to experiment with this complex situation. Finally, simulation accommodates research attempting to extend current theory (Davis, Eisenhardt, and Bingham 2007), as is the case with this research.

1.4 Research overview

Chapter One describes the research motivation, objectives, and methodology rationale. Chapter Two synthesizes the product variety literature, identifies gaps in the literature, and develops an experimental framework. Chapter Three discusses the research design, methods, and experimental design. Chapter Four discusses the results of the experiments. Chapter Five provides conclusions of the research and synthesizes the results.

CHAPTER II: LITERATURE REVIEW

2.0 Introduction

This chapter develops the theoretical foundation for the research. First, the chapter reviews theories relating to product variety. Second, the research examines the literature that developed product variety constructs and identifies key research gaps. Third, the research gaps are developed into an experimental framework. Finally, the chapter develops the hypotheses generated by extending existing theory.

2.1 Theoretical foundation

Two paradigms provide rationale regarding why attribute value influences the supply chain. First, Prospect Theory (Kahneman and Tversky 1991) provides evidence that customers prefer structured choices. Organizing product features within a product line to make customer choice more intuitive increases demand and lowers demand variance. Second, the total cost paradigm suggests that product variety decisions should be made with the total network costs in mind. Understanding the effects of these two divergent theories may help marketers and supply chain managers make better product variety decisions.

2.1.1 Prospect theory

The attribute theory of customer choice is based on prospect theory (Kahneman and Tversky 1991). Prospect theory suggests that personal choices are not as simple as people evaluating several alternatives and then selecting the utility maximizing item. Rather, prospect theory illustrates that it is the framing of alternatives that largely determines choice. Schwartz (2004) uses differently worded descriptions for the same vital medical dilemma to highlight this framing effect. The first framed decision follows.

"Imagine that you are a physician working in an Asian village, and six hundred people have come down with a life threatening disease. Two possible treatments exist. If you choose treatment A, you will save exactly two hundred people. If you choose treatment B, there is a one-third chance that you will save all six hundred people, and a two-third chance that you will save no one. Which treatment do you choose, A or B?"

When framed in this manner, the majority of respondents chose treatment A. Schwartz (2004) suggests that this is because they prefer saving a definite number of lives rather than risk saving none. When the scenario was worded as written below, however, the responses change.

"You are a physician working in an Asian village, and six hundred people have come down with a life threatening disease. Two possible treatments exist. If you choose treatment C, exactly four hundred people will die. If you choose treatment D, there is a one-third chance that no one will die, and a two-third chance that everyone will die. Which treatment do you choose C or D?"

Schwartz (2004) finds that in this situation the overwhelming majority of respondents choose treatment D, even though the risks in the two situations are identical. They would rather risk losing everyone than lose four hundred with certainty. Prospect theory suggests that when making choices between alternatives that involve risk or uncertainty, people prefer a small, sure gain to a larger uncertain gain. When alternatives are framed in a manner that allows people to easily judge the risks, choices become more predictable (Kahneman and Tversky 1991).

The attribute theory of customer choice suggests that the framing of product choices influences customer choices. If the attributes that create product variety are presented in a specific way, the customer perceives greater certainty in her decisions. Therefore demand might increase, as customers are surer they have found the product that meets their needs. In addition,

demand variance may decrease as customers purchase specific products with greater predictability. Therefore, prospect theory suggests that the way in which attributes are presented to customers influences both the demand and demand variance of the supply chain.

2.1.2 Total cost paradigm

As demand and demand variance are influenced, supply chain costs are also influenced (Nyaga, et al. 2007). The most frequently used paradigm to understand supply chain costs is the total cost paradigm. In fact, the total cost model has been used in supply chain management research since 1956 (Bowersox, Closs, and Cooper 2007: page 25). The total cost paradigm suggests that managing entire system costs rather than individual functional costs, creates the lowest total cost alternative (Forrester 1959; Lee, Padmanabhan, and Whang 1997; Bowersox, Closs, and Cooper 2007: page 25). In the product variety literature, the total cost paradigm can be used to extend Lancaster's (1990) premise that increased costs decrease the number of profitable product variants.

Two primary supply chain costs considered in this research are volume related costs and market mediation costs (Randall and Ulrich 2001). First, volume related costs are those costs that increase as economies of scale decrease. Specifically, manufacturers often receive scale discounts when material quantities exceed a certain amount (Fisher and Ittner 1999). As material variety is increased, economies of scale are decreased. Additionally, increasing product variety creates higher distribution costs (Ramdas 2003). Transportation economics demonstrates that the per-unit cost of transportation decreases as load size increases (Bowersox, Closs, and Cooper 2007: page 168). Therefore, as product variety increases, the volume related costs from material discounts and distribution costs are expected to increase. Second, market mediation costs are

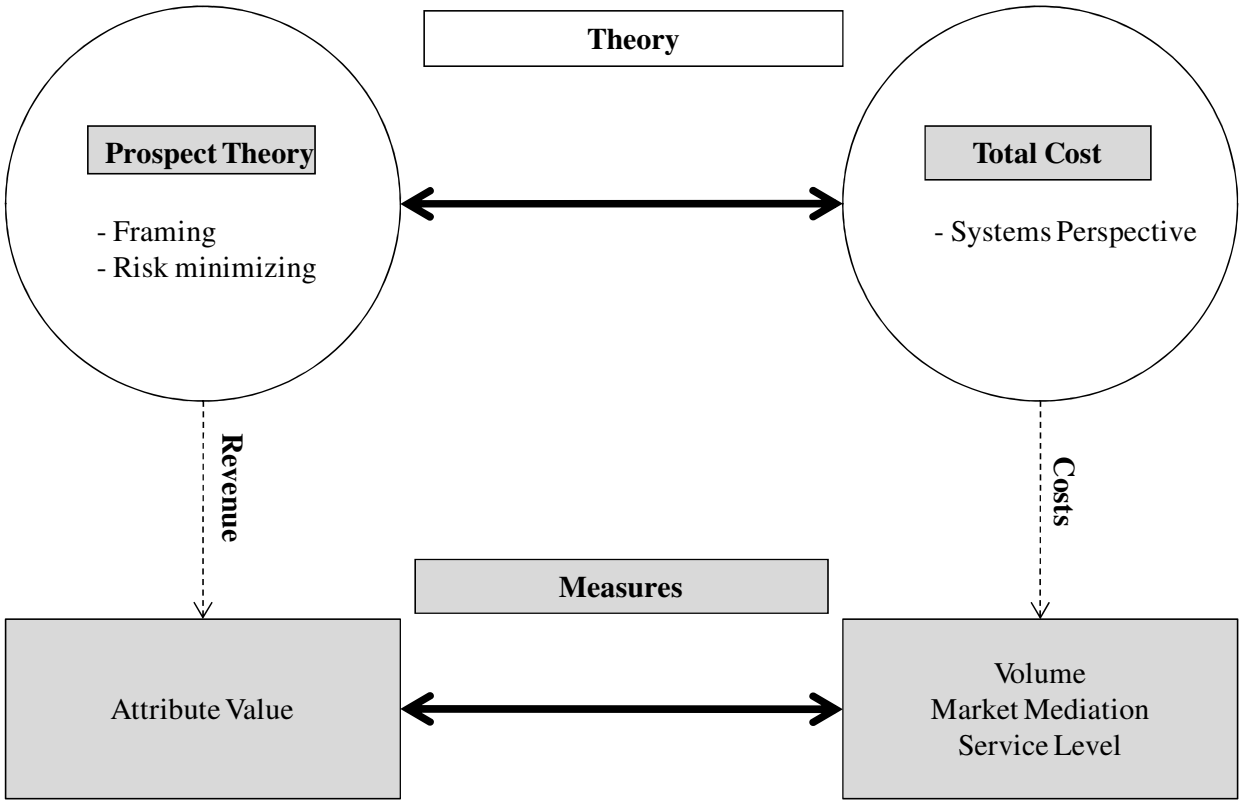
those costs that increase as demand becomes more unpredictable. In response to increased demand variability, firms expect increased inventory costs and increased stock-outs (Randall and Ulrich 2001). Increased inventory costs result because firms hold extra inventory to buffer against stock-outs when demand is uncertain. As a result, inventory-carrying costs increase as demand variance increases. Sometimes in reaction to the uncertainty, firms choose to carry fewer inventories to reduce costs. In this case, demand outpaces supply and firms stock-out.

In dealing with product variety, total costs must be understood within the context of revenue. In other words, it may be worthwhile to raise total costs if revenues rise as well. This integration of revenues and costs reflect profit as firms' ultimate goal.

2.1.3 Prospect theory and the total cost paradigm

In summary, prospect theory and the total cost paradigm are related through demand and demand variance. As choices are framed in logical ways that minimize perceived risk, customer buying becomes more certain. As a result, both demand and demand variance are influenced. Changes in demand drive volume related costs while changes in demand uncertainty drive market mediation costs. When these costs are understood in terms of their relationship to revenue, decision rules for the most profitable product variety can be derived. Therefore, understanding customer choice and its effect on total costs and revenues drives product variety profitability. Figure 2-1 demonstrates the relationships between prospect theory, total cost, demand and demand variance. Furthermore, Figure 2-1 demonstrates how the literature review ties constructs of product variety to their respective theories.

Figure 2-1, Theory and Constructs



2.2 Overview of the literature

A key to creating the most profitable product variety is to understand the effects that SKU breadth and attribute value ultimately have on profit. The first portion of this section defines SKU breadth and discusses how breadth of the product line influences customer behavior. The literature review then discusses how customer behavior leads to changes in demand and demand variance. It then explores how the resulting change in demand and demand variance influence revenues and costs. Finally, the profit impact resulting from cost and revenue trade-offs is hypothesized. The second portion of this section defines three levels of attribute value. It then discusses how each level affects customer behavior. Once again, the review

focuses on the relationships between each attribute value level, demand and demand variance. In addition, the review suggests how demand and demand variance influence costs and revenues.

2.3 SKU breadth

The first product variety decision that firms encounter is product line breadth. Increasing SKU breadth by adding features appeals to a greater number of customers (Kahn 1998). Extensive product line breadth ensures that each customer finds exactly the product features that she wants. Additionally, customers may have an inherent desire to try different alternatives, and more SKUs offer them valuable options (Kahn 1998). Therefore, it is a generally accepted theory that offering more products allows firms to increase market share (Kekre and Srinivasan 1990; Desai 2001). However, research also recognizes that increasing the number of products may reduce economies of scale and increase supply chain costs (Lancaster 1990; Quelch and Kenny 1994; Fisher and Ittner 1999; Randall and Ulrich 2002). The manager is then faced with competing objectives. If the product line is too broad, costs may outweigh potential revenues. If a product line is too lean, the firm passes up potential revenue that they may have captured. The goal for firms is to find the product variety that creates the greatest profitability (Lancaster 1990).

2.3.1 SKU breadth and demand

Marketing literature supports the premise that broader product lines create greater revenue. Kekre and Srinivasan (1990) investigated the positive and negative effects of the product line on the firm's performance. Using data from the Profit Impact of Marketing Strategies database, they discovered the impact of a broader product line on market share. They found that a broader product line in industrial markets increases market share by 3.5 points. In customer markets, a broader product line increases market share by 6.3 points. Overall, Kekre

and Srinivasan (1990) suggest that a broader product line increases return on investment by 4 percent in industrial markets and 10 percent in customer markets. Therefore, increasing SKU breadth increases revenue and demand.

Kahn (1998) suggests why a broad SKU portfolio increases demand. First she suggests that customers have heterogeneous preferences. Creating a broad product line meets the individual preferences of a greater number of heterogeneous customers. This increases market share and precludes competitors from entering the firm's existing niche. Second, customers have a variety seeking need. This tendency of individuals to seek diversity in their choices over time (Khan, Kalwani, and Morrison 1986) is more frequently satisfied when a firm has a broader product line. As a result, the firm's demand is increased as variety-seeking customers meet their needs.

To add further insight to the importance of SKU breadth, Brynjolfsson, Hu, and Smith (2003) found that successful on-line retailers thrive because of product variety. They found that Amazon's increase in the variety of books for sale also increased Amazon's revenue by between $731 million and $1.03 billion in the year 2000. Additionally, Ghose, Smith, and Telang (2001) suggest that by adding used books to new book product lines, on-line booksellers increase new book sales. Thus, a more varied product line at on-line retailers rewards this channel with greater revenue. From this literature we learn that customers reward broad product lines with increased demand.

2.3.2 SKU breadth and demand variance

Adding SKU breadth to the product line not only adds demand but also increases demand variance. In fact, Fisher, Hammond, Obermeyer, and Raman (1997) blame product variety and its resulting demand variance for a three-fold increase in store markdowns between 1972 and

1990. There are two main reasons for the increase in demand variance. First, as SKU breadth increases, products within the product line become more alike and substitution becomes more likely. As a result, expanding SKU breadth may cause the firm to cannibalize its own product line (Srinivasan, Ramakrishnan, and Grasman 2005; Mason and Milne 1994). The second reason that SKU breadth increases demand variability is that it increases the number of products managed by a firm. This fragments total demand, which increases demand variance for each variant (VanRyzin and Mahajan 1999). The result is that increasing SKU breadth increases demand variance.

2.3.2.1 Cannibalization

The phenomenon of cannibalization is not well developed in the literature but appears to be a major cause of reduced profit (Hui 2004; Desai 2001; Mason and Milne 1994; Moorthy and Png 1992). The literature suggests two types of cannibalization. The first is niche encroachment, which represents a product with attributes that appeal to more than one market segment. This creates the opportunity for a product from one market segment to encroach on the niche of a second market segment. The second type of cannibalization is substitutability. This occurs when the firm creates multiple products, which have such similar features that customers don't perceive any differences between the products.

Mason and Milne (1994) researched cannibalization within cigarette product lines. Attributes such as hard packs or soft packs, filtered or unfiltered, regular or menthol, regular or light, were evaluated as attributes defining line variants within the same brand. Customers fell within a specific niche when they were similar to each other in their attribute preferences as evidenced through their purchases over time. Mason and Milne (1994) found that 11 to 76 percent of new product sales were taken from another product within the firm's product line.

They also found that as the number of product variants increased so did this percentage of cannibalization. This suggests that as the product line becomes broader, the probability that some attributes will encroach on the boundaries of their neighboring niche increases (Desai 2001).

The second cause of cannibalization is that the product line does not differentiate. In other words, the products within the product line have attributes with differences so slight that customers treat them as a single product. Therefore when customers do a price quality trade-off analysis, the customers will most likely choose a less costly version (Moorthy 1984; Desai 2001). Volkswagen provides a good example of this type of cannibalization. In the 1990s, Volkswagen reportedly saved 1.5 billion dollars due to increasing the common attributes among their four brands: Volkswagen, Audi, Skoda, and Seat (Wilhelm 1997; Bremmer 1999). However, too much commonality caused cannibalization as customers had difficultly discerning differences between the Audi luxury brand and the lower-end Volkswagen brand. This dramatically hurt profitability as people were buying lower-end models instead of higher-end, more profitable models (Miller 1999).

In both cases of cannibalization, demand cannot be as accurately forecasted when a product cannibalizes demand in the product line (Mason and Milne 1994; Srinivasan, Ramikrishnan, and Grasman 2001). When customer differentiation and product variegation are slight, market segments are not well defined. This lack of definition leads to greater variability. Therefore, cannibalization causes demand variance.

2.3.2.2 Disaggregating demand

In addition to cannibalization, disaggregating demand also creates demand variance. When a single product is produced in a product line, demand variance is easily understood.

However, a firm offering two variants carries more finished goods inventory than when a single product is produced. This is mostly due to the increased uncertainty surrounding the demand forecast (Eppen 1979). The result is that as product breadth grows, demand becomes more uncertain.

2.3.3 SKU breadth and volume costs

The literature thus far has demonstrated that increasing SKU breadth increases both demand and demand variability. This section reviews the cost implications as demand and demand variance increase. Supply chain research confirms that product variety increases supply chain costs (Fisher and Ittner 1999). In fact, Quelch and Kenny (1994) found that increasing SKU breadth increases cost by a minimum of 25 and a maximum of 45 percent more than the theoretical cost of producing only the most popular item in that product line. The literature recognizes two main cost types associated with variety: volume related cost and market mediation cost.

Volume related costs increase due to loss of scale economies (Randall and Ulrich 2001). For instance, product variety increases production costs by reducing quantity discounts in purchasing (Randall and Ulrich 2001; Fisher, Hammond, Obermeyer, and Raman 1997). Increasing product variety also reduces economies of scale in distribution as loads become smaller and transport economies are lost. Therefore, increasing product variety increases volume related supply chain cost.

2.3.4 SKU breadth and market mediation costs

Market mediation costs tend to dominate SKU breadth costs (Quelch and Kenny 1994). For example, Olavson and Fry (2006) demonstrate that low volume personal computer (PC) sales at Hewlett-Packard have ten-times-greater-per-unit cost of variability than a high volume PC.

Therefore, adding SKUs beyond the most popular products creates higher market mediation costs. The cost of variability occurs because too much inventory increases inventory-carrying costs, while too little inventory incurs stock-outs.

Since increased SKU breadth adds diversity in the product line, it also increases market segment diversity. Attracting diverse market segments increases market mediation cost. Randall and Ulrich (2001) evaluated the product variety in the over $200 bicycle market. Their research demonstrates that firms producing bicycles overseas tended to make less differentiated bicycles than firms that produced domestically. They also demonstrate that the median performance cycle time for Asian located manufacturers was 90 days while U.S. located manufacturers was 34.5 days. The research concludes that firms locate closer to their target markets when demand variety is high (Thoneman and Bradley 2002). The local firms become more agile by locating closer to the customer (Randall and Ulrich 2001). However, these domestic firms are much more expensive than overseas producers. This in turn means that the firm with higher product variety must create a supply chain with higher cost. The conclusion from the literature is that adding variety increases market mediation costs.

2.3.5 SKU breadth and production costs

Suarez, Cusamano, and Fine (1991) suggest that the degree to which product variety influences direct costs is a function of a firm's flexibility. For example, Kekre and Srinivasan (1990) found that increasing SKU breadth added *no significant production cost* in Fortune 500 firms. MacDuffie, Sethuraman, and Fisher (1996) reported that automobile firms that increased car options significantly *improved* productivity. This is because manufacturers in innovative industries more frequently invest in flexible supply chain structures and systems that minimize product variety costs (Netessine and Taylor 2007, Randall and Ulrich 2001). Therefore,

production cost due to variety is generally realized in fixed costs (Netessine and Taylor 2007; Ramdas 2003; VanRyzin and Mahajan 1999; Fisher and Ittner 1999). For this reason, these costs are not considered in this research.

2.3.6 SKU breadth and profit

The literature suggests that when marginal costs equal marginal revenues, both the customer and the firm benefit from SKU breadth. This represents the point where the firm can maximize profits through offering an extensive product line, but not offer so many products that the firm loses money on its product line (Lancaster 1990). Unfortunately, increased cost is very difficult to identify when increasing SKUs. As demand is added so are volume related costs and market mediation costs. Due to the difficulty in capturing costs, the literature has failed to capture variety related supply chain costs beyond production costs (Ramdas 2003). Therefore, this research addresses this gap by investigating variety's total supply chain costs. Additionally, the literature does not address how adding demand variance increases costs, revenues and profits. This research addresses this gap as well. In addressing both of these gaps, this research uncovers the effects of SKU breadth on profitability.

2.4 Attribute value

The relationships between product line breadth, revenue, cost and profit are not as straightforward as it may seem from the previous sections. Prospect theory suggests that breadth of choice is only a single factor of a multi-factored, customer behavior (Gourville and Soman 2005). While the number of SKUs may represent variety to the firm, customer perceptions of variety differ (Boatwright and Nunes 2001; Markham and Medin 1995). The attribute-based choice model frequently used in consumer behavior research describes how consumers perceive variety (Lancaster 1990; Markham and Medin 1995; Kahn 1998; Chernev 2003). Attributes in

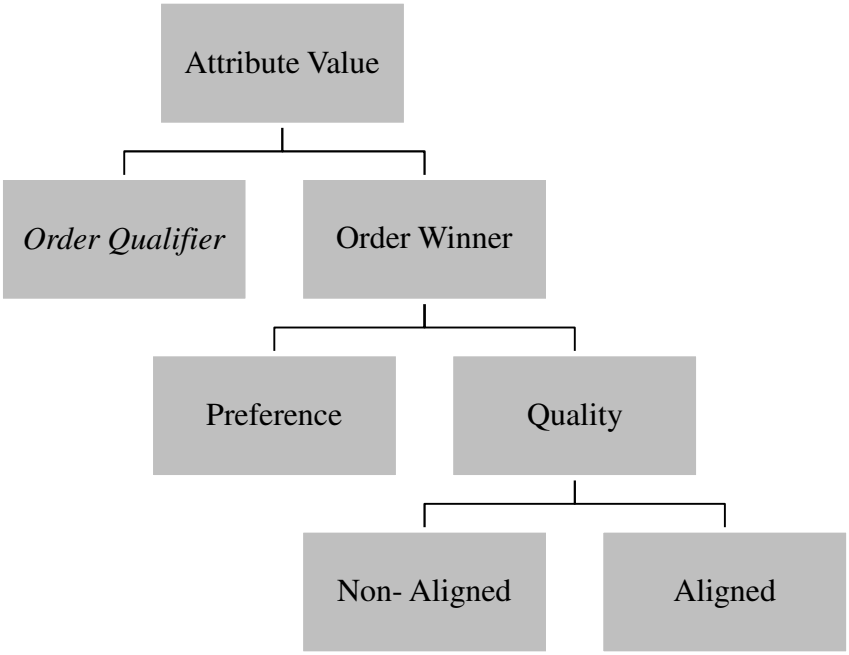
this model are seen as those features that variegate one product from another. Consumer product variety increases by increasing the attribute value from one product to another (Randall and Ulrich 2001). Some attributes are more important to some customers than to others. Therefore, it is important to identify and target those attributes which customers value most (Chernev 2003; Boatwright and Nunes 2001).

Attributes may be best understood by evaluating how they are used to position products for specific market segments. For instance, one can look at the use of attributes to position the Ford Focus, Taurus, and Mustang. Customers may choose from these three car models by selecting from three attributes: gasoline mileage, carrying capacity and horsepower. The Focus offers superior gasoline mileage, low carrying capacity, and low horsepower at a modest price and is targeted to appeal to a budget conscious market segment. Of the two cars remaining, the Taurus clearly appeals to the "family segment" that desire average gasoline mileage, greater carrying capacity, and average horsepower at an average price. Muscle car enthusiasts prefer the Mustang for its horsepower, and will pay a premium for this iconic car. Through evaluating attributes, marketers can define key customer segments through their specific attribute preferences making demand more certain. Marketers can also identify the need to add or modify attributes to existing products in order to attract either more customers or attract higher paying customers (Kahn 1998; Hui 2004).

The literature infers that there are three attribute value levels that influence the customer's perception of product line variety (Figure 2-2). At the first level, an attribute may be an order qualifier or an order winner. At the second level are quality and preference attributes (Moorthy and Png 1992; Desai 2001; Randall and Ulrich 2003). At the third level, quality attributes must align or make straightforward comparison between products (Herrmann,

Heitman, Morgan, Henneberg, and Landwehr 2009; Boatwright and Nunes 2003; Iyenger and Lepper 2000). These levels represent a hierarchy. If it is not clear which attributes are order winners, the firm may attempt to differentiate on unvalued attributes. If the firm does not understand the differences between quality and preference attributes, they will not be able to understand the differing supply chain outcomes. At each level, the literature has not addressed how attribute value influences the cost and revenue trade-offs in the supply chain. This is another major gap that this thesis examines.

Figure 2-2, Attribute Types



2.4.1 Order winning and order qualifying attributes

Ramdas (2003) suggests that a key to strategically creating product variety is recognizing the differences between non-differentiating attributes and differentiating attributes. This research defines order-qualifying attributes as those features that customers must have in a

product, but that do not differentiate the product. For instance, most customers would not buy a personal computer without a cooling fan. However, few customers would concern themselves with the type of fan within their computer. Fans are an order-qualifying attribute. On the other hand, order winning attributes are defined as those features that help customers differentiate between products. For instance, most customers perceive the central processing unit (CPU) as the most important differentiating attribute in personal computers (Moorthy and Png 1992). CPUs are an order-winning attribute. Customers differentiate based on the order winner, the CPU, and not the order qualifier, the fan. The most cost effective strategy for managing products is to provide common parts between products for order qualifying attributes and to provide differentiating parts for order winning attributes (Closs, Jacobs, Swink, and Webb 2008). This research does not examine order qualifiers and focuses only on differentiating attributes.

2.4.2 Preference attributes

At the next lower level of attribute value are preference attributes. Preference attributes are those features that customers require to meet their personal tastes (Randall and Ulrich 2002; Desai 2001). A good example of a preference attribute is bicycle color (Randall and Ulrich 2001). Bicycle colors generally do not signal that one bicycle is superior to another, but usually provide meaningful variety within a single hierarchical level. For instance, a customer may know that he wants an aluminum bicycle at a certain price range. The customer may also like red bicycles. Therefore, having multiple colors, the preference attribute, in the aluminum bicycles provides consumers with valuable choices. However, if the customer finds no red bicycles, he may still buy a black bicycle if it is aluminum (Randall and Ulrich 2001). Customer tastes are varied and many. Preference attributes satisfy the variety seeking behavior and heterogeneous nature of customers (Kahn 1998).

The literature suggests that two different types of consumers (see Table 2-1) treat preference attributes differently. Customers that have pre-existing tastes (fixed preference customers) will purchase if the expanded product line carries the specific preference attribute(s) they seek. Having more preference attributes increases the likelihood that this customer type will find the choice they seek (Chernev 2003). This leads to increasing demand with increasing product variety. However, customers that do not have pre-existing preferences (flexible preference customers) are more likely to purchase when the product line is smaller rather than larger (Iyenger and Epper 2000). For example, Chernev (2003) tested how pre-existing personal tastes related to customer likelihood to purchase. Subjects in this experiment were asked to articulate their pre-existing preferences in four preference attributes: chocolate type (solid chocolate, truffle, praline, caramel), cocoa content (dark chocolate, milk chocolate, white chocolate, espresso chocolate), flavor (original, vanilla, strawberry, cherry), and nut content (none, almonds, hazelnuts, walnuts). The subjects were then presented with product lines made of some or all these attributes for selection. Following an imagined purchase, subjects were rewarded with one of the assorted chocolates in the product line to take home.

Table 2-1, Types of Consumers

	Fixed Preference Consumer	**Flexible Preference Consumer**
Definition	Consumers that will only purchase a specific preference attribute.	Consumers that might purchase any preference attribute.
Example	A consumer buying a refrigerator will only purchase the color that matches their interior design plans.	A consumer buying a refrigerator may substitute a different color.

2.4.2.1 Preference attributes and demand

Fixed preference customers and flexible preference customers were different in the chocolates that they took home. Fixed preference customers were more likely to take home the same product that they imagined purchasing. This suggests that when consumers have fixed preferences that a broader product line ensures they will match their pre-existing preference. Therefore in this case, adding preference attributes increases demand. However, flexible preference customers switched choices more frequently. Additionally, flexible preference customers were less likely to switch when presented with fewer SKUs. This suggests that when pre-existing preferences are uncertain, smaller product lines consolidate demand. To add more evidence to this conclusion, Iyengar and Lepper (2000) also found that customers given samples of jam flavors were more likely to purchase jam when presented with a smaller product line. Therefore, when customers have fixed preferences, a broad product line increases demand. However, when customers have flexible preferences, a broad product line discourages demand.

2.4.2.2 Preference attributes and demand variance

Randall and Ulrich (2001) suggest that preference attributes are also associated with high variability. Two main points highlight this variability. First, in Chernev's (2003) experiments, flexible preference customers switched between alternatives more frequently when the assortment was large (16 different SKUs) than when the assortment was small (4 different SKUs). This switching behavior implies that broader preference attribute breadth creates greater demand variability. This condition applies to both fixed preference customers and flexible preference customers. Second, customers' tastes and their strength of desire for their tastes vary greatly. Fixed preference customers may not always wait for their specific preference attribute, but may be satisfied with a substitute. For instance, customers may prefer to buy red

automobiles. If red is not available, they may instead choose a white automobile rather than not buy. Their demand would then be added to the demand for white automobiles. When their red color automobile is offered, they will switch back to their strongest preference. Therefore, greater demand variance occurs because of the extensive switching behavior relating to the strength of consumer preferences.

2.4.2.3 Preference attributes conclusion

To summarize, preference attributes are order winners that relate to customers' personal tastes. Preference attributes increase purchase certainty when they include an attribute close to a fixed preference customer's pre-existing tastes. However, when customers have flexible preferences, demand may decrease as the product line increases. Additionally, because customers' tastes and strengths of preferences are varied, preference attributes increase demand variability. Nevertheless, the effect that these preference attributes have on costs, revenues, and profits remains an unexplored research area.

2.4.3 Quality attributes

Quality attributes are substantially different from preference attributes. Quality attributes are those features that customers perceive as defining the product line's hierarchy (Randall and Ulrich 2002; Kahn 1998; Desai 2002; Netessine and Taylor 2008; Hermann et al. 2001). For instance, Apple's iPod product line uses video capability, touch capability, and memory size as quality attributes. The firm can use these three features to easily decipher which product the customer perceives as having the highest value. The iPod lowest on the value scale has no video capability, no touch screen capability, and very little memory. The customer expects these iPods to be inexpensive. The average iPods have video screens, more memory, but no touch screens, so the customer expects these iPods to be moderately priced. The premier value iPods have

enhanced video capability, touch screens, and the most memory. The customer expects these iPods to be expensive. Quality attributes help the firm and the customer judge the relative value of products.

2.4.4 Attribute alignability

The effect of quality attributes on demand and demand variability varies depending on whether the attribute is aligned or non-aligned. Alignability frames customers' choices in a way that helps them better understand purchase risks. Gourville and Soman (2005) conducted three experiments that explain this phenomenon. In the first experiment, subjects were asked to choose from two brands. The Panasonic brand[1] had only one microwave in the choice set and thus represented the simplest choice. The Sharp brand's first microwave had exactly the same attributes as the Panasonic brand. However, the extended Sharp product line reached a total of five SKUs. In the aligned setting, all of the Sharp brand microwaves were differentiated by capacity. In the non-aligned setting, the Sharp brand microwaves were differentiated by varying features. Table 2-1 below is taken from Gourville and Soman (2005) to demonstrate the different choices that subjects were given. The aligned attributes on top and non-aligned attributes on bottom are boxed.

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[1] Brands were counterbalanced throughout the experiment to ensure that brand preference did not confound the experiment.

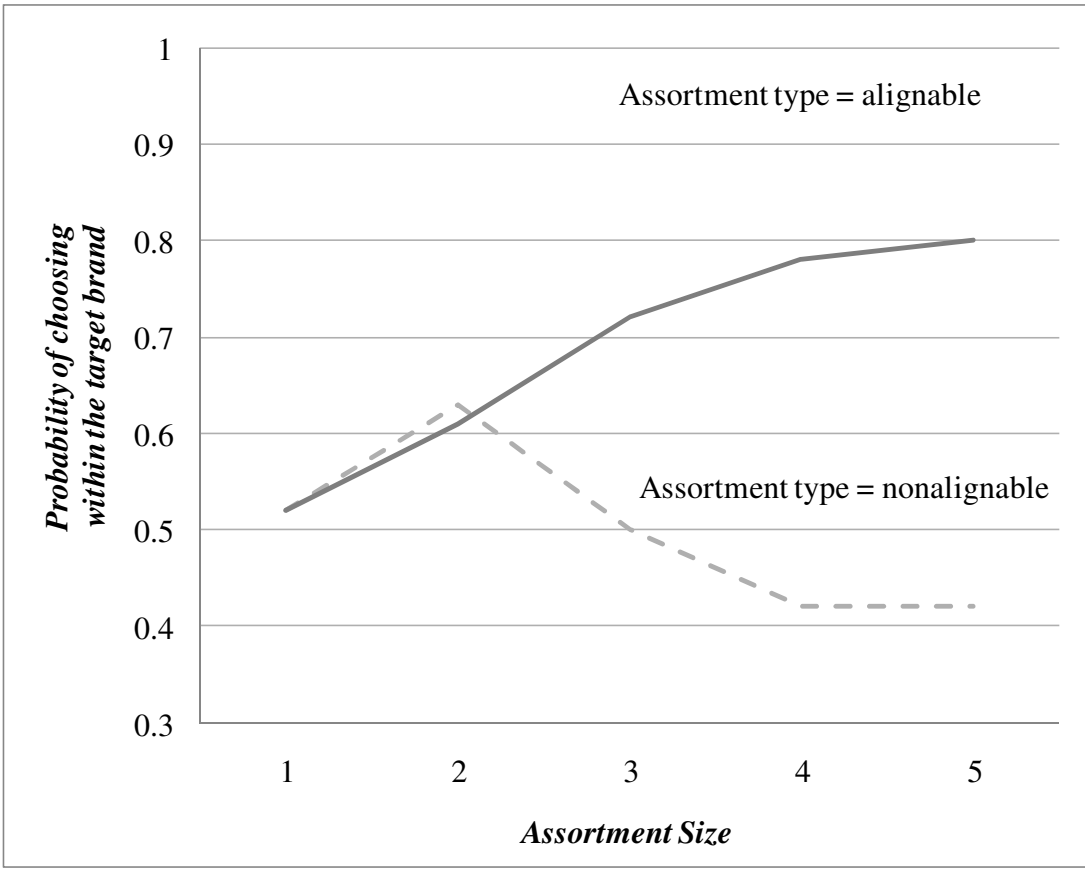
Table 2-2, Gourville and Soman (2005) Experimental Design

	Competitor	Target 1	Target 2	Target 3	Target 4	Target 5
Alignable assortment condition						
Brand	Panasonic	Sharp	Sharp	Sharp	Sharp	Sharp
Capacity	1.1 Cu. Ft.	1.1 Cu. Ft.	1.3 Cu. Ft.	1.5 Cu. Ft.	1.7 Cu. Ft.	1.9 Cu. Ft.
Power Output	700 Watts	700 Watts	700 Watts	700 Watts	700 Watts	700 Watts
Warranty	30 Months	30 Months	30 Months	30 Months	30 Months	30 Months
Features	On-line help	On-line help	On-line help	On-line help	On-line help	On-line help
Price	$140	$140	$160	$180	$200	$220
Non-Alignable assortment condition						
Brand	Panasonic	Sharp	Sharp	Sharp	Sharp	Sharp
Capacity	1.1 Cu. Ft.	1.1 Cu. Ft.	1.1 Cu. Ft.	1.1 Cu. Ft.	1.1 Cu. Ft.	1.1 Cu. Ft.
Power Output	700 Watts	700 Watts	700 Watts	700 Watts	700 Watts	700 Watts
Warranty	30 Months	30 Months	30 Months	30 Months	30 Months	30 Months
Features	On-line help	On-line help	Adjustable Speed TT	Moisture Sensor	Hold Warm Feature	Programmable Menus
Price	$140	$140	$160	$180	$200	$220

2.4.4.1 Aligned attributes and demand

As Gourville and Soman (2005) hypothesized, attribute alignment influenced demand. In fact, when attributes were aligned demand increased in the target SKU brand from 53 percent with a single SKU to 80 percent with the fifth SKU. When the SKUs were non-aligned, the demand initially increased from 53 percent to 63 percent with the second SKU, but demand fell to only 42 percent with the fifth SKU (Figure 2-3). This finding explains research by Boatwright and Nunes (2001) and Jacobs (2008), which suggested that increasing SKU breadth reduced demand. In other words, adding non-aligned attributes to extend the product line decreases demand.

Figure 2-3, Gourville and Soman (2005) Experimental Findings



Source: Gourville, J.T. and Soman, D. (2005). "Overchoice and assortment type: When and why variety backfires," *Marketing Science*, 24 (3): 382-95

2.4.4.2 Causes of decreased demand

The main reason that demand decreases with non-aligned attributes is that these attributes do not help customers frame the relative purchase risks. This confuses customers. For instance, Gourville and Soman (2005) experimentally demonstrate that cognitive overload causes reduced demand. In their experiment, subjects who were contemplating buying a digital camera compared three cameras from two brands. One group was shown all information about the cameras and the second group's information was framed to show only camera differences. In the

group with full information, only 32 percent chose the target brand. In the group with pertinent information, 77 percent chose the target brand. This demonstrates that cognitively simpler tasks led to greater probability of increasing demand. Framing through attribute alignment makes the task of product selection cognitively simpler.

The second reason that demand decreases with non-aligned attributes is that non-aligned attributes increase the potential for regret. In their final experiment, Gourville and Soman (2005) had subjects buy golf balls for their best friend's father on his birthday. The three, same-priced, golf balls were from two different brands (counterbalanced throughout the experiment). Additionally, the attributes were not aligned so that customers would not have a clear preference. The experimental factor in this case was that in the first group the sale was final. In the second group, the subjects could get a gift receipt and the friend's father could then exchange the golf balls. In the "sales are final" group, the target brand declined from a total demand of 55 percent for a single golf ball to a total demand of 42 percent for two golf balls. In the exchange group there was an increase from 44 percent to 65 percent. This demonstrates that when the potential for regret is higher, that risk is also perceived as higher. Therefore, the subjects choose the least risky alternative. Gourville and Soman (2005) suggest that when customers are presented with non-aligned attributes, cognitive overload and potential for regret decrease demand.

2.4.4.3 Aligned attributes and demand variance

Hierarchy is also important to demand variability. When attributes are aligned customers can quickly frame the relative value of each product and purchase with greater certainty (Herrmann et al. 2009). This creates less demand variance (Gourville and Soman 2005). Herrmann et al. (2009) provide experimental evidence that aligned attributes reduce demand variance. Herrmann et al. (2009) presented people who identified themselves as shopping for a

new car with a computer program to configure the cars' features. In the first experiment, they found that when presented with eight features that were aligned, customers made more decisive purchasing decisions and were more satisfied with their selections. In the second experiment, Herrmann et al. (2009) found that when customers were presented with non-aligned trim options that their selections tended to be more variable. However, when the trim options were given hierarchical sounding names (basic, basic plus, business, business plus, exclusive, exclusive plus, and luxury), customers tended towards average type trim packages. In their final experiment, they found that when labels assigned a quality level to attributes that customers purchased more consistently. The result is that aligned attributes decrease demand variance. Non-aligned attributes increase demand variance.

2.4.4.4 Aligned attributes conclusion

The product attribute choice model reveals gaps in both the supply chain literature and the marketing literature. The product variety, supply chain literature is myopically focused on SKU breadth. Therefore, customers' perception of product variety and their effect on the supply chain are rarely evaluated (Randall and Ulrich 2001 provide a rare exception). As a result, the supply chain manager accepts demand and demand variance without being able to influence the demand drivers. Simultaneously, the marketer does not understand the costs that are created by attribute value. Additionally, neither the supply chain manager nor the marketer understand how attribute related demand and demand variance influence profit.

2.5 Literature synthesis

This chapter highlights three research gaps in the product variety literature and presents an experimental framework for this research. First, product variety costs in the literature are focused on production costs (Ramdas 2003). The total cost paradigm predicts that not looking at

all costs creates poor decision making. To fill this gap, this research explores the total supply chain costs of product variety. A second gap in the literature is the examination of demand and demand uncertainty caused by customer's perceptions. There is no research that explores the impact of attribute value on demand or demand variance. This research addresses attribute value cause and effect issues. Finally, the extant literature fails to explore the interaction between SKU breadth and attribute value on the costs and revenues of the supply chain. This research evaluates the holistic effects of the changing demand and changing demand variance on costs, revenues and profit. Consequently, this study seeks to fill these gaps by using simulation modeling to examine the influence of SKU breadth and attribute value on supply chain profitability.

2.6 Experimental design and hypotheses

This research suggests that a product line balancing both revenue and cost creates the most profitable value chain. The problem with product variety is that the balancing point is frequently not known. The trade-offs between the cost drivers and revenue drivers are not explicit leading managers to manage by trial and error. Understanding the trade-offs provided by the total system creates synergies where only conflict existed previously.

2.6.1 SKU breadth hypotheses

The literature review demonstrates that broader SKU breadth, without considering attribute value and assuming constant prices, tends to increase revenue through increasing market share. Increasing product line breadth, however, reduces economies of scale and should increase supply chain costs (Quelch and Kenny 1995). The increase in SKU breadth also tends to cause cannibalization (Mason and Milne 1994; Desai 2001) and disaggregation leading to more demand variance. This demand variance in turn leads to greater market mediation costs (Randall

and Ulrich 2002). As long as the marginal revenues created by finding new customers outweigh the costs introduced, the product line will be profitable. As a result, increasing SKU breadth should create greater profits. These relationships suggest four hypotheses.

H1. Increasing SKU breadth when price is held constant

a. Increases revenue.

b. Increases cost.

c. Increases profits.

d. Increases market share.

2.6.2 Preference attribute hypotheses

Understanding the hypothetical effects that preference attributes have on revenues and costs leads to understanding profitability. First, preference attributes may increase demand as increasing preference attributes appeal to fixed preference customers (Chernev 2003). Second, preference attributes may decrease demand as increasing preference attributes confuse flexible preference customers. Third, preference attributes tend to increase volume costs. Fourth, because they relate to individual tastes, preference attributes create greater demand variance and therefore greater market mediation costs (Chernev 2003). Finally, because profitability depends on customers' pre-existing preferences, profit gains may be offset by profit losses. Therefore, the number of profitable products in the product line should change little as preference attributes are added. Preference attributes suggest the following hypotheses.

H2. Adding preference attributes

a. Increases revenue.

b. Increases cost.

c. Increases profits.

d. Increases market share.

e. Does not change the number of profitable SKUs in the product line.

2.6.3 Aligned quality attribute hypotheses

The differences between aligned and nonaligned attributes create additional hypothesized results. Aligned quality attributes create more predictable demand due to customers' ability to make clearer decisions. This in return should reduce market mediation costs. In addition, adding aligned quality attributes drives up volume costs due to reduced economies of scale. However, since market mediation costs tend to dominate attribute's effect on the supply chain an overall reduction in costs is expected. Additionally Gourville and Soman (2005) have shown that aligned quality attributes increase demand. Therefore, aligning attributes are expected to increase profitability and the number of profitable products in the product line. Five hypotheses result.

H3. Aligning quality attributes

a. Reduces revenue.

b. Increases cost.

c. Increases profits.

d. Increases market share.

e. Increases the number of profitable SKUs in the product line.

2.6.4 Non-aligned quality attribute hypotheses

Non-aligned quality attributes create less predictable demand due to customers' confusion and potential for regret (Herrmann et al 2009; Boatwright and Nunes 2001). This should increase market mediation costs. In addition, non-aligned, quality attributes still add

components to products and drive up volume related costs. Gourville and Soman (2005), Jacobs (2008) and Boatwright and Nunes (2004) demonstrated that non-aligned quality attributes might decrease market share thus decreasing demand. Therefore, non-aligned attributes are expected to decrease profitability and decrease the number of profitable products in the product line. The relationship between non-aligned attributes and firm profitability create hypothesis four.

H4. Creating non-aligned quality attributes

a. Increases revenue

b. Reduces cost

c. Reduces profits

d. Decreases market share

e. Decreases the number of profitable SKUs in the product line

2.7 Conclusion

This chapter evaluates the intersection of prospect theory and the total cost model to understand how product variety influences profitability. The chapter reviews the literature and identifies three main research gaps. It then identifies constructs and the relationships between constructs to develop an experimental framework. The research then suggests four hypotheses to test the relationships in an experimental framework.

The next chapter discusses simulation as an appropriate research methodology to test these hypotheses and also outlines the research design.

CHAPTER III: RESEARCH METHODS

3.0 Introduction

Chapter Three discusses the experimental design for testing the hypotheses. The chapter first rationalizes why simulation is an appropriate research methodology. Then, the chapter provides an overview of the simulation model. Third, the rigor of the simulation model is discussed. Fourth, the experimental scenarios, inputs, controls, and outputs of the model are discussed. The chapter concludes by describing how the statistical techniques used in the fourth chapter are congruent with the research design.

3.1 Method

Computer simulation refers to studying real world systems by using software designed to imitate a real systems' operations (Kelton et al. 2006). This research uses ARENA Enterprise Edition 12, a dynamic simulation software tool that combines SIMAN simulation language with a graphics component (Kelton, Sadowski, and Sturrock 2006). Computer simulation allows this research to study a simplified model of a complex supply chain with the objective of isolating the effects of product variety. There are four main reasons why simulation is appropriate for this research.

First, simulation is very effective at evaluating how differing factors influence relative performance results. Product variety and the supply chain can be viewed as an input/output system. Consumer product choice creates demand and demand variance. The supply chain processes produce revenue, cost, and profitability as an output. The effect of product variety on the supply chain can then be evaluated by changing the type of consumer choices. Simulation is

a very fitting methodology for this experiment (Kelton, Sadowski, and Sturrock 2003: page 8-10).

Second, simulation is useful when the focal phenomena involve multiple and interacting processes (Davis et al. 2007). In other words, simulation allows very complicated systems to be imitated by simplified models (Kelton, Sadowski, and Sturrock 2003: page 8). The attribute model of consumer choice represents a complex, customer-decision making system. Supply chain management is a dynamic and complex system that is difficult to holistically study. Computer simulation is one approach that can be used to explore these complex systems (Venkateswaran and Son 2004).

Third, previous product variety research generally used mathematical models with strict assumptions (Netissine and Taylor 2009; Randall and Ulrich 2002; Srivasanan et al. 1990). Simulation allows this research to relax strict assumptions and expand testable boundaries (Davis et al. 2007). For instance, the extant research rarely evaluates SKU breadth beyond two product qualities: high product quality and low product quality (Netessine and Taylor 2009; Carlton and Dana Jr. 2008). This research includes three quality attributes and three preference attributes thereby expanding product variety breadth. Because simulation relaxes strict assumptions, this research creates the opportunity to expand phenomenological understanding.

Finally, product variety's incomplete theoretical understanding begs for a flexible yet rigorous methodology (Davis et al. 2007). For instance, the exact effects of cannibalization and preference attributes are not well established by extant literature. Simulation's flexibility allows this research to make assumptions based on the existing literature to expand knowledge about the understudied phenomena of cannibalization and preference attributes. In total, simulation is a very good fit to investigate this research.

3.2 The simulation model

This section discusses the simulation setting, structure, and the sequence of events. The real-world setting gives the simulation face validity. The structure and event sequence reveals the logic and processes of the studied system and indicates how the simulation captures these real world events.

3.2.1 Simulation setting

A side-by-side, refrigerator product line was used as the setting to ground this simulation. There were two main reasons that a refrigerator was a good fit for this research. First, refrigerator features demonstrate preference, aligned, and non-aligned quality attributes. Second, appliance manufacturers compete in a mature industry. Therefore, their product variety strategies and their supply chain structures are well established. Figure 3-1 illustrates the product line strategies of both a high variety firm and a low variety competitor.

Figure 3-1, Refrigerator Strategic Setting

For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this dissertation.

MSRP	$899	$999	$1099	$1199	$1299	$1399	$1499	$1599	$1899
Target Brand									
Aligned Quality	No E-Star.	E-Star.	E-Star.	E-Star	E-Star.	E-Star	E-Star	30% E-Star	30% E-Star
Non-Aligned Quality		Door insert	Black Handle	Smooth door	SS handle	Low hinges	LCD control	SS handle	Cont door
Colors	1	3	1	3	1	4	5	6	5
MSRP	$899	$999	$1099	$1199	$1299	$1399	$1499	$1599	$1899
Competitor Brand									
Aligned Quality			No E-Star		No E-Star		E- Star		E- Star
Non-Aligned Quality			None		None		Twin cool system		LED lighting
Colors			2		2		3		3

The first reason that an appliance manufacturer makes a good setting for the simulation is that its feature assortments produce all the attribute types. For example, Figure 3-1 illustrates that refrigerator price typically increases as energy efficiency improves. Therefore, a 30 percent energy star refrigerator is generally priced higher than a regular energy star refrigerator, suggesting an aligned attribute. The product line attributes also show that once a consumer decides on the aligned attribute (energy star), they may have as many as seven colors (a preference attribute) from the high variety manufacturer to decide on as well. After the color is

selected, some refrigerator lines create non-aligned attributes through adding in-door icemakers, in-door water dispensers, and in-door digital displays. Therefore, the side-by-side refrigerator product line provides the full breadth of attribute types on which to base the simulation.

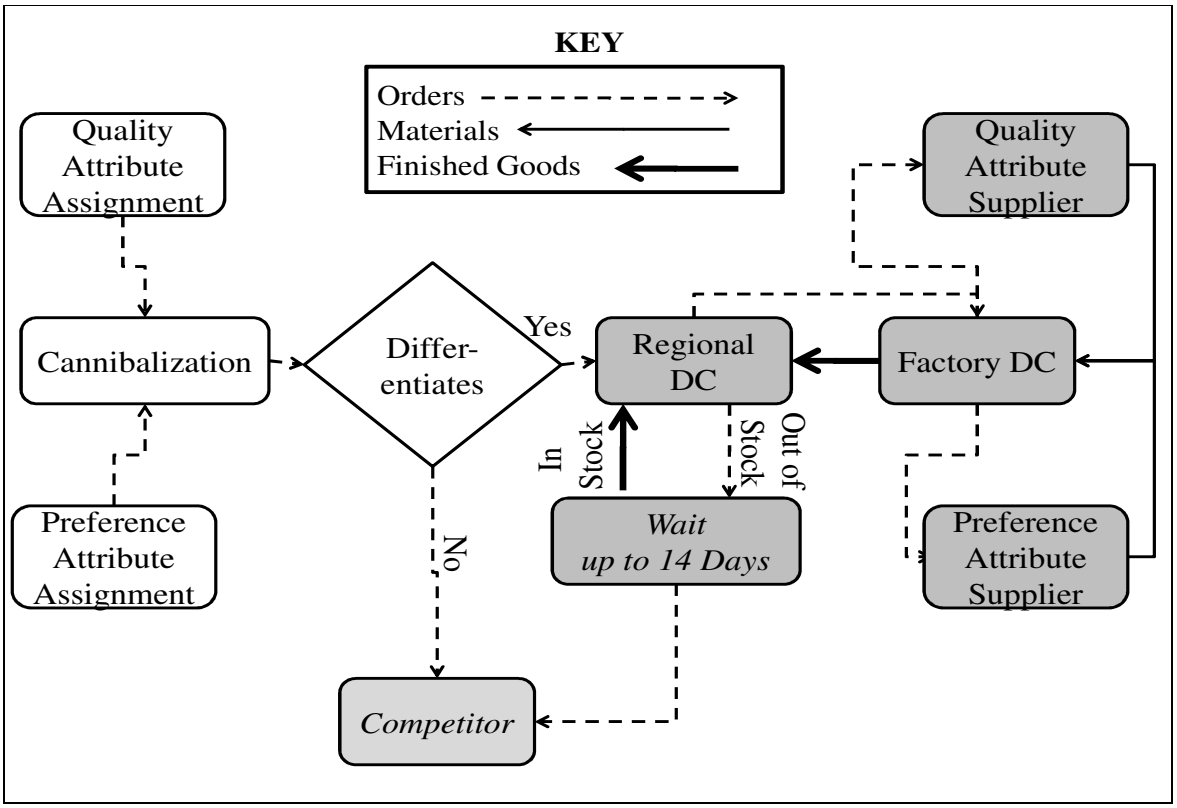
The second reason that the simulation is based on a refrigerator manufacturer is that side-by-side refrigerator competition is a mature industry. This maturity is important because it reveals the existing and contrasting product variety strategies. For example, the high variety manufacturer in Figure 3-1 offers a different side-by-side refrigerator at $100 increments starting at a low-end refrigerator of $899 to the high-end refrigerator at $2,299. This strategy is in contrast with the low cost competitor that offers few choices at only the most frequently purchased price points. Figure 3-1 illustrates this through not only limited models for the low variety manufacturer, but also limited color choices, and limited energy star choices. The contrast offered by the industry allows the research to closely simulate the existing and opposing variety strategies.

The simulation also benefits from the appliance manufacturer's mature supply chain. Manufacturing generally takes place in North America. Each factory has its own distribution center. Customers either take delivery of product to their regional distribution centers or to a manufacturer's regional distribution centers. The manufacturer has nine different customers representing nine different channels. Their "A" customers are generally home repair and hardware stores or construction suppliers. The maturity of this supply chain allows the simulation to be created based on a known structure with understood supply chain parameters. This allows the simulation to recreate the important aspects of this supply chain with few assumptions thereby increasing the simulation's face validity.

3.2.2 Simulation structure

The supply chain network under investigation is dynamic and multi-echeloned, comprising consumer preference decisions, distribution functions, production functions, supplier functions, information flows, capital flows, and inventory flows. The simulation creator wrote the simulation as the general representation of the supply chain of a single product family at one distribution center competing with a second, low-variety brand at a second supply chain. The competitor accommodates a certain percentage of demand and takes demand that the target brand cannot supply. Figure 3-2 illustrates the simulated supply chain network with inventory flows represented by solid arrows and demand information flows represented by a dashed arrow.

Figure 3-2, Simulation Model Structure



In this network, consumers with specified attribute preferences seek to purchase a specific refrigerator from a specific brand. The distributor orders and replenishes finished goods from the manufacturer. The manufacturer orders and receives preference attributes and quality attributes from two different suppliers.

3.2.3 Simulation sequence of events

On a typical simulated day, the following event sequence occurs:

1. Consumers are assigned their attributes at the day's beginning. Their order is sent to either the regional distribution center (RDC) or to the competitor.

Consumers are assigned preferences for both a quality attribute and a preference attribute. Quality attribute assignments and preference attribute assignments are subject to change based on experimental conditions.

2. The RDC receives replenishment shipments from in-transit inventory.

Partial shipments are sent to the RDC from the factory distribution center (FDC) if distributor stock is not sufficient for demand. Backorders are not allowed because they add unnecessary complexity to the simulation.

3. The RDC receives consumer orders.

If RDC inventory in stock meets customers demand, customers purchase the product. If there is not sufficient inventory for all consumers at the retailer, some customers leave to purchase from the competitor. Other customers delay delivery of their purchase for up to 14 days. If the item is not in stock during those 14 days, the customer leaves to purchase from the competitor.

4. The RDC creates replenishment requirements based on an order-up-to policy.

Whenever inventory levels drop below reorder points, orders are placed to bring the combination of on-hand inventory and in-transit inventory up to a certain target level. The target level and reorder point are defined in days of demand at each location.

5. Distributors create replenishment orders for the manufacturer.

Distribution center inventory position and replenishment requirements are evaluated using an order-up-to policy. Distributors then create replenishment orders to the manufacturer.

6. Manufacturers fill all incoming replenishment orders by producing products.

Manufacturers can immediately begin producing orders when they are received and do not incur any changeover penalties. When the total order amount passes through the manufacturing process, the total manufacturing cost for that order is calculated. The simulation moves the finished goods automatically to the FDC. These products are then available to be shipped to the RDC.

7. The manufacturer orders quality attribute parts and preference parts from two separate suppliers.

Once again this is done using an order-up-to policy for each component part.

8. Suppliers fill all incoming replenishment orders from the manufacturers.

The model fills the order based on a FIFO system and assumes no supplier lead times. Therefore, materials move from the supplier to the manufacturer with only shipping delay times.

9. Lastly, the simulation collects statistics.

The simulation computes demand, demand variance, stock outs, inventory carrying costs, cost of goods sold, transportation costs, revenue, and profit for each SKU, for each market segment, and for the entire product line.

10. The system returns to the first event after the last event completes, repeating the same sequence until the simulation period of 365 days is over. It repeats this for a total of thirty replications.

3.3 Rigor

Methodological rigor represents other researchers' abilities to conclude that experimental replication would lead to similar conclusions (Cook and Campbell 1979). Four types of model validity and verification are generally considered in simulation experiments (Sargent 2008).

Conceptual model validity tests that the theories and assumptions underlying the conceptual model are accepted by those involved in the real world system. Computerized model verification ensures that the computer programming and implementation of the conceptual model are correct. Operational validity determines whether the model output behavior has sufficient accuracy. Finally, data validity ensures that data necessary for model building, model evaluation and testing, and conducting of model experiments are adequate and correct. In addition to the four types of validity, the research also discusses replications as an important indicator of rigor. Table 3-1 gives an overview of the verification, validation, and sample size techniques used to ensure rigor in this simulation.

Table 3-1, Simulation Rigor

Test	Purpose	Technique Utilized
Conceptual Model Validity	Computer model is consistent with its intended application	Supply chain model based on major appliance manufacturer data Consumer behavior model based on published experimental data Managers and academics reviewed the model
Computer Model Verification	Computer programming and computer model implementation are correct	Traces of each submodel compared to analytical hand calculations Traces to verify relationships of the entire simulation
Operational Validity	Model output behavior has sufficient accuracy and consistency	Degeneracy testing Parameter variability and sensitivity analysis Initialization bias testing
Data Validity	Data used in model building, evaluation, and testing are adequate and correct	Input parameters based on experimental literature Demand data from manufacturer compared to simulation output data with no significant differences
Replications	Sample size creates adequate statistical reliability	Law and Kelton (2000:512) technique for determining sample size

3.3.1 Conceptual model validity

Conceptual model validation refers to "substantiation that a computerized model within its domain of applicability possesses a satisfactory range of accuracy consistent with the intended application of the model" (Sargent 2008). Several model validation techniques are discussed in literature to test conceptual validity (Sergeant 2008; Law and Kelton 2000).

Face validity determines that the model's output behavior has sufficient similarity for its intended purpose. Critics frequently dismiss simulation as lacking face validity due to its artificiality. This type of validity concerns inferences regarding the extent to which a causal relationship holds over variations in persons, settings, treatments and outcomes (Shadish, Cook, and Campbell 2002). In order to be relevant, simulation must dually satisfy theoretical needs and practical needs.

There are two practices that increase face validity. First, Shafer and Smunt (2004) suggest that combining simulation with empirical data bridges the gap between academic rigor and managerial applicability. Shafer and Smunt (2004) encourage researchers to gather data from sources that ensure face validity. In this research, the simulation uses supply chain data derived from interviews, data and presentations from a major appliance manufacturer (Archer 2009). Additionally, the consumer behavior data was gleaned from experimental, theoretical literature and the appliance manufacturer's demand data. By using these two types of data, the simulation ensures that face validity is established. The second practice that increases face validity is to have experts evaluate the model to ensure that it seems reasonable for its intended purpose. This research accomplishes face validity through consultation with subject matter experts.

3.3.2 Computerized model verification

Sargent (2008) defines model verification as "ensuring that the computer program of the computerized model and its implementation are correct." The simulation creator accomplished computerized model verification by using two tests. The first test examined each subroutine to ensure it was programmed correctly. Traces ensured that unwanted or nefarious code did not exist. In trace technique, the state of the simulated system is displayed after each submodel. Then calculations throughout the simulation are compared with hand calculations to see whether the program is passing information as intended (Law and Kelton 2000). A file with each activity performed (i.e., consumer preferences, replenishment requests, inventory shipments, etc.) was created and any errors detected in the model were evaluated and fixed.

The second step was to run traces to verify the entire simulation (Law and Kelton 2000; Sargent 2008). Relationships between consumer behavior inputs and supply chain outputs were tested using deterministic values. These were in turn compared to analytical values. The traces through the system found no significant deviations from expected outcomes, verifying the simulation model.

3.3.3 Operational validity

Operational validity ensures that model output behavior has sufficient accuracy and consistency (Sargent 2008). Many validation techniques can be used to establish this internal validity. In this research, two techniques are used: Degenerative Tests and Parameter Variability–Sensitivity Analysis (Sergeant 2008).

The degeneracy of the model's behavior is tested by appropriate selection of values for the input and control parameters. For example, an increase in lead-time in one stage of the model resulted in an increase in stock-outs and higher inventory carrying costs. In parameter

variability–sensitivity analysis, values of the input and internal parameters of a model are changed to extreme values to determine the effect upon the model's behavior and its output. Consumer behavior parameters were altered to check if the resulting demand reflected data found in the literature (Gourville and Soman 2005; Chernev 2003). The extreme parameters caused no unexpected results suggesting that the simulation is internally consistent and valid.

An additional threat to operational validity is initiation bias. This occurs when the simulation goes through a warm-up period. Statistics collected during this period may bias output data from the steady state period. To identify this bias, Chen and Kelton (2008) suggest comparing histograms of the performance variables for various run-lengths at independent time periods. A researcher, using this technique, selects the shortest run-time with stable histogram quartiles (Chen and Kelton 2008). This technique was used and significant initialization bias was discovered. In order to counter this bias, the simulation was run for the first week with deterministic demand and with initial inventory levels equal to demand. This allowed the simulation to prime itself. Follow-on examination of performance histograms showed that the initialization bias was removed.

3.3.4 Data validity

Data validity ensures that the data necessary for model building, model evaluation and testing, and conducting of model experiments are adequate and correct (Closs, Nyaga, and Voss, 2010). The simulation used stochastic input parameters from the literature. The demand data derived from the retailers was examined after initial pilot runs for consistency. No outliers were discovered. The internal validity tests found few anomalies and fixed the code for those that were discovered.

3.3.5 Simulation replications

Simulation replications represent sample size, which determines output data statistical reliability. This simulation model used Law and Kelton's (2000: page 512) procedures to calculate the replications required to estimate population mean at a specified precision. According to this procedure, an approximate expression for the minimum number of replications, na*(β), required to obtain an absolute error of β is given by: na*(β) = min {i ≥ n: t_i-1,1-α/2√ (S^2(n)/i) ≤ β}. The na*(β) can be determined by iteratively increasing i by one until a value of i is obtained for which t_i-1,1-α/2√ (S^2(n)/i) ≤ β. In this simulation, to estimate profit with an absolute error, β, of 0.05 and a confidence level, α, of 90 percent, initial pilot runs of the nine SKU scenarios were done and initial mean (μ) and variance (s^2) of service level were computed. An s^2 = .0182 was obtained from 23 replications. Critical values of t give t(22,0.1) = 1.717. Using the equation {i ≥ n: t_i-1,1-α√ (S^2)/i) ≤ β}, 23 replications satisfy t_i-1,1-α/2√S^2(n)/i ≤ β requirement. Although a 23-replication sample size may have sufficed, a larger sample size was used. A statistically large, 30-replication sample size produced an estimate of actual relative error (the previously calculated confidence interval divided by the mean) of .049 or an alpha of 95 percent. (Law and Kelton 2000: page 513). Thus, this research used 30 replications per experimental condition to increase faith that the confidence interval captures the true mean.

3.4 Simulation experimental design

In simulation, experimental inputs are processed by a model to examine the changes in outputs (Kelton, Sadowski, and Sturrock 2003: page 611). In this particular simulation, the consumer behaviors associated with attribute types are modeled as the inputs. Then, the

simulated supply chain acts as a control model. The resulting outputs are dependent variables that enable the research to make conclusions about the effects of consumer behavior on total profitability. The following sections define the inputs, describe the supply chain model, and discuss the dependant variables.

3.4.1 Experimental parameters

The research manipulates six, demand-related parameters to create a full factorial design. Scenarios describe the group of experimental settings that create individual experiments. The design resulted in a total of 628 scenarios. Differences in demand volume are used to approximate the influence of quality attribute alignability on a consumer's likelihood of purchasing the target product. Demand variability models the relative certainties that consumers exhibit when attributes are aligned or non-aligned. Cannibalization variables model how customer demand for quality attributes or preference attributes steal demand from existing SKUs. Finally, demand variability for color models the effect of consumer's pre-existing preferences on preference attributes. Table 3-2 gives an overview of these variables.

Table 3-2, Experimental Variables

Variable	Simulates	Levels	Operationalization
SKU Breadth (SKU)	The addition of SKUs to the product line	9	**SKU 1** = Average quality, painted SKU **SKU 2** = SKU 1 + average satina SKU **SKU 3** = SKU 1,2 + average stainless SKU **SKU 4** = SKU1,2,3 + Budget quality, painted SKU **SKU 5** = SKU1,2,3,4 + Budget satina SKU **SKU 6** = SKU1,2,3,4,5 + Budget stainless SKU **SKU 7** = SKU1,2,3,4,5,6 + Premium quality, painted SKU **SKU 8** = SKU1,2,3,4,5,6,7 + Premium satina SKU **SKU 9** = SKU1,2,3,4,5,6,7,8 + Premium stainless SKU
Quality Attribute Demand Volume (DEM)	Likelihood of consumer purchasing the product due to customer confusion and potential for regret.	2	**Aligned:** Quality attributes demand volume increases as SKUs are added. **Non-Aligned:** Quality attribute demand volume decreases when premium attributes are added
Quality Attribute Demand Variance (QUALVAR)	Decisive purchase behavior of consumers when quality attributes are aligned	2	**Aligned:** Quality attributes demand variance is low (C.V. = .1) **Non-Aligned:** Quality attributes demand variance is high (C.V. = .4)
Quality Attribute Cannibalization (SUB)	Substitution behavior of consumers when products fail to variegate	3	**Low:** Quality attribute substitution is low as determined by sensitivity analysis (15%) **Moderate:** Substitution is moderate as determined by sensitivity analysis (45%) **High:** Substitution is high as determined by sensitivity analysis (75%)
Preference Attribute Demand Variance (PREFVAR)	Decisive purchase behavior when preference attributes are not in their color	2	**Pre-existing preference (fixed):** Each of three colors selected equally **No pre-existing preference (flexible):** Colors randomly selected for each consumer

Table 3-2 (cont'd)

Preference Attribute Cannibalization (NICHE)	Behavior of consumers when preferred preference attribute is not found in the existing product line.	3	**Low (fixed consumers):** Niche encroachment is low as determined by sensitivity analysis (15%) **Moderate (fickle consumers):** Niche encroachment is moderate as determined by sensitivity analysis (30%) **High (flexible consumers):** Niche encroachment is high as determined by sensitivity analysis (75%)

3.4.1.1 SKU Breadth

SKU breadth increases incrementally in the experimental design. The order of SKU introduction is given in Table 3-3. This incremental increase allows comparison of the effect of few SKUs (cost minimization approach) to many SKUs (revenue maximization approach). The experiments introduce SKUs in the order that is most likely to maximize demand. Therefore, the average quality SKUs were added first, followed by budget SKUs, and then premium quality SKUs. Within each quality attribute, colors were also added incrementally. The experiments added painted SKUs first, then Satina SKUs, and then stainless SKUs.

Table 3-3, SKU Introduction Sequence

	SKU 1	SKU 2	SKU 3	SKU 4	SKU 5	SKU 6	SKU 7	SKU 8	SKU 9
Average Quality									
Painted	X	X	X	X	X	X	X	X	X
Satina		X	X	X	X	X	X	X	X
Stainless			X	X	X	X	X	X	X
Budget Quality									
Painted				X	X	X	X	X	X
Satina					X	X	X	X	X
Stainless						X	X	X	X
Premium Quality									
Painted							X	X	X
Satina								X	X
Stainless									X

3.4.1.2 Demand volume

SKU breadth generally increases demand volume (Kahn 1998, Kekre and Srinivasan 2001). The experiments simulate consumer behavior's effect on demand volume by creating a daily average of 100 consumers. The consumers seek a specific quality attribute based on a Pareto distribution (80 percent chose an average quality product, 15 percent chose a budget quality products, and 5 percent chose a premium quality products). However, if a consumer demands a SKU that is not currently available, the competitor wins that demand. Therefore, as SKUs are added to the product line, the total demand for the product line generally increases.

However, nonaligned quality attributes change the SKU breadth and demand relationship. Demand eventually decreases when quality attributes are nonaligned. The percentages of increased or decreased demand follow the findings from Gourville and Soman (2005) and are described in Table 3.4 below. In the simulation, nonaligned attributes only influence demand when the premium quality attribute is introduced. The simulation models demand in this way to

mirror the experimental findings that suggest non-alignment does not influence demand until the product line gets long enough to invite confusion. Therefore, a difference in demand is expected when the seventh SKU (the first premium attributes SKU) is introduced.

Table 3-4, Market Share for Aligned and Nonaligned Attributes

	Market Share Aligned	Market Share Non-Aligned
1 Quality Attribute	50%	50%
2 Quality Attributes	60%	60%
3 Quality Attributes	75%	40%

3.4.1.3 Demand variance

Demand volume is not the only factor influenced by attribute alignment. When attributes are aligned, Herrman et al. (2009) suggests that consumers have more certainty in their purchases. Therefore when the quality attributes are aligned, the simulation uses a low (.1) coefficient of variation [2] (CV) (Nyaga 2006). When quality attributes are non-aligned, consumers demonstrate less certainty in their purchase decisions (Herrman et al. 2009). Therefore, when quality attributes are non-aligned, the simulation applies a high (.4) CV (Nyaga 2006; Croxton and Zinn 2005). Table 3-5 lists the resulting demand distributions for the aligned and non-aligned setting.

[2] A CV of .2 is used for premium goods. This CV is used because the premium goods represent such a low percentage of demand that Quelch and Kenney (1998) suggest its variance would be up to 40 percent greater than the average product. In addition, adding only .1 CV would create unrealistic demand of 4.5 and 5.5.

Table 3-5, Aligned and NonAligned Demand

	Aligned Attributes	Non-Aligned Attributes
Budget Quality Consumers	TRIA (13, 15, 17)	TRIA (9, 15, 21)
Average Quality Consumers	TRIA (72, 80, 88)	TRIA (48, 80, 112)
Premium Quality Consumers	TRIA (4, 5, 6)	TRIA (3, 5, 7)

3.4.1.4 Cannibalization

The next experimental variable used in the simulation is cannibalization. There are two types of cannibalization used as experimental variables. The first, substitution, occurs when customers have a difficult time differentiating between quality attributes within a product line. The second type, niche encroachment, occurs when a preference attribute in the new product has greater appeal than a similar attribute in an existing product. In both cases, cannibalization influences the realized demand of the simulation.

3.4.1.4.1 Substitution

Substitution influences the quality attribute's demand. The literature suggests that non-aligned attributes fail to differentiate between products. The resulting confusion creates high levels of cannibalization. Mason and Milne (1994) and Srinivasan et al. (2005) suggest a low level of cannibalization exists when new products take about 15 percent of existing product demand and the highest levels exist when about 75 percent of new product demand is from existing products. A moderate amount of substitution would be between the high and low. Therefore the quality attribute cannibalization is modeled as low (15 percent) when quality

attributes are aligned; moderate (45 percent) when quality attributes are average; and high (75 percent) when quality attributes are non-aligned.

The low, moderate, and high settings were based not only on the literature, but also on sensitivity analysis of the substitution parameter. Figure 3-3 represents the post hoc testing for homogeneous groups. The examination was performed on 15 percent increments in substitution using thiry replications for each percentage level. Although there was not a clear break between most categories, 15 percent was always homogeneous with zero suggesting a low level of substitution. 45 percent is homogeneous with the middle category of values suggesting a moderate level of substitution, and 75 percent generally takes in high values suggesting a high level of substitution.

Figure 3-3, Sensitivity Testing for Substitution Parameters

Sub Level	Subset					
	1	**2**	**3**	**4**	**5**	**6**
0						$3,324,389
15						$3,152,227
30					$2,771,451	
45				$2,498,999		
60				$2,255,449		
75			$1,880,832			
90		$1,391,463				
100	$1,039,826					
Sig.	1.0	1.0	1.0	1.0	1.0	.522

Tukey HSD

Means for groups in homogeneous subsets are displayed based on observed means.
The error term is Mean Square (Error) = 1061614671829.671.

a. *Uses Harmonic Mean Sample Size = 270.000.*
b. *The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.*
c. *Alpha = .05.*

Figure 3-3 (Cont'd)

Sub Level	Subset			
	1	**2**	**3**	**4**
0				.5685
15				.5694
30				5689
45				.5681
60			.5654	.5654
75		.5604	.5604	
90	.5557	.5557		
100	.5503			
Sig.	.097	.236	.192	.452

Tukey HSD

Means for groups in homogeneous subsets are displayed based on observed means.

The error term is Mean Square (Error) = .001.

a. *Uses Harmonic Mean Sample Size = 270.000.*
b. *The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.*
c. *Alpha = .05.*

Figure 3-3 (Cont'd)

Sub Level	Subset		
	1	**2**	**3**
0	.8851		
15		.9005	
30		.9103	
45			.9219
60			.9265
75			.9274
90			.9310
100			.9324
Sig.	1.0	.137	.087

Tukey HSD

Means for groups in homogeneous subsets are displayed based on observed means.

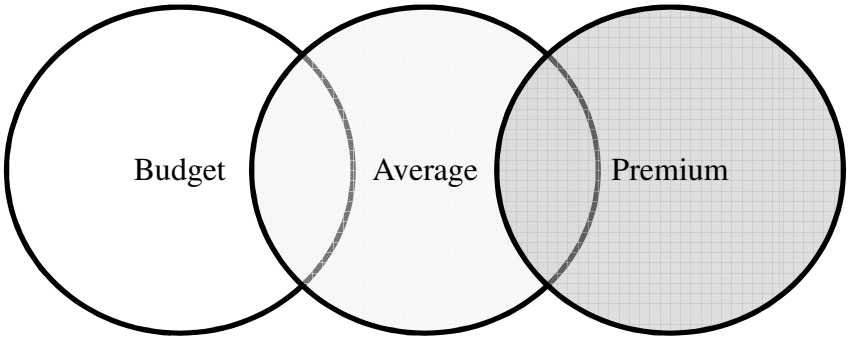
The error term is Mean Square (Error) = .002.

a. *Uses Harmonic Mean Sample Size = 270.000.*
b. *The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.*
c. *Alpha = .05.*

In addition, Figure 3-4 demonstrates that when substitution occurs it is generally because customers thinks they can purchase a similar quality product for a lower price. Therefore, the less expensive budget quality product cannibalizes the average quality product and the average quality product cannibalizes demand of the premium quality product. It is however, important to

realize that due to price differentials, it would be rare for the budget quality product to cannibalize a premium product.

Figure 3-4, Quality Attribute Cannibalization



3.4.1.4.2 Niche encroachment

Niche encroachment influences preference attributes' demand. Niche encroachment means that a firm has released a product with a preference attribute closer to some consumers' pre-existing preferences than an existing product. For instance, a customer may want a Satina[3] refrigerator, but is satisfied with a stainless steel refrigerator. However, once the Satina refrigerator is released, the consumer who would have purchased the stainless refrigerator will now purchase Satina. The cannibalization is therefore not for a different model of refrigerator or for a better refrigerator, but simply for a different color of the same model.

Once again, the simulation models three levels of niche encroachment: low, moderate and high. Low encroachment, taking 15 percent of existing demand, occurs when most

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[3] Satina is vinyl clad metal finish that imitates the look of stainless steel. Some consumers prefer it to Stainless Steel because it is less expensive and does not show fingerprints.

customers have fixed preferences. In this case, a consumer's preferences are fixed on stainless steel and the consumer will generally not buy outside of their niche. Moderate encroachment, 30 percent of existing demand, occurs when consumers have average pre-existing preferences (Chernev 2003). High encroachment, 75 percent of demand, occurs when customers have flexible preferences and will therefore usually buy whatever color is in stock. Therefore, preference attribute cannibalization is modeled as low (15 percent) when preference attributes are fixed, moderate (30 percent) when preference attributes are average, and high (75 percent) when preference attributes are flexible.

The low, moderate, and high settings were based not only on the literature, but also on sensitivity analysis using post hoc tests of the niche encroachment parameter. As seen in Figure 3-5, 15 percent is homogeneous with zero percent and 75 percent generally takes in high values. 30 percent was used as a moderate value because it generally fell in with other moderate values.

Figure 3-5, Preference Attribute Sensitivity Analysis

COST				
Niche Encroachment Percentage	**Number**	Subset		
		1	2	3
0	270	$23,913,851		
15	270	$24,188,440	$24,188,440	
30	270	$24,949,122	$24,949,122	$24,949,122
45	270	$25,376,609	$25,376,609	$25,376,609
60	270	$25,700,647	$25,700,647	$25,700,647
75	270	$25,987,871	$25,987,871	$25,987,871

Figure 3-5 (continued)

90	270		$26,290,892	$26,290,892
100	270			$26,457,879
Significance		.066	.059	.393

Tukey HSD

Means for groups in homogeneous subsets are displayed based on observed means.
The error term is Mean Square (Error) = 67443568055619.300.

a. *Uses Harmonic Mean Sample Size = 270.000.*
b. *The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.*
c. *Alpha = .05.*

SERVICE LEVEL					
Niche Encroachment Percentage	**Number**	**Subset**			
		1	2	3	4
0	270	.7082			
15	270	.7160			
30	270	.7427	.7427		
45	270		.7567	.7567	
60	270		.7709	.7709	.7709
75	270			.7839	.7839
90	270				.7972
100	270				.8028
Significance		.066	.059	.393	

Figure 3-5 (continued)

Tukey HSD

Means for groups in homogeneous subsets are displayed based on observed means.
The error term is Mean Square (Error) = 67443568055619.300.

a. Uses Harmonic Mean Sample Size = 270.000.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. *Alpha = .05.*

REVENUE			
Niche Encroachment Percentage	**Number**	**Subset**	
		1	2
0	270	$27,348,960	
15	270	$27,610,989	
30	270	$28,393,439	$28,393,439
45	270	$28,782,384	$28,782,384
60	270	$29,156,238	$29,156,238
75	270	$29,540,609	$29,540,609
90	270		$29,922,466
100	270		$30,062,967
Significance			

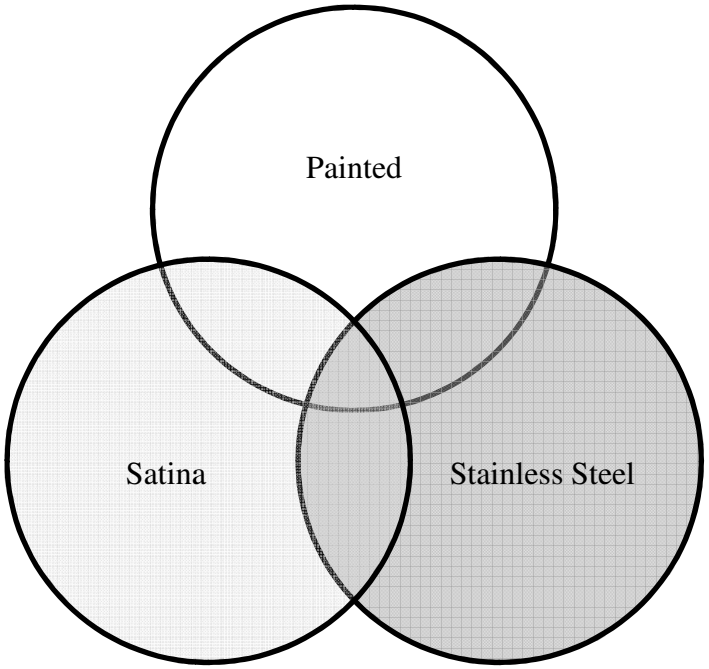
Tukey HSD

Means for groups in homogeneous subsets are displayed based on observed means.
The error term is Mean Square (Error) = 67443568055619.300.

a. Uses Harmonic Mean Sample Size = 270.000.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.
c. Alpha = .05.

In addition, Figure 3-6 demonstrates that niche encroachment of preference attributes may take demand from any other preference attribute. Since preference attributes relate to individual preference, a customer that purchased a painted refrigerator may have actually wanted a stainless refrigerator or a Satina refrigerator. The result is that niche encroachment takes place with all colors within the same quality attribute level.

Figure 3-6, Preference Attribute Cannibalization



3.4.1.5 Preference attribute demand variability

Preference attributes also influence demand variance. In this simulation, two levels of preference attributes are modeled. In the first level, preference attributes are predictable and fixed. Since these preferences are unlikely to vary, each of the three colors is assigned to consumers with an equal probability. In the second level, consumers have no pre-existing preferences, and therefore are randomly assigned one of three colors.

3.4.2 Fixed parameters

The experimental design is controlled using process flows and parametric values. Six different fixed parameters, modeled as supply chain processes, occur within the simulation. The following sections discuss the processes and related parameters: supply, production, ordering, storage, transportation, and delay.

3.4.2.1 Supply

Parts procurement was modeled after the supply chain of the appliance manufacturer. There are two separate suppliers in the simulation. One supplier produces quality attributes and a separate supplier provides preference attributes. The suppliers are modeled as unconstrained suppliers located in a foreign country. Material costs are modeled in the simulation.

The component parts costs are estimated based on their contribution to the finished good. The simulation creates costs for supplies by multiplying the suggested retail prices listed by the manufacturer (Archer 2009) with the cost of goods sold suggested by the firm's 10k, Annual Report from the years 2005 through 2007 (http://sec.edgar-online.com/whirlpool-corp-de/10-k-annual-report/2008/02/22/Section29.aspx). Randall and Ulrich (2001) suggest that preference attributes are relatively inexpensive. There, the simulation assigns preference attributes ten percent of the total costs of goods sold. Quality attributes orders are assigned the remaining 90 percent of cost of goods sold. All supply orders receive a 15 percent discount when orders exceed five days' supply. This discounting suggests that suppliers experience some economies of scale with larger quantities and pass these savings onto manufacturers.

3.4.2.2 Production

Since the purpose of the simulation is to test consumer behavior and not production capacities, capacity is modeled as an unconstrained "black box." No economies of scale are modeled to de-emphasize production costs. Modeling production as an agile system without penalties for small batches is consistent with flexible manufacturing systems that do not penalize product variety (MacDuffie et al. 1996; Kekre and Srinivasan 1990; and Netessine and Taylor 2002). Furthermore, modeling unconstrained production emphasizes the inventory holding costs rather than emphasizing constrained production. Since the manufacturer's factory operates on a make to stock strategy, the manufacturer holds extensive inventory in their FDC (16 days). This results in high inventory carrying costs and buffers any constraints on production.

3.4.2.3 Ordering

The refrigerator company uses an "order up to" system with a continuous review cycle in all of its storage facilities. Under this strategy, each node of the supply chain checks its inventory daily. When a node hits an inventory level equal to or less than the lead-time from its upstream partner, an order to meet a specified number of days supply is sent (Nyaga 2006). When sufficient inventory does not exist to satisfy an order, the simulation ships the total amount in stock and records the partial order as a unit stock-out. If the reorder point is not met another order is generated. This particular strategy requires all supply chain nodes to hold extensive safety stock and to maintain high service levels.

3.4.2.4 Storage

Storage refers to the parameters governing inventory-carrying cost. Inventory carrying cost is generally understood to be the cost of the average amount of inventory in a system multiplied by an inventory carrying cost (ICC) percentage (Bowersox, Closs, and Cooper 2007).

The simulation calculates the average daily inventory at the end of each replication. In this case, ICC is estimated at twenty percent of the value of average inventory, a conservative estimate based on ICC percentages published in textbooks (Bowersox, Closs, and Cooper 2007; Coyle, Bardi and Langley 2003). The cost of inventory at various nodes of the supply chain depends on the value added to the product at that point in time. For instance, materials would have greater value once they are assembled. The overall inventory carrying costs is then the sum of the inventory carrying costs for the supplied goods, the FDC, and the RDC.

3.4.2.5 Transportation

Another simulated process is transportation. Transportation is modeled as transfers between suppliers and manufacturers and between FDCs and RDCs. Table 3-6 highlights the two parameters that model transfers: transit times and costs.

Table 3-6, Transportation Time and Cost

	Supplier to Factory	Factory DC to Regional DC
Transit Time (Days)	TRIA (6,7,8)	TRIA (1,2,3)
Transit Cost per Unit	$30 for quality attributes $3 for preference attributes	$60

The simulation models two specific lead-times: transit time from suppliers to manufacturers, and transit time from manufacturers to distributors. The timelines to ship materials to the factory are based on the studied manufacturer's supply chain. All transit times are based on estimates from either freightquote.com or freight88.com for a truckload or shipment of 25 refrigerators. Truckload times and rates were used because the refrigerator company rarely used LTL shipments (Archer 2009).

The lead-time of each shipment was calculated using actual freight quotes. The triangular distribution and stochastic lead times are used to represent the average transportation times and the time variances quoted for transportation. Transit time from the supplier to the factory is modeled in the simulation as TRIA (six, seven, eight) or the estimated rail times between Monterey, Mexico and Iowa (www.freightquote.com). The FDC to RDC shipment was based on transferring freight from an FDC in Iowa to a RDC in North Carolina. The shortest possible transit time for a truckload shipment from the FDC to the RDC was one day, the longest was three days, and the most frequently quoted was two days. This was represented in the simulation as TRIA (one, two, and three).

The managers suggested that material parts shipment was always done on a full container load basis. Therefore, the cost to ship quality attribute parts (e.g. – refrigerator compartments) to the factory was based on a forty foot standard trailer going rail from Monterrey Mexico to Amana Iowa (freightquote.com). The simulation assumes that without doors and with reduced collapsible parts, a shipper could double the number of component parts going into the trailer. Therefore, the total cost of $1,500 was split between 50 refrigerators for a unit cost of $30. Preference attributes on the other hand tend to be much smaller than quality attributes. Therefore one could expect more per finished unit equivalents of preference attributes to be shipped in a trailer than quality attributes. The simulation assumes that shipping preference attributes is only 10 percent of the cost of shipping quality attributes or three dollars for each refrigerator. The lowest estimated cost of going from the FDC in Iowa to the RDC in North Carolina was $1,500. The simulation therefore uses a cost of shipping finished goods between the FDC and the RDC to be $60 per unit ($1,500 quote / 25 units).

3.4.2.6 Delay

When purchasing refrigerators, consumers often find that the model or color they desire is not in stock. It is common practice in the industry to wait for several days for at-home delivery of the desired items. Customer service representatives from Lowes, Home Depot and Best Buy all verified that their policies generally require up to 14 days for home delivery from the RDC. Therefore, if a retailer sent an order to the RDC and the item was not in stock, the order will be resent to that DC each day for 14 days. If the item comes into stock anytime during those 14 days, the order is satisfied. If the item does not come into stock, it is recorded as a stock-out.

3.4.3 Dependent variables

The five dependent variables explored in this research are revenue, cost, profit, service level, and market share. Revenue is calculated as the price multiplied by the volume sold. Cost measures include the cost of goods sold, transportation cost, and inventory cost. Profit is the difference between revenue and price. Service levels are evaluated through order fill rates. Market share is the portion of total demand captured by the target firm in the simulation. These performance measures are widely used in extant literature and important when considering total cost performance (Chow, Heaver, and Henriksson 1994; Glasserman and Wang 1998; Doloi and Jaafari 2002).

3.4.3.1 Supply chain profitability revenue

Profitability is calculated by subtracting total cost from revenue. Profitability examines the trade-off between reducing costs and increasing revenues. If revenues increase and costs simultaneously increase, the marginal value of variety can be negligible. If costs decrease while revenues increase, the added variety has added value. If revenues decrease while costs increase,

the product variety has cost the firm. Because of these relationships, the marginal value of adding the next attribute is the unit of analysis within profitability. This measure is found by comparing the per unit profit as each new attribute is added.

3.4.3.2 Total Cost

Total cost is the second measure calculated by the simulation. The simulation aggregates costs of goods sold, inventory carrying costs, and transportation costs to determine the total cost of variety.

Cost of goods sold relates to the total cost for materials from suppliers. This cost has been previously discussed, but it is important to note that larger orders earn greater economies of scale. Therefore, costs should be lower on a per unit basis when variety is lower. This results because demand is concentrated on single types of supplies and materials rather than fragmented over several differing types of materials and supplies.

Inventory carrying costs are also an effective measure of market mediation costs (Randall and Ulrich 2004). Greater variation in demand makes predicting average demand more difficult. Since inventory replenishment and holding decisions in the simulation are based on average demand, inventory-carrying costs provide strong indicators for the cost of variety.

Transportation cost is used in the simulation as another way to determine the impact of demand volume. When volume is concentrated on a single SKU rather than on several SKUs, one expects that fewer shipments will be needed to keep satisfactory inventory levels. The expected result is that transportation costs increase as product variety increases.

3.4.3.3 Service level

Lower service levels result from a firm's difficulty in balancing demand and supply. Order-fill rates indicate how well a company is able to complete customer orders. An order with

an item missing is considered incomplete. Therefore, order-fill rates measure complete shipments as a percentage of total orders. This measure is captured at the final exchange between customer and supply chain. Order fill rates provide evidence of a firm's ability to fulfill customers' expectations.

3.4.3.4 Market share

Market share is calculated as the number of sales for the target brand divided by the total number of sales for the market. The market share rate indicates how much a firm owns of the total market for the particular product line. The system is modeled as a duopoly, so any demand not satisfied by the target brand goes to the competitor. In addition, depending on the conditions set in the simulation, some demand automatically goes to the competitor. Market share provides evidence of a firm's ability to differentiate themselves from competitors. Table 3-7 offers the different strategies that may be at work when the relationships between profit and market share are considered.

Table 3-7, Profit and Market Share Variety Strategies

	Increased Marginal Profit	**Decreased Marginal Profit**
Increase Market Share	Best Variety	Customer Seeking Variety
Decreased Market Share	Customer Rationalizing Variety	Bad Variety

3.5 Data analysis

After all data is collected, analysis will be done to determine differences between scenarios. This section describes and rationalizes the techniques used to analyze the experimental data.

Multivariate analysis of variance (MANOVA) is used to evaluate the experimental main effects and interaction effects of the scenarios. MANOVA is a dependence technique that measures differences for two or more dependent variables based on a set of categorical variables acting as independent variables (Hair et al. 1998). Therefore, MANOVA enables comparison of the experimental conditions in the set of dependent variables.

MANOVA is used for an additional reason. The research also delves into whether more than one dependent variable (e.g. – revenue) changed at the same magnitude as another dependent variable (e.g. – cost). Post hoc tests such as the Scheffe method (Hair 1998: page 356) are used to determine the magnitude of differences between dependent variables. Therefore, MANOVA is a fitting analysis technique to answer the research hypotheses.

CHAPTER IV: RESULTS

4.0 Introduction

This chapter discusses the results of the simulation experiments and statistical analyses. The first section reviews the critical assumptions for using MANOVA, discusses the effects of violating MANOVA assumptions, and reviews the study data's conformity to these assumptions. The second section provides the multivariate and univariate results from the simulation studies. The third section reviews the level of support for each hypothesis. The final section discusses the implications of the results.

4.1 Conformity to MANOVA assumptions

MANOVA enables comparison of groups formed by categorical independent variables on interval dependent variables (Hair et al. 1998). There are four assumptions regarding data conformity that must be tested in order for MANOVA validity:

1. Units are randomly sampled from the population.
2. Observations are statistically independent from one another.
3. Dependent variables must follow a multivariate normal distribution within each group.

   If data is non-normal, departures from normality should not be due to outliers. (Hair et al. 1998: page 348-9; Bray and Maxwell 1985).
4. The variance-covariance matrices should be equal for all treatment groups.

Even though these assumptions are mathematical requirements for MANOVA; datasets seldom meet each assumption precisely (Bray and Maxwell 1985). Fortunately, MANOVA is

relatively robust to violations of all except the first two assumptions. The following sections discuss the validity of these assumptions with respect to the sample data.

4.1.1 Random sampling, statistical independence

The data consists of all the scenarios generated from a full factorial design of the six independent variables. There were 648 (9x3x3x2x2x2) scenarios run. Each scenario included 30 replications producing a large sample size of 19,440. The experimental design used independent scenarios and independent replications (through random seeds) for data generation. This satisfied the assumptions for random sampling from the population and for statistical independence between scenarios.

4.1.2 Tests of normality and outlier analysis

Tests demonstrating univariate normality of each dependent variable usually suffice as a sufficient test of multivariate normality. The most frequent normality test is the Komogorov-Smirnov test which examines whether the distribution of dependent variables is equivalent to the standard normal distribution. Table 4-1 shows the results of the test which rejects the null hypothesis that the dependent variables and the standard normal distributions are the same.

Table 4-1, Kolmogorov – Smirnov Test of Normality

Kolmogorov – Smirnov Test of Normality with Lilliefors Significance Correction			
	Statistic	**Degrees of Freedom**	**Significance**
COST	0.076	19,440	.000
REVENUE	0.075	19,440	.000
PROFIT	0.067	19,440	.000
SERVICE LEVEL	0.043	19,440	.000
MARKET SHARE	0.137	19,440	.000

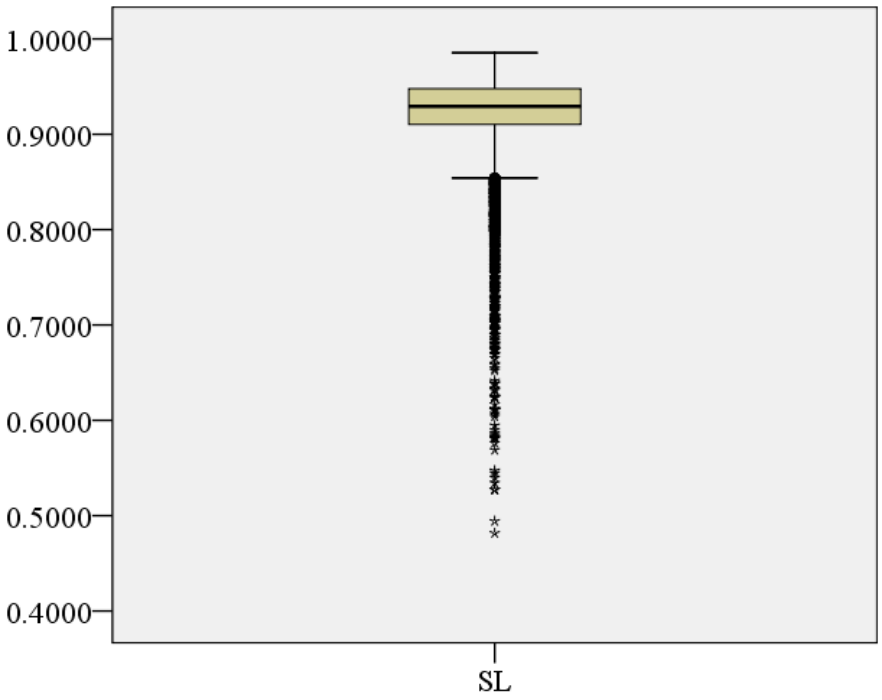
In addition to the Kolmogorov-Smirnov Test, the descriptive statistics show that for the Service Level (SL) variable, significant departures from normality exist. This is not unexpected. Service level, because it is bounded at 100 percent at the upper levels, is expected to be a non-normal variable. This is particularly true for scenarios with high service levels. This truncates the upper service level tail while making lower service level tails look like outliers. Nevertheless, Hair et al. (1998: page 38) suggest that skew statistics outside the range of a negative one to one are substantially skewed. The skewness for SL is -2.79, meaning the data is substantially biased towards lower service levels. Additionally, the SL data is remarkably peaked. West, Finch, and Curran (1995) recommend concern if kurtosis is greater than seven. Table 4-2 shows SL kurtosis is 14.263. Although the F statistic is very robust to deviations from skew, it is sensitive to kurtosis departures and can be greatly influenced by outliers (Lindeman 1974). Therefore, the research next explored the outliers in the SL data.

Table 4-2, Descriptive Statistics for Dependent Variables

	#	Mean	Standard Deviation	Skew	Standard Error	Kurtosis	Std Error
Cost	19,440	$20,314,970	$6,256,190	0.589	0.018	-0.024	0.035
Revenue	19,440	$22,676,920	$6,857,483	0.460	0.018	-0.193	0.035
Profit	19,440	$2,325,399	$1,170,603	0.159	0.018	-0.504	0.035
Service Level	19,440	0.923	0.042	-2.790	0.018	14.263	0.035
Service Level (Outliers Replaced)	19,440	0.928	0.029	-0.677	0.018	0.748	0.035
Market Share	19,440	0.515	0.146	0.605	0.018	-0.652	0.035

A boxplot is used to evaluate outliers for the service level (SL) variable. The boxplot graphically demonstrates the SL distribution by displaying the median, quartiles, minimum, maximum, and outliers. Outliers represent data points that reside more than 1.5 quartiles away from the end of the box (Hair et al. 1998: page 42). Outliers create an impact on multivariate analysis that is disproportionate to other data. This greatly increases the likelihood of type I error, increases error variance, and reduces the power of statistical tests (Osbourne and Overbay 2004; Hair et al. 1998). The boxplot shown in Figure 4-2 demonstrates that many data points fall below the lower quartile.

Figure 4-1, Boxplot for Service Level



A review of the entire dataset shows that outlying replications represented a rare departure from other replications within the same scenario. In these rare cases, the simulated supply chain could not catch up with stocked-out demand and quickly spiraled into low service levels. The conclusion was that these data points represent extreme but valuable data. In the real-world system, a "death spiral" such as the one described can quickly decimate customer service. Therefore, additional analysis was done regarding the feasibility of retaining the outlying SL data.

There were eleven scenarios where removing the outliers would cause the scenario data to have fewer than 24 replications and give less than a 95 percent confidence interval. Table 4-3 shows these 11 scenarios with the first six columns representing the settings for the particular

scenario and the last column showing how many replications would be left if the outliers were removed.

Table 4-3, Scenarios with Low Confidence after Outliers Removed

SKUs	Demand	Quality Variance	Sub	Preference Variance	Niche Encroachment	Replications Remaining
8	1	1	15	1	75	16
8	1	1	15	2	75	17
8	1	2	15	1	75	17
8	1	1	15	1	15	18
8	1	1	15	1	30	20
9	1	1	15	1	15	21
9	1	1	15	1	30	21
9	1	1	15	1	75	21
8	1	1	15	2	30	23
8	1	2	15	2	30	23
8	1	2	15	2	75	23
9	1	1	15	2	15	23
9	1	1	15	2	30	23
9	1	1	15	2	75	23

To test the MANOVA sensitivity to removing the outliers, the SL outliers (554 data points representing 2.85 percent of the SL data) were selectively removed from the dataset. Table 4-2 demonstrates that the removal of the SL outliers brought the SL skew and kurtosis into acceptable ranges. MANOVA analysis was performed for both the complete dataset and the dataset with the SL outliers removed. No significant differences were observed between MANOVA outcomes for the two datasets. Nevertheless, because SL values in the dataset are non-normal, readers should assume diminished confidence in univariate SL analysis.

In conclusion, the weak assumption of normality is violated by the dataset. However, the benign impact of the SL outliers and dataset size satisfy the requirements for multivariate analysis.

4.1.3 Variance-Covariance matrices

Levene's test of homogeneity of variance is used to test the weak assumption that each category of independent variables has similar variance. Levene's test is significant for all dependent variables at the $p<.000$, which indicates that data fails the assumption of equal variances. A second test, the multivariate Box's M test, is a test for the equality of the group covariance matrices. For sufficiently large samples, a non-significant p-value means that there is sufficient evidence that the matrices differ. The null hypothesis that the observed covariance matrices of the dependent variables are equal across groups is rejected at $p<.001$. Therefore the data violates the weak assumptions of variance-covariance matrices.

As a final test, general linear hypotheses models assume linearity among variables. It is very important to test for non-linear relationships. To determine if measures are significantly correlated, Bartlett's test of sphericity was used. The test examines correlations among all dependent variables and determines whether, collectively, significant intercorrelation exists. Bartlett's indicates that significant intercorrelations exist (Chi-Square = 245,015.645 with ten degrees of freedom and significance < .001), justifying the use of MANOVA.

The decision to proceed with MANOVA for significance testing was made for three reasons. First, the most stringent assumptions of MANOVA were met through the experimental design. Second, MANOVA is robust to non-normality. Because SL outliers have been tested, it is assumed MANOVA will not be adversely influenced by non-normality. Finally, because SL outliers were retained rather than removed, all treatment groups have equal sample size making

the robustness of the analysis stronger despite violations to equal variance-covariance assumptions.

4.2 Multivariate analysis

In this study, six independent variables were tested: stock keeping units (SKU - nine levels), substitution (SUB - three levels), niche encroachment (NICHE - three levels), increasing/decreasing demand (DEM - two levels), preference attribute variance (PrefVar - two levels), and quality attribute variance (QualVar - two levels). There were five dependent variables: Revenue, Cost, Profit, Service Level, and Market Share. MANOVA tests of multivariate analysis were done using the SPSS, PASW Statistics 18 package.

SPSS provides four unique tests of multivariate differences between groups: Wilkes' Lambda, Hotelling's trace, Roy's Largest Root, and Pillai's Trace. Wilkes' Lambda examines whether groups are different without concern for linear combinations differences of the dependent variables. Wilkes' Lambda is appropriate when all MANOVA assumptions appear to be met. Hotelling's Trace differs only in minor ways from Wilkes' Lambda and is safely ignored in most cases. Roy's Largest Root measures group difference on only the first canonical root. It is most appropriate when all dependent variables are strongly intercorrelated on a single dimension. However, Roy's Largest Root is the technique most severely affected by violations of MANOVA assumptions. Pillai's Trace is the measure used in this study. It is the sum of the variance that can be explained by the calculation of discriminate variables. It is also the most robust of the tests when MANOVA assumptions are not met. Therefore, Pillai's trace is reported in Table 4-4.

The multivariate test results show that all main effects and interaction effects for the dependent multivariate are significant. This is probably the result of the large sample size which

can cause even trivial effects to have significant p-values (Levine and Hullett 2007). Therefore, Table 4-4 shows only the interactions and the dependent variables with at least a small effect size.

Table 4-5 has seven columns. The "effect" column shows independent variables and the interactions between them. The next column shows the "F-ratio." F-ratio focuses on independent variables and seeks to answer whether each independent variable has a significant effect. A larger F statistic signifies a greater likelihood that mean differences are due to something other than chance. The "degrees of freedom" columns indicate the number used to obtain observed significance levels of the multivariate test.

Table 4-4, Multivariate Results

Multivariate Tests						
Effect	**F**	**Hypothesis df**	**Error df**	**Sig**	**Partial η^2**	**Observed Power**
SKU	1,681.56	40	93,960	0.000	0.417***	1
Niche Encroachment	2,473.97	10	37,578	0.000	0.397***	1
Preference Variance	183.35	5	18,788	0.000	0.047 **	1
Increasing Demand	738,522.61	5	18,788	0.000	0.995***	1
Substitution	3,129.47	10	37,578	0.000	0.454***	1
SKU * Niche Encroachment	286.52	80	93,960	0.000	0.196***	1
SKU * Increasing Demand	594.01	40	93,960	0.000	0.202***	1
SKU * Substitution	590.76	80	93,960	0.000	0.335***	1
Increasing Demand * Substitution	332.57	10	37,578	0.000	0.081 **	1
SKU * Increasing Demand * Substitution	87.32	80	93,960	0.000	0.069 **	1
SKU * Substitution * Niche Encroachment	8.04	160	93,960	0.000	0.014 *	1

The fifth column indicates "significance" (p-value). This is the conditional probability that a relationship as strong as the one observed in the data would be present if the null hypotheses were true (probability of making a Type I error). Typically, results that yield $p<.05$ are considered borderline significant while lower p-values, i.e., $p<.001$, are considered highly significant. All results in this case are highly significant.

The sixth column shows "Partial Eta Squared" (partial η^2). This measure is the proportion of total variability in the dependent multivariate that is accounted for by variation in the independent variable. It also excludes other factors from total non-error variation (Cohen 1973; Levine and Hullett 2002; Pierce et al. 2004). Partial η^2 measures effect size or the magnitude of the relationship. Partial η^2 values range from zero to one, with larger values indicating stronger effect. Cohen (1988) suggests that certain benchmarks exist for effect size in behavioral sciences research with 0.20 suggesting a small but significant effect, 0.50 suggesting a medium effect, and 0.80 suggesting a very large effect. However, these benchmarks have been criticized for being overly conservative and others have been offered. For instance, Kittler, Menard and Phillips (2007) suggest more liberal rules for the medical sciences with small = 0.01, medium = 0.06, and large = 0.14. Since simulation is able to control some extraneous variance, these more liberal benchmarks of partial η^2 were applied in this study.

Four of the six main effects (SKU, IncDem, SUB, and Niche) had large effects on the dependent variables. Three interactions (SKU * SUB, SKU * Niche, and SKU * IncDem) also had large effect sizes. The PrefVar main effect, IncDem * Sub, and SKU * IncDem * Sub all had medium-sized effects. SKU * PrefVar, SKU * Sub * PrefVar, and SKU * Sub * Niche all had small-sized effects on the multivariate. For all other variables, although the MANOVA showed that means were significantly different from the null, the effect size was very small. The partial η^2 was below .009, which means the factor by itself accounts for less than one percent of the overall (effect and error) variance.

The last column, observed power, indicates the power of the test or the ability to reject the null hypotheses when it is actually false (chance of making Type II error). High observed power values (i.e., over 0.9) are recommended. All power values are over 0.9.

In MANOVA, the interaction terms represent joint effect and should be examined first. These interaction terms will be followed by a discussion of the main effects.

4.3 Univariate analysis

This section discusses univariate test results for interaction and main effects. Univariate tests evaluate the relationship between independent variable interactions or an independent variable on a single dependent variable. The result is a series of univariate tests. These tests give greater detail into how the independent variable is influencing individual dependent variables.

4.3.1 Univariate results: Four-way and greater interactions

There were no multivariate, four-way, five-way or six-way interactions with even a small effect size. However, univariate analysis shows that for some four-way, five-way, and the six-way interactions, market share showed a small effect. Table 4-5 presents these results.

Table 4-5, Four-way, Five-way, and Six-Way Interaction Univariate Results

Between Effects Tests						
Source	**Dependent Variable**	**F**	**DF**	**Sig**	**Partial η^2**	**Observed Power**
SKU * IncDem * SUB * Niche	Market Share	7.291	32	.000	0.012 *	1.000
SKU * QualVar * SUB * Niche	Market Share	6.821	32	.000	0.011 *	1.000
SKU * SUB * PrefVar * Niche	Market Share	7.471	32	.000	0.013 *	1.000
SKU * IncDem * QualVar * Sub * Niche	Market Share	6.615	32	.000	0.011 *	1.000
SKU * IncDem * Sub * PrefVar * Niche	Market Share	6.655	32	.000	0.011 *	1.000
SKU * QualVar * Sub * PrefVar * Niche	Market Share	6.885	32	.000	0.012 *	1.000
SKU * IncDem * QualVar* Sub * PrefVar * Niche	Market Share	6.838	32	.000	0.012 *	1.000

As can be seen in Table 4-5, these multiple interactions show a fairly consistent pattern. In all cases, the interaction proves both significant and to have a small effect size on market share. This can interpreted as the interaction between preference attributes and quality attributes is mostly realized by a very minor increase in market share.

4.3.2 Univariate results: three-way interactions

The multivariate result for those variables with three-way interactions and at least small effect sizes showed three significant interactions. Table 4-6 presents univariate results for these three-way interactions.

Table 4-6, Three-Way Interaction Univariate Results

Between Effects Tests						
Source	**Dependent Variable**	**F**	**DF**	**Sig**	**Partial η^2**	**Observed Power**
SKU * Increasing Dem * Substitution	COST	41.391	16	.000	0.034 *	1.000
	REV	67.157	16	.000	0.054 *	1.000
	PROFIT	9.037	16	.000	.008	1.000
	SL	2.145	16	.005	.002	.982
	MARKET	25.870	16	.000	0.022 *	1.000
SKU * Substitution * Preference Variance	COST	4.813	16	.000	.004	1.000
	REV	5.589	16	.000	.005	1.000
	PROFIT	2.079	16	.007	.002	.978
	SL	1.844	16	.021	.002	.958
	MARKET	15.646	16	.000	0.013 *	1.000
SKU * Subsitution * Niche Encroachment	COST	2.755	32	.000	.005	1.000
	REV	3.100	32	.000	.005	1.000
	PROFIT	.988	32	.486	.002	.905
	SL	.648	32	.937	.001	.687
	MARKET	10.533	32	.000	0.018 *	1.000
*** - Large effect size, ** - Medium effect size, * - Small effect size						

Table 4-6 reveals that substitution influences the relationship between SKU and IncDem. Increasing SUB along with increasing SKU and IncDem decreases cost, decreases revenue, and

decreases market share. Profits and service levels are significantly influenced in this interaction as well, but with inconsequential magnitude.

This relationship is very important to this research. Because an item with increasing demand and decreasing substitution relates to the properties of an aligned quality attribute, one can quite clearly see that aligning quality attributes has a positive effect on costs, revenues, and market share as the number of SKUs is increased. A less clear relationship is seen with profitability. Having aligned attributes may make customer decisions easier; but it may not drive profitability or make service level management easier. The plots in Figures 4-2, 4-3, and 4-4 demonstrate this influence on revenue, cost, and market share.

Figure 4-2, SKU * DEM * SUB Affect on Cost

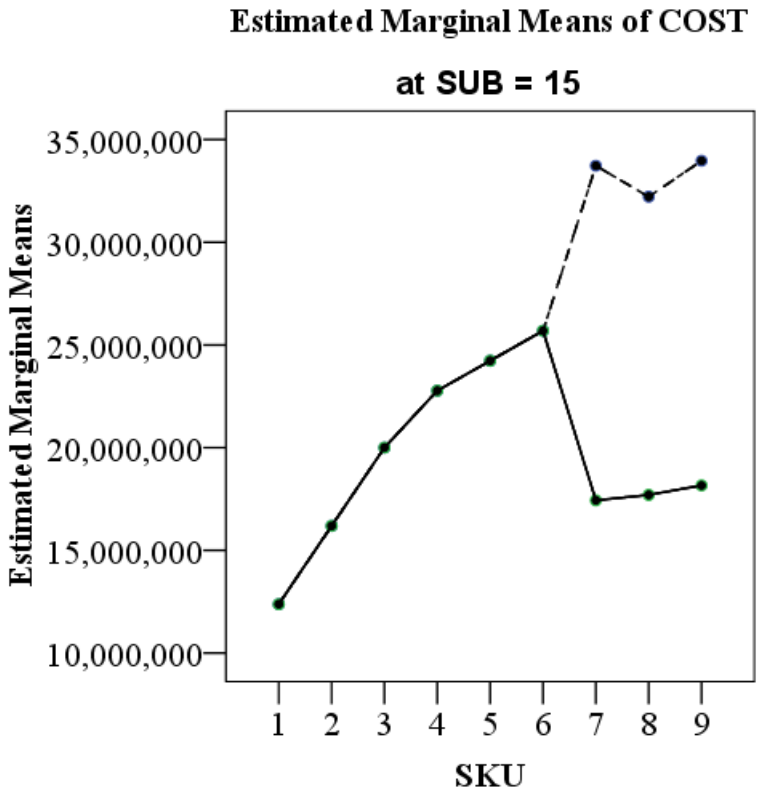


Figure 4-2 (cont'd)

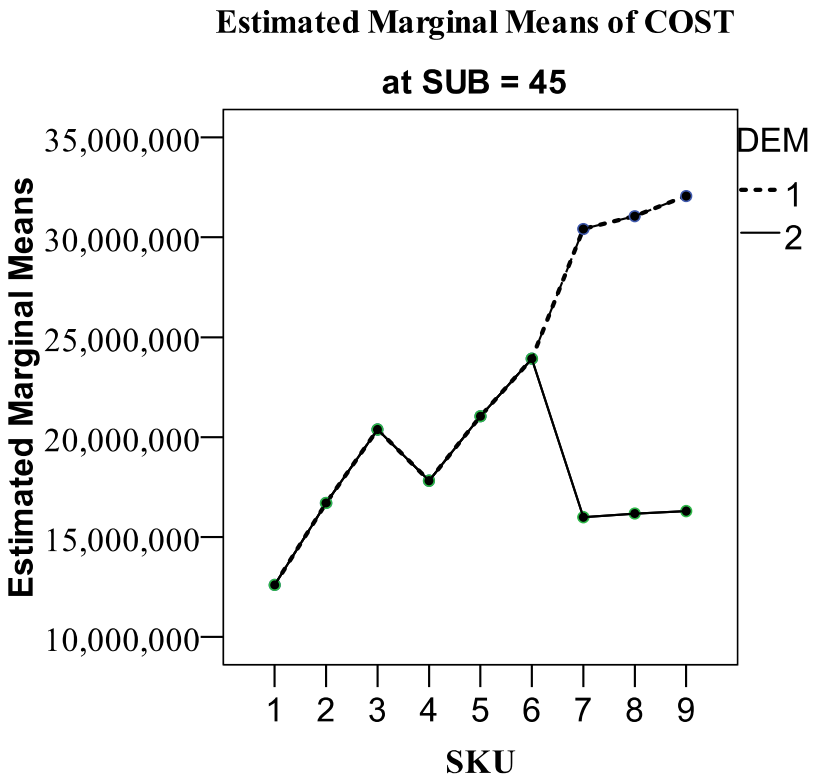


Figure 4-2 (cont'd)

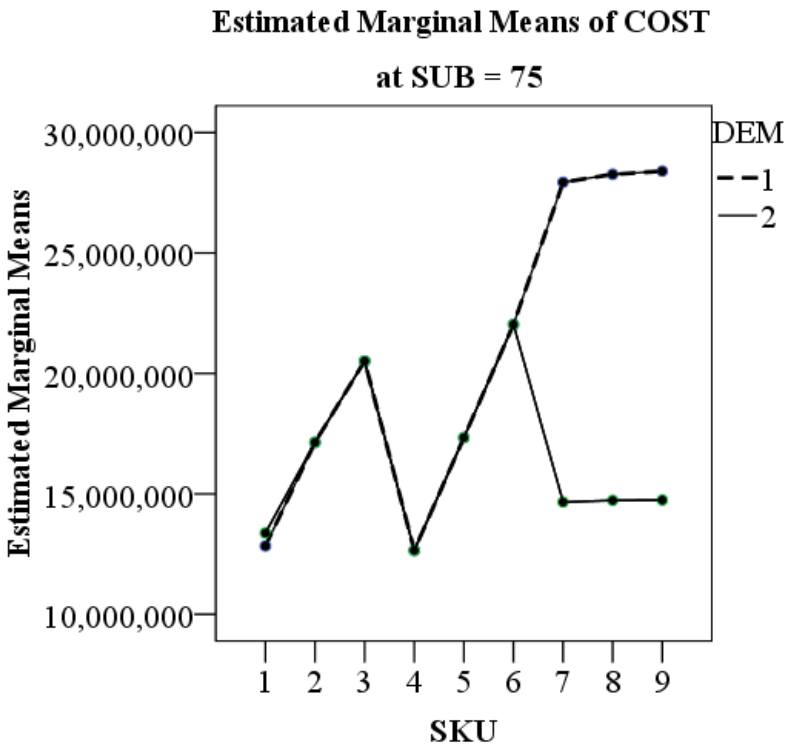


Figure 4-3, SKU * DEM * SUB Affect on Revenue

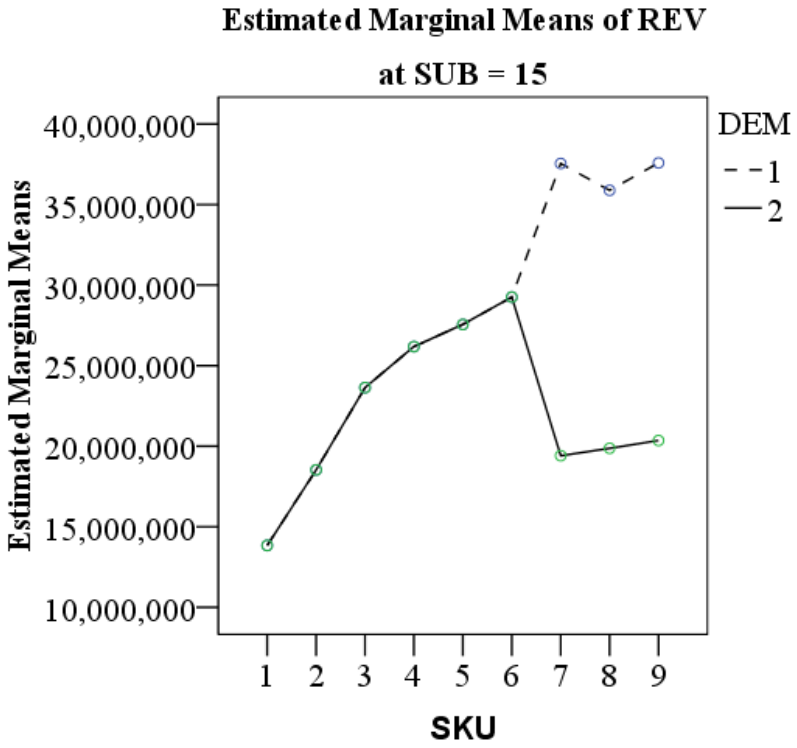


Figure 4-3 (cont'd)

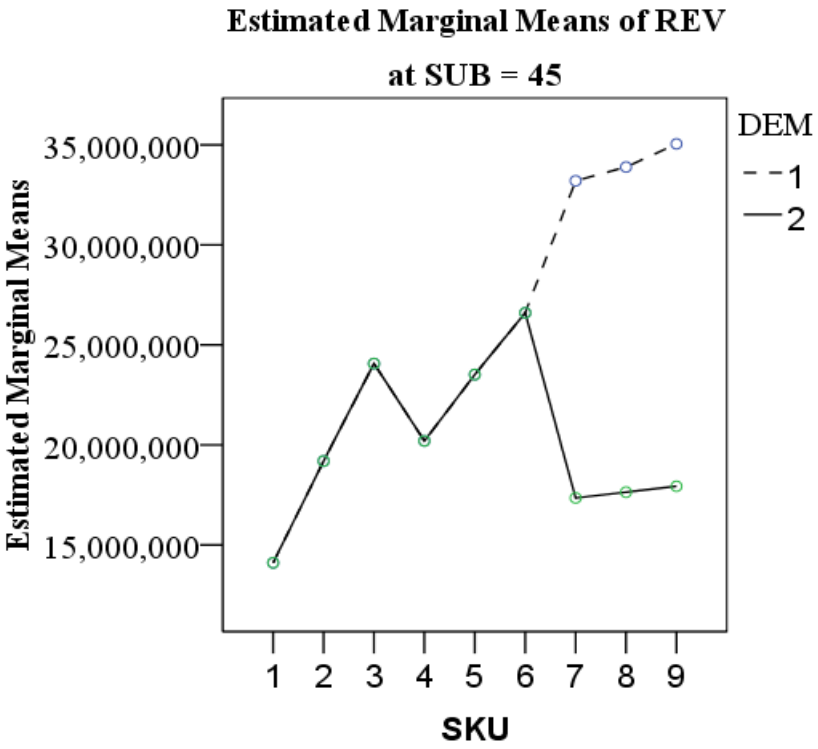


Figure 4-3 (cont'd)

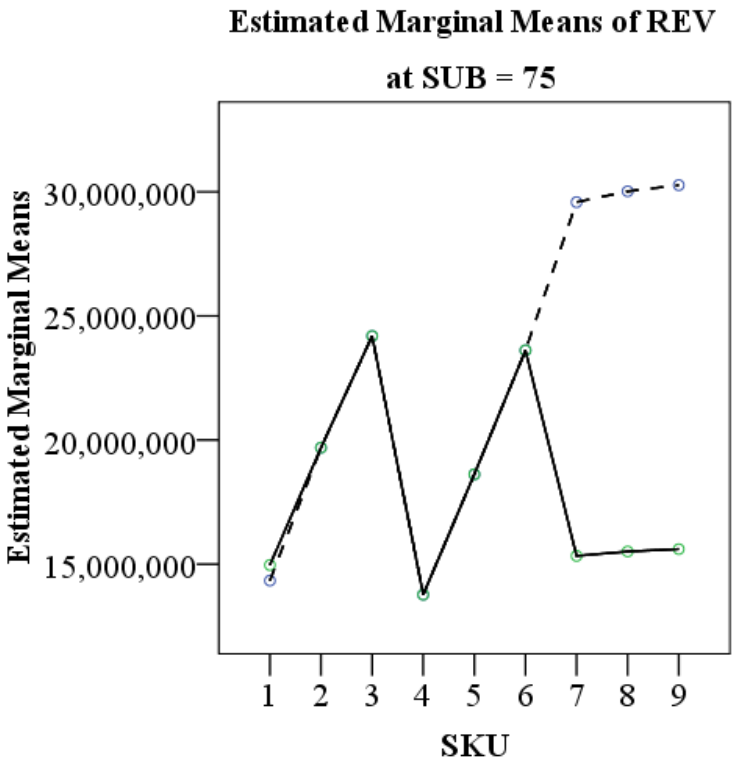


Figure 4-4, SKU * DEM * SUB Affect on Market Share

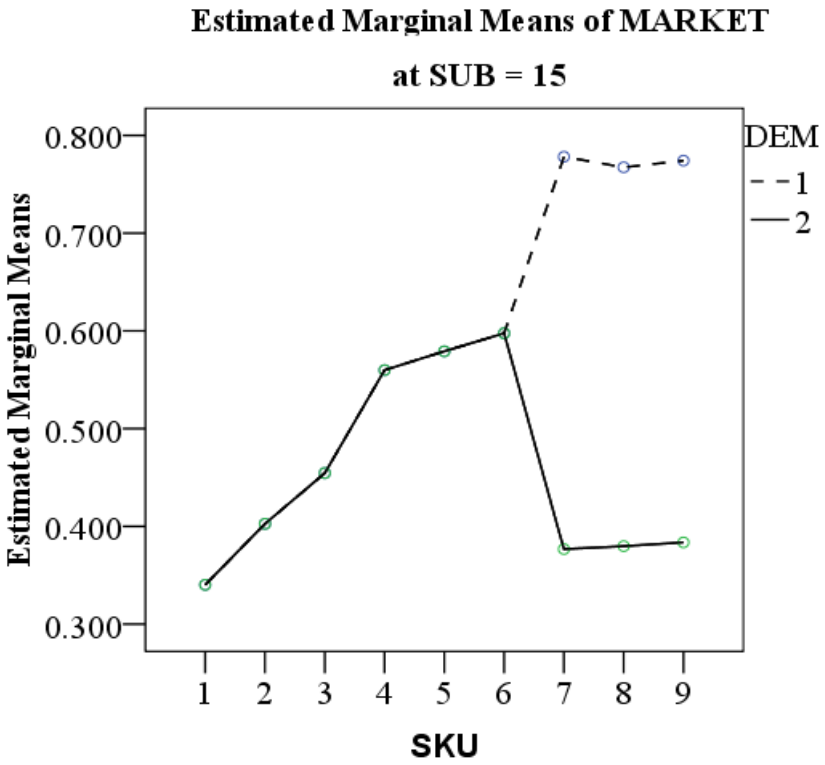


Figure 4-4 (cont'd)

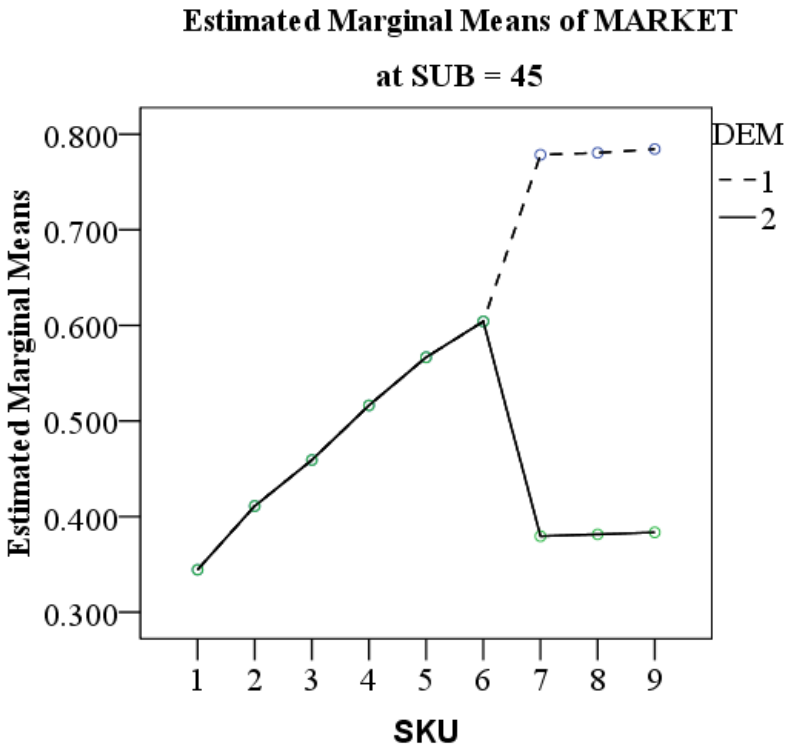
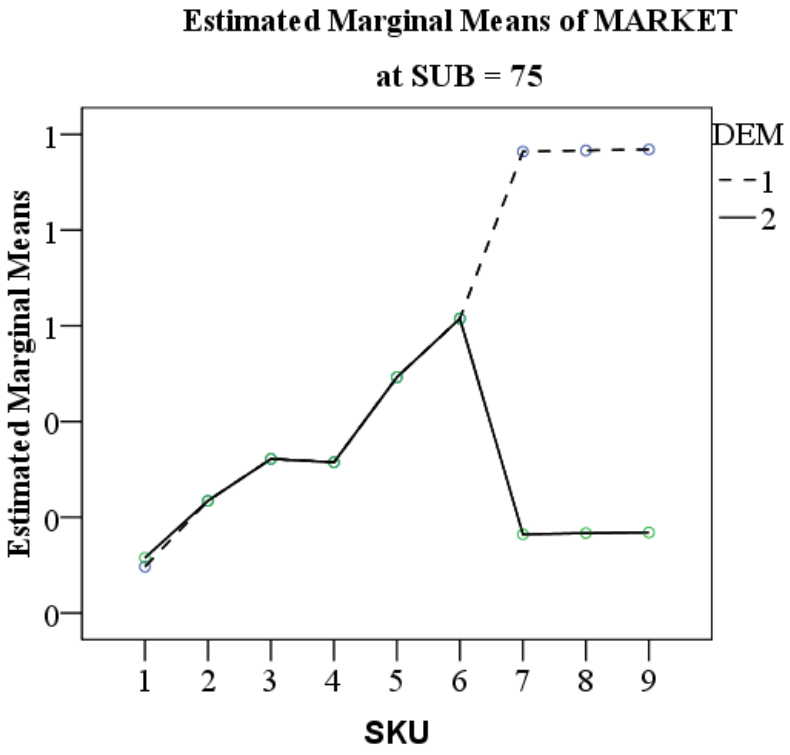


Figure 4-4 (cont'd)



Furthermore, Figures 4-5 and 4-6 demonstrate that both niche encroachment and preference attribute variance influence the relationship between SKU and substitution. When increasing either of these variables during SKU and substitution interaction, a decrease in market share occurs. All other dependent variables are significantly influenced by these interactions as well but with an inconsequential effect size.

Both of these three-way interactions are relevant to this research because they represent the interaction of quality attributes and preference attributes. Preference variance increases (condition two) when consumers do not have pre-existing preferences towards a product. The preference variance interaction shows that when a preference attribute interacts with an aligned quality attribute, that market share is affected. Additionally, the interactions with niche

encroachment, also a condition of preference attributes, show that preference attribute interaction influences quality attributes.

Figure 4-5, SKU * SUB * NICHE Affect on Market Share

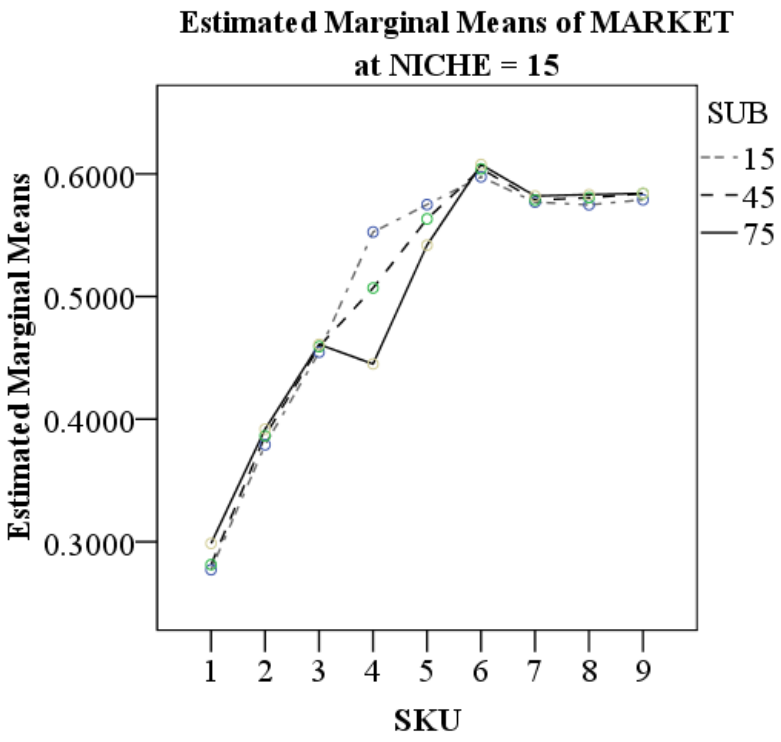


Figure 4-5 (cont'd)

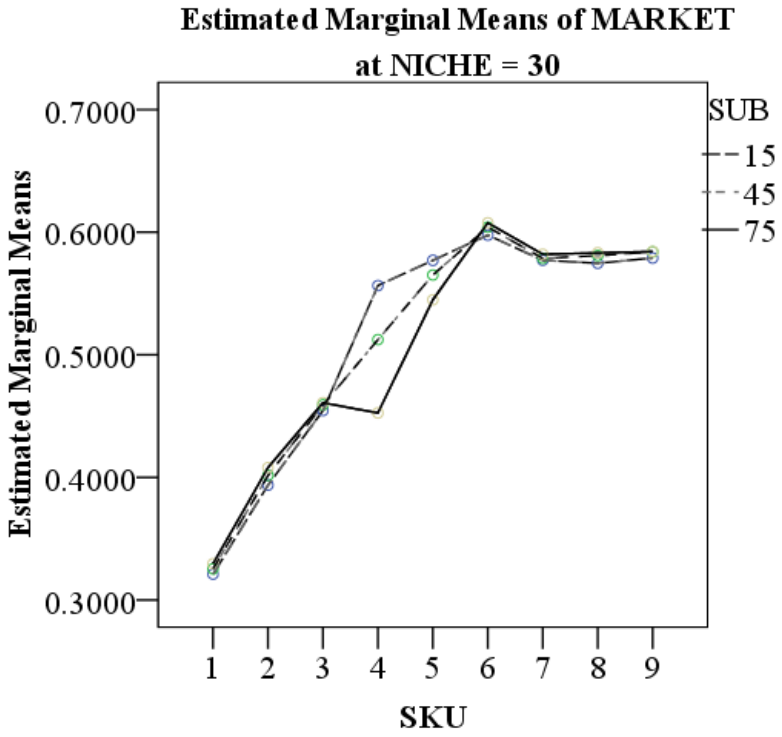


Figure 4-5 (cont'd)

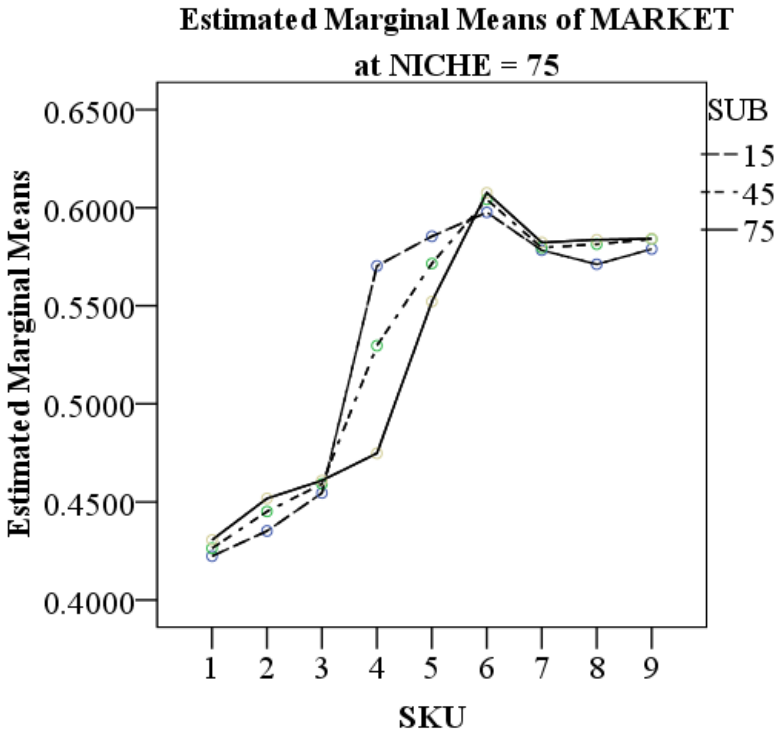


Figure 4-6, SKU * SUB * PrefVar Affect on Market Share

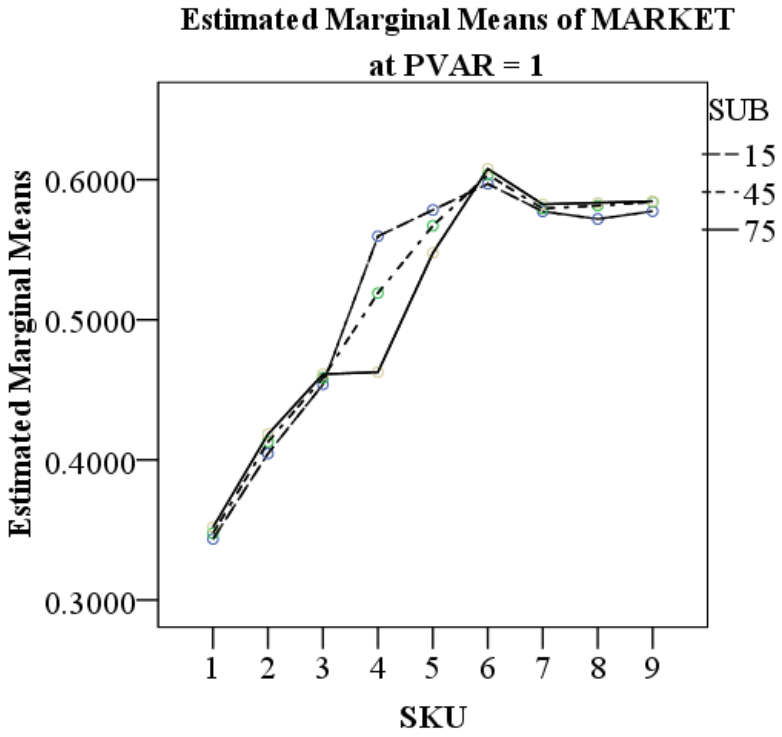
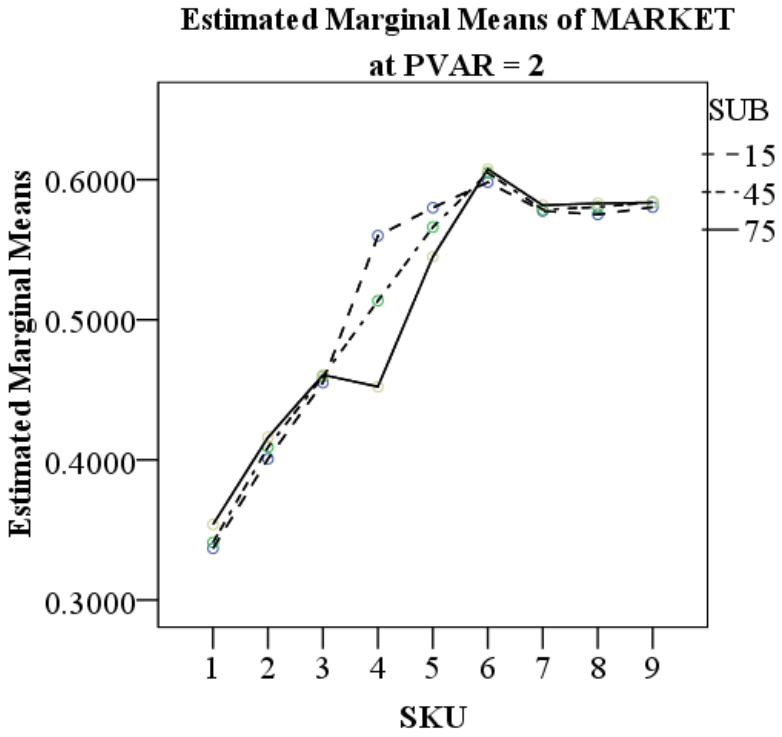


Figure 4-6 (cont'd)



4.3.3 Univariate results: two-way interactions

The multivariate results for those variables with significant two-way interactions and at least small effect sizes revealed five interactions. Table 4-7 shows the univariate results of these interactions.

Table 4-7, Univariate Test for Two-Way Interactions

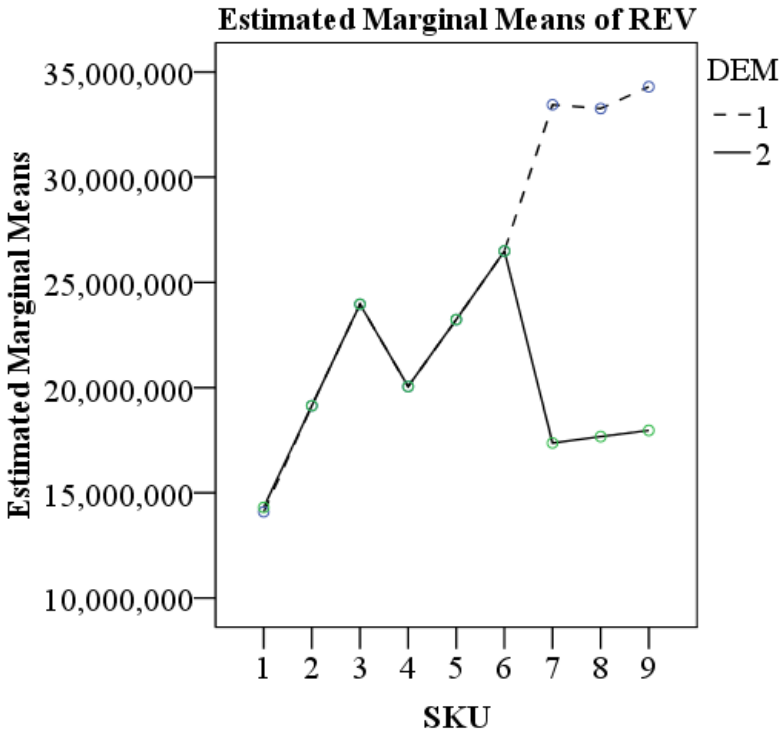
Source	Dependent Variable	F	DF	Sig	Partial η^2	Observed Power
SKU * Increased Demand	COST	17,660.163	8	.000	0.882 ***	1.000
	REV	21,898.088	8	.000	0.903 ***	1.000
	PROFIT	431.936	8	.000	0.155 ***	1.000
	SL	218.948	8	.000	0.085 **	1.000
	MARKET	244,410.322	8	.000	0.990 ***	1.000
SKU * Substitution	COST	1,511.025	16	.000	0.562 ***	1.000
	REV	2,481.865	16	.000	0.678 ***	1.000
	PROFIT	351.634	16	.000	0.230 ***	1.000
	SL	109.046	16	.000	0.085 **	1.000
	MARKET	3,013.623	16	.000	0.719 ***	1.000
SKU * Niche	COST	938.331	16	.000	0.444 ***	1.000
	REV	1,179.774	16	.000	0.501 ***	1.000
	PROFIT	30.424	16	.000	0.025 *	1.000
	SL	42.232	16	.000	0.035 *	1.000
	MARKET	4,888.573	16	.000	0.806 ***	1.000
SKU * Preference Variance	COST	7.146	8	.000	.003	1.000
	REV	9.830	8	.000	.004	1.000
	PROFIT	3.711	8	.000	.002	.988
	SL	17.071	8	.000	.007	1.000
	MARKET	31.788	8	.000	0.013 *	1.000
Increased Demand * Substitution	COST	147.814	2	.000	0.015 *	1.000
	REV	252.068	2	.000	0.026 *	1.000
	PROFIT	35.796	2	.000	.004	1.000
	SL	0.190	2	.827	.000	.080
	MARKET	22.394	2	.000	.002	1.000
*** - Large effect size, ** - Medium effect size, * - Small effect size						

The two-way interactions are mostly composed of interactions with SKUs. SKUs in this study are regarded as the natural growth of a product family. Therefore, when a characteristic of attribute value is combined with SKU breadth, the outcome is the effect of increased SKU breadth using a particular type of attribute. In the case of demand volume, substitution, and demand variance the effect of aligned or non-aligned quality attributes are seen. In the case of niche encroachment and preference variance, the effects of preference attributes are seen.

*4.3.3.1 SKU * Demand interaction*

The SKU * Demand interaction demonstrates the effect that increasing or decreasing demand while adding SKUs has on the dependent variables. When demand increases during attribute alignment and SKUs increase as the product family grows, all dependent variables are significantly affected. Revenue, cost, profit, and market share all have a large effect size, while service level demonstrates a medium effect size. These results are shown in Figures 4-7 through 4-12 and discussed following each plot.

Figure 4-7, SKU * DEM Affect on Revenue



The revenues show that as the SKUs were added and when the increase/decrease condition was assigned that revenues were significantly impacted. The difference in means between aligned and non-aligned attributes at SKU seven was $16.1 million. Figure 4-9 shows the interactions effect on profits.

Figure 4-8, SKU * DEM Affect on Cost

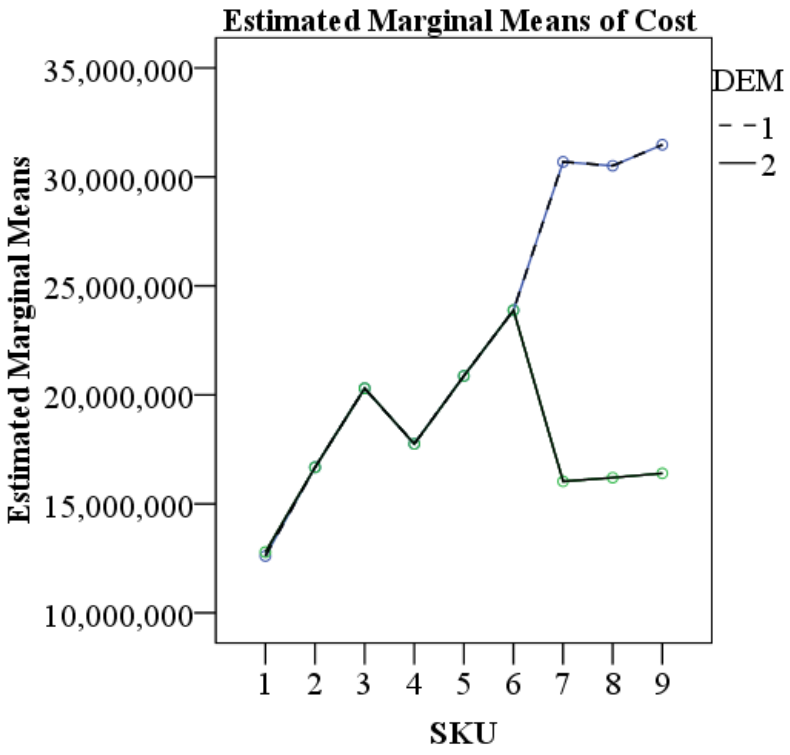
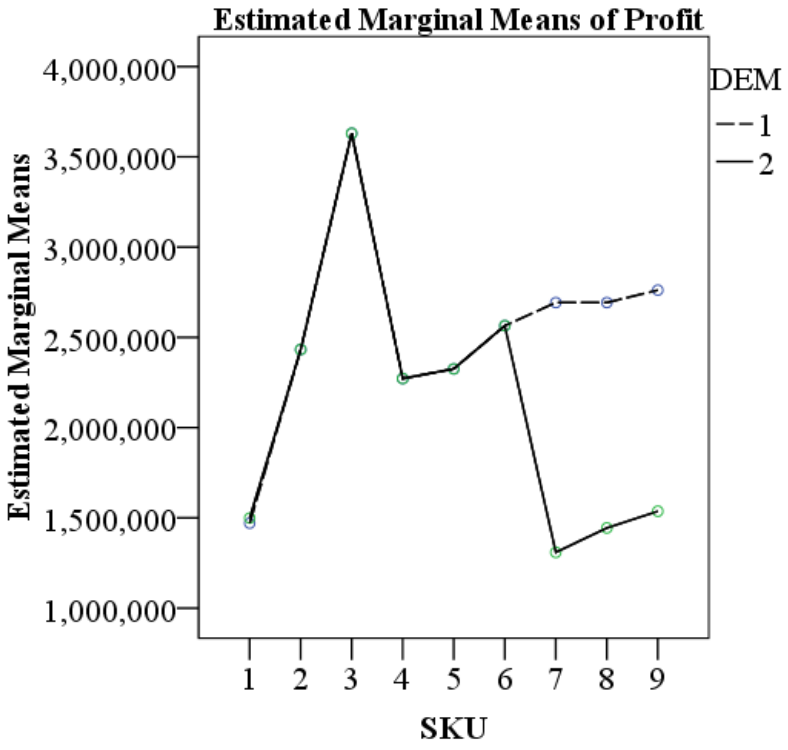


Figure 4-8 reveals that this interaction also has a similar, significant effect and large effect size on costs.

The interaction of SKU * Dem created a large increase in the cost. As mentioned in the literature review, when quality attributes are aligned, demand generally increases. The decrease in demand was instituted in the simulation only at the introduction of the premium quality attribute. The research modeled the decreased demand at the seventh SKU to reflect the behavioral findings of Gourville and Soman (2005). The Gourville and Soman (2005) research demonstrated that customer confusion only started to decrease demand after the product line was lengthy enough to make comparison difficult. Therefore, at the inclusion of the third quality

attribute, demand either increased or decreased depending on attribute alignment. The increase in demand created higher costs as more supplies, transportation, and inventories were needed. Figure 4-7 shows that at SKU seven the cost differences between increasing demand and decreasing demand was $15.7 million.

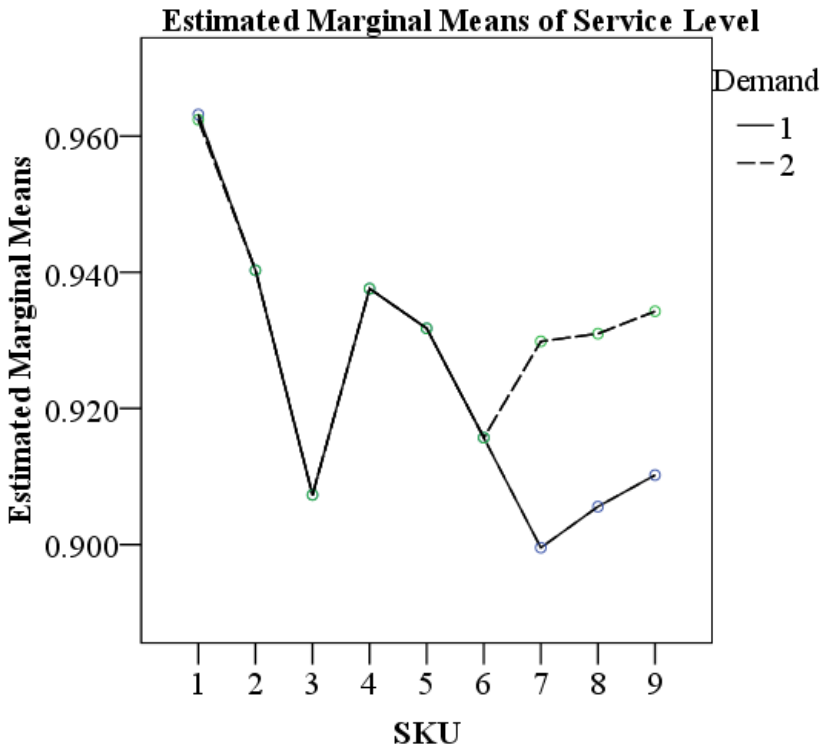
Figure 4-9, SKU * DEM Affect on Profit



Once again, the graph demonstrates a significant effect on the dependent variable as the product family grows and demand increases. The difference in the mean profits between increasing and decreasing conditions at SKU seven was $1.4 million. The shape of this graph also reveals that the most profitable product family is the single, average quality variable with the full array of preference attributes (SKUs one, two and three).

Figure 4-10 graphs the relationship with the SKU * Demand interaction and service level.

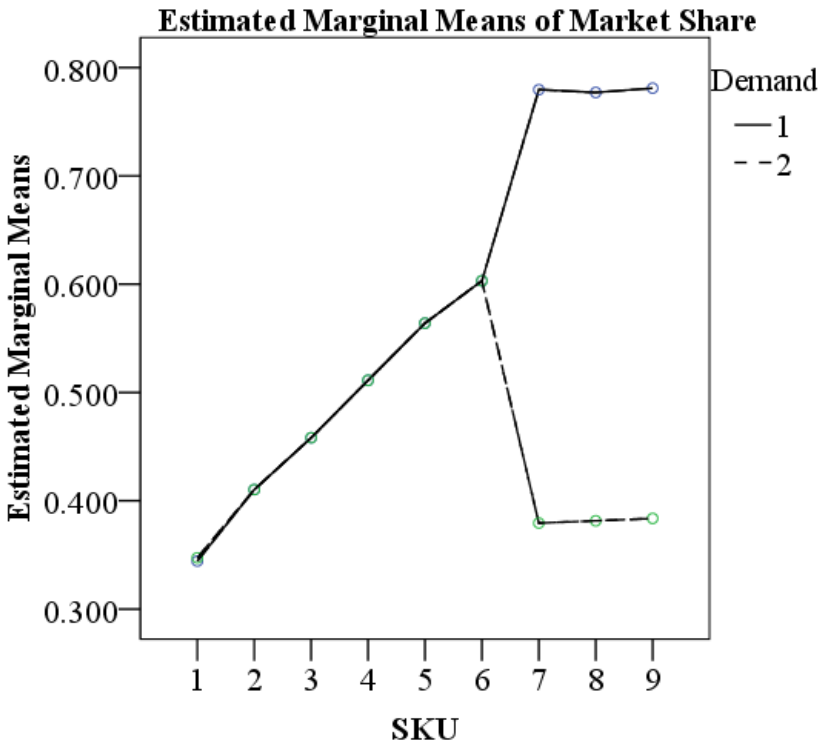
Figure 4-10, SKU * DEM Affect on Service Level



This particular graph shows an interesting result. When demand is decreased in condition two, the service level actually increases. This occurs primarily because when demand decreases, needed supply also decreases. The supply chain is better able to cope with the lower demand levels.

Figure 4-11 shows the relationship of the SKU * DEM interaction and market share. The data labels on this graph show the marginal means. It is very apparent in this graph that there is a significant difference and great effect. The difference between marginal means in premium SKUs is almost 50 percent market share.

Figure 4-11, SKU * DEM Affect on Market Share



*4.3.3.2 SKU * Substitution interaction*

The SKU * Substitution interaction demonstrates how lack of quality attribute differentiation when adding SKUs impacts the dependent variables. Substitution while adding SKUs significantly affected all dependent variables. Revenue, cost, profit, and market share all demonstrated a large effect size, while service level demonstrated moderate effect size. Figures 4-12 through 4-17 illustrate these results which are discussed following each plot.

In general, each plot demonstrates that the main substitution effect occurs with the addition of quality attributes. For instance, adding the budget quality attribute to the product family at SKU four dramatically decreases revenue, cost, and profit when substitution is

increased. This is because customers have a difficult time justifying price differences between the attributes and select the less expensive product. At SKU four, we see that revenue, cost, and profit decline because the new lower-priced and lower-costing item is cannibalizing sales from average quality products. However, the effect is not as dramatic at SKU seven when the premium quality attribute is added. This diminished effect happens because the premium demand added is only about five percent of total demand. Additionally, SKU seven's cannibalization is different than SKU four's cannibalization. When the premium item is added at SKU seven and substitution is high, the newly introduced products do not cannibalize demand from an existing SKU. Instead, the newly introduced product fails to variegate itself from existing products. As a result of this lack of differentiation, there is not as great of an effect on the dependent variables.

Figure 4-12, SKU * SUB Affect on Revenue

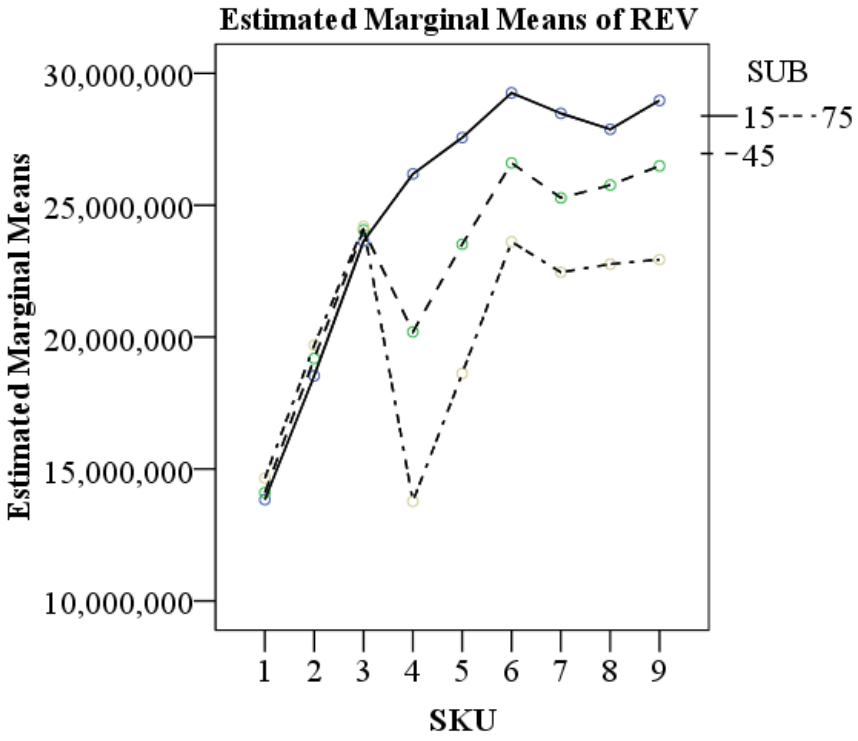


Figure 4-13 illustrates an interaction effect on revenue. Because consumers select the less expensive, budget product instead of the average product, revenue declines. At SKU four and when substitution is high, revenues decrease because existing consumers purchase the new lower-priced and lower-cost item. At SKU seven, new consumers are selecting more average quality products.

Figure 4-13, SKU * SUB Affect on Cost

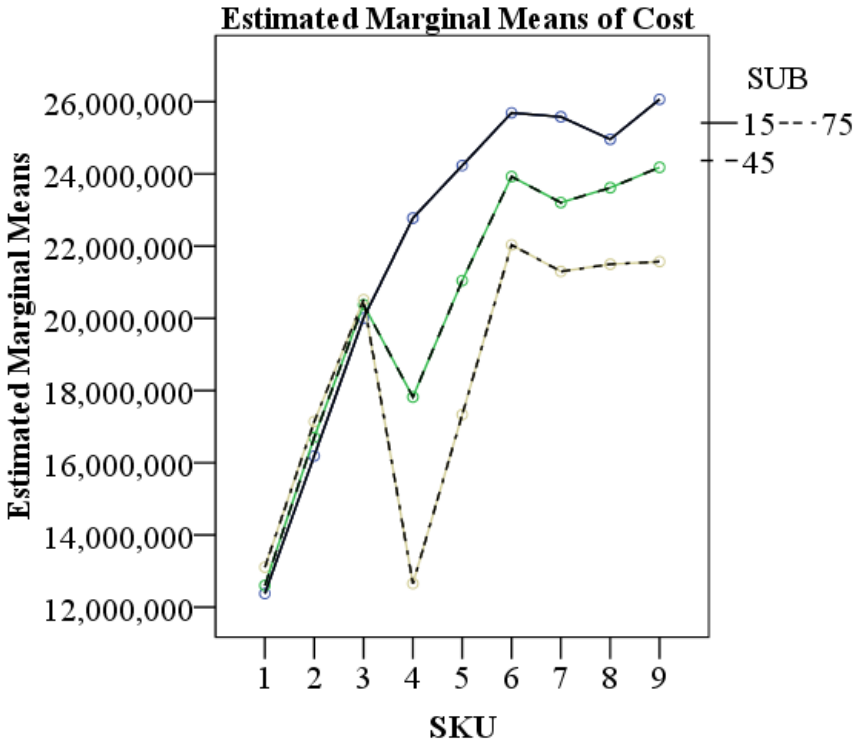


Figure 4-12 illustrates the SKU * SUB interaction effect on cost. At SKU four, the graph illustrates that both medium and high levels of substitution dramatically affect the marginal cost means. In this particular case, where one would expect incrementally increasing cost, they actually decrease whenever a competing quality attribute is added to the product line. Again, this large effect is much more pronounced at SKU four than at SKU seven.

Figure 4-14, SKU * SUB Affect on Profit

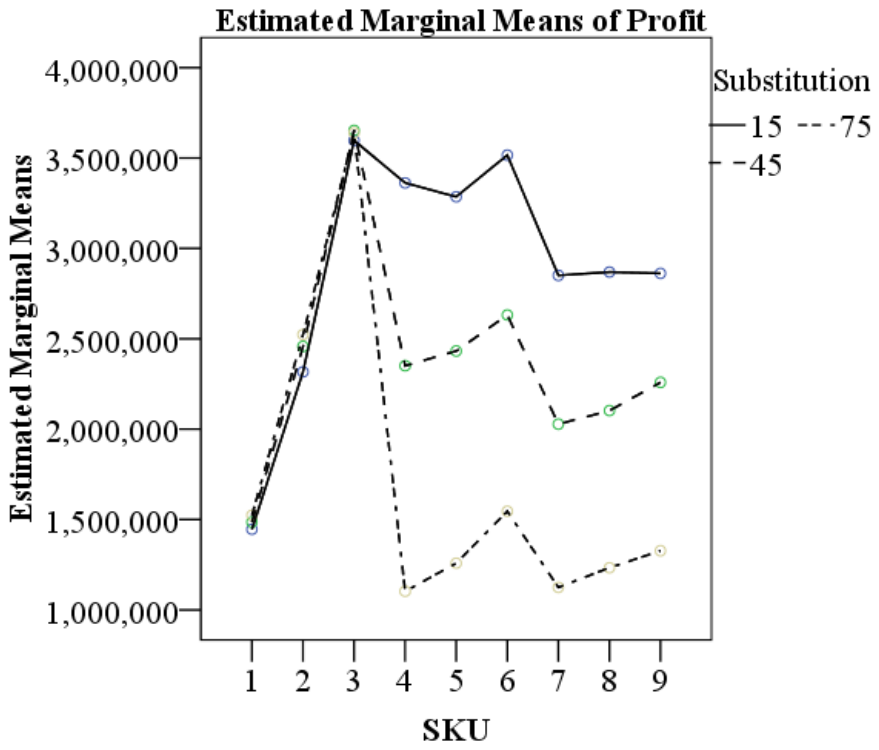


Figure 4-14 illustrates an interaction effect on profit similar to cost and revenue interactions. The pooling effect of cannibalization causes more purchases of lower-priced items. The result is diminishing profits. At SKU four and when substitution is high, revenues decrease because existing consumers are purchasing the new lower-priced and lower-cost item. At SKU seven, new consumers are selecting more average quality products.

Figure 4-15, SKU * SUB Affect on Service Level

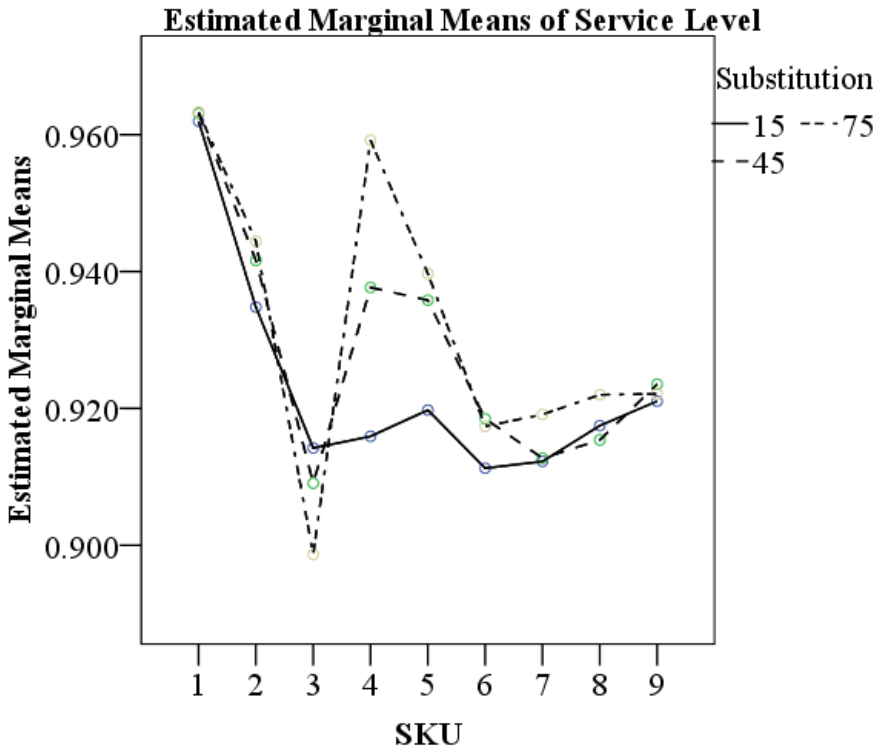
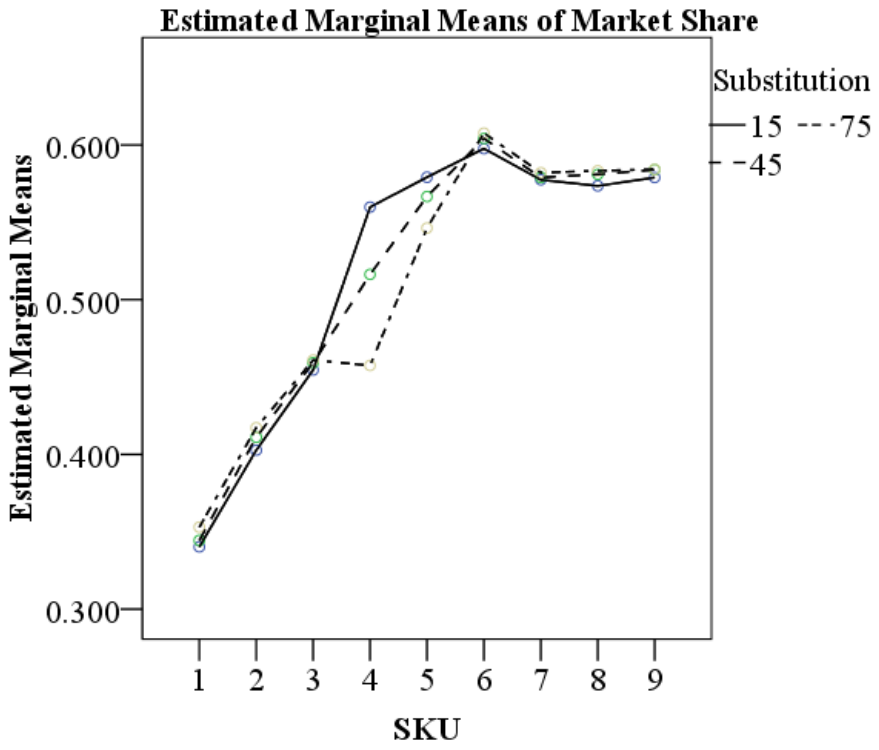


Figure 4-15 illustrates an interaction effect on service levels that is initially confusing. At SKU four, substitution leads to higher service levels. Once again, this is the pooling effect of cannibalization causing less variation in consumer selection. At low substitution rates, the consumers select from four SKUs, while at the highest substitution rates, consumers are selecting from a single SKU. Substitution limits demand variety thus raising service level. At SKU seven, because substitution is reversed (old demand stealing from what should be new demand), new consumers are selecting more average quality products and service levels are not greatly influenced.

Figure 4-16, SKU * SUB Affect on Market Share



What is most surprising about Figure 4-16 is the lack of substitution effect on market share at SKU seven. The results illustrate that there is a slight decline in market share at SKU seven with very little difference between the three substitution levels. In addition, the difference between cannibalization (where the new SKU steals from an existing SKU) and lack of differentiation (where the old SKU takes new SKU demand) is very pronounced. Substitution at SKU four illustrates that the new product taking demand away from existing demand has a large effect on market share. This happens at high substitution levels because consumers do not want to purchase a more expensive quality attribute that does not differentiate. Therefore, the demand increase that would result from offering another product is lost. The result is that rather than a

marginal increase in demand at SKU four, there is no increase when substitution is high. At SKU seven there is no pronounced market share effect because the three premium SKUs represent only about five percent of total demand. This small portion of demand disproportionally influences revenue, cost, or profit because these premium SKUs cost more, have higher prices, and generate greater profit margins. However, in terms of market share, the premium attribute SKUS are a very small piece of the total market.

*4.3.3.3 SKU * niche interaction*

The SKU * niche interaction demonstrates the effect of one preference attribute characteristic on the dependent variables. The increased niche encroachment, while increasing SKU breadth significantly, affected all the dependent variables. Revenue, cost, and market share all demonstrate a large effect size, while profit and service level demonstrate a small effect size. These results are shown in Figures 4-17 through 4-22 and discussed following each plot.

Niche encroachment occurs in two steps. First, flexible preference consumers buy refrigerators that are not their preferred color when their preferred color is not available. Second, when their preferred color becomes available, the consumers stop purchasing their non-preferred color and purchase their preferred color. In the simulation, a higher niche encroachment condition means that more consumers have flexible preferences. In the highest niche condition, 75 percent of consumers that wanted a certain color of refrigerator purchased any available color of refrigerator when their desired color was not available. However, when their color became available, they selected their preferred color. Figure 4-17 illustrates the observed effect of niche encroachment on revenue.

Figure 4-17, SKU * NICHE Affect on Revenue

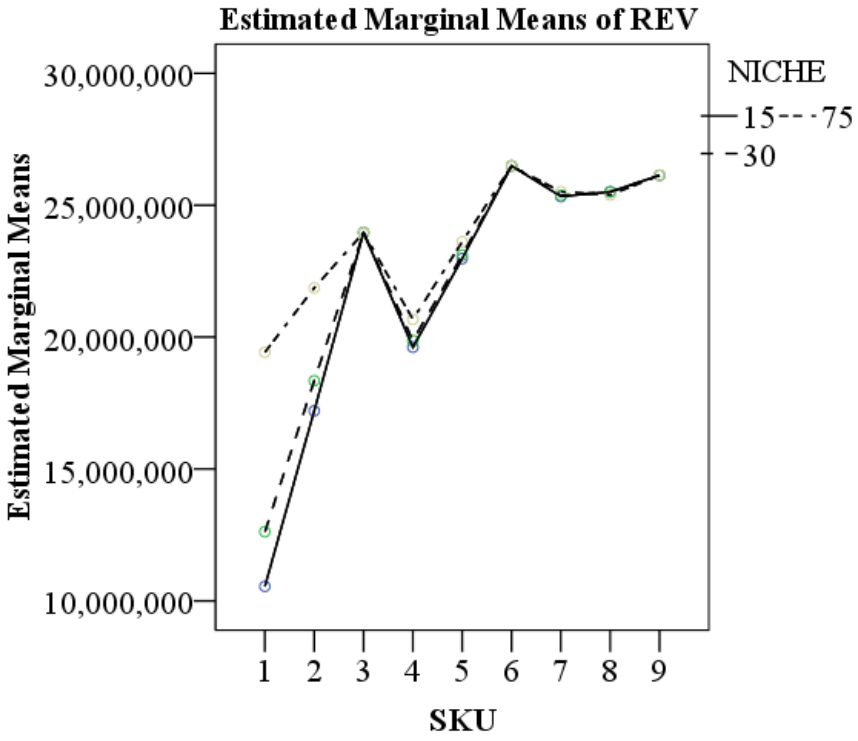
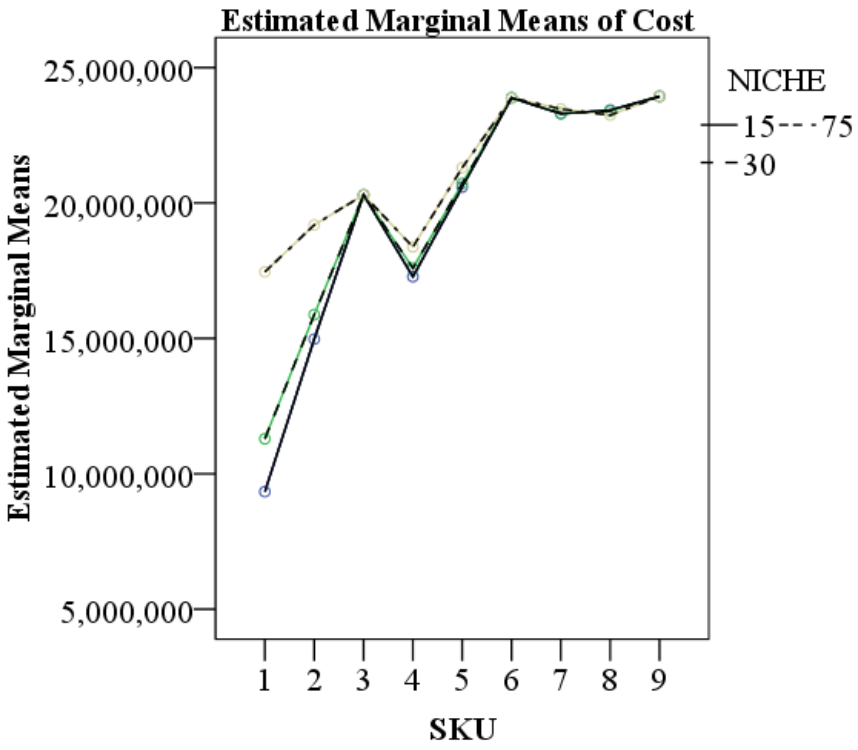


Figure 4-18 illustrates that the SKU * NICHE interaction causes an effect. High encroachment levels create more revenue with fewer SKUS but dampen the revenue impact of adding more colors. Once again, a large difference is illustrated between the moderate and high levels.

Figure 4-18, SKU * NICHE Affect on Cost



As expected, niche encroachment increases cost most significantly at the first two SKUs. Since consumers at high niche rates demonstrate less fixed preference towards a color, they are more likely to buy whatever color is in stock. As a result, cost starts out much higher because the firm is selling more refrigerators without having to add colors. At high encroachment levels, adding colors does not significantly increase costs. Of particular interest in this cost plot is the minor difference between the low level (15 percent) cost of niche encroachment and the moderate level cost (30 percent) of niche encroachment. However, the plot shows a significant difference between the moderate level of niche encroachment and the high level (75 percent) of niche encroachment. This suggests that somewhere between the moderate and high levels of

niche encroachment, there may be an inflection point where a larger effect is realized. Finding this inflection point should be the topic of future cannibalization studies.

Figure 4-19, SKU * NICHE Affect on Profit

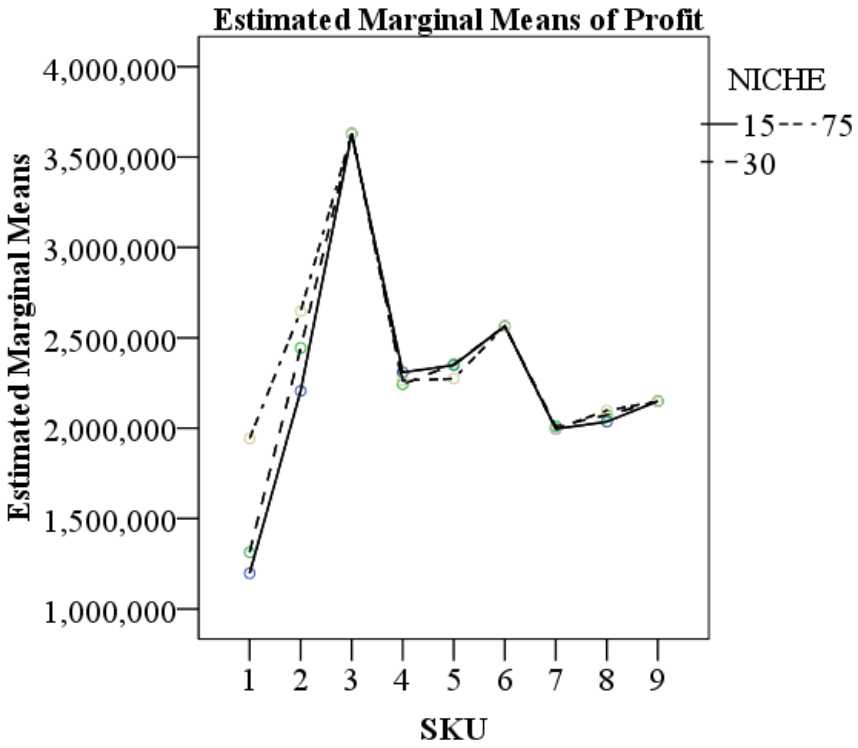


Figure 4-19 illustrates that because costs are increasing at about the same rate as revenues, niche encroachment has a very small effect on profit. Once again, the largest effect is at the first two SKUs. Interestingly, SKU four and SKU five show that higher encroachment levels actually slightly decrease profits rather than increase profit as seen in SKU one and SKU two. These flipped results suggest a greater increase in cost at SKU four and five than revenue at SKU four and SKU five and some unpredictability about the effects of niche encroachment on profitability.

Figure 4-20, SKU * NICHE Affect on Service Level

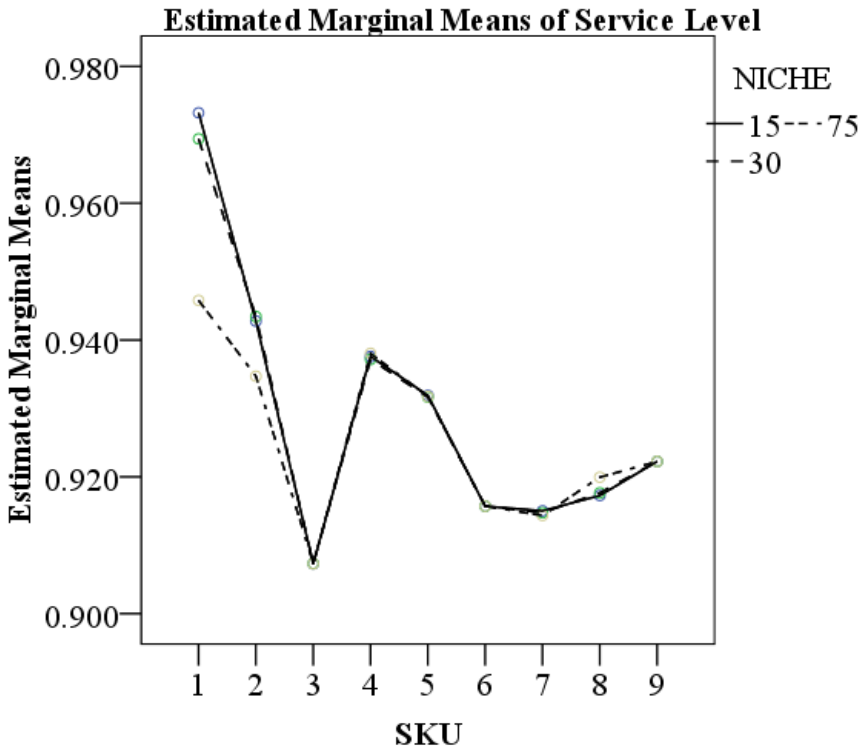


Figure 4-20 illustrates that high niche encroachment primarily influences service level at SKU one and two. As in profit, the effect size with this interaction is very small. The initial lower service level only differs by about two percent.

Figure 4-21, SKU * NICHE Affect on Market Share

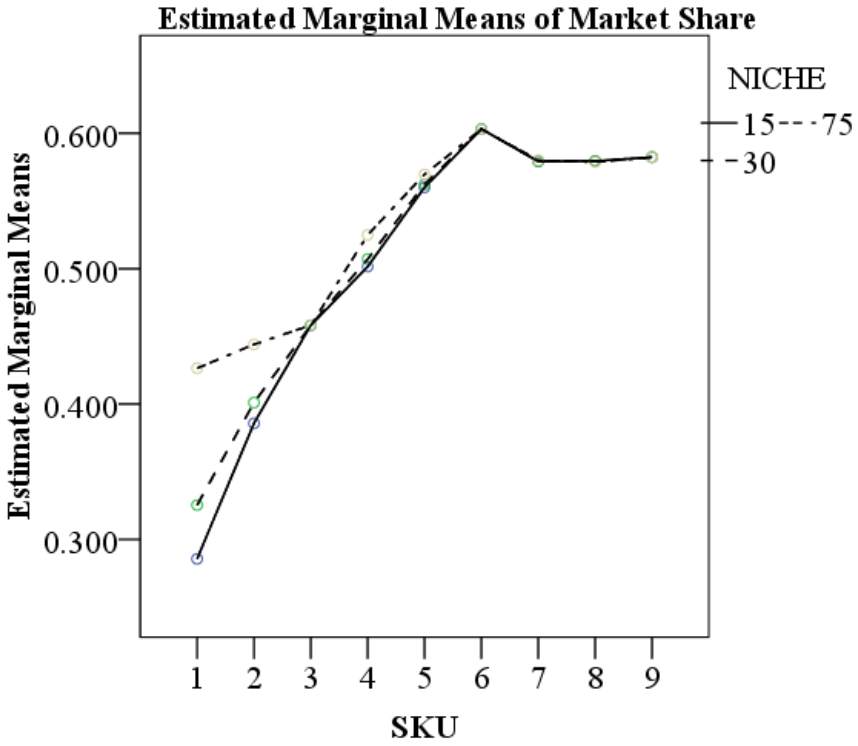


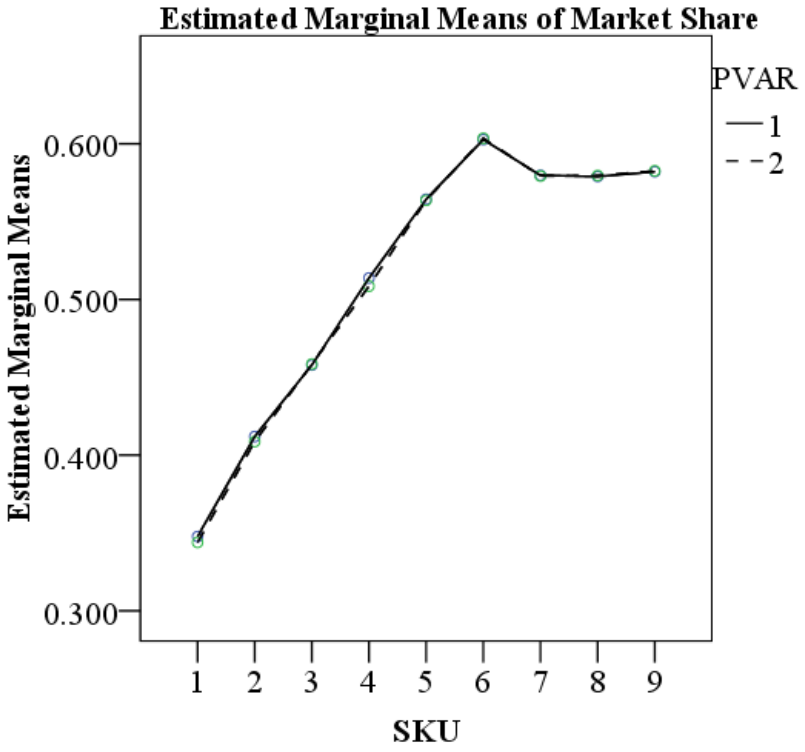
Figure 4-21 additionally illustrates that high niche encroachment primarily influences SKU one and SKU two. The initial higher market share at higher encroachment levels means that fewer preference attributes are needed to satisfy demand. This also means that adding preference attributes does not necessarily increase market share.

The relationships between the SKU * NICHE interaction is revealing. Niche encroachment increases revenue and cost due to the demand increase. It does not, however, cause a great increase in either profit or service level. The increase in demand also increases market share. This suggests that one consideration when adding preference attributes must be that the resulting cannibalization may hinder profitability. However, adding preference attributes to increases both revenue and market share.

*4.3.3.4 SKU*Preference variance interaction*

The SKU * PVAR interaction demonstrates the effect of preference variance on the dependent variables. The plot illustrates that increasing preference variance creates a small effect on market share. Figure 4-22 shows that this difference is so small as to be imperceptible in the graph.

Figure 4-22, SKU * PVAR Affect on Market Share



*4.3.3.5 Demand * substitution interaction*

The Demand * Substitution interaction represents the synergistic effects of quality attributes.

Figure 4-23, Demand * Sub Affect on Revenue

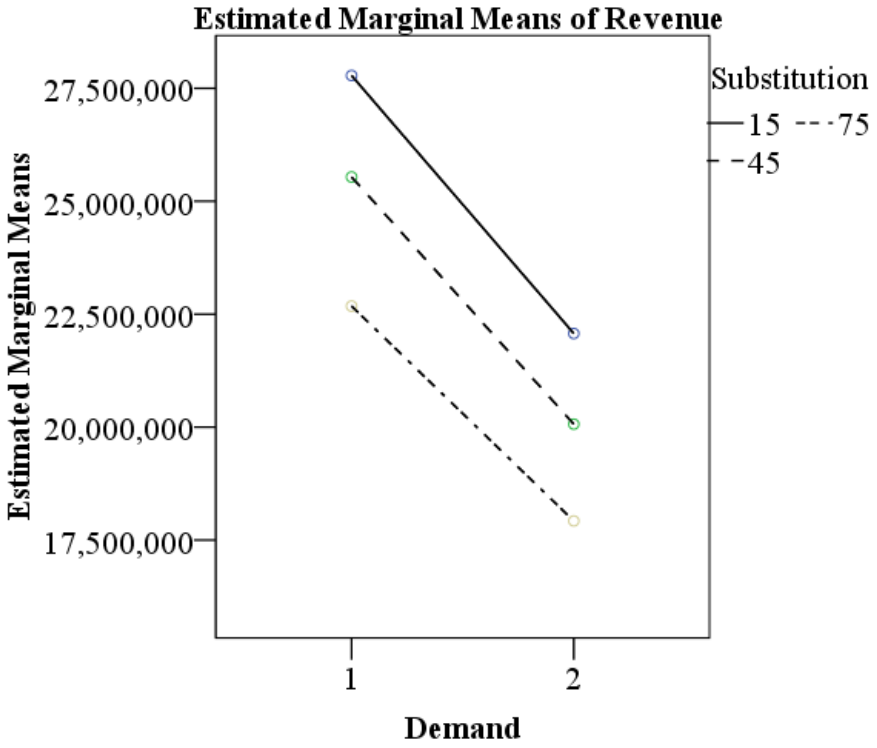


Figure 4-23 illustrates a corresponding decrease in revenue. The result is that the interaction between these two independent variables explains only around 0.4 percent of the profit variation.

Figure 4-24, Demand * Sub Affect on Cost

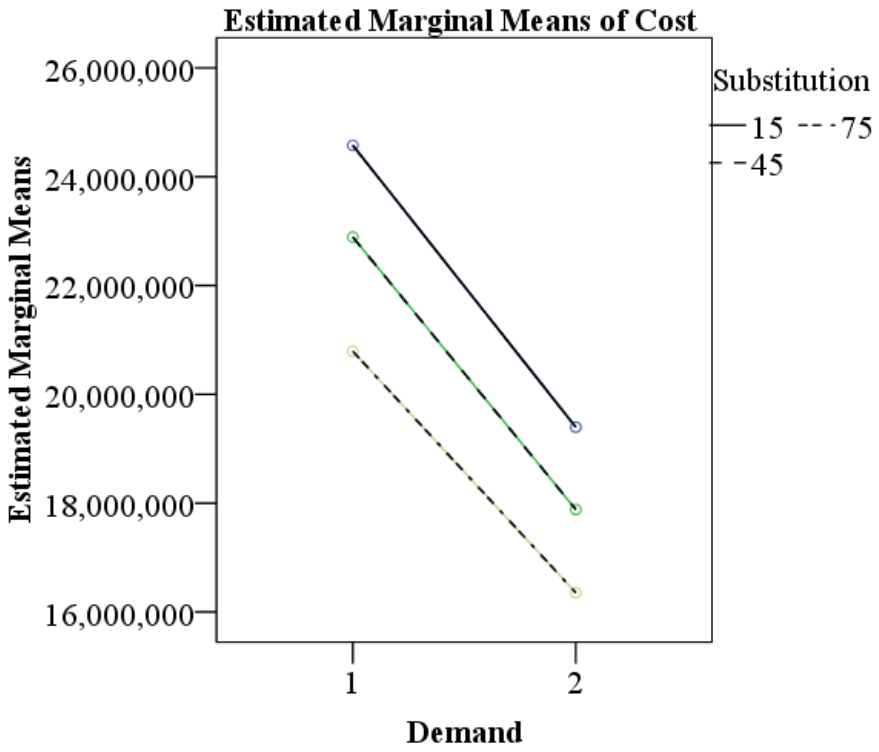


Figure 4-24 illustrates the Demand * Sub influence on cost. As can be seen, when a substitution increase is accompanied by a demand decrease, there is a corresponding drop in cost. The graph demonstrates that the effect is consistent between levels. It also demonstrates that aligned quality attributes have a higher cost than non-aligned attributes.

4.3.4 Univariate results: main effects

Table 4-8 provides univariate tests for significant main effects. Except for quality variance and preference variance, all independent variables significantly affect performance variables at $p<.001$. Quality variance did not have any significant effect on dependent variables and is not included in the table. Furthermore, partial eta squared values indicate that effects sizes

for preference variance variables had effect sizes that explain so little variance as to be insignificant. Overall the independent variables associated with aligned or non-aligned quality attributes have the strongest effect on the dependent variables.

Table 4-8, Univariate Test for Main Effect

Main Effects Tests						
Source	**Dependent Variable**	**F**	**DF**	**Sig**	**Partial η^2**	**Observed Power**
SKU	COST	19,980.823	8	.000	0.895 ***	1.000
	REVENUE	22,968.694	8	.000	0.907 ***	1.000
	PROFIT	1,384.892	8	.000	0.371 ***	1.000
	SERVICE LEVEL	1,420.917	8	.000	0.377 ***	1.000
	MARKET SHARE	202,956.818	8	.000	0.989 ***	1.000
Increasing Demand	COST	69,725.594	1	.000	0.788 ***	1.000
	REVENUE	86,399.262	1	.000	0.821 ***	1.000
	PROFIT	1,681.766	1	.000	0.082 **	1.000
	SERVICE LEVEL	836.983	1	.000	0.043 *	1.000
	MARKET	969,952.369	1	.000	0.981 ***	1.000
Substitution	COST	11,407.627	2	.000	0.548 ***	1.000
	REVENUE	21,898.768	2	.000	0.700 ***	1.000
	PROFIT	4,510.939	2	.000	0.324 ***	1.000
	SERVICE LEVEL	272.944	2	.000	0.028 *	1.000
	MARKET	1,276.747	2	.000	0.120 **	1.000
Preference Variance	COST	1.474	1	.225	0.000	.229
	REVENUE	8.008	1	.005	0.000	.808
	PROFIT	7.517	1	.006	0.000	.783
	SERVICE LEVEL	16.580	1	.000	0.001	.983

Table 4-8 (cont'd)

	MARKET	78.194	1	.000	0.004	1.000
Niche Encroachment	COST	2,643.440	2	.000	0.220 ***	1.000
	REVENUE	3,218.992	2	.000	0.255 ***	1.000
	PROFIT	51.255	2	.000	0.005	1.000
	SERVICE LEVEL	59.251	2	.000	0.006	1.000
	MARKET	13,170.700	2	.000	0.584 ***	1.000
*** - Large effect size, ** - Medium effect size, * - Small effect size						

4.3.4.1 SKU main effects

Figure 4-25 illustrates that increasing SKU breadth has a large effect on revenue, cost, and profit. This is consistent with the literature on SKU breadth and is an expected result. What is notable about the cost is the continual increase until the next quality attribute is added. SKU four demonstrates a $2.5 million decrease in cost from SKU three. This valley results because of the large effect that substitution creates in SKU four. Revenue also demonstrates this same relationship. The profitability of SKU breadth increases reveals that adding SKUs does not always create marginal increases in profitability. In fact, it appears the strategy that is most effective in adding SKU is to add preference attributes to increase profitability. The addition of quality attributes appears to initially decrease profitability.

Figure 4-25, SKU Breadth Affect on Revenue, Cost and Profit

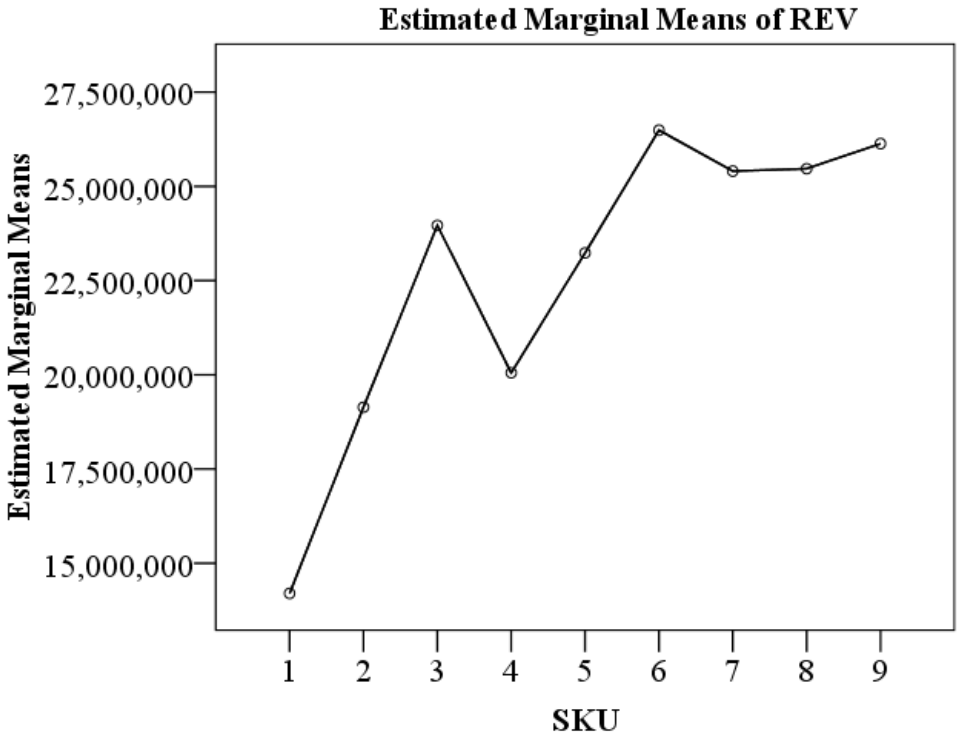


Figure 4-25 (cont'd)

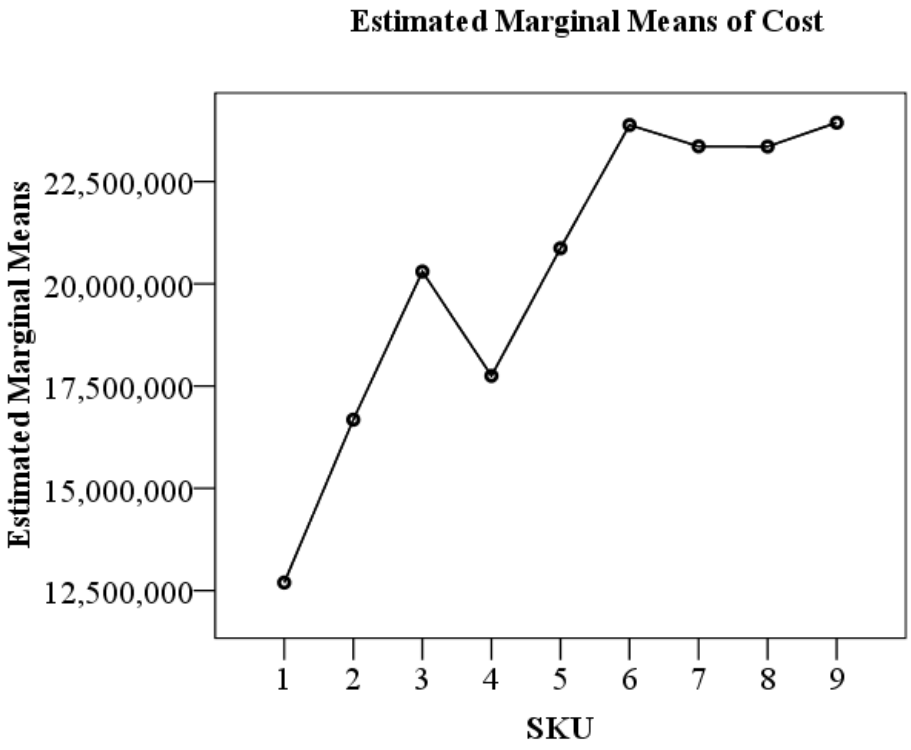


Figure 4-25 (cont'd)

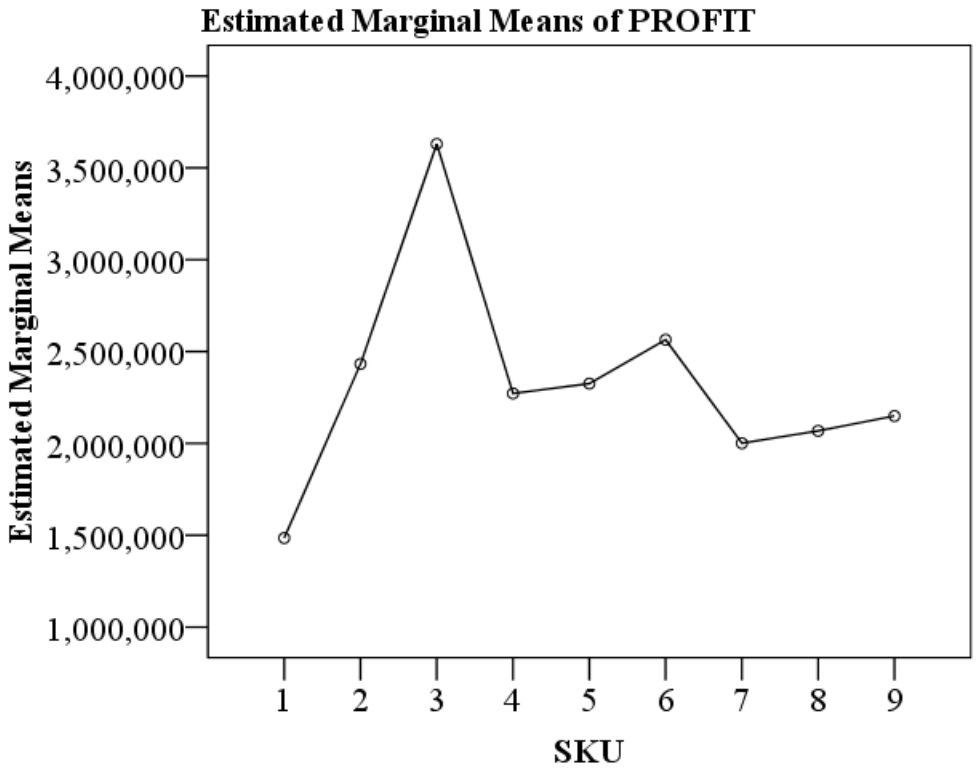


Figure 4-26 illustrates the effect of SKU breadth on service level and market share. Initially, as more SKUs are added, service level drops. This is intuitive as managing a greater diversity of SKUs increases the difficulty in managing the portfolio. When substitution is encountered at the fourth SKU, there is some pooling of the variance. This increases service level. Market share also increases as the SKU breadth increases. This result empirically demonstrates what the literature suggests, that one of the primary reasons to increase the product family is to increase market share. This frames a fundamental trade-off of product variety management, that increasing SKU breadth may not increase profit, but generally does increase market share.

Figure 4-26, SKU Breadth Affect on Service Level and Market Share

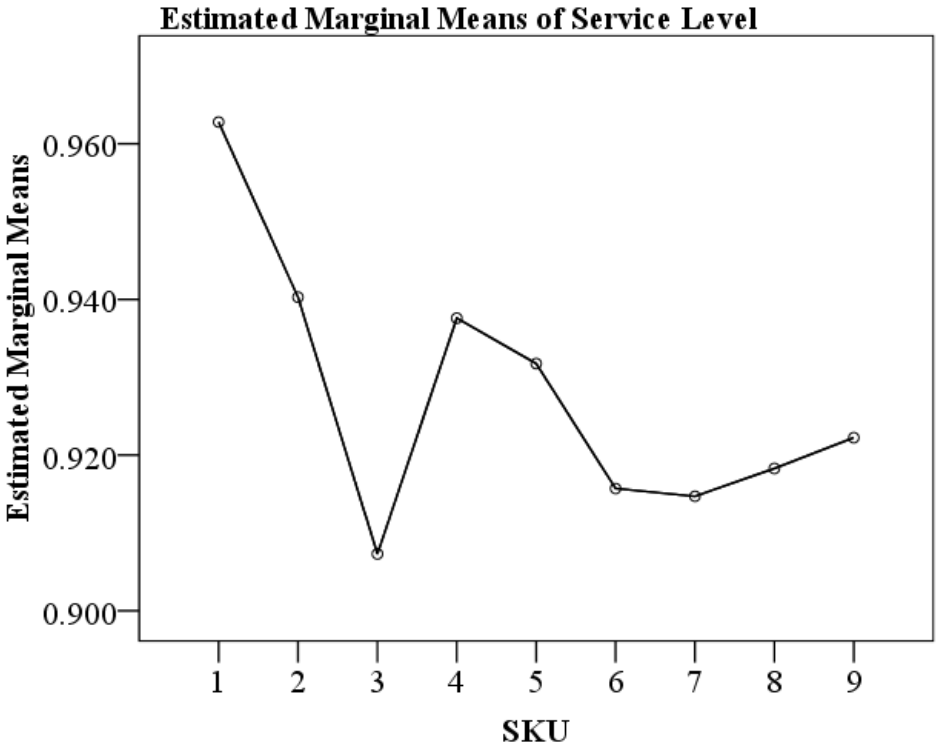


Figure 4-26 (cont'd)

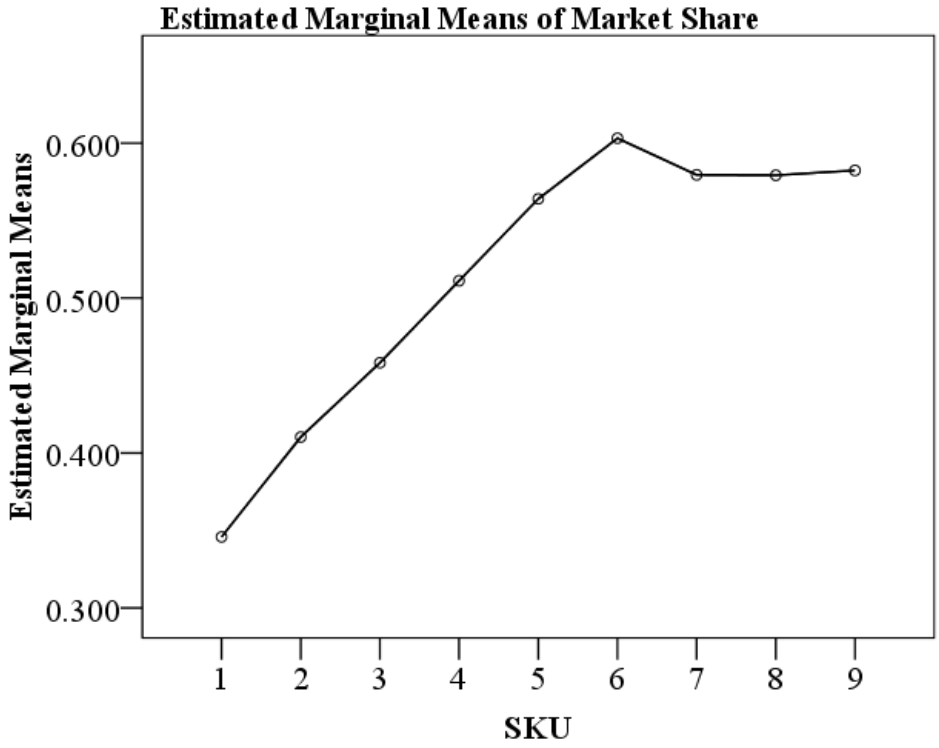


Figure 4-27, Demand Volume Affect on Revenue, Cost and Profit

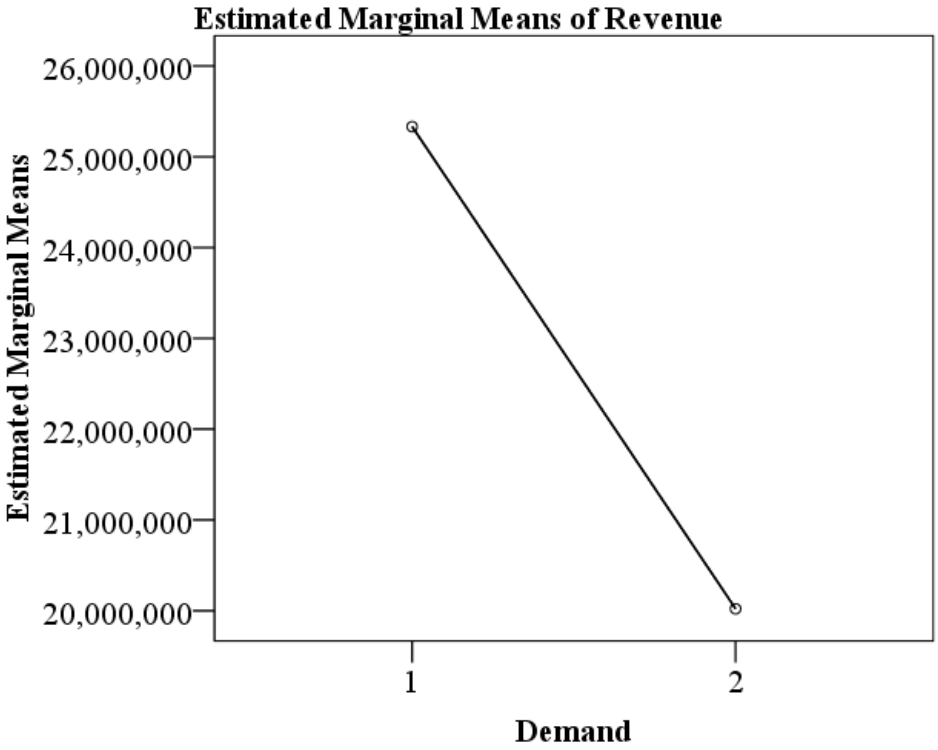


Figure 4-27 (cont'd)

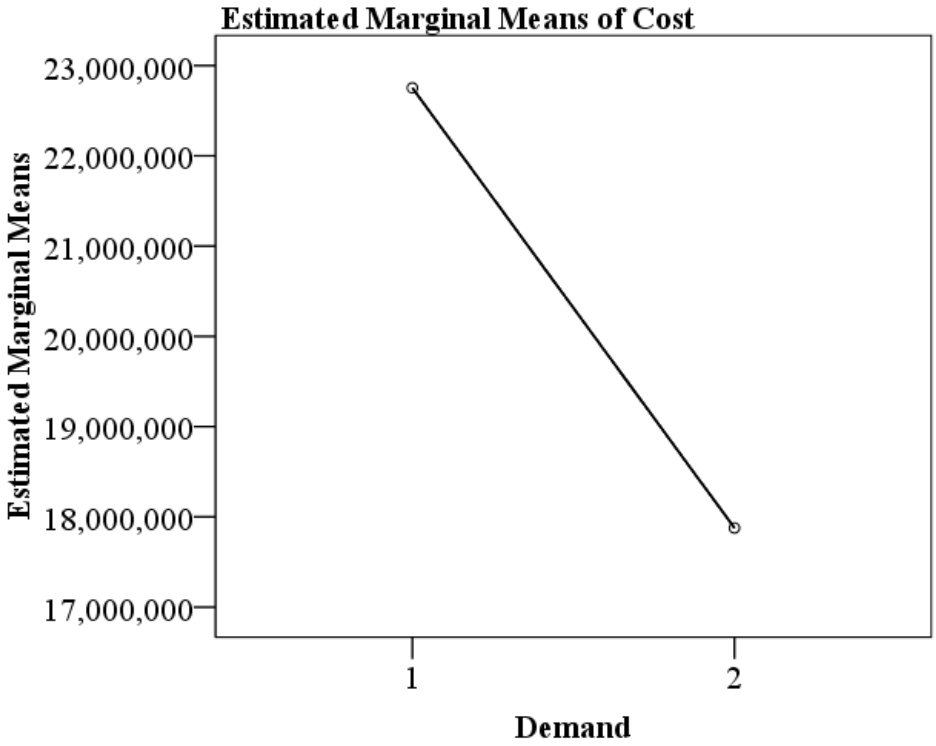
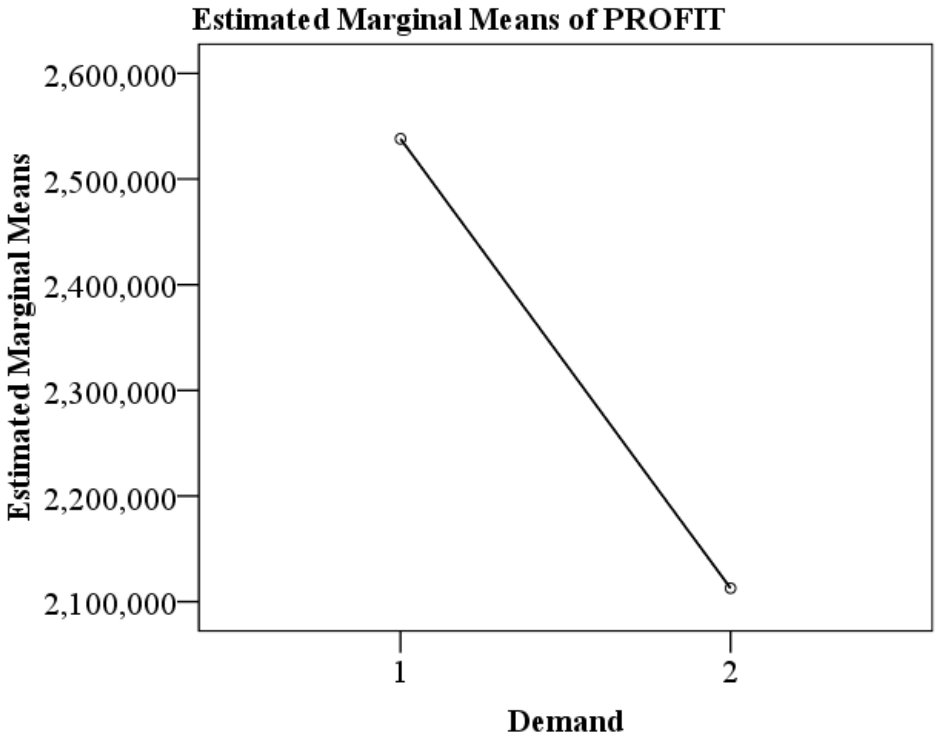


Figure 4-27 (cont'd)



4.3.4.2 Demand volume main effects

Figure 4-27 illustrates that increasing demand increases revenue, cost and profits. The increase of revenue and cost is almost proportional to the increase in demand. Some economies of scale are realized in the costs. However, these scale economies are slight. The difference between the marginal means of cost when demand increased (condition one) instead of decreased (condition two) is $4.9 million. The difference in revenue is $5.3 million. This resulted in a profit increase of $425 thousand. Furthermore, the univariate effect demonstrates that increasing demand volume has a large effect on cost and revenue, but only a medium effect on profit. Once again, increasing demand by increasing the product family does not always greatly improve

profitability. Revenue may increase dramatically; however, the increased revenue is offset by increased costs.

Figure 4-28, Demand Volume Affect on Service Level and Market Share

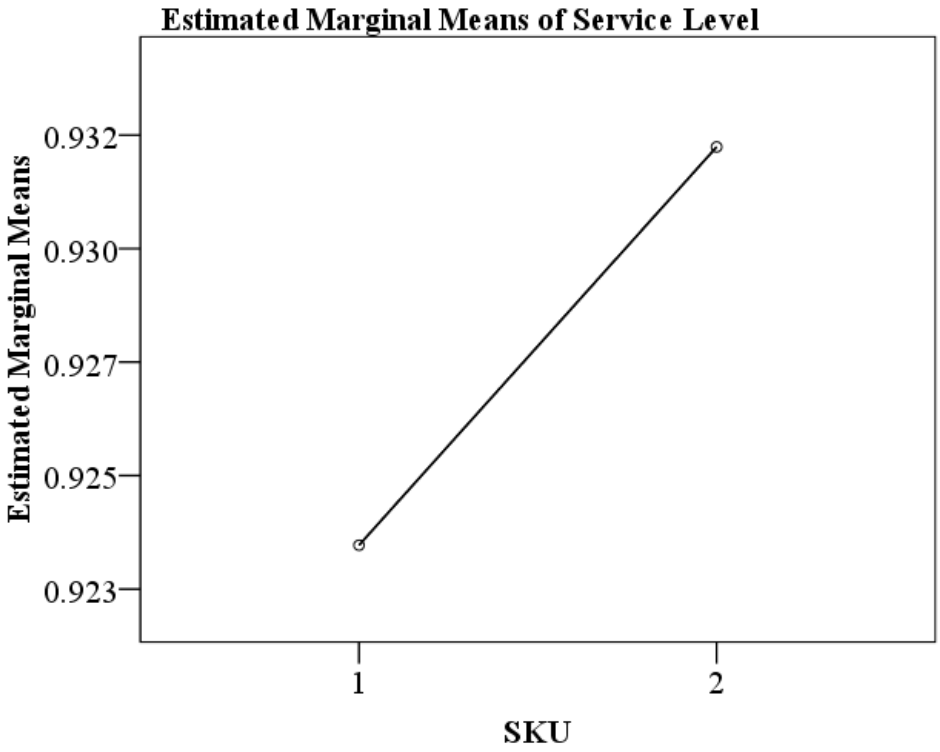
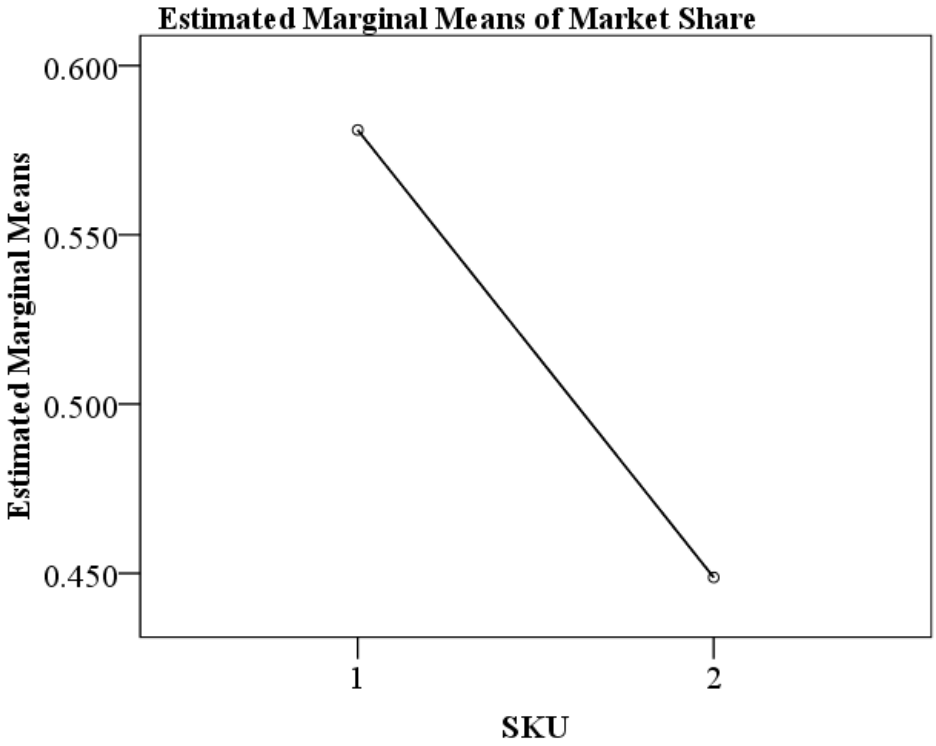


Figure 4-28 (cont'd)



Increased demand also influences the system efficiency (service level) and the response to competition (market share). Figure 4-28 demonstrates that increasing demand (condition one) actually decreases service levels while increasing market share. The small effect size indicated in the decrease in service level suggests that an increase in demand makes managing the supply chain slightly more difficult. However, the large effect size of market share suggests that this lack of management control may be offset by an increase in market share

4.3.4.3 Substitution main effects

Substitution also had significant effects with large effect size on revenue, cost and profit. Figure 4-29 shows that great differences occur between small, moderate, and large substitution conditions. Increasing substitution decreases costs, decreases revenues and decreases profits. Costs decrease because consumers chose not only fewer SKUs from those available, but also less expensive SKUs. This means that variety in demand decreases and material costs decreases. For example, a small substitution level (15 percent) instead of moderate substitution (45 percent) had a higher cost marginal mean of $1.6 million. The difference in means between moderate and large (75 percent) substitution was $1.8 million. Cannibalization reduced costs.

Figure 4-29, Substitution Affect on Revenue, Cost and Profit

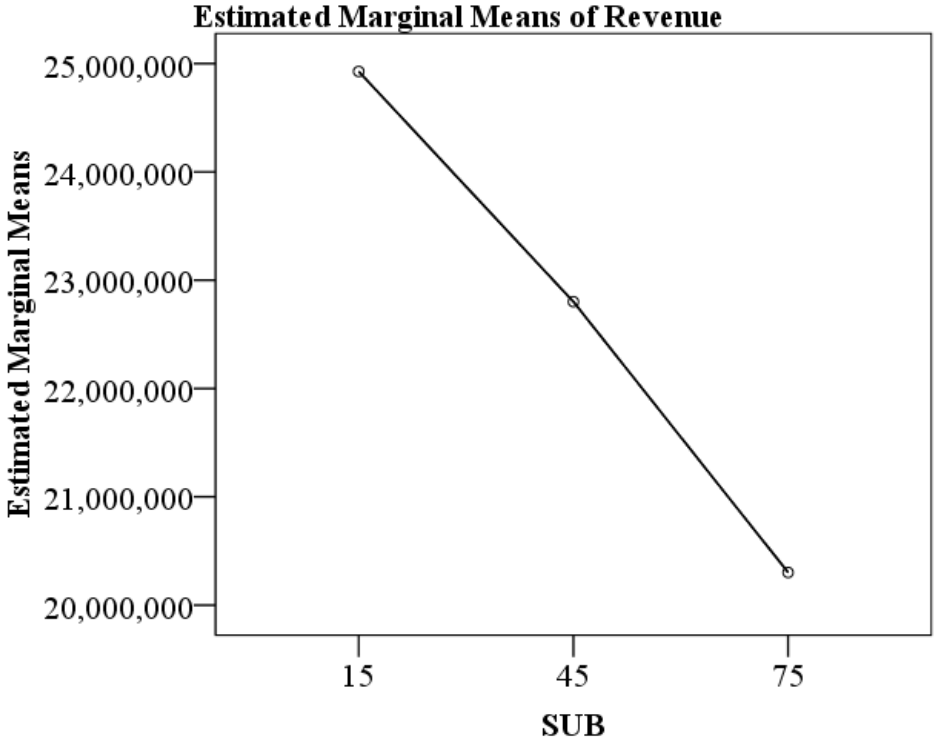


Figure 4-29 (cont'd)

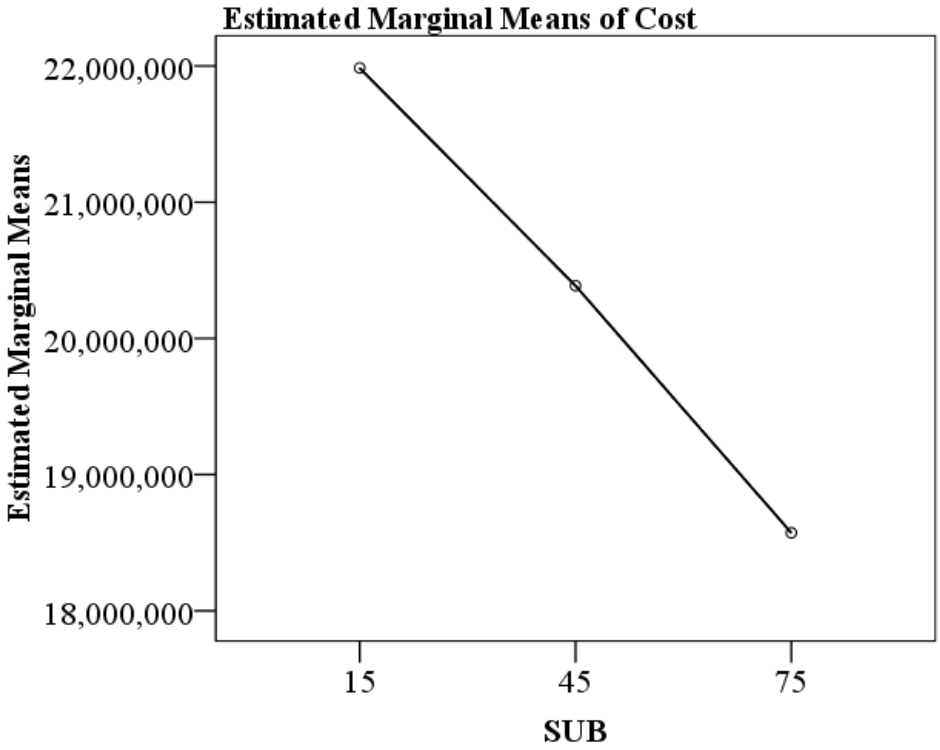
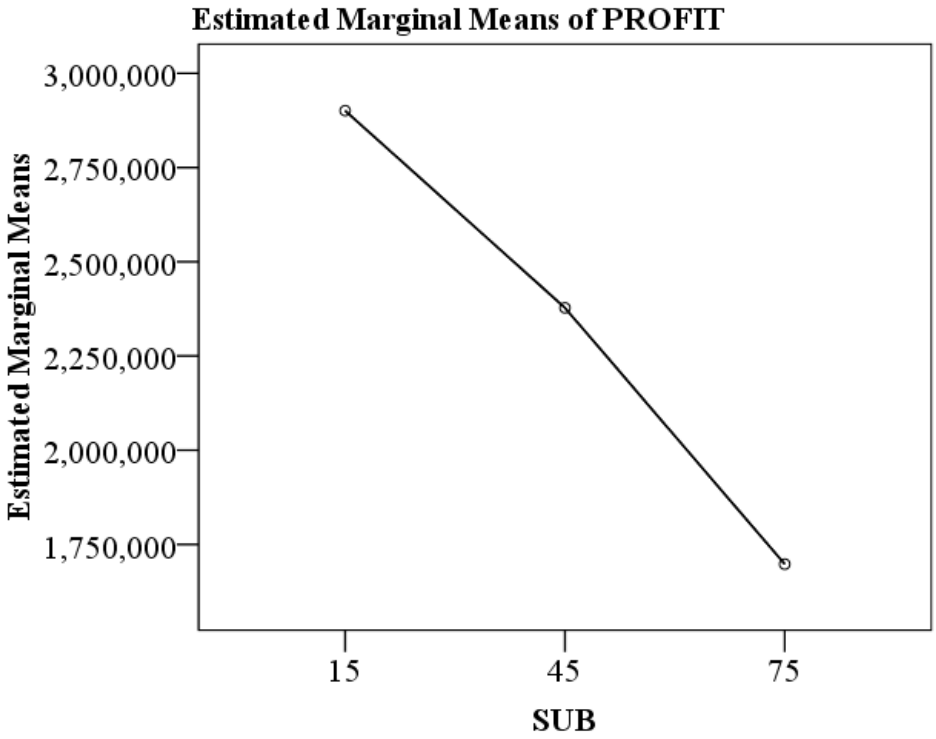


Figure 4-29 (cont'd)



In revenue, the differences also reduced revenues $2.1 million and $2.5 million respectively. Again, this was because consumers selected lower priced goods. The decrease in cost and corresponding decrease in revenue as substitution increased, depressed profits. In this case, if a firm experienced moderate substitution as opposed to small substitution, they could expect to lose $523 thousand in profit. If a firm experienced large substitution instead of moderate substitution, they could expect to lose $680 thousand. This shows that increasing SKU breadth may actually decrease profitability.

Figure 4-30, Substitution Affect on Service Level and Market Share

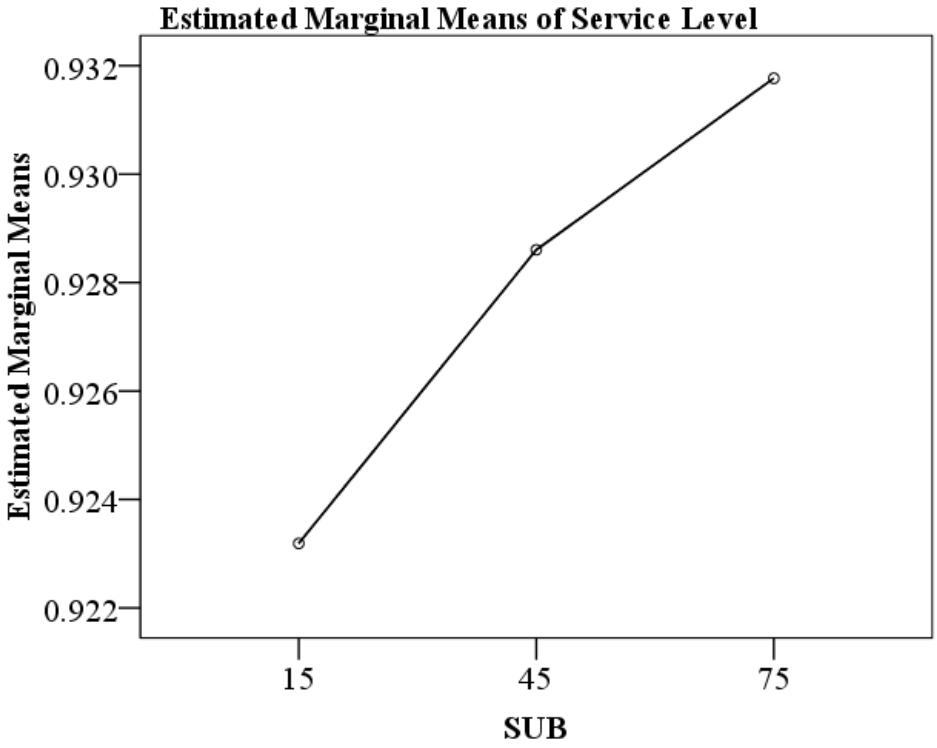
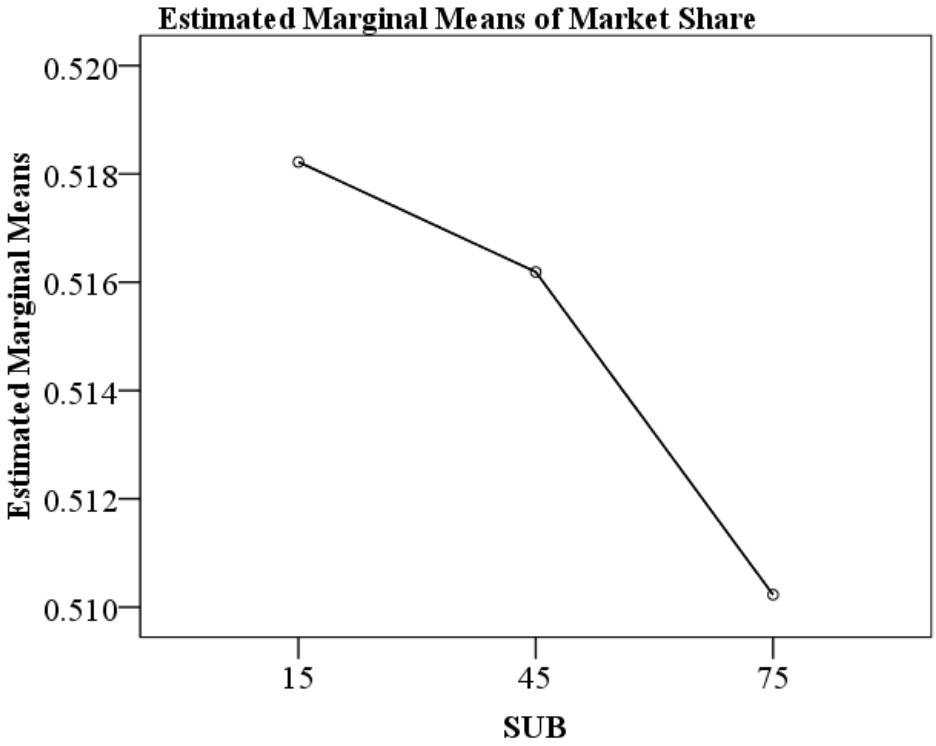


Figure 4-30 (cont'd)



Although the effect sizes of service level and market share suggest a small and medium sized effect, the graphs do not demonstrate much difference between substitution levels. In service level, there is a .006 difference between the substitution levels. In market share, there is a .006 difference and a .003 difference. These marginal means hardly seem to suggest even a small effect size. The result appears to suggest that the effect on both service level and market share is negligible.

Figure 4-31, Niche Affect on Revenue, Cost and Market Share

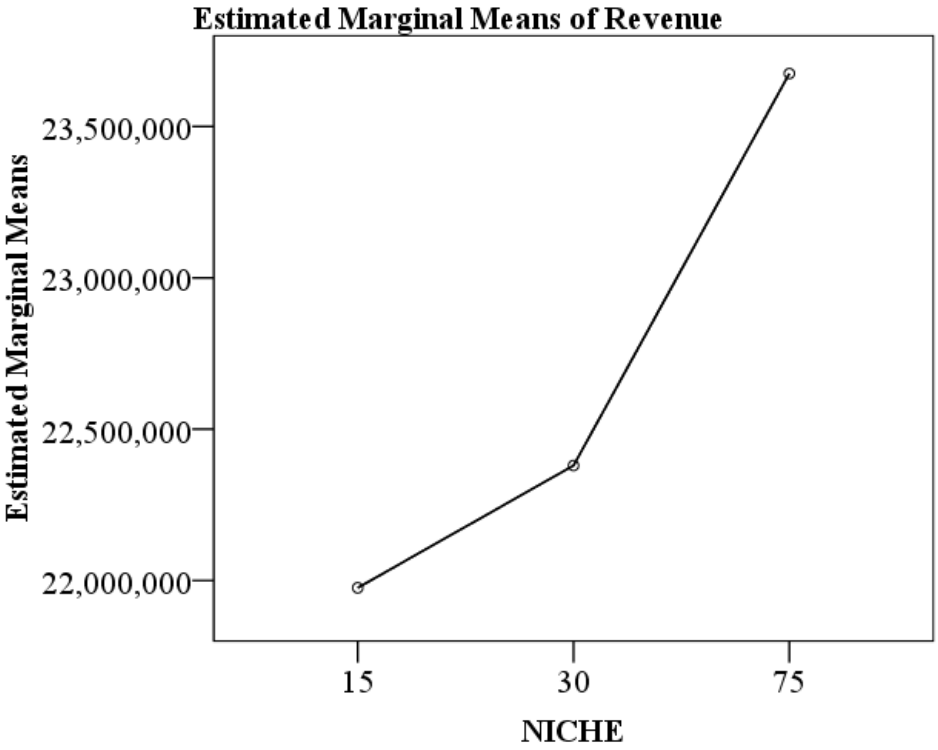


Figure 4-31 (cont'd)

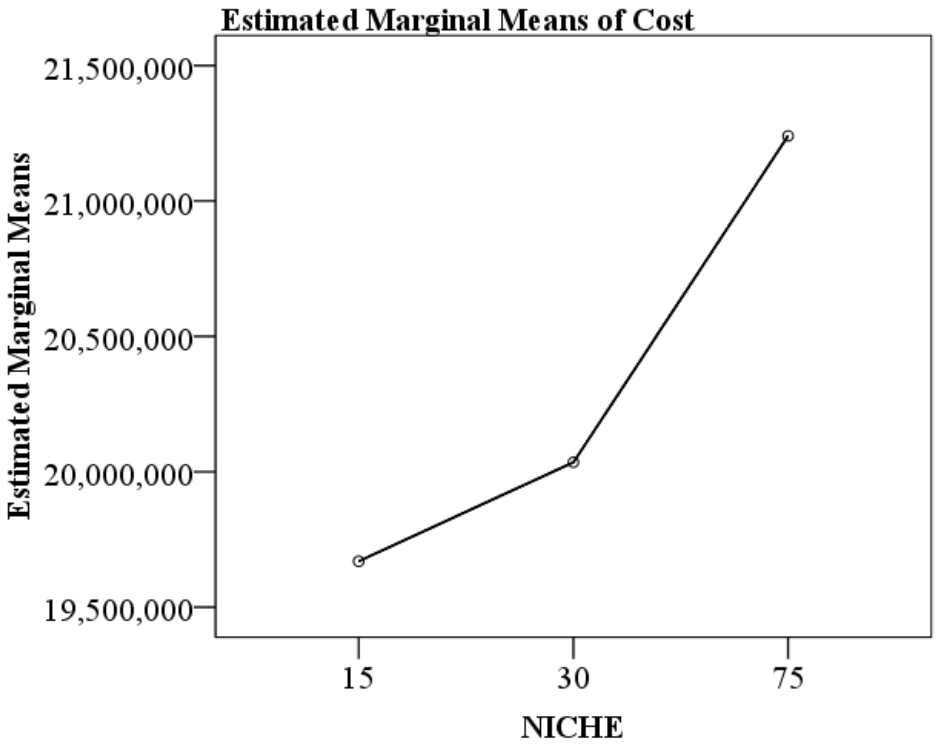
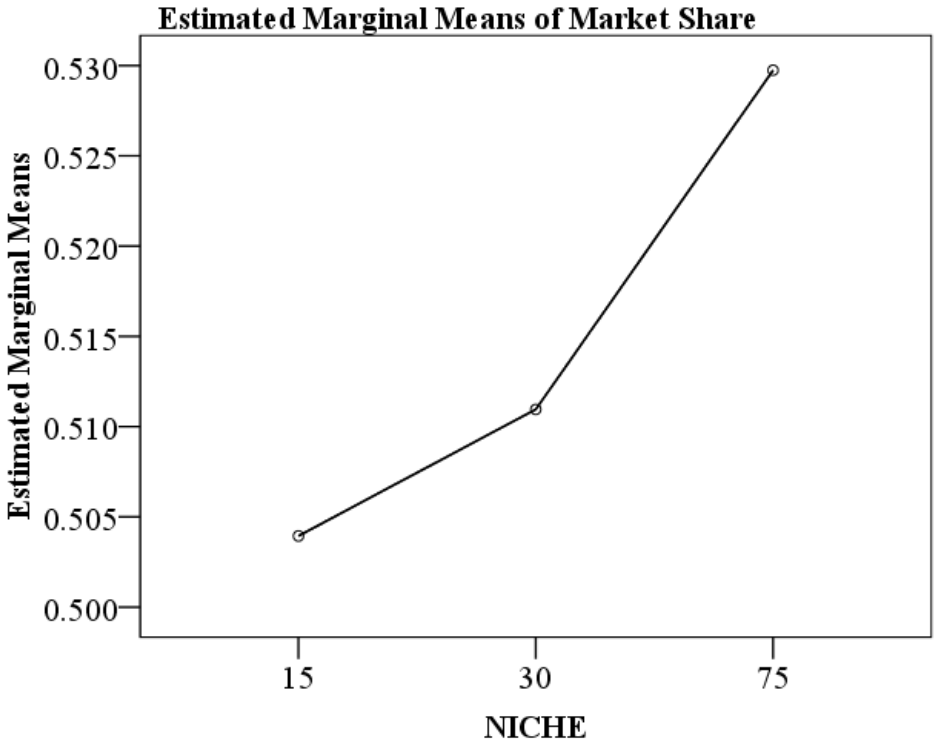


Figure 4-31 (cont'd)



4.3.4.4 Niche encroachment main effect

Niche encroachment showed significant effects with large effect size on revenue, cost and market share. The effect size with profit and service level was so small as to be insignificant. Figure 4-31 shows that great differences occur between small, moderate, and large substitution conditions. Of particular note in this variable is the greater effect between moderate and large encroachment than between small and medium encroachment. This suggests some non-linear effect in niche encroachment with regards to costs and revenues. In the case of profits, niche encroachment increases costs and revenues at roughly the same rate leading to no significant increase or decrease in costs. This happens for two main reasons. First, niche encroachment appears between preference variables, which are relatively inexpensive. This makes it difficult

to drive much profitability in this situation. Second, the simulation allowed more expensive preference variables (Satina and Stainless) to take demand from the existing niche of painted refrigerators. As a result, no economies of scale or extraordinary revenue were generated.

The market share results show that as niche encroachment increases, so does the amount of market share. This results because greater niche encroachment corresponds to more flexible preference customers. In other words, when niche encroachment is high, consumers that want stainless steel but cannot find it will choose painted refrigerators. However, when their preferred color becomes available, they will choose that color. The result is that when niche encroachment is high, more customers purchase even though their color choice is not available. The increased market share occurs because there are fewer customers going to competitors because of refrigerator color.

4.4 Hypotheses testing

This section discusses how the results support the research hypothesis. Table 4-9 outlines the findings in the research.

Table 4-9, Hypotheses Supported

Hypothesis	Result
H1a. Increasing SKU breadth when price is held constant increases revenues.	Partially Supported
H1b. Increasing SKU breadth when price is held constant increases costs.	Partially Supported
H1c. Increasing SKU breadth when price is held constant increases profits.	Partially Supported
H1d. Increasing SKU breadth when price is held constant increases market share.	Partially Supported
Hypothesis	**Result**
H2a. Adding preference attributes increases revenues.	SUPPORTED
H2b. Adding preference attributes increases costs.	SUPPORTED
H2c. Adding preference attributes increases profits.	Not Supported
H2d. Adding preference attributes increases market share.	SUPPORTED
H2e. Adding preference attributes does not change the number of profitable SKUs in the product line.	Not Supported
Hypothesis	**Result**
H3a. Adding aligned quality attributes increases revenues.	SUPPORTED
H3b. Adding aligned quality attributes reduces costs.	Not Supported
H3c. Adding aligned quality attributes increases profits.	SUPPORTED
H3d. Adding aligned quality attributes increases market share.	SUPPORTED
H3e. Adding aligned quality attributes increases the number of profitable SKUs in the product family	SUPPORTED
Hypothesis	**Result**
H4a. Adding non-aligned quality attributes reduces revenues.	Not Supported
H4b. Adding non-aligned quality attributes increases costs.	SUPPORTED
H4c. Adding non-aligned quality attributes reduces profits.	SUPPORTED
H4d. Adding non-aligned quality attributes decreases market share.	Partially Supported
H4e. Adding non-aligned quality attributes decreases the number of profitable SKUs in the product family	SUPPORTED

4.4.1 SKU breadth hypotheses

The literature suggests four relationships between increasing SKU breadth and the dependent variables.

4.4.1.1 SKU breadth affect on revenue

This hypothesis states that, "*Increasing SKU Breadth when price is held constant increases revenue*." Multivariate and univariate test results (Table 4-5 and 4-8) indicate that the effects of SKU breadth on the multivariate and on revenue are all statistically significant at $p<.001$. Furthermore, evaluation of partial η^2 values and marginal means plots of SKU breadth effect and SKU breadth interaction effects on revenue suggests large effect sizes. However, the marginal means plots demonstrate (Figure 4-27) that increased revenues are strongly influenced by both substitution and demand. As substitution increased in SKU four, the expanded SKU breadth did not substantially increase revenues. Additionally, Figure 4-27 demonstrates in SKU seven through SKU nine that when the demand increase is very small or subject to demand fluctuations, marginal revenues may actually decrease. Therefore, Hypothesis H1a is only partially supported.

4.4.1.2 SKU breadth affect on cost

This hypothesis states that, "*Increasing SKU Breadth when price is held constant increases cost*." Multivariate and univariate (Table 4-5 and 4-8) test results indicate that effects of SKU breadth on cost are all statistically significant at $p<.001$. Moreover, evaluation of partial η^2 values and marginal means plots of SKU breadth effect on cost suggests a large effect size. However, the marginal means plots illustrate (Figure 4-27) that increased cost is strongly influenced by both substitution and demand. As substitution increased in SKU four, the expanded SKU breadth decreased costs. Additionally, Figure 4-27 demonstrates in SKU seven through SKU nine that when the demand increases only slightly or decreases, marginal costs also decrease. Therefore, Hypothesis H1b is partially supported.

4.4.1.3 SKU breadth affect on profit

This hypothesis states that, "*Increasing SKU Breadth when price is held constant increases profit.*" Multivariate and univariate test results (Table 4-5 and 4-8) indicate that the effects of SKU breadth on the multivariate results and on profit are all statistically significant at $p<.001$. Furthermore, evaluation of partial η^2 values and marginal means plots of SKU breadth effect and SKU breadth interaction effects on revenue suggests large effect sizes. However, the marginal means plots of the interaction between SKU breadth and demand (Figure 4-9) and SKU breadth and substitution (Figure 4-14) demonstrate (Figure 4-27) that both substitution and demand as the product line increases may negatively influence profit. Figure 4-14 demonstrates in SKU seven through SKU nine that when demand decreases as the result of SKU breadth, marginal profits also decrease. Therefore, Hypothesis H1c is only partially supported.

4.4.1.4 SKU breadth affect on market share

This hypothesis states that, "*Increasing SKU Breadth increases market share.*" Multivariate and univariate test results (Table 4-5 and 4-8) indicate that the effects of SKU breadth on the multivariate and on revenue are all statistically significant at $p<.001$. Furthermore, evaluation of partial η^2 values and marginal means plots of SKU breadth effect and SKU breadth interaction effects on market share suggest large effect sizes. However, the interaction marginal means plots (Figure 4-11 and Figure 4-16) demonstrate that both demand and substitution influence SKU Breadths effect on market share. Figure 4-11 shows that the substitution increase accompanying an increased SKU breadth, does not marginally increase market share. Figure 4-16 illustrates that when SKU breadth increases and demand decreases, marginal market share decreases. Therefore, Hypothesis H1d is only partially supported.

4.4.2 Preference attribute hypotheses

The simulation models preference attributes as colors for the refrigerators. Low-end colors were generically called painted, middle ranged colors were Satina, and high end colors were stainless steel. Differences in preference attributes were represented in the experiment by both preference variance and niche encroachment variables. Preference variance increased when consumers did not have predetermined preferences for a particular color. However, much of the variance introduced into the simulation was attenuated because consumers delayed purchasing for as long as 14 days. Therefore, the preference variation variable associated with preference attributes had little effect on the dependent variables. Niche encroachment attributes related to whether or not the addition of Satina or Stainless Steel created new demand or poached demand from the existing colors. When niche encroachment was higher, consumers were more willing to buy a color they did not want. The result was that when the color they actually wanted came into the product line, the painted color lost the consumers' demand to their true color preference. These two aspects of preference attributes are expected to combine to effect revenue, cost, profit, market share, and the ideal size of the product line.

4.4.2.1 Preference attributes affect on revenue

This hypothesis states that, "*Adding preference attributes increases revenue.*" Multivariate and univariate (Table 4-5 and 4-8) test results indicate that effect of niche encroachment on revenue are all statistically significant at $p<.001$. Moreover, evaluation of partial η^2 values and marginal means plots of SKU breadth effect on cost suggests a large effect size. Furthermore, the SKU*NICHE marginal means plots demonstrate (Figure 4-18) that firms can expect increased revenue as each preference attribute is added. In fact, Figure 4-31 shows

that as niche encroachment increased, more revenue was captured. This was because consumers were purchasing an item even before the color they really wanted was available. The overall revenues were then higher as more expensive color options became available. Hypothesis 2a is therefore supported.

4.4.2.2 Preference attributes affect on cost

This hypothesis states that, "*Adding preference attributes increases cost.*" Multivariate and univariate (Table 4-5 and 4-8) test results indicate that the effects of niche encroachment on the multivariate and on cost are statistically significant at $p<.001$. Moreover, evaluation of partial η^2 values and marginal means plots of the effect niche encroachment has on cost suggests a large effect size. The increase in costs as preference attributes are added to the product line is evident. Additionally, as preferences become less fixed, the differences in costs increase (Figure 4-29). However, Figure 4-17 demonstrates that high niche encroachment inflates costs of the earliest introduced SKUs. In the high niche encroachment condition, consumers bought a color even though it was not the color they really wanted. When the color consumers want is available, they poach demand from the existing color. This has the effect of loading costs on the first SKU introduced within a particular product quality attribute category. When new preference attributes are added and consumers have very fixed preferences, the new attributes do increase costs. When new preference attributes are added and consumers have flexible preferences, the cost increase is marginally lower with each added SKU. Therefore, preference attributes do increase cost. However, the increased cost is marginally much lower when consumers have flexible preferences. Hypothesis H2b is supported.

4.4.2.3 Preference attributes affect on profit

This hypothesis states that, "*Adding preference attributes increases profits.*" Multivariate and univariate (Table 4-5 and 4-8) test results indicate that the effects of SKU breadth on cost are all statistically significant at p<.001. However, evaluation of partial η^2 values and the marginal means plot of SKU*NICHE (Figure 4-19) suggests a very small effect size. In fact, the variance in profits explained by niche encroachment was only 0.5 percent of the total variance. This may be because preference attributes account for so little of the total profitability of the finished good. It appears that adding preference attributes does not increase profits. Therefore, Hypothesis H2c is not supported.

4.4.2.4 Preference attribute affect on market share

This hypothesis states that, "*Adding preference attributes increases market share.*" Multivariate and univariate (Table 4-5 and 4-8) test results indicate that the effects of SKU breadth on cost are all statistically significant at p<.001. Moreover, evaluation of partial η^2 values and marginal means plots of SKU breadth effect on cost suggests a large effect size. Furthermore, the marginal means plots of SKU * NICHE (Figure 4-21) demonstrates that high niche encroachment allows early SKUs to capture more demand. The marginal increase in demand is lower, but the overall effect is to capture more market share earlier when consumers do not have fixed preferences. Therefore, Hypothesis H2d is supported.

4.4.2.5 Preference attribute affect on product line length

This hypothesis states that, "*Adding preference attributes increases the number of profitable SKUs in the product line.*" This hypothesis was not directly tested by the experiment but can be deduced because it is the synthesis of the other hypothesis. Preference attributes

increase revenues, cost, and market share. However, adding preference attributes did not increase profit. Preference attributes appear to be very effective at protecting markets and expanding current market base without a profit. Therefore, Hypothesis H2e is not supported.

4.4.3 Aligned quality attribute hypotheses

In the simulation, refrigerator size was modeled as the aligned quality attribute. Larger refrigerators were assumed to be better than smaller refrigerators. Aligned quality attributes were represented in the experiment by lower quality variance, demand increases, and lower substitution rates. Once again, most of the variance introduced into the simulation was attenuated by consumers' willingness to delay purchasing. Therefore, the quality variation variable had little effect on the dependent variables and is not discussed in hypothesis testing.

4.4.3.1 Aligned quality attribute affect on revenue

This hypothesis states that, "*Adding aligned quality attributes increases revenue.*" Multivariate and univariate (Table 4-5 and 4-8) test results indicate that the effects of substitution and demand on the multivariate and on revenue are statistically significant at $p<.001$. Moreover, evaluation of partial η^2 values and marginal means plots demonstrate a large revenue effect for these variables. Figure 4-27 illustrates that revenue increases when attributes are in the aligned condition. Additionally, when demand increases as SKUs are added to the product family as depicted in Figure 4-8, revenue also marginally increases. The result is that aligned conditions increase revenue. Therefore, hypothesis 3a is supported.

4.4.3.2 Aligned quality attribute affect on cost

This hypothesis states that, "*Adding aligned quality attributes decreases costs.*" Multivariate and univariate (Table 4-5 and 4-8) test results indicate that the effects of substitution

and demand on the multivariate and on cost are statistically significant at p<.001. Moreover, evaluation of partial η^2 values and marginal means plots show a large increased cost effect for these variables. Figure 4-27 illustrates that when substitution decreases in the aligned condition, cost actually increases. Additionally, when demand incrementally increases as SKUs are added to the product family, cost also increases. The experiments showed no decrease in cost due to aligned attributes experiencing less demand variation because consumers were allowed to delay their purchases thereby smoothing demand variation. As a result, costs associated with increased demand increase in the aligned attribute condition; costs associated with demand variance are not affected by the aligned attribute condition. Therefore, hypothesis 3b is not supported.

4.4.3.3 Aligned quality attribute affect on profit

This hypothesis states that, "*Adding aligned quality attributes increases profits.*" Multivariate and univariate (Table 4-5 and 4-8) test results indicate that the effects of substitution and demand on the multivariate result and on revenue are statistically significant at p<.001. Moreover, evaluation of partial η^2 values and marginal means plots illustrate a large profit effect resulting from substitution and a medium-sized effect for increased demand. Figure 4-27 shows that when attributes are in the aligned condition that profits increase substantially. Additionally, when demand increases as SKUs are added to the product family (Figure 4-9) the difference in profits between the two conditions average $1.2 million. The reason the demand and profit effect is not stronger is that the increased demand variable only differs between conditions for the premium quality attribute (SKU seven). Overall, in these experiments, the aligned condition creates greater profit. Therefore, hypothesis 3c is supported.

4.4.3.4 Aligned quality attribute affect on market share

This hypothesis states that, "*Adding aligned quality attributes increases market share.*" Multivariate and univariate (Table 4-5 and 4-8) test results indicate that the effects of substitution and demand on the multivariate result and on market share are statistically significant at $p<.001$. Moreover, partial η^2 values illustrate a medium profit effect for substitution and a large-sized effect when demand increased. Figure 4-27 illustrates that when attributes are in the aligned substitution condition that market share increases only slightly from 51.0 percent market share at the highest substitution condition, to 51.6 percent market share at the medium condition, to 51.8 percent market share at the lowest condition. Given the accuracy of the simulation model, substitution associated with alignment does not appear to be driving significant differences in market share. There is, however, a 14 percent difference between the aligned and non-aligned condition due to the demand variable (Figure 4-28). In total, aligned attributes increase market share because of the increased demand and hypothesis 3d is supported.

4.4.3.5 Aligned quality attribute affect on product line length

This hypothesis states that, "*Adding aligned quality attributes will increase the number of profitable SKUs in the product line*." Quality attributes increase revenue, cost, profit, and market share. The increase in costs is the largest concern regarding quality attributes because creating a new quality attribute is expensive and these costs are passed on to the consumer. Even with the increase in costs, adding quality attributes increases the profitability of the product line. Quality attributes also tend to increase the market share. Managers can expect that the best way to increase profitability and market share is by adding aligned quality attributes. Therefore, hypothesis 3e is supported.

4.4.4 Non-aligned quality attribute hypotheses

In the simulation, refrigerator door inserts are modeled as the non-aligned quality attribute. No hierarchy was assumed between door inserts so consumers were left confused and with high potential for regret. Non-aligned quality attributes were represented in the experiment by higher-quality variance, demand decreases as the SKUs increased past the sixth SKU, and higher substitution rates. Once again, most of the variance introduced into the simulation was attenuated by consumers' willingness to delay purchasing. Therefore, the quality variation variable had little effect on the dependent variables and is not discussed in hypothesis testing. Additionally, rather than restate what has previously been written about aligned quality attributes, only nuanced differences are discussed.

4.4.4.1 Non-aligned quality attribute affect on revenue

This hypothesis states that, "*Adding non-aligned quality attributes decreases revenue."* The discussion for hypothesis 3b shows this to be the case. Non-aligned attributes lose revenue streams because customers either buy less expensive items in the product line or they buy the competitor's product. Therefore, hypothesis 4a is supported.

4.4.4.2 Non-aligned quality attributes affect on cost

This hypothesis states that, "*Adding non-aligned quality attributes increases cost.*" As the discussion for hypothesis 3a demonstrates, this is not the case. There are two main reasons that non-aligned attributes decrease cost. First, non-aligned attributes cause high substitution. When substitution is high, consumers tend to purchase a higher percentage of less-expensive items from the product line. Therefore, material costs are much lower. Second, because demand is lower as a result of customer confusion, fewer items are purchased. Therefore, volume related cost is less. Therefore, hypothesis 4b is not supported.

4.4.4.3 Non-aligned quality attributes affect on profit

This hypothesis states that, "*Adding non-aligned quality attributes decreases profit.*" The discussion for hypothesis 3c demonstrates this to be the case. However, it is important to realize that the small amount of demand accounted for by the premium SKUs results in a medium effect size. This suggests that the largest effect of non-aligned attributes on profit is realized when the consumer substitutes for a less expensive feature. Therefore, hypothesis 4c is supported.

4.4.4.4 Non-aligned quality attribute affect on market share

This hypothesis states that, "*Adding non-aligned quality attributes decreases market share*." The discussion for hypothesis 3d demonstrates this to be the case. However, the greatest effect is from the decreased demand variable. This suggests that the largest effect of non-aligned attributes is the loss of consumers to competitors. Since only one of the three tested variables appear to influence market share, hypothesis 4d is only partially supported.

4.4.4.5 Non-aligned quality attribute affect on product line length

This hypothesis states that, "*Adding non-aligned quality attributes decreases the number of profitable SKUs in the product line*." This was shown by the results. Even with the reduction in cost, the non-aligned attributes negatively influenced both profit and market share. Therefore, hypothesis 4e is supported.

4.5 Discussion

The main objectives of this research are to examine how SKU breadth and attribute value influence the performance of a product line. To realize this objective, the research examines effects of SKU breadth, preference variance, niche encroachment, quality variance, substitution, and increasing demand on product line performance. Table 4-10 outlines the results suggested by the analysis.

Table 4-10, Results by Attribute Type

	Preference Attribute	Aligned Quality Attribute	Non-Aligned Quality Attribute
Uncertainty	Buffered by delayed delivery	Buffered by delayed delivery	Buffered by delayed delivery
Adding to the Product Line	Low cost and easier to add to the product line Increases costs, revenue and market share Does not increase profit Protects or increases customer base	High cost and harder to add to the product line Increases costs, revenues, profits, and market share Increases customer base and profitability	High cost and harder to add to the product line Decrease costs thereby confusing managers Decrease revenues, profits, and market share
Cannibalization	Niche encroachment front end loads costs Bad when preferences are fixed Good when preferences are flexible	Not a major issue because consumer can easily variegate the product line	Significantly influences profitability Significantly influences market share Two types: lack of differentiation and substitution Non-linear effect suggest large reward for management attention

First, the temporal postponement created by consumers' willingness to wait for an out-of-stock item buffers demand variance uncertainty. Results illustrate that neither variance has a partial η^2 value that suggests even a small effect size on the dependent variables. Therefore, the

ability to expand the time that consumers are willing to wait for a durable good delivery appears to be a strategic advantage.

Second, results indicate that preference and quality attributes perform much different roles for the firm. Preference attributes are very effective at inexpensively increasing revenue and increasing market share as they capture frustrated demand. Preference attributes also raise costs and do not significantly contribute to profits. This suggests that firms seeking to protect or grow markets can do so by adding colors and other preference attributes to their products. On the other hand, aligned quality attributes increase revenue, profit and market share. These attributes give meaning to price differences and create surety in consumer decision-making. Aligned quality attributes are an expensive alternative to increase profit and market share. The result is that while preference attributes can be added very quickly to a product line, quality attributes require significant planning.

Third, non-aligned attributes are greatly inferior to aligned attributes in terms of profit and market share. Non-aligned attributes lose customers because these attributes do not create hierarchies. Marketers are punished by including non-aligned attributes because the firm loses revenue, profit and market share. However, the decrease in volumes also decreases cost. Therefore, while marketers are punished, supply chain managers may be rewarded for non-aligned attributes.

Fourth, the fixed or flexible nature of consumers dictates the effect of niche encroachment on the supply chain. For instance, Apple has expanded the selection of iPod colors available. However, white is the standard iPod color and most buyers will accept a white iPod if their preferred color is not available. The consumers have flexible preferences. The results show that when consumer preferences are flexible, niche encroachment allows the firm to

capture more demand from earlier introduced SKUs. The firm can also expect smaller increases in demand from introducing new preference attributes when consumer preferences are flexible. This results because some of the new color demand comes from consumers that would have bought the generic color if the new color was unavailable.

Refrigerator buyers on the other hand, are very unlikely to purchase a kitchen appliance color that does not satisfy their interior design plans. These consumers have fixed preferences. The results demonstrate that when consumer preferences are fixed, the firm must introduce the "correct" preference attribute in order to earn that customers demand. As a result, larger increases in demand can be expected as more colors are added to the product line and fixed customers find their exact color choice. A firm's ability to predict consumers' fixed or flexible nature towards preference attributes is strategically important.

Fifth, quality attribute substitution negatively affects the supply chain when attributes are not aligned. When customers cannot discern a hierarchy within the product line, they tend to buy less expensive products. The results demonstrate that although this decreases cost, it also decreases revenue, profit, and market share. Once again, the supply chain manager may be rewarded for reducing costs while decreasing supply chain value. The results suggest that substitution manifests itself in two distinct ways. The first is when a newly introduced, "lower-quality" product substitutes for an existing, "higher-quality" product. This cannibalization is especially detrimental to the firm because it usually reduces revenue, profit and market share as customers abandon more expensive product for the new less expensive product. The second manifestation of substitution is "variegation failure." This happens when a firm introduces a more expensive and "higher-quality" product that consumers cannot differentiate from existing, "lower-quality" products. In this case, the variegation failure manifests itself as a product

attribute that does not create substantial new demand. Therefore, management effort to improve customer perceptions of product hierarchy should increase revenue, profits, and market share and should be worthy of strategic consideration.

CHAPTER V: CONCLUSION

5.0 Introduction

The main question that initiated this research was how marketing and supply chain managers can better coordinate product variety decisions. This chapter answers this question in four sections. The first section uses the results discussed in Chapter Four to guide management strategy for product variety decision-makers. Specifically, it discusses how durable goods managers can use the research findings to develop strategic product variety advantage. The second section discusses the theoretical contributions of the research. It expands current theory and demonstrates how integrating prospect theory with total cost theory creates cohesive guidance. The third section describes the methodological contributions of the research. Specifically, it highlights the complementary strengths of using simulation methodology in conjunction with human behavioral research. Finally, the chapter concludes by identifying the limitations of the current research and suggesting future research studies.

5.1 Strategic managerial contributions

The research offers managers strategic insight to guide their firms in the determination of the product line "sweet spot." Understanding the cost and value of extending the product line helps marketing and supply chain managers agree on product line strategy. This section serves as an overview of the findings and discusses the contributions of SKU breadth and product attribute value.

5.1.1 Managing SKU breadth

The research demonstrates that extending SKU breadth generally provides value to the firm. However, interaction with cannibalization and attribute alignment create situations where

adding SKU breadth does not help the firm. Most managers assume that extending the product line will always win new demand, protect current market share, and increase customer satisfaction. This research demonstrates that the relationship between SKU breadth and supply chain value is very complex. When managers extend the product line, they must understand that simply increasing SKUs does not necessarily increase consumers' perception of breadth. The following sections detail the complexity of the situation.

5.1.2 Managing attribute value

Product attribute value describes how consumers perceive increased SKU breadth. Managers that are extending their product line can use this prescriptive advice to help develop product portfolios that customers perceive as valuable. Table 5-1 provides an overview of attribute value management. Four rows discussing risk, reward, strategic use, and management advice are discussed for each type of attribute. Risk is discussed so that managers understand the trade-offs that they may face. There are two types of risk for each attribute: risk associated with revenue, cost, profit and risk associated with consumers. Reward is discussed so that managers may understand the benefits of the different attributes. The reward is generally discussed in terms of revenue, cost and profit. Implications for market share and customer service are discussed as well. Strategic use shows how an attribute may be used to the manager's advantage. Management advice is included to help marketing managers and supply chain managers understand the traps and opportunities associated with attribute types. Table 5-1 should help managers understand how each type of attribute strategically benefits their product portfolio.

Table 5-1, Managing Attribute Value

	Attribute Type		
	Preference	**Aligned Quality**	**Non-Aligned Quality**
Risk	- May not increase profitability - Difficult to discern customer fixed or flexible nature	- Expensive attributes to develop - Difficult to discern customer perceived hierarchy	- Distorts new features success - Confuses customers - Increases probability of substitution
Reward	- Expands markets and revenues - Satisfies fixed customers	- Increases profit - Increases market share - Increases revenue - Lowers probability of substitution	- Reduces costs - Introduces new feature to the market
Strategic Use	- Protects markets - Expands markets	- Protects markets - Expands markets - Expands profitability	- Introduces new feature to the market
Management Advice	- Prioritize as the first product line extension - Use primarily to protect and grow markets - Focus market research on consumer flexibility	- Judiciously develop as the most important product line extension - Expend most of R&D budget on aligning attributes - Focus market research on customer perceived hierarchy	- Identify non-alignment before the attribute is released to the market - Use non-aligned attributes primarily to test new features - Focus market research on the individual attribute

5.1.2.1 Managing preference attributes

The primary risk with preference attributes is that they may not be profitable. These are generally low cost, low price features that do not generate significant profit. Managers must therefore realize that adding preference attributes to a product portfolio may not enhance their bottom line.

The research demonstrates that the risks associated with preference attributes relate directly to how fixed consumer preferences might be. In the simulation, fixed preferences related to low preference variance and low niche encroachment. Fixed consumers know the color they want and are unlikely to buy any other color. Flexible consumers are more likely to buy the first color that is released. However, when a new color is released that flexible consumers like better, they might choose the new color. The risk is that managers will over-forecast demand because they mistake flexible consumers for fixed consumers. Rather than get a large increase in demand with the introduction of a new color, the research demonstrates that flexible consumers only offer a modest demand increase. Furthermore, because preference attributes are inexpensive, firms may add too many to the product line. Management should closely track preference attribute marginal profit to discern when the maximum is achieved.

Nevertheless, the research also illustrates that there are definite rewards for adding preference attributes to the product line. Preference attributes increase both revenue and market share. This occurs as fixed preference consumers finally purchase the color they want. To take strategic advantage of preference attribute effects on the supply chain, firms should focus on preference attributes to protect markets from competitors. Adding more preference attributes to an existing portfolio captures lifetime value from fixed preference customers. Additionally, preference attributes create inexpensive differentiation. This increases market share as new

preference attributes capture fixed customers that cannot find their ideal color in the competitor's brand.

The prescriptive advice to product line managers regarding preference attributes is threefold:

Preference attributes should be the first type of attribute used to extend the product portfolio. These attributes are inexpensive and are able to capture market share. This allows the firm to capture as much demand as possible and take away a possible lifetime stream of revenue from competitors.

Preference attributes should be used to grow market share and increase revenues. Managers must make preference attribute extension decisions with the understanding that they may not increase profitability. The goal of adding preference attributes is to capture demand.

Most market research focuses on consumer likes and dislikes. Instead, market researchers should focus on the consumers' degree of flexibility for a given preference attribute. For instance, market researchers generally ask consumers to rank a series of colors in order of preference. Instead, market researchers should ask consumers questions about what they would do if their first-ranked color was not available. Managers must understand the flexibility of the customer to help understand the potential market and revenue increase associated with flexibility.

5.1.2.2 Managing aligned quality attributes

Quality attributes are generally substantial features that are expensive to create. The primary risk regarding quality attributes is that if they are perceived as not creating a hierarchy, they confuse customers, reduce demand, and increase substitution. Substitution is particularly problematic as it pushes consumers towards the least profitable products. Additionally,

hierarchies are very difficult for managers to judge because they are created by consumer perception. Therefore, firms risk spending extensive time and money developing new quality attributes that consumers may not be able to differentiate from existing attributes.

However, when a manager develops aligned quality attributes the reward is substantial. Managers can expect increased revenues, increased profits, and increased market share. Aligned quality attributes represent the best product extensions available. Managers can therefore use aligned quality attributes to protect existing markets, expand into new markets and create greater profitability. The research offers managers two prescriptive techniques regarding quality attributes:

Quality attributes should be judiciously developed. These attributes are expensive, but if aligned positively, increase revenue, profit, and market share. Managers should devote more of the firm's research and development budget to these types of attributes.

Market research should focus on whether or not consumers perceive a hierarchy within quality attributes. For instance, current market research may ask if a consumer prefers one refrigerator size over another. The question that market researchers should ask consumers is whether they would pay for the difference between refrigerator sizes. Managers must understand the consumer-perceived hierarchy to ensure alignment.

5.1.2.3 Managing non-aligned quality attributes

The best prescriptive advice for non-aligned attributes is to avoid them. If adding non-aligned attributes cannot be avoided, there are two things managers can do:

Identify the non-alignability of the attribute before it hits the market. Use market research to help identify the lack of a hierarchy and develop pricing strategies and forecasts accordingly.

Use non-aligned attributes primarily to test new features. When these attributes are implemented, they should be done primarily in small, test markets. Broad market exposure should be reserved until a hierarchy can be created for the new attributes.

5.1.3 Managing cannibalization

Managers that are expanding their product lines should be cognizant of cannibalization. If unmanaged, cannibalization can reduce profits and decrease market share. Table 5-2 provides an overview of cannibalization management.

Table 5-2, Managing Cannibalization

	Cannibalization Type	
	Niche Encroachment	**Substitution**
Conditions for Cannibalization	- Generally occurs with preference attributes. - Consumers' preference flexibility determines extent of encroachment.	- Generally occurs with non-aligned quality attributes. - The relationship between the existing product line's attributes and the new attribute determines the type of substitution.
Manifestation of Cannibalization	- Flexible preference consumers Newly added preference attributes add very minor new demand and cannibalize extensively from existing demand. - Fixed preference consumers Newly added preference attributes add new demand and steal very little from existing demand.	- Cannibalization (less expensive attribute added to more expensive product line) Newly introduced quality attribute adds minor new demand and steals demand from existing quality attributes. - Lack of variegation (more expensive attribute added to less expensive product line) Newly introduced quality attribute adds very minor new demand.

Table 5-2 (cont'd)

Management Strategy	- Use marketing research to determine fixed or flexible nature of consumers. 1. When customer preferences are fixed, expect less niche encroachment. 2. When customer preferences are flexible, expect more niche encroachment.	- Use marketing research to determine consumers perceptions of quality attribute's hierarchy. 1. If consumers perceive a hierarchy, expect less substitution. 2. If consumers do not perceive a hierarchy, expect more substitution.

Niche encroachment may or may not present problems for the product portfolio. In the case of niche encroachment, the consumer's pre-existing preferences determine whether or not niche encroachment will negatively influence the firm. When consumers have flexible preferences, adding more preference attributes to the product portfolio results in more demand from an existing niche. Therefore, when consumers are flexible and niche encroachment is high, demand will not marginally increase as much as when preferences are fixed. When market research shows that consumers are flexible, it makes little sense to significantly increase the breadth of preference attributes. The high niche encroachment that ensues will not substantially increase revenue. When consumer preferences are fixed, adding preference attributes will significantly increase revenues and market share.

Managing substitution is much more difficult. When consumers cannot differentiate a hierarchy within the product portfolio, adding new attributes reduces profits and market share. Therefore, this research suggests that differences between products should be discernable and valued. Aligning attributes by having real, hierarchical differences between products is the most effective way of reducing this type of cannibalization. Therefore, managers should ensure that a

product is not only differentiated from competitors, but also is hierarchically different within its own product portfolio. It is much easier to create variegation with a product portfolio before it reaches the market, than after consumers conclude that the entire product line is the same quality. Finally, managers should understand that lack of differentiation may manifest itself as a new, higher quality product that did not succeed. If consumers cannot tell the difference between the new product and old product, they will choose the less expensive product. Managers that are cognizant of both cannibalization and lack of differentiation can identify and remedy this situation by strengthening the hierarchy of the new item.

5.2 Theoretical contributions

Theoretical contributions differ from managerial contributions. Where managerial contributions are practical, theoretical contributions focus on explaining and predicting phenomenon (Whetten 1998). Two major theoretical contributions emerged from this research.

5.2.1 Categorization of attribute value

One theoretical contribution of this research is categorizing the different types of attribute values. The preference and quality attribute paradigm (Figure 2-2) provides greater granularity in the attribute product model. Previous research (Gourville and Soman 2005; ChurnerChernev 2003; Iyengar and Lepper 2000) alluded to these categories, but did not treat them as different types of attributes. This research treats preference and quality attributes differently to develop a more comprehensive understanding of attribute value. For instance, the ability to separate preference attributes from quality attributes guides greater understanding regarding the different types of cannibalization. This increases the explanatory power of existing theory and creates a more comprehensive theory of product line extension.

5.2.2 Total value of consumer behavior

A second theoretical contribution is the increased understanding regarding the supply chain value of consumer behavior. Previous research was myopically conducted to either understand consumer behavior to attribute value or to gauge firm response to SKU breadth. This research extends consumer behavior research. Specifically, where previous research demonstrated that consumer behavior influenced demand and demand variance, this research demonstrates the resulting effects on revenue, cost, profit and market share. Empirically demonstrating the value of specific product selection behaviors related to product attributes expands product portfolio theory.

5.3 Methodological contributions

This research also demonstrates that the simulation methodology has wider application than previously discussed in simulation literature. Davis et al. (2007) propose that simulation is particularly well suited for expanding existing theory and building new theory. This research shows that simulation is also well suited for investigating complex phenomena that is best explained and predicted through multiple theories. Additionally, this research shows that simulation is also well suited for creating greater contextual understanding of human behavior research.

5.3.1 Multi-paradigmatic value of simulation

Researchers frequently face situations where a broad and complex phenomenon is observed. In order to make theoretical sense of the phenomena, researchers frequently simplify the phenomenon's scope to accommodate theoretical limitations. While simplifying effectively describes portions of the phenomenon, it fails to explain and predict the entire, observed phenomena. Methodologies that combine multiple theoretical perspectives into a single

metaparadigm create powerful insights (Lewis and Grimes 1999; Gioia and Pitre 1990). In this study, total cost theory focuses on the supply-side cost of increasing SKU breadth; while prospect theory focuses on the value of attributes. Individually, the theories did not comprehensively explain product portfolio behavior. Together they create a unifying strategy of product portfolio expansion. Simulation is uniquely suited for incorporating multiple paradigms into research.

5.3.2 Extending human behavior experimentation through simulation

This research relied on simulation's ability to extend human behavioral research. Simulation complements human behavior research. Behavioral research removes non-human factors in the environment to control against confounds. Simulation combines both human behavior and non-human, environmental factors and still retains control. In this study, supply chain structure and firm policy were combined with observed consumer behavior to develop more complete, product attribute understanding.

Simulation can accomplish this type of multi-paradigmatic research for three main reasons. First, simulation is flexible. This flexibility allows researchers to create parameters similar to observed experimental behaviors. However, simulation can extend simulated behaviors beyond observed experimental limits. This helps to understand the extremes of a phenomenon. In this research, simulation allowed deeper investigation into extreme ranges of cannibalization. Second, simulation is well suited for complex and interacting systems (Law and Kelton 2000). This includes interacting theories. In this research, the situation was so complex that a single theory failed to capture the entire phenomenon. Simulation allowed consumer choice to interact with total cost. Finally, simulation research is controlled. One of the primary problems with placing human behavioral experimental research in its natural context is the loss

of control. Since researchers can govern the systems and settings in simulation, it enhances the generalizability of the human behavioral research. In summary, extending behavioral research through simulation is a good methodological course for multi-paradigmatic research.

Table 5-3 provides a summary of the managerial contributions and table 5-4 provides a summary of the theoretical contributions.

Table 5-3, Managerial Contributions

Managerial Application	
Increasing SKU Breadth	1. Does not always win new demand, protect market share, or increase customer satisfaction. 2. Should be strategically used only when attribute value is understood.
Increasing Preference Attributes	1. Introduces a relatively inexpensive product extension into the product line. 2. Should be the first attributes introduced because it is inexpensive and easy to add. 3. Might not increase profitability. 4. Increases revenue, cost and market share. 5. Creates strategy dependent on consumer flexibility. *Fixed preferences* suggest that firms should increase preference attributes to grow markets and increase revenue. *Flexible preferences* suggest that firms should be cautious about increasing preference attributes. 6. Suggests market research should focus on consumer flexibility.
Increasing Quality Attributes	1. Introduces a relatively expensive product extension into the product line. 2. Creates different effects depending on consumer's perception of hierarchy. *Aligned attributes*increase revenue, cost, profit and market share. *Non-Aligned attributes*decrease revenue, cost, profit and market share. 3. Creates stategy dependent on consumers perception of a hierarchy. *Aligned attribute* - Firms should devote most of the research and development budget to create hierarchal, quality attributes. Managers should include these attributes in the product line to increase profit and market share. *Non-Aligned attributes* - Firms should use these attributes only when testing a new feature. 4. Suggests that market research should focus on whether the quality attribute creates a hierarchy.

Table 5-3 (cont'd)

Managing Cannibalization	1. Preference attributes depend on consumer preference flexibility and degree of niche encroachment. *Fixed consumer preferences* create minor encroachment so new preference attributes will create new demand. *Flexible consumer preferences* suggest that the product line will experience extensive encroachment and that new preference attributes may mostly steal demand from existing demand. 2. Quality attributes depend on consumer perceptions of a hierarchy and experience substitution. *Aligned attributes* create minor substitution so new quality attributes may create significant new demand. *Non-aligned attributes* create extensive substitution so new quality attributes may create very little new demand.

Table 5-4, Theoretical Contributions

Theory	
Attribute Types	1. Divides order winning attributes into two distinct types. ***Preference attributes*** which relate solely to consumer's personal tastes. These are attributes such as color or flavor that do not create a distinct hierarchy. ***Quality attributes*** which relate to an explicit hierarchy between products in a product line. These are attributes such as engine size that frame consumer choices in a logical price sequence. 2. Refines the study of attributes in the product line.
Total Value of Consumer Behavior	1. Expands the application of consumer behavior beyond the retail level. 2. Details the effect of consumer behavior on the durable goods supply chain. 3. Creates theoretical understanding about extended effects of product variety.
Methodology	1. Demonstrates the value of simulation when phenomena is too broad to be explained by a single theory. 2. Demonstrates the power of simulation to extend human behavioral research to more generalizable contexts.

5.4 Limitations and future research

There are some limitations and future research implications for this research.

5.4.1 Limitations

In simulation, researchers make certain assumptions to limit the scope of analysis. For example, this study made assumptions regarding inventory policies, transit lead times, demand

patterns, and material costs. These assumptions limit the findings to specific situations. Although the assumptions were based on interviews and high quality information, they may be too limiting. For instance, the assumption that 80 percent of demand will select an average quality product may not apply to some durable goods. Future research should examine the effect that changing parameters and changing industry settings have on the findings.

Second, the simulation modeled a simplified supply chain consisting of one regional DC, and one manufacturer. The simulation also targeted a single product line and modeled competition as duopoly. This neglects dynamics that may occur in a more complex setting. More product lines and more competitors may reveal important dynamics not considered in this research. Future research should evaluate a more comprehensive supply chain network with more horizontal complexity and greater product complexity.

Third, production effects were not modeled due to extensive, prior research in this area (Ramdas 2003). However, production complexity might provide more granular insight into product variety. Additionally, the interplay between supply, production, and delivery might develop key managerial insights. Future research should consider the interaction between production and other supply chain functions in product line decisions.

Fourth, the cannibalization literature was vague regarding observed "real world" occurrences of cannibalization. In order to classify cannibalization types this research performed sensitivity analysis. Ideally, these parameters should be based on field research and the experimental parameters based on empirical data. Future research should delve more extensively into the cannibalization phenomenon.

Finally, this research was grounded in a durable goods context. However, individual industries tend to have different dynamics that may not reflect outcomes in other industries. For

example, consumer behavior towards candy is based almost solely on preference attributes. This may mean that the supply chain revenue, cost, profitability, and market share is different for candy. Future research should find additional and diverse industrial settings to test the robustness of the findings.

5.4.2 Future research

In the course of the study, two additional study topics emerged. First, the extant literature on substitute, delay, and leave behavior (SDL) has only occurred in a consumable goods setting and could benefit from expansion into durable goods. Second, the sequence of product introduction was limited during the simulation. This lends itself to the question of whether or not the sequence involved in product introduction creates divergent results.

The research demonstrates that delaying purchases, a commonly accepted practice in the durable goods setting, buffered much of product variety's demand uncertainty. The SDL literature has only evaluated consumers' responses for consumable goods, giving no expectation of a temporal postponement effect. Durable goods retailers appear to differ in their business practices and durable goods consumers appear to differ in their SDL behavior. Further analysis of temporal delays could reveal differences in the buffering phenomenon and lead to the strategic use of timing delays. Future research should focus on the durable goods setting to replicate and expand the SDL research done on consumable goods.

Another of the key findings showed differences in the manifestation of substitution. These findings were predicated on the introductory sequence of quality attributes. In the simulation, the average quality attributes were introduced first, followed by the budget attributes, and then the premium attributes. This sequence was based on the idea that a firm created a new product, and then introduced a lower-cost version to keep competitors at bay. Finally, a quality

product was introduced to appeal to more affluent consumers. However, several other sequences can be envisioned. For instance, an international firm may offer their budget product first in order to "under price" competitors. The average quality product would be added as a "step up" product, and then the premium product would follow. The "Innovators Dilemma" (Christensen 2003) also invites another sequence. In this scenario, a firm creates a disruptive technology that is premium quality. Steps down to the average quality level and budget quality level would naturally follow. Future research should see if the introductory sequence influences the effects of attribute value.

5.5 Conclusion

The preceding discussion pinpointed key managerial implications, research contributions, research limitations, and opportunities for future research. It highlighted important findings that managers and researchers will find useful. The study extended consumer behavior research by evaluating consumer behavior effects on the durable goods supply chain. It also made important contributions in advancing product attribute knowledge and proposing management strategies. Managers should implement the strategic findings while researchers should expand the theoretical findings.

APPENDIX

APPENDIX – PRODUCT VARIETY DEFINITIONS

Table A-1, Product Variety Definitions

Term	Definition	Example	Level	Literature Example
Brand	Identifies the product manufacturer.	Colgate identifies the specific manufacturer of personal care items.	Firm	Hui 2004
Product Portfolio	The total range of products created by a firm.	Colgate's product portfolio includes tooth care products, soaps, shampoos, etc.	Firm	Srinivasan, Ramakrishnan, and Grasman 2005, Anand 2008
Product family or brand category	A similar, same brand, group of items that meet a similar group of consumer needs.	Colgate's tooth care products: toothpaste, toothbrushes, and dental floss	Firm	Kim and Chhajed 2000, 2001, Krishnan and Gupta 2001
Product line or product group	A sub-family of similar products that meets specific consumer needs.	Colgate toothpaste	Firm	Kekre and Srinivasan 1990 Roberts and McEvily 2004, Gourville and Soman 2005, Netessine and Taylor 2007
Product	A particular grouping of attributes within a product line that is usually represented by a single SKU.	Colgate, cinnamon flavored, 12 ounce toothpaste	Firm, Distributor, and Retailer	Kahn 1995, 1998, Desai 2001, Schmidt and Chernev 2003, Druehl 2006
Product Category	Products of different brands, sizes, quality, etc. that all group into the same type of product line.	Tooth care items from all brands.	Retailer or Distributor	Brynjolfsson, Hu, and Smith 2003

Table A-1 (cont'd)

Single product brand category	A single brand, group of items the meets specific customer needs. Analogous to the product line but at the distributor or retail level.	Colgate's Toothpaste	Retailer or Distributor	Lancaster 1990, Hui 2004
Product Assortment	The SKU breadth on the retailers shelf	The total of number of shampoo SKUs at Wal-Mart.	Retailer or Distributor	Hoch 1998, Ryzin and Mahajan 1999, Boatwright and Nunes 2001, Caro and Gallien 2007, Montrala et al 2009

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