ABSTRACT

Title of Document: THE IMPACT OF PRODUCT VARIETY ON RETAILER OPERATIONAL PERFORMANCE AND SALES: EVIDENCE FROM CHINA.

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Providing higher levels of product variety has long been shown to generate increased revenues for both retail and manufacturing firms. However, recent research has also shown that higher levels of product variety can have a negative impact on firm operational performance. This dissertation is a two essay study using archival data provided by a single retail firm based in Shanghai, China, on the effects of product variety on retailer inventory levels, stock out rates, and sales. The first essay examines how product variety, as measured by the number of SKUs carried in the retailer's product category assortment, affects inventory levels, stock out rates, and sales. The second essay investigates whether different types of product variety (namely brands, sizes, and product lines) impacts store inventory levels, stock out rates, and sales differently.

The first essay investigates how the size of the product assortment impacts inventory levels, stock out rates, and sales. Greater product variety has the potential

to generate higher revenue for the retailer, but also brings the potential for more complications in inventory and supply chain management processes. While previous research has examined this relationship within a manufacturing context, no research has investigated the tradeoff in a retail context. Also, this research is the first to consider the impact of product variety on a firm's inventory levels. This is an important inclusion as inventory levels directly impact the stock out rate of a retailer. Furthermore, this paper investigates whether characteristics of a product category, such as the hedonic or utilitarian nature of the product category, moderate the relationship between product variety, operational performance, and sales. Using simultaneous equations and a three stage least squares regression methodology, results suggest that product variety has a positive relationship with inventory levels, stock out rates, and sales. Finally, the relationship between a product categories' stock out rate and sales is stronger for hedonic product categories than utilitarian product categories.

In the second essay, this dissertation examines whether the relationship between product variety, inventory levels, stock out rates and sales differs between different types of product variety. In particular, this essay investigates whether brand variety has a larger impact on retailer inventory levels, stock out rates, and sales than do size variety or product line variety. Again, using a simultaneous equation model and a three stage least squares methodology, the results suggest that brand variety is associated with higher inventory levels, lower stock out rates and higher sales than size or product line variety in the retail context.

THE IMPACT OF PRODUCT VARIETY ON RETAILER OPERATIONAL PERFORMANCE AND SALES: EVIDENCE FROM CHINA

By

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Dissertation submitted to the Faculty of the Graduate School of the
University of Maryland, College Park, in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
2015

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Dedication

To Julia, Don, Mei, Cameron, Alex, Eddy, Jan, and Steve. Thanks to all of you for being there for me in your own ways when I needed it the most. I never would have completed this undertaking without your help, guidance, and friendship.

"And I asked myself about the present: how wide it was, how deep it was, how much was mine to keep."

— Kurt Vonnegut, Slaughterhouse-Five

Acknowledgements

This dissertation would never have been completed without the support and encouragement of my chair, my committee members, and my friends and family.

I would like to express a deep gratitude to Bob Windle for his never ending encouragement and guidance during the dissertation and job hunt process. Without his help, this dissertation would never have been completed. He spent enough time and energy on me for two students, and I cherish all of the advice and help I received while studying under him.

I would also like to give a special thanks to Oliver Yao for presenting me with this fantastic opportunity, as well as your friendship. Without your timely offer of assistance, I would never have undertaken this topic, which is and continues to be of great interest to me.

I would also like to thank Martin Dresner and Phil Evers for their assistance and willingness to meet with me during my time in the Ph.D. program as well as my time writing this dissertation. The feedback, input, and encouragement that you offered greatly enhanced the dissertation and made me a better scholar.

I would like to thank Stephanie Eckerd, Thomas Corsi, Yan Dong, and James Campbell for helping me understand what it means to be a good colleague. Finally, I would also like thank Xiang, Rodrigo, Adams, Anupam, Isaac, Heidi, John Patrick, Camil, Alan, Matt, Kate, Xiaodan, Shweta, Mustafa, Justina, Seoungwoo, Kalinda, Jared, Chad, and Peter for their friendship and never ending support while I was in the Ph.D. Program.

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Chapter 1: Introduction

Most grocery retailers today carry well over 30,000 SKUs in their product assortment, and that amount has been slowly increasing over time (Kök and Fisher, 2007). Offering a larger product assortment can help improve the financial performance of retailers via several different mechanisms. There are two main ways product variety can directly increase retail sales: (1) higher amounts of product variety can entice new customers into a product category by offering a product variant that provides increased utility for some segment of previously non-purchasing customers, or (2) more product variety can increase utility for some current product category customers (also known as variety seeking customers) and encourage them to purchase more product from that product category (Baumol and Ide, 1956; Kekre and Srinivasan, 1990; Lancaster, 1990). Besides potentially increasing sales directly, product variety can also help prevent lost sales for retailers. For example, higher amounts of product variety can increase the probability that a customer purchases a substitute product when their original product of choice is out of stock (Zinn and Liu, 2001; Ton and Raman, 2010).

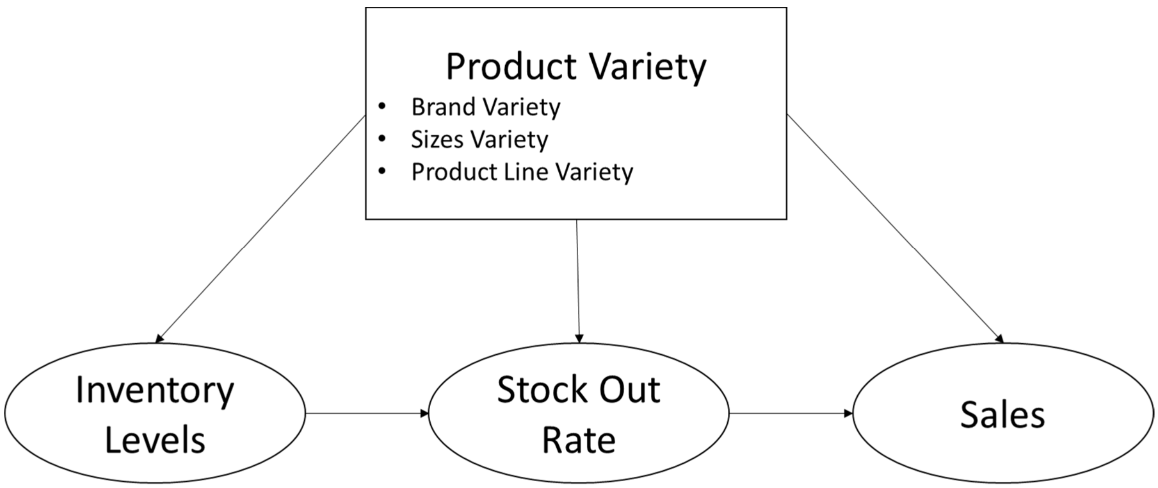
Despite the potential benefits of product variety, many retailers and brand manufacturers are starting to remove SKUs from their product assortment. For example, some women's clothing retailers are removing the traditional women's sizes (00, 0, 2, 4, etc.) in favor of alpha sizing (S, M, L, etc.). Additionally, the majority of grocery retailers have claimed that they wish to reduce the size of their product assortment in order to reduce their supply chain complexity (Taylor and Chaudoir, 2010; Holmes, 2014). These firms believed that they could reduce the complexity of their supply chain and inventory operations, which become more difficult and costly to manage in the presence of higher amounts of product variety, by offering a smaller product assortment. Research in operations and supply chain management suggests that higher product variety is associated with higher inventory levels at retailers (Dubelaar et al., 2001) as well as lower fill rates for brand manufacturers (Closs et al., 2010; Wan et al., 2012; Wan et al., 2014) and also with higher rework rates and more overhead in manufacturing firms (Fisher and Ittner, 1999).

More recent work has modeled operational performance and sales simultaneously as a function of product variety (e.g. Wan et al., 2012; Wan et al., 2014). However, no research the author is aware of has examined the relationship between product variety, operational performance, and sales in tandem with inventory levels or how the relationship between these performance metrics and sales manifests at the retail level. The distinction between the retail and brand manufacturer context is an important one, as retailers tend to offer a vastly different type of product assortment than manufacturers, such as different brands of the same base product or carrying multiple product categories in a single location (Ramadas, 2003). The inclusion of inventory levels in the simultaneous model is also an important step, because the ability to fill a customer's order is a function not only of the total number or types of SKUs offered in the retailer's product assortment but also the amount of inventory in each of those SKUs that the retailer chooses to carry.

The full hypothetical model of the dissertation is partly based on previous research in the brand manufacturer context (e.g. Wan et al., 2012) and is presented in

Figure 1. Product variety is assumed to have a direct effect on retailer inventory levels, stock out rates, and sales. A store's stock out rate is expected to have a direct effect on sales, and a store's inventory levels are expected to have a direct effect on a store's stock out rate.

Figure 1 Theoretical Model



The first essay investigates the relationship between product variety, operational performance and sales within the context of a retail firm. More specifically, this essay will empirically test how larger product assortments impact product category inventory levels, stock out rates, and sales. The first essay also investigates whether these relationships are potentially moderated by the characteristics of the product category being examined. In particular, previous research by Sloot et al. (2005) on consumer reactions to stock outs has shown that hedonic product categories, which tend to feature products that offer a more experiential consumption (e.g. salty snacks, candy, cigarettes) tend to be less substitutable than utilitarian product categories, which are consumed more for their functional use (e.g. cleaning supplies, vegetables, juice, toilet paper). The general substitutability of the product category could change the impact of product variety on operational performance and sales, as a higher amount of substitutability could be a reason for a retailer to carry less inventory in a product category or could make the stock out rate in that product category have a lesser effect on category sales than in a product category with less substitutability.

The second essay of this dissertation examines how the different types (or attributes) of product variety at a retailer can impact operational performance and sales. Previous research in the retail industry has shown that different types of product variety, such as brands, sizes, and product lines (alternatively known as flavors or lines) can have different effects on product category sales (Boatwright and Nunes, 2001). Size variety and product line variety have also been empirically shown to have different effects on fill rates and sales for a brand manufacturer (Wan et al., 2014). However, to this author's knowledge, no one has yet investigated how the different types of product variety might impact operational performance and sales simultaneously at the retail level. Again, the distinction between retailer and brand manufacturer is important in this context because retailers will typically deal with multiple brands and brand manufacturers in their supply chain and inventory operations, which is uncommon in the brand manufacturer context. Brand variety could potentially be harder for the retailer to deal with than size variety or product line variety due to the differences in shipping and inventory processes that might be present for different brand manufacturers in the same product category. This essay aims to answer the following question: does brand variety have a larger effect on the operational performance and sales of a retailer than size or product line variety?

1.1 Research Questions

This dissertation investigates the relationships between product variety, inventory levels, stock out rates and sales in the retail context. The following research questions are addressed across the two essays presented in this dissertation:

1. Does the size of the product assortment offered by a retailer in a product category effect their inventory levels, stock out rates, and sales?
2. If the size of the assortment offered by a retailer in a product category does affect their inventory levels, stock out rates, and sales, does the hedonic or utilitarian nature of the product category moderate these relationships?
3. Does the amount of brand variety present within a product category at a retailer impact the inventory levels, stock out rates, and sales of a retailer?
4. If the amount of brand variety present within a product category at a retailer does affect inventory levels, stock out rates, and sales of a retailer, is the effect of brand variety on these metrics different than the effect of size variety or product line variety on those same metrics?

This dissertation attempts to answer each of these questions in the essays that follow.

1.2 Research Contributions

This dissertation makes several contributions to the extant literature on product variety, operational performance, and sales. First, this dissertation is the first to simultaneously model inventory levels, stock out rates, and sales as a function of the product variety offered at a retailer. While previous research has simultaneously modeled the relationship between fill rates and sales in a brand manufacturing context (Wan et al., 2012; Wan et al., 2014) and simultaneously modeled the relationship between inventory levels and sales at the retail level (Dubelaar et al., 2001), this is the first research to synthesize all three components into a single model. This is an important step because inventory levels, stock out rates, and sales are inherently linked. The managers of a retail firm can modify one of these aspects of operations in an attempt to control another (for example, a store manager might decide to try to lower stock out rates by increasing inventory levels). This also contributes an important step to the analysis of how product variety is evaluated at firms. Previous research has focused solely on either the sales impacts of product variety (Wan et al., 2012) or the operational impacts of product variety (e.g. Fisher and Ittner, 1999; Fisher and Raman, 2001; Closs et al., 2010). By including inventory levels in the simultaneous model, we can begin to establish a method for examining the total impact of product variety on firm revenues and costs, which is the first step to empirically examining the total effect that product variety might have on firm profits, not just on firm revenues.

Secondly, this dissertation looks to separate out the effect of different types of product variety on inventory levels, stock out rates, and sales at a retailer. While previous literature has examined the simultaneous impact of size variety and product line variety on fill rates and sales in the brand manufacturer context (Wan et al., 2014), the shift in context to retailers adds another type of variety to the mix that must be accounted for by retailer managers: brand variety. Again, while the effects of brand, size, and product line variety has been examined on sales for an online grocery store (Boatwright and Nunes, 2001), the simultaneous impact of brand, size, and product line variety on inventory levels, stock out rates, and sales has not been examined.

Chapter 2: Literature Review

In order to provide context for the rest of this dissertation, this chapter will provide a comprehensive look at previous analytical and empirical works that have examined the relationships between product variety, operational performance, and sales in both the retailer and brand manufacturer contexts.

This literature review is presented in three main sections. The first section details studies that have analyzed the relationship between product category assortment size, operational performance, and sales of a firm. The second section details studies that have examined how retail customers react to stock outs and how stock outs might impact store sales, as the operational performance variable of interest in this study is the product category stock out rate. Finally, the third section of the literature review details how different types (or attributes) of product variety, such as brand variety, size variety or product line variety can affect the operational performance and sales of a firm. By detailing what previous research in the supply chain, operations management, marketing, and retailing literature has found, this chapter will identify some research gaps within contemporary product variety literature which lays the foundation for how this dissertation addresses those gaps.

2.1 The Relationship between Assortment Size, Operational Performance, and Sales

This section of the literature review presents studies that examine how assortment size can impact the operational performance and sales of a firm. In particular, this section focuses on two different streams of literature: (1) how assortment size effects firm operational performance with a focus on inventory levels, fill rates and stock out rates, and (2) how assortment size effects firm sales.

2.1.1 The Relationship between Assortment Size and Operational Performance

The literature investigating the impact of product variety on operational performance has generally shown that a larger product assortment as measured by the total number of SKUs offered by a firm has a negative impact on firm operational performance by being associated with higher inventory levels, lower fill rates for distribution centers, higher stock out rates for retailers, more inventory record inaccuracies, and a higher occurrence of phantom products in the supply chain.

The first study to examine the relationship between product variety, inventory levels and sales was Baumol and Ide (1956). Using an analytical model this paper showed the potential for a positive relationship between product variety, inventory levels and sales as well as firm profits, which was used to explain the rise of large metropolitan grocery stores.

The first empirical paper to test the relationship between inventory levels and sales for individual retailers was done by Hise et al. (1983). Using survey data from 132 mall retail stores and a linear regression methodology, the authors showed that inventory levels and the number of employees were positively related to sales. Somewhat unexpectedly, store size (as measured in thousands of square feet) was negatively related to sales, but that was after controlling for number of employees and inventory levels. However, this work did not relate either sales or inventory levels to the level of product variety present at the retailer.

Dubelaar, Chow, and Larson (2001) examined the relationship between sales and inventory levels from a different perspective: they considered inventory levels to be determined from sales instead of sales being determined from inventory, which was a significant departure from previous literature. Utilizing a voluntary survey instrument to construct a linear regression model on a sample of 100 grocery retailers, they found that inventory increased with the square root of sales, product variety correlated positively with inventory, and that demand uncertainty was not statistically related to inventory levels. This research showed that product variety is positively related to firm inventory levels and hypothesizes that current inventory levels could be a function of past sales. This concept was extended by Dong et al. (2014) with a slightly different twist which claims that current inventory levels could be a function of past sales at the retailer and as a consequence past sales should be controlled for when modeling retailer inventory levels.

A recent paper by Cadeaux and Dubelaar (2012) used a structural equation model to investigate the relationship between product variety and various performance metrics, such as store sales, profit margins, and inventory levels. The results showed that store assortment size was positively correlated with sales and inventory levels, but not statistically significantly related to retailer profit margins. The structural equation model in this research used survey data, and the inventory and assortment questions were benchmarked against the retailer's competitors (for example, "How does business compare with others of similar size and type in terms of number of different stock-keeping units in the retail section?", and "How does business compare with others of similar size and type in terms of dollar value of inventory typically on hand in total front store?" p. 255), and the authors did not use any archival data to verify the relationships they discovered using their survey instrument.

In the brand manufacturer context, early work focused on the impact of product variety on manufacturing complexity. Skinner (1974) hypothesized that larger amounts of variety in factories was a key cause of decreased performance and productivity at manufacturing firms. This was later investigated by MacDuffie et al. (1996) who empirically demonstrated that manufacturing plants that manufactured a larger variety of products had lower rates of employee productivity. The reasoning provided for the existence of this relationship was that more product variety at a manufacturing plant increased the managerial complexity involved in manufacturing a larger assortment of products.

In their seminal study, Fisher and Ittner (1999) examined if the product variety present at a brand manufacturer was associated with product rework rates. Using a linear regression, the authors found that higher degrees of product variety present in automobile factories was positively associated with rework rates for products. The authors speculate that this relationship could be due to the added complexity introduced by product variety, causing workers to pick the wrong part for their manufacturing process. Other work by Fisher (1997) speculates that higher degrees of product variety might be associated with more inaccurate forecasting, longer lead times, and higher inventory levels at all nodes of the supply chain.

More contemporary work has examined the relationship between product variety and specific operational metrics, such as fill rates. Some studies using simulation have shown that operational performance in terms of order fill rates (the percentage of orders completely delivered by a supplier / distribution center) and unit fill rates (the percentage of total order quantities delivered by a supplier / distribution center) can deteriorate in the presence of more product variety (Closs et al., 2010). A study by DeHoratius and Raman (2008) examined the link between various aspects of inventory and the likelihood of inventory record inaccuracies, which occur when inventory records do not match the amount of inventory on hand at a retailer. Utilizing analytical data provided by a brick and mortar retailer and constructing a hierarchical linear model, they found that the amount of product variety present in a retailer was positively associated with inventory record inaccuracy. This finding was further enhanced by Ton and Raman (2010), who found that higher amounts of product variety are linked with larger amounts of phantom inventory, or "products that are physically present at the store, but located in storage areas where customers cannot find or purchase them (Ton and Raman, 2010, p.546)."

Wan, Dresner, and Evers (2012) explored the relationship between product variety and operational performance using data provided by a large soft drink bottler. Using the number of SKUs as a measurement of product variety, Wan et al (2012) ran a two stage least squares regression model on the impact of product variety on weekly unit fill rates as well as the impact of both product variety and weekly unit fill rates on sales. They found that product variety was negatively associated with weekly unit fill rates but positively associated with sales. They also found a positive association between weekly unit fill rates and sales, indicating that while product variety had a positive direct effect on sales, it had a negative indirect effect on sales through lower fill rates.

2.1.2 The Relationship between Assortment Size and Sales

Assortment planning is one of the most difficult issues facing retail firms in today's marketplace (Mantrala et al., 2009). In the marketing literature, product variety has been seen as a way to increase sales, market share, and the perception of a brand. Introducing more product variety in a firm's product assortment profile has been shown to have numerous benefits for the firm, including increased sales, significant increases in the market share, and higher overall profitability (Baumol and Ide, 1956; Kekre and Srinivasan, 1990; Ton and Raman, 2010). This is because having more product variety can allow firms to reach and sell to more potential customers who might have more diversified preferences compared to their typical market segment (Lancaster, 1990; Xia and Rajagopalan, 2009). Product variety also provides a mechanism by which retailers can segment their customers (Bayus and Putsis, 1999). A higher degree of product variety for a particular brand can also function as a signal of better quality for firms that manufacture products (Berger et al., 2007). Additionally, offering a wide variety of products may also lower the total cost of production if a firm has positive economies of scope inherent in the production of their products or develops strong economies of scope over time (Panzar and Willig, 1977; Panzar and Willig, 1981; Lancaster, 1990).

For a retailer, having additional products available within a product category gives the customer the possibility of purchasing a similar product in the event that their first choice product is unavailable, assuming there is some substitutability between products (Mahajan and van Ryzin, 2001). In general, product variety can provide a way for a retailer to pool the supply risk between two similar products that can be a result of demand uncertainty (Alfaro and Corbert, 2003; Vaagen and Wallace, 2008).

Some economics literature has also directly examined the relationship between retailer inventory levels and sales. This literature on the inventory level and sales relationship has focused on the inventory to sales ratio, which is defined as the total amount of inventory in stock divided by the total amount of sales for a firm for a given time period (Irvine, 2003). Most contemporary literature on this topic has focused on the manufacturing sector (e.g. Eroglu and Hofer, 2011; Obermaier, 2012). A notable exception to this is Irvine (2003) who examined the inventory to sales ratios over time for the retail sector and showed that inventory to sales ratios have been increasing, indicating falling sales or higher inventory levels in retail firms over time (Irvine, 2003).

2.2 Retailer Stock Outs and Sales

The main operational performance metric of interest in this study is the retailer's stock out rate. In order to better understand how a retailer's stock out rate might impact their sales, this section of the literature review details how retail customers react to out of stock situations and how these reactions might influence retailer sales.

Empirical studies have shown that product stock out rates have been fairly constant across the last ten years, with an average of about 8% of SKUs at a retailer out of stock at any given time (Peets, 1996; Hardgrave et al., 2005; Gruen and

Corsten, 2007). However, this number can vary across different countries and product categories. While the USA and Asia average around an 8% stock out rate, some countries in Eastern Europe average stock out rates as high as 11% (Gruen et al., 2002). Further complicating the analysis is that out of stock rates tend to vary across different product categories: the lowest out of stock rates belong to salty snacks, with an average out of stock rate of about 5%, while the highest average out of stock rate typically belongs to haircare products, with about a 10% average out of stock rate worldwide (Gruen et al., 2002).

The impact of a stock out on the sales of a firm depend partly on the type of firm under consideration and the reaction of customers to out of stock occurrences. When a retail store stocks out of an item a customer has several options: (1) they can substitute another product for their preferred product, (2) they can delay their purchase until another time, (3) they can purchase the item at another store, or (4) they could decide not to purchase an item, in what is known as the "Substitute, Delay, or Leave" paradigm (Emmelhainz et al., 1991; Campo, et al., 2000; Zinn and Liu, 2001; Corsten et al., 2002). Each of these outcomes has different implications for retailers and the manufacturers. If a customer decides to substitute another item, the retailer doesn't lose sales but the manufacturer could lose sales if the customer switches to a different brand. If the customer decides to not purchase the item, then both the manufacturer and the retailer lose sales. If the customer decides to go to another retail store to purchase the product, then the retailer loses sales while the manufacturer does not. Finally, if the customer decides to delay their purchase to another visit then neither the manufacturer nor retailer lose sales but will suffer from slowed cash flows and exaggerated demand fluctuations (Corsten et al., 2002).

There have been many experiments and empirical studies that address how customers respond to an out of stock situation at a retail store (e.g. Peckham, 1963; Walter and Grabner, 1975; Schary and Christopher, 1979; Emmelhainz et al., 1991; Verbeke et al., 1998; Campo et al., 2000; Fitzsimons, 2000; Zinn and Liu, 2001; Campo et al., 2003; Sloot et al., 2005). This stream of literature has utilized two main tactics for gathering data: experiments that remove the inventory of a product from a store and observe how customers react, and post shopping trip surveys that ask if the shopper experienced a stock out during their shopping trip and how they responded. This research stream has examined the relationship between stock outs and many different customer specific and store specific variables. While the goal of early studies was to discern the frequency of stock out occurrences (Peckham, 1962; Walter and Grabner, 1975; Schary and Christopher, 1979), later literature began to examine the link between store and customer characteristics on customer reactions to stock outs. For example, Emmelhainz (1991) showed that urgency of product need and usage patterns were factors in the substitution decision, and that brand loyalty played a role in the specific product substitution decision if a substitution was made.

Using the above information, Campo et al. (2000) developed an analytical model to explain how stock outs could impact the sales of both the retailer and the manufacturer. In their model the authors hypothesized that the retailer could mitigate their potential sales losses by carrying larger product assortments, but that the brand manufacturer had fewer options to mitigate their lost sales due to stock outs. Further analytical and simulation studies have provided additional support for the notion that brand manufacturers stand to lose more from stock outs than retailers (Campo et al., 2003). Overall, the sales loss to retailers from stock outs is estimated to be around 4% of total sales on average, with some differences by product category and locality (Corsten and Gruen, 2003).

The most comprehensive empirical study to date on the cause of retail stock outs was done by Gruen and Corsten (2007). This work identified five key drivers of stock out occurrences: inaccurate or incomplete demand forecasts, ordering the wrong quantity (due to miscommunication between store employees, inaccurate inventory records, or fixed sized ordering), product proliferation, promotional behavior on the part of stores and suppliers, and insufficient employees at the retail store.

Sloot et al., (2005) hypothesized that characteristics of the product category where the stock out occurred might affect customer's reactions to a stock out in that product category. In their study, the authors consider four different clusters of antecedents from previous literature to customer stock out reactions: product related variables (e.g. availability of acceptable alternatives, brand loyalty, perceived risk of switching to alternative), store related variables (e.g. store loyalty), situation related variables (e.g. item urgency, required quantity, available shopping time), and consumer related variables (e.g. total purchase size, purchasing attitude). In addition, the authors added a new potential antecedent to customer stock out reactions: the hedonic level of the product category. According to marketing literature, all products have a utilitarian and hedonic component to them (Hirschmann and Holbrook, 1982). The utilitarian component of a product refers to the product's practical use, while the hedonic component of a product refers to the product's level of fun or the experience of consumption. In this study, the hedonic level of a product category was ranked on a continuum by food experts from hedonic (products that are primarily consumed for fun, pleasure, or excitement such as potato chips, cigarettes, and beer) to utilitarian (products that are primarily consumed for their function, such as toilet paper, milk, eggs, and butter). The results of their analysis showed that the hedonic level of the product category did affect customer's reactions to stock outs in a product category, with customers choosing to substitute products less in more hedonic product categories.

While this stream of literature has shown that customer reactions to stock outs can be different between hedonic and utilitarian product categories, it has not shown these differences using archival data, nor has it linked this distinction to actual retail sales. The first essay of this dissertation will use models based on other empirical examinations into operational performance and sales (e.g. Dubelaar et al., 2001; Wan et al., 2009; Dong et al., 2014) to investigate whether the hedonic level of a product category moderates the effect of product variety on inventory levels and stock out rates, and whether the relationship between stock outs and sales is different for hedonic product categories than in utilitarian categories.

2.3 How Different Types of Product Variety can Impact Operational Performance and Sales

There is evidence in the existing product variety literature that different types or categories of product variety can have distinct impacts on firm operational performance and sales. Recent research in revenue management suggests that intelligent expansion of assortments based on certain key attributes, such as brand, size, or flavor can lead to increased sales and success rates of the introductions of new SKUs (Fisher and Vaidyanathan, 2014; Fu and Fisher, 2014). Utilizing some advanced assortment planning heuristics (known as forward greedy and reverse greedy heuristics), it is possible to predict which combinations of product variety characteristics would have the highest demand when introduced in a retail environment. This research stream provides a thorough breakdown of the different types of product variety that retailers consider when adding more items to their assortments. While some of the types of product variety considered were unique to specific product categories, some of the types of product variety considered were consistent across product categories, including brand variety, pack size variety and product line variety (also known as flavor or line variety).

In their seminal work on product variety and retailer sales, Boatwright and Nunes (2001) explored how product assortment reductions along different variety dimensions, such as brand, size, and product line in the pasta sauce product category of an online grocery store effected the purchasing behavior of the store's customers. The author's main research question was whether reductions in each of these different types of variety would lead to decreased or increased sales for the pasta sauce product category and if the effect across different types or attributes of product variety were distinct. They found that sales in the pasta sauce category did not decrease much when the product being cut was a "redundant product", which meant that the removal of that brand – size combination did not completely remove a brand or a size from the product category. When eliminating a brand or size from the pasta sauce product category, they found that a small reduction in brands or sizes led to an increase in sales, while removal of a large number of brands or sizes from the category decreased sales. A small reduction in redundant sizes led to decreased sales for the product category, while a large reduction in sizes led to increased sales for the product category. Furthermore, the magnitude of the impact of a brand reduction was much larger than the magnitude of a flavor reduction, indicating that dropping a small number of brands from the existing product assortment led to a larger sales increase than dropping a small number of product lines from the pasta sauce product category.

Other researchers have looked at how different attributes of product variety impact the operational performance of a brand manufacturing firm. Wan et al (2014) investigated two different types of product variety: product line variety and pack size variety. Product line variety was defined as the number of SKUs that were distinct based on brand, flavor, color, or composition. Pack size variety was defined as the number of SKUs that were distinct based on container material, size, or shape. Using a two stage least squares regression model the authors showed that product line variety had a greater positive effect on brand manufacturing firm sales and a smaller negative impact on firm operational performance than pack size variety.

Recent research has also shown different rates of substitution in the case of a stock out along different product attributes. According to Verhoef and Sloot (2006), brand switching is the most common customer reaction to an out of stock (34%), while purchase delay (23%), store switching (19%), and item switching (18%) account for almost all of the rest of the customer responses to stock outs. In this context, item switching refers to purchasing a similar item in the same product category from the same brand, while brand switching refers to buying a similar item in the product category from a different brand. In cases where a customer switches items, brand switching accounts for almost 65% of all switches, while switches to an item of the same brand account for only 35% of switching behavior. In addition, the rate of brand substitution versus item substitution varies by product category: for example, the rate of brand substitution to item substitution when a preferred item is out of stock in laundry detergents is about 50% for brands and items, while brand switching is much more common in the potato chip category, with brand switching making up almost 70% of the substitutions.

There are some questions that remained unanswered in this stream of literature. While Boatwright and Nunes (2001) investigated the relationship between brand variety, size variety, line variety and sales, they only examined this relationship within the context of a single product category and did not consider the impact of these different types of product variety on the retailer's operational performance. Furthermore, while Wan et al. (2014) investigated the relationship between size variety, line variety, unit fill rates and sales, they did so in the context of a brand manufacturer instead of a retailer while not distinguishing between brand variety and line variety in their work. Furthermore, neither of these studies examined how different types of product variety could impact inventory levels alongside other operational performance and sales metrics.

2.4 Conclusion

While previous literature has investigated how the size of a firm's assortment offering can affect firm operational performance and sales simultaneously (Wan et al., 2012), this has not been completed in a retail context. Furthermore, no studies have simultaneously investigated how retailer inventory levels might impact a retailer's stock out rate, and sales. Additionally, almost all studies that have analyzed the link between assortment size, operational performance, and sales have not examined how these relationships might be moderated by the type of product category under consideration, which has been shown to affect how customers react to a stock out in different product categories (Sloot et al., 2005). The first essay of the dissertation aims to address these gaps in the literature.

While previous marketing literature has investigated how different types of product variety could impact sales at retailers (e.g. Boatwright and Nunes, 2001) and how different types of product variety could simultaneously impact operational performance and sales in the brand manufacturer context (e.g. Wan et al., 2014), no literature has examined how the different types of product variety can effect inventory levels or how brand variety could affect operational performance differently compared to size variety or product line variety. The second essay of the dissertation aims to address these research questions.

Chapter 3: The Impact of Product Assortment Size on Inventory Levels, Stock out Rates, and Sales of a Grocery Retailer

3.1 Introduction

Most grocery retailers today carry well over 30,000 SKUs in their stores, and have been slowly increasing the size of their product assortment offerings over time (Kök and Fisher, 2007). The large variety of products offered by grocery retailers allows for these retailers to potentially increase their market share and sales through a number of different mechanisms: (1) they can entice new customers into a product category by offering a product variant that provides increased utility for some previously non-purchasing customers, (2) the potential for increased sales to customers that gain additional utility from the presence of variety in a product category (also known as "variety seeking" customers), and (3) the possibility of substitution between products when a customer's preferred product is out of stock (Baumol and Ide, 1956; Kekre and Srinivasan, 1990; Lancaster, 1990; Ton and Raman, 2010).

However, increased product proliferation can come with a significant downside for retail firms, such as higher costs and decreased supply chain and inventory performance. Many firms have begun to take a longer look at this tradeoff and have taken steps to downsize their assortment offering. For example, many clothing retailers are beginning to abandon the traditional women's sizing scheme for clothing (such as 00, 0, 2, 4, etc.) in favor of "alpha-sizing", where a clothing firm begins to offer women's clothing in the same size categories that have been traditionally offered in men's clothing (such as S, M, L, XL, etc.). This has been done to cut down on the forecasting and inventory management difficulties associated with managing many different sizes of the same product (Holmes, 2014). In another recent news article, Proctor & Gamble announced the sale of 100 brands under their control, which leaves the company with just 85 remaining brands. The reasoning for this sale was to allow Proctor and Gamble to "focus their supply chain and marketing efforts on their core brands," (Kumar, 2014).

Grocery retailers are also subject to some of the same complications associated with ever increasing product variety. A 2010 survey of grocery store chains conducted by the Nielsen Group showed that more than 50% of grocery retailers surveyed were actively pursuing ways to decrease their assortment size, compared to 30% wishing to maintain their current assortment size and 20% wishing to increase their assortment size. Of those that stated that they wanted to decrease their assortment size, 71% said that "achieving better inventory control" was their primary reason for seeking to reduce the size of their product assortment. However, despite a concentrated commitment from the majority of grocery retailers to cut their assortment offerings, the total number of SKUs offered by grocery retailers from 2008 to 2009 fell by less than 1% (Taylor and Chaudoir, 2010).

There is no shortage of literature on the impact of product variety on the operational performance of firms (e.g. Skinner, 1974; Srinivasan, 1994; MacDuffie et al., 1996; Fisher and Ittner, 1999; Closs et al., 2010; Wan et al., 2012; Wan et al., 2014). While these studies provide many insights on the impact of product variety on operations in manufacturing firms, few studies have specifically examined the impact of product variety on retail store operations. When examining the impact of product variety on firms, the distinction between manufacturers and retailers is an important one because they face different issues with respect to product variety (Ramadas, 2003). The scope of product variety at a retailer is typically much greater than the scope of product variety at a manufacturer. The sheer number of SKUs offered at some large retailers is much larger than most manufacturers and can greatly complicate inventory management. Additionally, most retailers offer products in many different categories which need to be managed concurrently. Finally, because of the small purchases made by a typical customer compared to manufacturing firms, retailers also have to deal with more potential substitution between their products by their customers. The higher possibility for product substitution can help the retailer when they face a stock out of some of their products, as customers can potentially substitute another product for their intended product, reducing the chance for lost sales at the retailer. On the other hand, this substitutability can make inventory and forecasting operations even more complicated which can decrease the operational performance of the retailer.

While previous literature (e.g. Wan et al., 2012; Wan et al., 2014) has examined the direct impact of product variety on sales and the indirect impact of product variety on sales through operational performance (in their case unit fill rates of a distribution center), it has not fully considered the increased costs that product variety can impose through higher inventory levels (Bayus and Putsis, 1999; Dubelaar et al., 2001; Cadeaux and Dubelaar, 2012). The product variety decision depends not only on potential revenues but also the additional costs that carrying product variety can impose on a firm. As a result, this paper will empirically examine the effect of product variety on inventory levels at retail stores while simultaneously modeling the effect of product variety on inventory levels with the effect of product variety on sales. This should provide a more comprehensive model of the decision that retailers face when considering an expansion or reduction in their product assortment.

Finally, this paper will examine all of these relationships in the context of different product categories. Because of the role that product substitution plays in complicating the inventory management of a retailer, a difference in substitutability between products within different product categories must be considered when modeling the effect of product variety on inventory and sales performance in different product categories.

This paper will attempt to fill these gaps in the product variety literature by modeling inventory levels simultaneously with operational performance and sales using data from a brick and mortar retail firm in China, allowing for a more comprehensive picture of the cost and sales trade off that retailers face when they consider adding additional product variety. Additionally, this paper is the first that the author is aware of that empirically tests the idea that product variety could have different effects on operational performance and sales in different product categories within the same retailer due to the different substitution effects present in different types of product categories.

The rest of this chapter is organized as follows: section 2 introduces the theoretical basis of the chapter and briefly covers the relevant literature. Section 3 introduces the hypotheses. Section 4 introduces the study setting, data, and empirical model used to test the hypotheses presented. Section 5 discusses the results of the empirical model, and section 6 discusses the results and their relevance to current business practices.

3.2 Theoretical Model

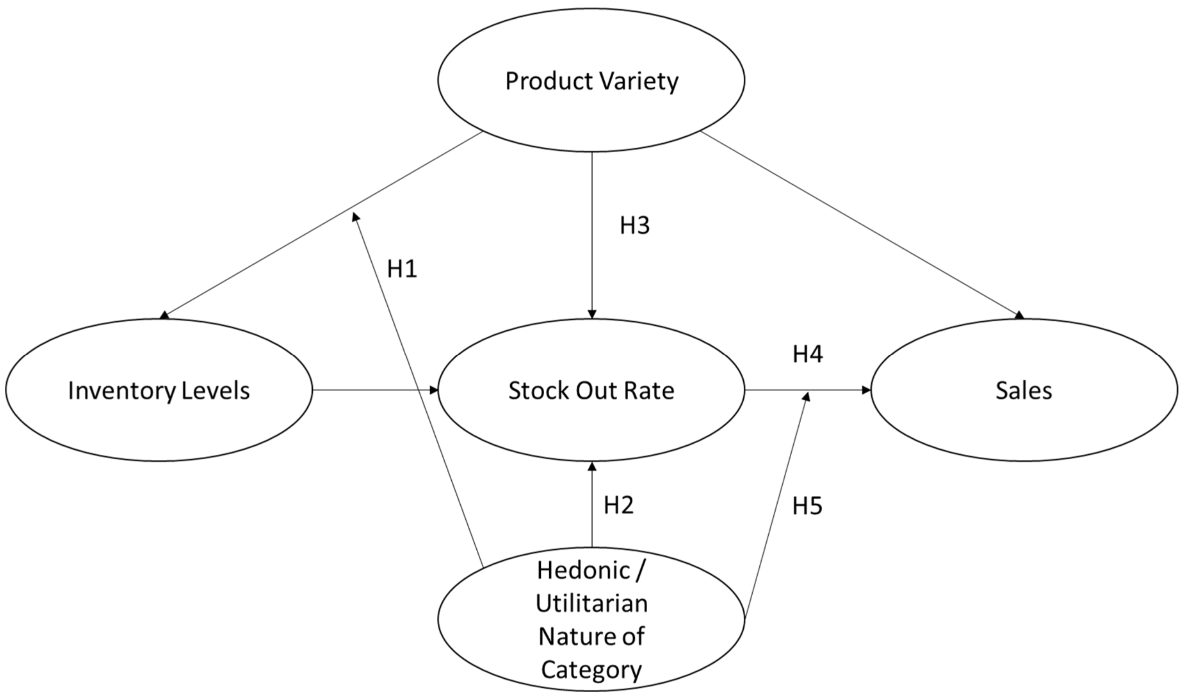
The impact of product variety on sales has always been a topic of great interest in the marketing and operations literatures. In the marketing literature, larger product assortments have been shown to have numerous benefits for the firms that carry them, including increased sales, increases in market share, and higher overall profitability (Baumol and Ide, 1956; Kekre and Srinivasan, 1990; Ton and Raman, 2010). There are a few mechanisms that are responsible for the positive association between larger product assortments and sales. More product variety allows firms to sell to more potential customers as well as entice customers that get higher utility from the presence of variety (known as "variety seeking" customers) to purchase more product (Lancaster, 1990). Having more product variety also increases the chance that a customer might substitute another product from the brand or product category if their first choice product is unavailable due to a stock out (Mahajan and van Ryzin, 2001; Zinn and Liu, 2001). Product variety can also allow the retailer or brand manufacturer to hedge against the inherent risk of products with a high demand variability. By offering many different SKUs in a product category, a firm can pool the risk associated with high demand variability and prevent lost sales (Alfaro and Corbett, 2003; Vaagen and Wallace, 2008).

However, the potential for increased sales does not come without drawbacks. Recent research has found that while product variety has a positive direct effect on firm sales, it also has an indirect negative effect on firm sales through decreased operational performance (Closs et al., 2010; Wan et al., 2012; Wan et al., 2014). Specifically, all of these studies have found that higher amounts of product or manufacturing variety within a firm can lead to lower fill rates, which in turn lead to lower sales. This means that the potential sales benefits of product variety in a manufacturing context may not be as large as previously thought due to the indirect negative effect of product variety on sales through operational performance.

Product variety can also impose additional costs on a firm beyond affecting sales. Previous literature has found that product variety is positively associated with firm inventory levels (Dubelaar et al., 2001; Kök et al., 2009; Cadeaux and Dubelaar, 2012). This is most likely due to the fact that when a firm has more product variety they will generally need to carry more total inventory due to the need to carry safety stocks for all of the additional products (Fisher and Raman, 2001). Thus, product variety can be directly responsible for additional costs to the firm through increased inventory levels. In order to get a more complete picture on the total effect of product variety on firm profits, the costs imposed by product variety (as measured by higher inventory levels) should be compared to the sales benefits of having more product variety on hand at the retailer. This will provide a more accurate notion of the revenue and costs trade off inherent in carrying product variety at the retail level.

The basic theoretical model for this research is presented in Figure 2 on the next page. This theoretical model states that product variety directly effects three different aspects of the retailer: inventory levels, stock out rates, and sales. There are also indirect effects of product variety on sales through the stock out rate and an indirect effect of product variety on stock out rates through the retailer's inventory levels.

Figure 2



These effects could depend on the substitutability of the items in question (Zinn et al., 1989; Charnes et al., 1995; Z.K. Weng, 1999). Thus, the effect of product variety on inventory levels and stock outs might be different for different product categories due to differing rates of product substitutability (Zinn and Liu, 2001; Gruen et al., 2002). In particular, the hedonic or utilitarian nature of the product category could impact product substitutability. According to Hirschmann and Holbrook (1982), hedonic products are products that offer a more "experiential consumption", and tend to be products that are consumed more for fun or pleasure (e.g. salty snacks, ice cream, and cigarettes) while utilitarian products are products that are purchased more for their functional use or benefit (e.g. toilet paper, laundry detergent, and juice). There is evidence that products that are more hedonic in nature are less likely to be substituted in case of a stock out than those products that are more utilitarian in nature, and that brands take on additional importance in hedonic product categories. One paper (Sloot et al., 2005) has examined the possible effect of the hedonic or utilitarian nature of a product category on customer reactions to stock outs at a retailer. They found that when faced with a stock out, customers would substitute another item for their preferred product at a higher rate in utilitarian product categories and at a lower rate in hedonic product categories.

The next section develops more concrete hypotheses with respect to the impact of product variety on inventory levels, stock out rates, and sales at a retail firm as well as the potential differences between hedonic and utilitarian product categories.

3.3 Hypothesis Development

Carrying more product variety at a retailer has been linked to higher inventory levels in operations management literature (Fisher and Raman, 2001). In particular, Dubelaar et al. (2001) found that higher levels of product variety were positively associated with inventory levels in dollars ($). This is because carrying different products requires some investment in safety stocks for each product carried by the retailer. These investments in safety stocks should generally lead to larger total inventories due to a disaggregation of demand risk unless the products have a high degree of substitutability (Zinn et al., 1989; Z.K. Weng, 1999). Higher substitutability between products within a product category potentially allows the retailer to carry less safety stock for each product, effectively reducing their inventory levels for a given level of product variety due to the presence of the risk pooling effect. The substitutability of a product within a product category can vary, but products in more utilitarian product categories are more likely to be substitutable than products in more hedonic product categories (Sloot et al., 2005). As previously stated, hedonic products are products that offer a more "experiential consumption", while utilitarian products are products that are purchased more for their functional use or benefit. If retail firms are aware of this difference in substitutability, it stands to reason that for a given level of product variety a retailer would choose to carry less inventory in a more utilitarian product category and more inventory in a more hedonic product category.

H1: For a given level of product variety and demand, retailers should carry more inventory in hedonic product categories than in utilitarian product categories.

Because hedonic product categories are less substitutable than utilitarian product categories, it is possible that the hedonic or utilitarian nature of the product category could impact stock outs. More specifically, if a product category is more substitutable, then customers are more likely to substitute a different product for their product of choice in the case of a stock out. This substitution would lead to higher stock out rates for the more substitutable product category, as demand for multiple products (some of which are out of stock) are more likely to be funneled to other products, increasing the chance of more stock outs in that product category.

H2: There will be a higher stock out rate for individual SKUs in utilitarian product categories rather than in hedonic product categories.

The relationship between product variety and sales is a bit more complex. Product variety has shown to have a direct positive effect on the sales of a firm (Baumol and Ide, 1956; Kekre and Srinivasan, 1990; Ton and Raman, 2010). This is because higher levels of product variety can allow firms to reach and sell to more potential customers who might have more diversified preferences compared to their typical market segment (Lancaster, 1990). However, recent research has shown that this relationship between product variety and sales is not as straightforward as previously believed. Previous research has shown that there is an indirect negative effect of product variety on sales through decreased operational performance, which diminishes the total positive effect of product variety on sales (Wan et al., 2012; Wan et al., 2014). This is because product variety greatly complicates certain aspects of inventory management, particularly forecasting demand (Fisher and Raman, 2001). Additionally, it can be harder for store employees to complete some of their tasks, such as restocking the store's shelves, with larger amounts of product variety present in the back room of the retailer as well as on the store shelves.

In a retail context, this decreased operational performance should manifest in lower product availability. Previous research has shown this for the manufacturing context, with more product variety leading to lower product fill rates (Thonemann and Bradley, 2002; Wan et al., 2012). This is because higher amounts of product variety are associated with more complex delivery and physical inventory management processes (Closs et al., 2010). Thus, the following hypothesis is proposed:

H3: For a retailer, higher amounts of product variety within a product category are associated with higher stock out rates for individual SKUs in that product category.

How does this decrease in operational performance due to higher amounts of product variety translate to retailer sales? In general, more stockouts should lead to fewer sales for a product category due to the lower product availability. However, this could depend on the type of product category in question. In more hedonic product categories, customers are less likely to substitute another product for their product of choice (Sloot et al., 2005), while in product categories that are more utilitarian customers are more likely to substitute another product (either in brand, attribute, or size) for their originally intended product. When customers substitute a product for their intended product when faced with a stock out, this prevents the retailer from losing sales because of that stock out. Thus, in a product category that is less substitutable, stock outs are likely to have a larger negative impact on sales than they are in product categories that are more substitutable. Thus, the following two hypotheses:

H4: Ceteris paribus, higher stock out rates for individual SKUs for a product category within a retailer lead to lower sales for that product category.

H5: The negative effect of stock out rates on product category sales should be larger for hedonic product categories than in utilitarian product categories, ceteris paribus.

3.4 Data and Methodology

This section of the chapter will provide information on the context and setting of this research, as well as describe in detail the methodology employed to test the hypotheses presented in the previous section.

3.4.1 Study Setting

This research uses data compiled from a large Chinese grocery retailer based in Shanghai, China. This retailer operates 3 different types of retail chains in China: a large department store chain, a medium sized grocery store chain, and a small convenience store chain. This research will use data provided by this retail firm from their large department store chain, which is a big box multipurpose retailer that also offers grocery products. This database includes data for 75 retail stores and a single distribution center, which serves as the only distribution center for these large department stores for several product categories. Of the available product categories, two are selected for use in this research: potato chips and juice. These two categories are selected because according to previous research, potato chips are typically classified as a hedonic product category for grocery retailers while juice and milk are classified as utilitarian product categories (Sloot et al., 2005).

There are a total of 186 SKUs between these two product categories with 128 SKUs in the juice product category and 58 SKUs in the potato chip product category. For a 7 month period from April 2011 to October 2011, different types of data were collected from the firm for each retail store and the focal distribution center, including order data, shipment data, inventory data, and sales data. For a more in-depth discussion of the firm's operations, as well as statistical breakdown of some aspects of the retail stores such as the total revenue of the stores or product variety breakdown of the product categories, please see the data appendix.

While all of the data used in this dissertation is provided by a single retail firm, the provided data encompasses the decisions of 75 different decision makers (at least one for each retail store). While they don't have full autonomy in deciding what products to carry in their store, they do have authority to make ordering and inventory management decisions for their store.

3.4.2 Model for Hypothesis Testing

The model that will be used for hypothesis testing in this chapter is similar to those used in previous research on the effects of product variety on operational performance and sales. In particular, a simultaneous regression model similar to the two stage model from Wan et al. (2012) will be used. The empirical model contains three equations for three different dependent variables: inventory levels, stock out rates, and sales. Each of the equations in the simultaneous equation model is detailed separately below with explanations for the inclusion of each of the variables.

This simultaneous equation model will be estimated using a three stage least squares regression methodology. A three stage least squares regression uses the same instrumental variable procedure as a two stage least squares equation, but also models correlation between error terms in successive equations (Greene, 2012). This helps control for the potential correlation of error terms between each stage in the regression, as the error terms for the regression on weekly inventory levels, stock out rates, and sales in a product category at a particular store during a week could potentially be correlated with one another. The instrumental variables approach helps model the possible endogeneity between inventory levels, stock out rates, and sales by generating estimated values for inventory levels using equation (1) to be used in the stock out rate equation (2) and estimated stock out rates using equation (2) to be used in the sales equation (3).

3.4.2.1 Inventory Equation

The inventory equation is loosely based on previous research on the impact of product variety on inventory levels as well as research on inventory levels and VMI (e.g Dubelaar et al., 2001; Dong et al., 2014). In their inventory equations, inventory levels were a function of previous period sales, product variety, and previous period stock out rates. This is because store managers might respond to previous sales or stock out rates by changing their inventory levels. The first equation is specified below:

$$
\begin{aligned}
InventoryValue_{itp} \\
&= \alpha_0 + \alpha_1 ProductVariety_{itp} \\
&+ \alpha_2 UtilitarianDum_p \; x \; ProductVariety_{itp} + \sum_{i=1}^{78} \alpha_3 StoreDum_i \\
&+ \sum_{t=1}^{30} \alpha_4 WeekDum_t + \alpha_5 UtilitarianDum_p + \alpha_6 OrderQuantity_{itp} \\
&+ \alpha_7 AverageStockoutRate_{itp} + \alpha_8 SalesForecast_{itp} \\
&+ \omega_{itp} \qquad (1)
\end{aligned}
$$

for retailer i during week t in product category p.

Product variety and the interaction term are included as a variable of interest. The rest of the variables are included as control variables. The weekly dummy variables are included to control for seasonality by modeling fixed week effects. The store dummy variables are included to control for potential store specific preferences for carrying (or not carrying) high levels of inventory. Order quantity is included as a control variable for inventory inflows from previous periods. The utilitarian dummy variable is included to account for differences in base inventory levels between product categories. The interaction term between the utilitarian dummy variable and product variety is included to test for hypothesis 1 that retailers will carry lower levels of inventory as product variety increases in utilitarian product categories than in hedonic product categories. The average stock out rate is controlled for because stores that have faced higher stock out rates in the past may react by carrying more inventory in an attempt to bring their stock out rate down. This average stock out rate is calculated as a four week moving average of the past four weeks of the stock out rate at retailer i in product category p. Finally, the sales forecast, calculated as the four week moving average of the last four weeks sales, is included because the retailer should be making their inventory management decisions with respect to previous sales for a particular period. In order to control for potential endogeneity between the stock out rate and sales, particularly since a week's stock out rate and sales are used in the simultaneous regression model, the average stock out rate and the sales forecast variables are created using past data. For a more detailed description of how these and other variables in the regression are created, please see section 3.4.3.

3.4.2.2 Stock Out Rate Equation

In accordance with previous research, stock out rates are used as a measurement of retailer operational performance (Ton and Raman, 2010). Other recent papers have used fill rates as an operational performance metric in the brand manufacturer context, which is similar to the stock out rate in the retail context (Wan et al., 2012). This paper utilizes the fill rate equation of Wan et al. (2012) as a basis for the stock out rate equation. The equation is as follows:

$$\begin{aligned} StockOutRate_{itp} &= \beta_0 + \beta_1 ProductVariety_{itp} \\ &+ \beta_2 UtilitarianDum_p \ x \ ProductVariety_{itp} \\ &+ \beta_3 InventoryValue_{itp} + \sum_{i=1}^{78} \beta_4 StoreDum_i + \sum_{t=1}^{30} \beta_5 WeekDum_t \\ &+ \beta_6 UtilitarianDum_p + \beta_7 OrderQuantity_{itp} \\ &+ \beta_8 PositiveSalesSurprise_{itp} + \beta_9 SalesForecast_{itp} \\ &+ \varepsilon_{itp} \qquad (2) \end{aligned}$$

Product Variety is again included as a variable of interest. Week dummy variables are included to control for weekly effects and seasonality's impact on the stock out rate. Store dummy variables are included to control for stores that may have higher stock out rates than others due to effects that are not controlled for through other variables, such as customer or management behaviors. Order quantity is included to control for the rate of product inflow into the dynamic inventory system. Positive sales surprise is included as a control variable because stores tend to experience more stock outs when sales are unexpectedly high for a given week. The utilitarian dummy is included to allow for the fact that the base stock out rate might be higher in utilitarian or hedonic product categories. The utilitarian dummy variable is interacted with product variety to test for the possibility that higher amounts of product variety in a utilitarian product category might lead to higher stock out rates than in a hedonic product category. Both of these terms are included as a test of hypothesis 2, as it is possible that a difference in stock out rates between hedonic or utilitarian product categories could be present either as a direct effect or moderated by the assortment size offered in that product category by the retailer. Finally, the sales is controlled for in the stock out rate equation, similarly to Dong et al. (2014) and Lee et al. (1999). Previous research has shown that retailers with higher sales experience higher stock out rates, which should be even higher in the presence of positive sales surprise. Additionally, previous sales serve as a measure of inventory outflows, which could complicate inventory management and raise stock out rates. Again, in order to help control for the potential endogeneity between the this week's stock out rates and this week's sales, particularly since sales is the dependent variable in the third equation, the average sales variable is constructed using a four week moving average of the previous 4 weeks average daily sales.

While sales and order quantity are both related to store size, they account for different aspects of the inventory system. Order quantities represent inflows to the dynamic inventory system, while sales account for outflows from the dynamic inventory system. While these should be in relative equilibrium in the long run, there can be short term differences between the inflows and outflows in the inventory system which could cause changes in inventory levels as well as changes in the retailer's stock out rate.

3.4.2.3 Sales Equation

The last equation in the simultaneous equation model is the sales equation. This equation is also constructed borrowing from the previous work of Wan et al. (2012). The sales equation is as follows:

$$Sales_{itp} = \gamma_0 + \gamma_1 StockOutRate_{itp} + \gamma_2 ProductVariety_{itp} + \gamma_3 ProductVariety_{itp}^2 + \gamma_4 UtilitarianDum_p \; x \; StockOutRate_{itp}^e + \sum_{j=1}^{78} \gamma_5 StoreDum_i + \sum_{k=1}^{30} \gamma_6 WeekDum_t + \gamma_7 UtilitarianDum_p + \gamma_8 OrderQuantity_{itp} + \gamma_9 LongRunPrice_{ip} + \gamma_{10} PriceChange_{itp} + \delta_{itp} \quad (3)$$

Product variety is included as the variable of interest in this equation. A squared term for product variety is included because previously literature has shown that the relationship between product variety and sales is non-linear (Boatwright and Nunes, 2001; Wan et al., 2012). The non-linear term in the sales equation is included to account for diminishing returns of product differentiation to sales, as it can be harder to find niches for products as more products are present in the product category. The weekly dummy variables are included to control for the potential seasonality of sales from week to week. The store dummy variables are included to control for aspects of the stores that might lead to higher sales that are not controlled for explicitly in the model, such as location or customer base. The utilitarian dummy variable is included to control for the base difference in sales between utilitarian or hedonic product categories. Order quantity is used to control for the size of the store. Stock outs are included as a variable of interest, and should be negatively associated with sales. The interaction term between the utilitarian dummy and the stock out rate is included to test hypotheses 4 that higher stock out rates impact sales differently in utilitarian product categories than in hedonic product categories. Price changes are included in the sales equation because price changes from week to week within a product category could impact product category sales. The last control variable used in the model is the long run average price. This variable is used to differentiate between different product mixes that might be present at different retailers.

3.4.3 Variable Definitions

Because this research is comparing two different product categories which are based in different units of measurement (liquid ounces for juices and weight in grams for potato chips), all variables are defined in monetary terms where possible. For variable definitions, please see Table 1.

One variable that needs more explanation than the table provides is the stock out rate variable. The stock out rate is calculated two different ways: an unweighted stock out rate and a weighted stock out rate. The weighted stock out rate is weighted by the percentage of product category sales for each SKU for each retailer in order to put more emphasis on stock outs of higher selling or more popular items at that retailer. To remain consistent with the inventory value and sales variables, this is also calculated as a stock out rate for product category p at retailer i during week t.

Because the inventory data set provided by the retail firm offered a daily inventory count, a few steps were required to create a weekly stock out rate.

Table 1 Variable Definitions

Variable	Description
$InventoryValue_{itp}$	The average daily inventory value in Chinese Yuan in product category p at retailer i during week t.
$ProductVariety_{itp}$	The number of different SKUs offered in product category p at retailer i during week t.
$UtilitarianDum_{itp}$	A dummy variable coded 1 when the product category is utilitarian (juice), and 0 otherwise (potato chips).
$StoreDum_{itp}$	A dummy variable coded 1 if store = i, and 0 otherwise to capture store fixed effects.
$WeekDum_{itp}$	A dummy variable coded 1 if week = t and 0 otherwise to capture week fixed effects.
$OrderQuantity_{itp}$	The 4 week moving average {t-4, …, t-1} of order value of the last 4 weeks in Chinese Yuan in product category p at retailer i.
$AverageStockoutRate_{itp}$	The 4 week moving average {t-4, …, t-1} of the stock out rate of the last 4 weeks in product category p at retailer i.
$SalesForecast_{itp}$	The 4 week moving average {t-4, …, t-1} of average daily sales of the last 4 weeks in Chinese Yuan in product category p at retailer i.
$PositiveSalesSurprise_{itp}$	The percentage of average daily sales in product category p at retailer i during week t that are above expected sales, as calculated using the $SalesForecast_{itp}$ variable.
$StockOutRate_{itp}$	The stock out rate in product category p for retailer i during week t.
$LongRunPrice_{ip}$	The average price for a single unit in product category p at retailer i during the duration of the data base.
$PriceChange_{itp}$	The percentage change in average price for a single unit in product category p at retailer i from week t-1 to week t.

First, the total number of inventory days for each store for each week is calculated. The total number of inventory days is defined as the number of SKUs carried by a store during each day of the week. For example, if a store has 20 SKUs listed in its inventory data set for a particular product category for each day of the week (which includes both out of stock products and products with positive inventory), then the total number of inventory days in that product category for that week would be 140.

For calculating the weighted stock out rate, a similar procedure is used. The total inventory days for each retailer for each week is counted, as is the total number of stock out days. Instead of taking the simple average of the unweighted stock out rate, each SKU is multiplied by the percentage of sales of the SKU for that retailer in its product category for the entire length of the data set. The reason for using a weighted stock out rate is to penalize stores that stock out of better selling SKUs, as unavailability of those SKUs are typically a bigger deal than stock outs of lesser selling SKUs.

As a basic example of the difference between the weighted and unweighted stock out rates, consider the following example: a retailer has 10 SKUs in a product category, each with 10% of the sales in that product category. In this case, the weighted and unweighted stock out rate would be the same, since the weight applied in both calculations would be identical. However, if that same product category had one SKU with sales of 55% of the product category's total sales and all other SKUs each had 5% of the product category's total sales, the weighted stock out rate would weight stock outs of the SKU with 55% of the sales more than stock outs of the 5% of sales SKUs, while the unweighted stock out rate would consider stock outs of both products to be equal.

There were originally 78 retail stores in the data set. The elimination of SKUs with sales of less than one unit per day resulted in the elimination of three stores. These stores had no SKUs in our two product categories that sold more than one unit per day on average. The remaining 75 stores each had 27 weeks of data, with the exception of two stores. These two stores had 20 weeks and 12 weeks of store data respectively. Both of these were included in the final analysis. It is unknown if the stores opened during this time period or simply did not begin data collection until a later date than the other stores.

Due to the right skewness of the some of the variables in the regression such as average daily sales, average daily order quantities, and average daily inventory levels, the natural log was taken for all continuous non-percentage variables before running the regression model. For the interaction term between product variety and the utilitarian product category dummy the natural log was taken of product variety first, then multiplied by the dummy variable. Additionally, in order to remove potentially complicating factors from the analysis, only items that sold at a rate of one item per day for the duration of the data set and stock outs that last for less than 10 days were included in the final regression analysis. Removing stock outs that lasted longer than 10 days prevented the possibility of including items that were removed from the retail store's product assortment but marked as out of stock from the final analysis. Items with less than a sale per day were excluded from the analysis because they are unlikely to contribute to forecasting or inventory management complexity due to their low rate of sale. For more information, please see the data appendix.

Summary statistics of the variables as they were used in the regression analysis are presented in Table 2.

The first thing to notice is that there is a large disparity in the size of the product categories between stores, as the minimum and maximum values of average daily inventory value and average daily sales are fairly spread out. While all of the stores in the data set are members of the large department store chain of the retail firm, there is no standard size of the product categories across different stores. The mean average daily inventory value is 23,506¥ while the mean average daily sales is about 609¥, which means that average daily inventory covers about 38 days of average daily sales.

Table 2 Min, Max, and Descriptive Statistics of Regression Variables prior to Natural Log

Variable	Min	Max	Mean	Std. Dev.
Inventory Value (yuan)	172.00	218588	23506	26594
Sales (yuan)	10.81	7393	608.92	696.96
Order Quantity (yuan)	0	7936.74	455.79	729.14
Product Variety	1	60	22.66	11.25
Stock Out Rate (%)	0	0.30	0.01	0.02
Weighted Stock Out Rate (%)	0	0.30	0.01	0.03
Positive Sales Surprise (%)	0	0.89	0.09	0.14
Long Run Price (yuan)	2.16	7.99	4.71	1.31
Price Change (%)	-0.88	5.32	0.02	0.21

This number is well within accepted standards for retail firms (Sowinski, 2013). The minimum variety in a product category for a retailer during a week was 1 SKU, and the maximum was 60 SKUs. The average daily order quantity is about 455¥, which is lower than average daily sales at 608¥, because the order quantity is calculated using the internal price of the SKU while the average daily sales are calculated using the price that the customer actually paid for the item. Thus, the difference between the two can be seen as the markup, which is about 33%. The unweighted and weighted stock out measures have similar means. At first glance, these stock out rates seem very low. Most previous studies have put the normal stock out rate for a retailer around 9% (Corsten and Gruen, 2003). There are two major reasons for the differences in stock out rates. Both of them are related to the way that previous studies have typically calculated the stock out rate they use. The majority of previous studies derived the stock out rate by going to the retailer and physically counting the SKUs that are out of stock at a given time. Because this method of determining stock outs was not feasible for this study, an inventory data base was used to discern stock outs instead. Because the unit of observation for this data base was daily, it can only identify stock outs that are logged in the inventory records. This means that some stock outs that occurred for only a short period of time (specifically less than a day) might not be recorded in the inventory records. Additionally, because these are inventory records taken by the firm, there is the possibility of phantom inventory in the inventory data base. Phantom inventory is inventory that a retailer believes they have for an SKU but is missing as the result of many things such as theft or misplaced inventory (Ton and Raman, 2010). Because previous methods did not typically use inventory data set records to identify stock outs, there is the possibility for the products that the data set considers to be in stock are actually out of stock. The presence of all of the above would lead to the stock out rate in this research to be lower than in previous studies.

The correlations between variables are presented in Table 3. As can be seen in Table 3, the correlations between average daily order quantities, average daily sales, and average daily inventory value are all high, as expected. Product variety also highly correlates with order quantities, sales, and inventory value.

Table 3 Correlation Table

Variable	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
Inventory Value [1]	1.00								
Sales [2]	0.76*	1.00							
Order Quantity [3]	0.77*	0.73*	1.00						
Product Variety [4]	0.69*	0.80*	0.64*	1.00					
Stock Out Rate [5]	-0.15*	-0.09*	-0.11*	-0.05*	1.00				
W. Stock Out Rate [6]	-0.13*	-0.07*	-0.11	-0.03*	0.78*	1.00			
Sales Surprise [7]	0.04	0.23*	0.03	-0.01	-0.04	-0.02	1.00		
Long Run Price [8]	0.51*	0.55*	0.46*	0.51*	-0.06	-0.01	-0.02	1.00	
Price Change [9]	0.02	0.04*	0.05*	-0.01	0.00	0.02	0.04	0.01	1.00

where * indicates $p < 0.05$

The weighted stock out rate and the unweighted stock out rate are also highly correlated. Finally, long run average price is fairly highly correlated with average daily inventory value, average daily order quantity, average daily sales, and product variety. This is probably because higher end stores tend to sell more expensive products, driving up average daily inventory value, average daily order quantities, and average daily sales.

In order to assess the potential presence of multicollinearity in the model, a variance inflation factor (VIF) analysis was completed on the variables included in the regression. The results of the VIF analysis are presented in Table 4. The results from Table 4 show a small presence of multicollinearity, but all VIFs for the variables in the data are below the commonly accepted threshold of 10 and the mean VIF is well below generally accepted values of 6 (O'brien, 2007).

Table 4 VIF for Regression Variables

Variable	**[1]**
Inventory Value	3.66
Sales	5.13
Order Quantity	3.01
Product Variety	3.42
Stock Out Rate	1.01
W. Stock Out Rate	1.03
Positive Sales Surprise	1.23
Long Run Price	1.54
Price Change	1.01
Mean VIF	2.50

3.5 Results

The model estimation results for both the unweighted and weighted stock out rate are presented in Table 5 as model 1 and model 2, respectively. Model 1.1 shows the estimation results for the effect of product variety on retailer inventory levels, model 1.2 shows the estimation results for the effect of product variety and inventory levels on the unweighted stock out rate, and model 1.3 shows the estimation results for the effect of product variety and stock out rates on product category sales. Model 2.1 show the estimation results for the effect of product variety on retailer inventory levels, model 2.2 shows the estimation results for the effect of product variety and inventory levels on the weighted stock out rate, and model 2.3 shows the estimation results for the effect of product variety and the weighted stock out rate on category sales.

The estimation results of both model 1 and model 2 are similar. There is no difference in significance or sign between equations (2) and (3) for both models, and the differences in coefficient magnitude are relatively minor. There is a slight difference in coefficient significance in equation (1), particularly for the average stock out rate coefficient. In model 1, that coefficient is statistically significant and negative, while in model 2 the coefficient is not statistically significant. The remainder of this discussion focuses on the results of model 2, which utilizes the weighted stock out rate.

The results of the regression for equation (1) indicate that product variety does have a positive and statistically significant relationship with inventory levels. However, neither the utilitarian dummy variable nor the interaction term between product variety and the utilitarian dummy variable are statistically significant, which does not support hypothesis 1 that retailers carry more average daily inventory for a fixed level of product variety for hedonic product categories. Order quantity, as a measurement for inflows to the dynamic inventory system, is positively and significantly related to inventory value, as expected. The weighted average stock out rate is not statistically significant, indicating that stores may not adjust inventories in response to stock outs for these product categories. Finally, the sales forecast variable is also statistically significant and positively associated with inventory value which indicates that stores that sell more (i.e. have larger short term outflows of the dynamic inventory system) tend to have higher inventory value, as expected.

Table 5 Regression Results

Variable	Unweighted Stock Out Rate			Weighted Stock Out Rate		
	Model 1.1 Log Inventory	Model 1.2 Stock Out	Model 1.3 Log Sales	Model 2.1 Log Inventory	Model 2.2 W. Stock Out	Model 2.3 Log Sales
Log ProductVariety$_{itp}$	1.2739*** (0.0592)	0.3197*** (0.0117)	2.0621*** (0.2345)	1.2597*** (0.0590)	0.3810*** (0.0129)	2.7492*** (0.2708)
Log ProductVariety$^{2}_{itp}$			-0.1857*** (0.0375)			-0.2873*** (0.0446)
Log OrderQuantity$_{itp}$	0.1373*** (0.0078)	0.0352*** (0.0015)	0.0128 (0.0080)	0.1359*** (0.0078)	0.0401*** (0.0016)	0.0049 (0.0099)
UtilitarianDum$_{itp}$	0.1631 (0.1311)	0.0359* (0.0188)	0.4512*** (0.0429)	0.1582 (0.1312)	0.0579*** (0.0210)	0.3983*** (0.0480)
Log ProductVariety$_{itp}$ x UtilitarianDum$_{itp}$	0.0212 (0.0427)	0.0053 (0.0061)		0.0316 (0.0429)	-0.0003 (0.0069)	
AverageStockoutRate$_{itp}$	-0.8400*** (0.2344)			0.3244 (0.2048)		
Log SalesForecast$_{itp}$	0.3055*** (0.0248)	0.0934*** (0.0050)		0.3488*** (0.0249)	0.1084*** (0.0055)	
Log InventoryValue$^{e}_{itp}$		-0.2684*** (0.0073)			-0.3081*** (0.0078)	
PositiveSalesSurprise$_{itp}$		0.0609*** (0.0052)			0.0597*** (0.0065)	
StockOutRate$^{e}_{itp}$			-12.4930*** (2.0689)			-13.9767*** (2.0086)
StockOutRate$^{e}_{itp}$ x UtilitarianDum$_{itp}$			9.0853*** (2.1328)			9.6779*** (2.0540)
Log LongRunPrice$_{ip}$			0.6410*** (0.0688)			0.7998*** (0.0795)
PriceChange$_{itp}$			0.0303 (0.0317)			0.0141 (0.0363)
StoreDummies	Included but not shown.					
WeekDummies	Included but not shown.					
X^2 Test Statistic	20,402.66***	2,431.48***	20,540.22***	20,461.10***	3,248.53***	12,895.89***
Observations	3260	3260	3260	3260	3260	3260

Standard errors are reported in parentheses. *** indicates p < 0.01, ** indicates p < 0.05, * indicates p < 0.10

The results of the regression for equation (2) indicate that higher inventory value is negatively associated with the stock out rate. Equation (2) also suggests that higher levels of product variety are associated with higher weighted stock out rates after controlling for the amount of inventory on hand. This lends support to hypothesis 3 that higher levels of product variety within a product category makes inventory more difficult to manage, leading to lower product availability and more stock outs. The utilitarian dummy variable is positive and significant, indicating a higher base stock out rate for the utilitarian product category, which lends support to hypothesis 2. However, the effect of product variety is consistent across product categories, as the interaction term between the utilitarian dummy variable and product variety is not statistically significant. Thus, support for hypothesis 2 shows up as a direct effect, and not an effect moderated by product variety. Order quantity is positively associated with stock out rates, indicating that stores with larger inflows to the dynamic inventory system have higher stock out rates. This is likely because larger inflows are harder for managers to handle, making inventory management mistakes more likely. The sales forecast is positively and significantly associated with stock out rates, indicating that stores that faced higher outflows from the inventory system in recent weeks are more likely to face a higher stock out rate in the present week. Taken together, the results indicate that retailers that face larger flow volumes into and out of their inventory system seem to experience higher rates of stock outs.

Finally, the positive sales surprise variable is positively and significantly associated with higher stock out rates, as expected. This is because weeks with unexpectedly high sales are more likely to result in stock outs for the retailer.

The results of the regression estimation for equation (3) indicate that the relationship between product variety and sales is positive and statistically significant in the linear term, but negative and statistically significant in the squared term. This finding is consistent with previous literature (Wan et al., 2012) and suggests that the positive relationship between product variety and sales is diminishing in both product categories as product variety continues to increase. The relationship between the weighted stock out rate and sales is negative and significant for hedonic product categories. To estimate the total effect of the stock out rate on sales of the utilitarian product category, we construct a non-linear combination of the weighted stock out rate coefficient and the coefficient of the interaction of the weighted stock out rate with utilitarian product category (Phillips and Park, 1988). This combination results in an estimate of the total effect of -4.2987 with a 95% confidence interval of (-5.4928, -3.1047). This, along with the negative and significant coefficient for hedonic product categories from the regression, provides support for hypothesis 4 and suggests that higher weighted stock out rates in a product category lead to lower sales in that product category for the retailer. The result of the non-linear combination also imply that the negative impact of stock outs on sales in the utilitarian product category is much smaller than the negative impact of stock outs on sales in the hedonic product category, providing support for hypothesis 5. The order quantity variable is not significant, which indicates that the effect of inventory inflows are captured by the impact of inventory levels or stock out rates on product category sales. The long run average price variable is positive and significant, indicating that high end stores tend to have higher sales than lower end stores. Finally, weekly price changes are not statistically significant in the model.

3.5.1 Total Effects of Product Variety on Product Category Stock Out Rates and Sales

There are a few remaining questions that can be explored using this model. First, the regression analysis suggests that product variety was directly positively related to product category inventory levels, stock outs, and sales. However, these results only concern the direct effect of product variety on inventory levels, stock out rates and sales. Product variety not only effects stock out rates directly, but also indirectly through its effect on inventory levels. In this case there is a potential ambiguity in the total effect of product variety on store stock out rates because while product variety is positively related to product category stock out rates, it is also positively related to store inventory levels, which are in turn negatively related to product category stock out rates. Put another way, product variety does seem to contribute to operational complexity for the retailer leading to higher stock out rates, but it also encourages the retailer to carry more inventory which helps lower the stock out rate. In order to investigate the total effect, a non-linear combination is constructed using the three stage least squares regression coefficients to evaluate the total effect of product variety on store stock out rates.

In order to determine the statistical significance of the total effect of product variety on the stock out rate, an estimate of the standard error of the total effect must calculated. A methodology for standard errors of total effect estimates in simultaneous equation models is presented by Sobel, (1982) and further described by Preacher and Hayes (2008). The resulting standard errors, along with estimates of the indirect and total effect of product variety on the stock out rate using the Sobel method are presented in Table 6.

Table 6 Indirect and Total Effect of Product Variety on the Stock Out Rate

Indirect Effect	Calculation	Method	Mean (Std. Error)	95% Confidence Interval
Product Variety on Stock Out Rate	$\alpha_1 * \beta_3$	Sobel	-0.3881 (0.0208)	(-0.429, -0.347)
Total Effect				
Product Variety on Stock Out Rate	$(\alpha_1 * \beta_3) + \beta_1$	Sobel	-0.0071 (0.0104)	(-0.028, 0.013)

As can been seen in Table 6, when the direct effect of product variety on stock out rates from regression equation (2) and the indirect of product variety on the stock out rate through inventory levels from regression equations (1) and (2) are combined, the resulting total effect of product variety on stock out rates is not statistically significant. This implies that the increased stock out rate brought on by the complexity of introducing product variety is almost completely mitigated by the increased inventory levels that retailers carry when offering more product variety for both product categories examined in this study.

Thus, while the direct effect from the regression model indicates that the impact of product variety on stock outs is positive and statistically significant, accounting for the corresponding increase in inventory levels brought on by higher product variety suggests that the total effect of product variety on stock outs is actually not statistically significant in this context. Furthermore, this relationship does not depend on the hedonic or utilitarian nature of the product category, as the effect of product variety on product category inventory levels and sales is not moderated by the hedonic or utilitarian nature of the product category in the results of the three stage least squares regression model. This is an important finding which suggests that the relationship between product variety and operational complexity may not be as straight forward as it seems, as while product variety can directly contribute to higher stock out rates, it can also encourage behavior by retailers that help mitigate them.

3.5.2 Total Effects of Product Variety on Product Category Profits and Profit Margins

Another interesting question that can be investigated using the model in this paper is the following: what is the effect of product variety on product category profits? Because the model used in this paper has a sales equation (3) which can be employed to estimate revenues and a cost component embodied in the inventory equation (1), we can investigate the ceteris paribus effect of product variety on store profits.

Due to the scope of the regression models, this discussion is only able to examine how changes in product variety impact inventory costs. Thus, all other costs (even those that are perhaps likely to increase with product variety, such as personnel costs) are assumed constant in what follows.

In order to investigate the effect of product variety on store profits, we need to first identify the effect of product variety on sales and the effect of product variety on costs. The total effect of product variety on sales can be calculated by constructing a non-linear combination of coefficients from the regression model. The total effect of product variety on sales will be different for hedonic and utilitarian product categories because the effect of stock out rates on sales is larger for hedonic product categories rather than utilitarian categories. For the calculation of this total effect of product variety on sales for both product categories, please see Table 7.

Table 7 Indirect and Total Effect of Product Variety on Product Category Sales

Indirect Effect	Calculation	Method	Mean (Std. Error)	95% Confidence Interval
Product Variety on Sales (Hedonic)	$((\alpha_1 * \beta_3) + \beta_1)*\gamma_1$	Sobel	0.0988 (0.1469)	(-0.189, 0.387)
Product Variety on Sales (Utilitarian)	$((\alpha_1 * \beta_3) + \beta_1)*(\gamma_1 + \gamma_4)$	Sobel	0.0304 (0.0449)	(-0.057, 0.118)
Total Effect				
Product Variety on Sales (Hedonic)	$((\alpha_1 * \beta_3) + \beta_1)*\gamma_1 + \gamma_2 + 2\gamma_3$ProductVariety	Sobel	2.8480-0.5746* ProductVariety (0.3111)	(2.238, 3.458)
Product Variety on Sales (Utilitarian)	$((\alpha_1 * \beta_3) + \beta_1)*(\gamma_1 + \gamma_4) + \gamma_2 + 2\gamma_3$ProductVariety	Sobel	2.7796-0.5746* ProductVariety (0.2747)	(2.241, 3.318)

Once the total effect of product variety on sales is estimated, the next step is to examine the additional inventory costs associated with higher product variety. Because equation (1) models the effect of product variety on inventory levels, the increase in carrying cost associated with an increase in product variety can be estimated employing typical retail carrying costs. Most estimates of retail carrying cost place it somewhere between 20 and 40% of inventory value per year (Ballou, 1989; Ganeshan, 1999). The added inventory cost for carrying an additional SKU an additional day would thus be given by multiplying the daily carrying costs times the inventory increase caused by that additional SKU. According to the regression results, a 1% increase in product variety leads to a 1.25% increase in inventory value in both product categories. By using median values for all variables in the equation for a particular product category and allowing product variety to vary, the changes in sales and inventory costs for an average store can be generated for different levels of product variety.

The total effect of product variety on average daily profits for an assumed 20% carrying cost is graphed in Figure 3 for the hedonic product category and Figure 4 for the utilitarian product category.

Figure 3. Relationship between Product Variety and Average Daily Profits (Hedonic)

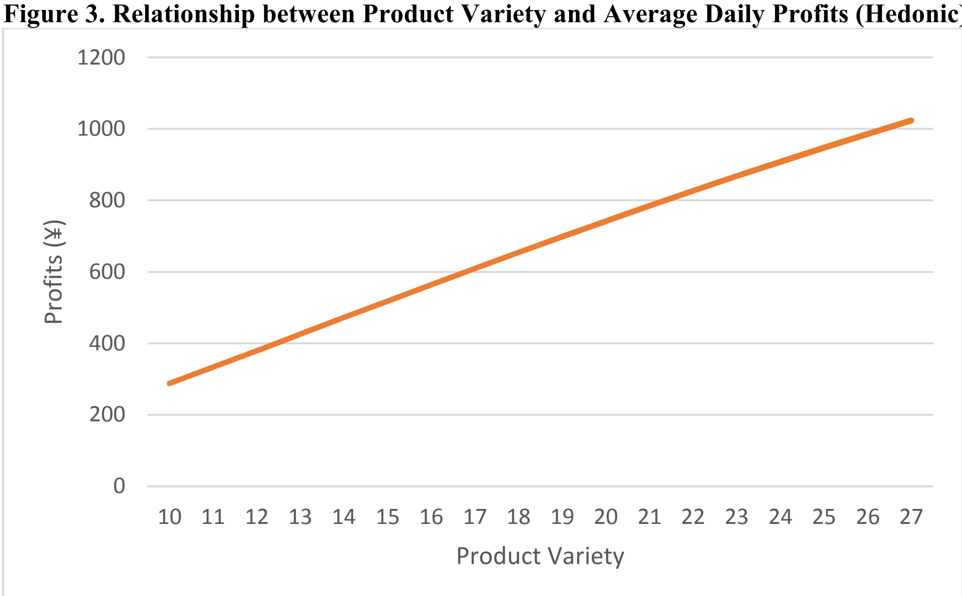
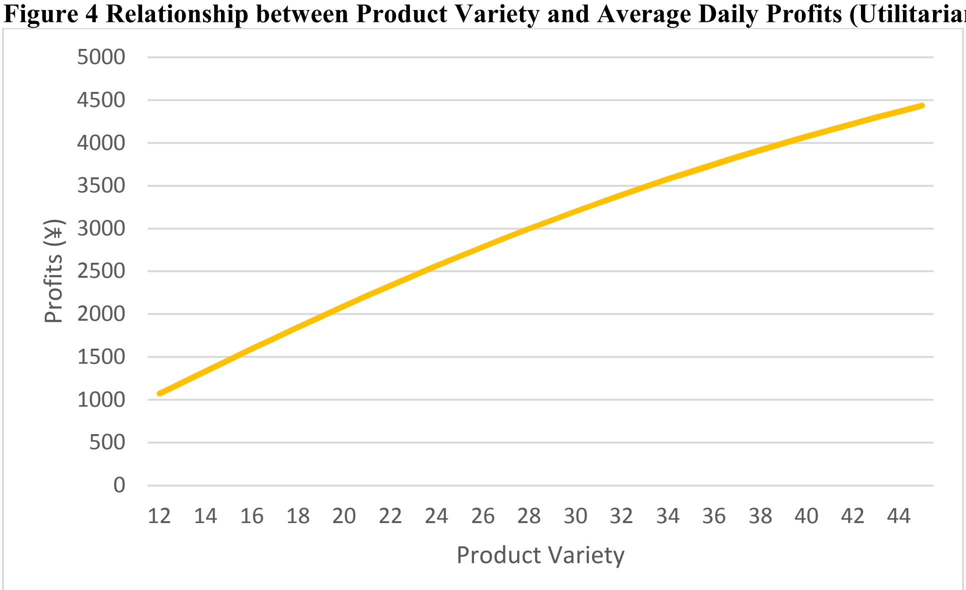


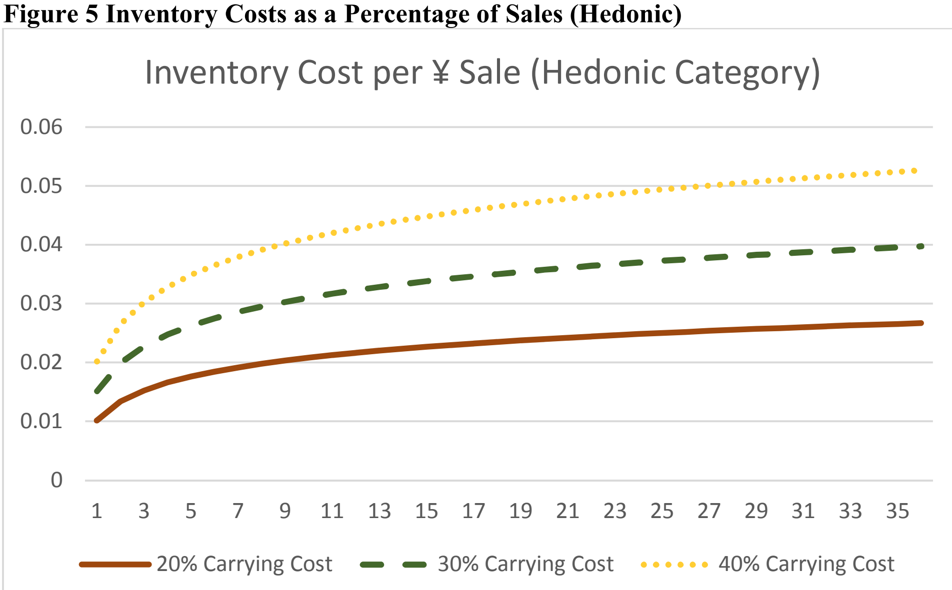
Figure 4 Relationship between Product Variety and Average Daily Profits (Utilitarian)



At most, an additional unit of product variety in the hedonic product category leads to around a 46.30 ¥ increase in average sales per day, while the additional daily inventory cost of product variety amounts to about 1.02 ¥ per day on average. For the utilitarian product category, an additional unit of product variety leads to a maximum increase of 130.00 ¥ per day and a 3.30 ¥ increase in average daily inventory costs.

While that may seem like a small increase, it does lead to an interesting finding. While profits are increasing in product variety for all values that are present in the data set, the ratio of inventory costs to sales is increasing. Figure 5 shows the total inventory carrying costs divided by the total sales for each level of product variety for the hedonic product category for different levels of carrying cost (20, 30, and 40%).

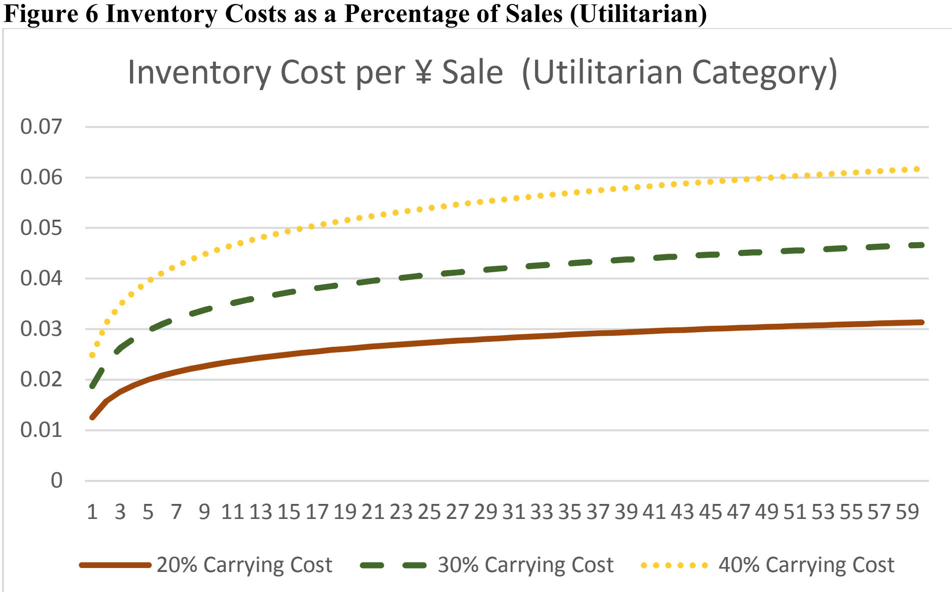
Figure 5 Inventory Costs as a Percentage of Sales (Hedonic)



Notice that inventory costs as a percentage of sales is increasing as product variety increases in the hedonic product category, starting at around 1.00% for a single SKU and increasing to 2.66% for 36 SKUs, assuming a 20% carrying cost. If prices and all other costs remain constant, this implies that inventory costs per Yuan

(¥) of sales is increasing as product variety increases. If this increase is not compensated for by higher prices or other decreased costs then this implies that the retailer's profit margin is decreasing as product variety increases. The same phenomena is shown for the utilitarian product category in Figure 6. With a 20% carrying cost, the percentage of inventory costs to sales starts at 1.25% for a single SKU and reaches 3.13% for 60 SKUs. These numbers are quite significant for retailer profit margins, as a typical profit margin for a grocery store is between 6% and 8% (Smith, 2004).

Figure 6 Inventory Costs as a Percentage of Sales (Utilitarian)



3.6 Discussion and Managerial Implications

This study looks to contribute to extant literature on the relationship between product variety, operational performance, and sales by investigating these relationships within two different product categories in the retail context. Previous literature has examined this relationship mostly at the brand manufacturer level (e.g. Closs et al., 2010; Wan et al., 2012; Wan et al., 2014), and literature that has examined this relationship at the retailer level has only examined portions of the relationship, such as the relationship between product variety and inventory levels, without examining the more robust relationship between product variety, inventory levels, availability, and sales (Dubelaar et al., 2001). This research makes three important contributions to the current operations management literature. First, this paper includes the impact of product variety on inventory levels as part of a system of equations of product variety on operational performance and sales, which is important as inventory is one of the mechanisms by which product variety impacts operational performance. Secondly, this paper shows that there are significantly different relationships between stock out rates and sales for hedonic and utilitarian product categories. Finally, this paper shows that the increased costs that retailers face due to higher levels of product variety can lead to inventory costs being a higher percentage of product category sales, which could lead to lower profit margins for retailers if prices and other associated costs remain constant.

These results have a few implications for managers of retail firms. First, the inventory and availability of hedonic product categories should be more closely monitored than in utilitarian product categories because the negative effect of stock outs on sales in a hedonic product category is much stronger than in a utilitarian product category. Secondly, while product variety can lead to higher sales, it can also lead to inventory costs being a higher percentage of total sales. This doesn't mean that product variety is unprofitable (far from it) but rather that increasing inventory costs due to product variety can have a negative impact on store profit margins if the store is unable to extract a price premium or decrease other costs by offering more product variety.

3.6.1 Limitations and Future Research Directions

This work has some obvious limitations. First, all of the data utilized for this study is from two selected product categories from a single retail firm. While these two product categories are distinct with respect to characterization as hedonic or utilitarian according to previous research (Sloot et al., 2005), incorporation of more product categories to further extend these results is clearly warranted. Furthermore, while this research investigated the impact of product variety on carrying costs, there are likely to be other costs associated with increased product variety (such as overhead or ordering costs) that could not be accounted for. Building a more complete picture on how product variety impacts the cost structure of retail firms would allow researchers to build an accurate representation of the trade-offs that firms face when deciding to add more products to their existing product assortment.

Chapter 4: The Impact of Brand Variety on Inventory, Stock Out Rates, and Sales at a Large Grocery Retailer

4.1 Introduction

Do different types or forms of product variety impact a firm's sales or operational performance metrics differently? Recent research has indicated that this might be the case, as while higher amounts of size variety and line variety can lead to lower fill rates for brand manufacturers, the impact of the two types of variety were not identical (Wan et al., 2014). While these two types of product variety certainly can make inventory operations more difficult for retail managers, these two types of variety represent only a portion of the variety present in the typical product assortment of a retailer. While most wholesalers and brand manufacturers will only carry products from a specific brand or parent company, retailers carry many different products from many different brand manufacturers in most of their product categories. Additionally, while brand manufacturers have to deal with different sizes and lines of products within their own product line, retailers must balance the additional complications from additional sizes and lines both within brands and across brands. This process can become further complicated by the fact that different brands within a product category are competing with each other for sales within a fixed shelf space at a retailer.

Besides introducing potential sales conflicts, multiple brands can also impose difficulties on a firm's store and inventory operations. Each of these different brands have different company contacts and sales representatives for the ordering and customer service process and often come with their own logistics and ordering processes. The addition of more brands, particularly if they overlap in line or size, can also greatly increase forecasting difficulties for the product category manager at the retailer (Fisher and Raman, 2001).

Understanding how different types of product variety impact the operational performance and sales of a retailer is an important step for helping retailers provide a product assortment that not only generates higher sales but also allows for firms to make informed decisions about how different types of product variety can impact their inventory management and their costs. While the relationship between different types of product variety and sales for retailers has been investigated (Boatwright and Nunes, 2001; Fisher and Fu, 2014), the relationship between different types of product variety and operational performance has only been investigated for brand manufacturers and wholesalers (Wan et al., 2014). As noted previously, retailers tend to carry a much different type of product assortment than wholesalers or distributors, not only carrying multiple brands but also typically carrying less flavors and sizes than brand manufacturers.

The goal of this paper is to extend the literatures that have examined 1) how different types of product variety affect retail sales and 2) how different types of product variety impact operational performance of firms by empirically investigating how different types of product variety simultaneously effect the operational performance and sales of a large grocery store chain. More specifically, using two product categories, one utilitarian (juice) and one hedonic (potato chips), this research examines how three different types of variety: brand, size, and product line (defined below) affect inventory levels, stock out rates, and sales in each of these product categories.

In order to address these two questions, a few terms must be defined. Three different types of product variety have been identified in previous literature: brand, size, and flavor (Boatwright and Nunes, 2001; Wan et al., 2014). Brand variety refers to the number of distinct brands offered by a retailer in a product category. An example of this type of variety from the potato chip category (one of the featured product categories in this study) would be Pringles and Lays. Size variety refers to the number of distinct sizes offered by a retailer in a product category. An example of this type of product variety from the potato chip category would be a 30 gram bag (around the size of a single serving bag) and a 100 gram bag (which would comprise multiple servings). The final type of variety investigated in this study is product line variety, also known as flavor variety or line variety in other studies (e.g. Boatwright and Nunes, 2001). This type of variety is the number of distinct types or flavors of products offered in a product category by a retailer. In the potato chip product category this would manifest as different flavors such as sour cream and onion, steak, crab, and BBQ. For a full list of the different brands, sizes, and product lines present in these two product categories please see the data appendix.

The distinction between these different types of product variety has been suggested to be important in the operational performance and sales of firms. Some literature has examined how different types of product variety (also known as product attributes) can impact overall product category sales for online retailers (Boatwright and Nunes, 2001) as well as brand manufacturers (Wan et al., 2014). However, no one has empirically examined the relationship between different types of product variety and sales for a brick and mortar retailer.

Firms may carry product variety for a number of different reasons. For a retailer, offering a product assortment that contains many products with different attributes allows for the retailer to introduce their product to new customers or encourage current "variety seeking" customers to purchase more product (Lancaster, 1990). Furthermore, offering more products in a product category can help increase the likelihood of product substitution when a customer's preferred product is out of stock (Zinn and Liu, 2001). The probability of substitution becomes more likely as the number of products with similar attributes to an out of stock product (brand, size, and flavor) are added to the retailer's product assortment (van Ryzin and Mahajan, 1999). While brand manufacturers may benefit from a larger customer base as well as some product substitution, they do not necessarily share the same incentives as retailers. For example, if a customer's preferred product was some variant of a Lays' potato chip but that product was out of stock and the customer decides to purchase Pringles instead, the store will still benefit from the sale but Lays will lose market share to a competing brand offered by the retailer.

There have also been studies that examined the impact of different types of product variety on operational performance, but only in the context of a brand manufacturer. Wan et al. (2014) investigate how size and product line variety effect fill rates for distribution centers of a large soft drink manufacturer. They found that size variety and product line variety did have different impacts on the unit fill rates of the distribution centers. In particular, they found that size variety had a larger negative effect on fill rates than product line variety, indicating that size variety was more associated with poor operational performance than product line variety.

However, no research has specifically tested the notion that different types of product variety can lead to different effects on operational performance in the retail context, which tends to feature not only product line variety and size variety, but also brand variety. Furthermore, retailers will tend to carry product line and size variety within and across different brands. In addition to investigating how different types of product variety can impact sales at a brick and mortar retailer, this research will simultaneously analyze how different types of product variety affect the operational performance of a retailer and how that impact on operational performance may affect retailer sales.

The rest of the chapter is organized as follows: section 2 presents a brief literature review, theoretical background, and presents hypotheses to be tested, section 3 provides some background on the retailer as well as the empirical model used in this work, section 4 presents the results of the regression, and section 5 concludes the chapter.

4.2 Theoretical Background

There are many different reasons that retailers may offer product variety. Product variety allows for retailers to increase their sales by enticing new customers to purchase from a product category that they typically do not, or by encouraging current product category customers to purchase larger quantities of products (Baumol and Ide, 1956; Lancaster, 1990). Additionally, the presence of more products within a product category increase the possibility that a customer will substitute a product for their intended product in case a desired product is out of stock (Vaagen and Wallance, 2008). Retailers might also carry higher amounts of product variety when facing significant amounts of local competition in the same industry as an attempt to differentiate themselves from rival firms in a bid to increase market share (Watson, 2009).

While there are benefits to product variety, there are also costs and problems associated with carrying additional product variety within a product category. For example, product variety has been associated with higher inventory levels, which leads to higher carrying costs for the retailer (Bayus and Putsis, 1999; Dubelaar et al., 2001; Sweeney et al., 2015). Furthermore, higher levels of product variety can complicate the inventory management and forecasting processes of a retailer (Fisher and Raman, 2000; Ton and Raman, 2010), which has been found to lead to the deterioration of operational performance in the case of a wholesaler, which can lower sales (Wan et al., 2012). However, this relationship has not been examined in the retail context.

When a retailer chooses to add (or remove) a product to their product assortment, they are not only adding (or removing) another SKU but they are potentially altering their current offerings of product brands, sizes, or flavors. Previous research has shown that higher levels of product variety, defined as the total number of SKUs offered by a retailer in a particular product category, can have a negative impact on retailer operational performance through increased inventory levels and higher category stock out rates (Dubelaar et al., 2001; Sweeney et al., 2015). However, previous research has not investigated the operational impact of the different types or forms of product variety, such as brands, sizes, or product lines. The prevalence of different types of product variety offered by a firm have been shown to negatively affect the operational performance of brand manufacturers. Wan et al. (2014) showed that both more size variety and more product line variety were related to lower fill rates for distribution centers, but the relationship was stronger for size variety than product line variety.

Brand variety may be more difficult for retailers to deal with than size variety and line variety because increased brand variety will typically introduce more complications than size or product line variety for the retailer. Each brand has different company contacts and sales representatives for the ordering and customer service process and often each has their own logistics and ordering processes that must be completed. The addition of more brands, particularly if they overlap in line or size, can also greatly increase forecasting difficulties for the product category manager at the retailer. Thus, brand variety might be associated with worse operational performance in the form of higher inventory levels and stock out rates than size or product line variety for a retailer.

H6: Brand variety is positively associated with inventory levels for a retailer holding demand constant. Furthermore, the relationship between brand variety and inventory levels will be larger than the association between size variety or product line variety and inventory levels.

H7: Brand variety is positively associated with stock out rates for a retailer, ceteris paribus. Furthermore, the relationship between brand variety and stock out rates *will be larger than the association between size variety or product line variety and stock out rates.*

Previous literature has also shown that there is a relationship between different types of product variety and sales. In the brand manufacturer context, product line variety was found to have a larger impact on sales than size variety by a factor of six (Wan et al., 2014). In the retailer context, Boatwright and Nunes (2001) investigated the impact of the three different types of product variety on product category sales for pasta sauce at an online grocery store. They found that decreases in product assortment along brand, size, or flavor (product line) dimensions actually increase sales for small decreases in assortment offerings, but lead to decreased sales as larger decreases were made to brands, sizes, or flavors. The effect of a brand cut was much more pronounced on product category sales than the effect of a size or product line cut, both for the initial increase in sales and the reduction in sales as brand cuts increased. While this result seems to contrast with previous literature finding that increases in product variety are associated with increased sales, it should be noted that the authors were specifically examining what happens when redundant product attributes (such as brands, sizes, or flavors) are removed from a product category that already has a large amount of product variety. Removal of large numbers of redundant attributes or removal of unique attributes were still associated with less overall sales.

Furthermore, there is evidence that a larger number of brands available at a retailer can lead to higher sales. In particular, Briesch et al. (2009) used household market basket data to show that the number of available brands at a store was positively related to the customer's choice to patronize that retailer. The authors suspected that this was due to stores with more brands being more likely to meet the brand preferences of local customers, which would lead to higher sales. Conversely, the number of SKUs per brand and sizes per brand were negatively related to the customer's choice of retailer. This indicated to the authors a preference of consumers for meaningful variety rather than just large assortments, as just increasing the number of SKUs without adding an additional size or brand to the existing product assortment would lead to a decreased probability that a customer would choose that retailer. This means that at a certain point simply adding product lines (or flavors) to existing brand offerings does not increase the likelihood a customer will patronize a retailer, and can have a negative impact on the consumer's likelihood to pick that retailer. In addition to the results, this paper is interesting because of the way that the authors operationalized the different types of variety. Instead of using raw counts of the attributes as has been done in previous literature (Boatwright and Nunes, 2001; Wan et al., 2014), they used SKUs per brand and sizes per brand as a measurement of retailer assortment shape.

For the retailer, offering a higher number of brands in a particular product category potentially allows them to fill more market niches with their product assortment offering and sell to more customers. Previous literature seems to suggest that brands have a larger effect on retailer sales than other types of variety, but no literature the author is aware of has explicitly tested this relationship within the context of a brick and mortar retailer using retailer sales data. Thus, the following hypotheses:

H8: Brand variety is positively associated with product category sales for the retailer holding inventory levels constant. Furthermore, the relationship between brand variety and sales will be larger than the relationship between size variety or product line variety and product category sales.

4.3 Data and Methodology

This section of the paper will briefly detail the setting for this study as well as the data to be used to test the hypotheses put forward in the previous section. Following that, a description of the empirical model used to test the hypotheses is presented.

4.3.1 Study Setting

This research uses data compiled from a large Chinese grocery retailer based in Shanghai, China. This retailer operates 3 different types of retail chains in China: a large department store chain, a medium sized grocery store chain, and a small convenience store chain. This research uses the data provided by this retail firm from their large department store chain, which is a big box retailer that sells products in a variety of product categories, including electronics, appliances, and food. This data set contains daily information for 75 different retailers and two product categories (juice and potato chips). All of the stores are linked through a single distribution center. This distribution center is the sole source for these two product categories available to the retailers.

There are a total of 128 SKUs offered across the firm in the juice product category with 31 different sizes, 25 different brands, and 19 different product lines (flavors). There are 58 SKUs offered across the firm in the potato chip product category with 15 different sizes, 8 different brands, and 18 different product lines (flavors). For a breakdown of the different sizes, brands, and product lines for both of these product categories, please see the attached data appendix.

The data used in this study was gathered for a 7 month period from April 2011 to October 2011. Different types of data were collected from the firm for each retailer and the focal distribution center, including order data, shipment data, inventory data, and sales data. For a more in-depth discussion of the firm's operations, as well as statistical breakdown of some aspects of the retail stores such as the total revenue of the stores or product variety breakdown of the product categories, please see the data appendix.

Finally, it should be noted that while the data used for the analysis in this paper is gathered from a single retail firm, the inventory and sales metrics represent the decisions of many different and independent managers that work for this firm. Although the retail managers do not directly control the product variety they offer at their particular store location, they do have autonomy for the store's inventory management decisions.

4.3.2 Empirical Model

The empirical model used in this research is an extension of the simultaneous equation models that have been used to model the effect of product variety on operational performance and sales (Wan et al., 2012; Wan et al., 2014, Sweeney et al., 2015). The simultaneous equation model is composed of three different equations, each with a different dependent variable: inventory levels, stock out rates, and sales, in accordance with previous literature (Sweeney et al., 2015). Each of these variables are hypothesized to be influenced by the levels of brand, size, and product line variety on hand at the retailer. The simultaneous equation model methodology is adopted to help model the endogeneity present in the relationships between weekly operational performance and sales, as inventory levels, stock out rates, and sales could be jointly determined by the retail managers.

This simultaneous model is estimated using a three stage least squares regression methodology. A three stage least squares regression model further generalizes the instrumental variable approach in a two stage least squares regression model, allowing the model to take into account potential correlation between the error terms of successive equations. This is necessary in this context because the error terms in the equations for inventory levels, stock out rates, and sales from the same week and retailer are likely to be correlated with each other. The instrumental variables approach helps model the endogeneity between inventory levels, stock out rates, and sales for a particular week.

As stated previously, there are three equations in the simultaneous system: weekly inventories, stock out rates, and sales. The inventory and stock out rate equations are included as indicators of operational performance of the retailer. Previous literature has shown that these metrics can be impacted by the product variety present at a retailer (Dubelaar et al., 2001; Sweeney et al., 2015). Sales are included as measurement of retailer financial performance, and have been used in many studies involving retailers (e.g. Boatwright and Nunes, 2001). Brand variety, size variety, and line variety are included as the variables of interest in each equation, along with the total number of SKUs as a way to differentiate the effect of total product variety from how the composition of a retailer's assortment impacts inventory levels, stock out rates, and sales. Furthermore, inventory levels, stock out rates, and sales can be affected by other aspects of the retailer and their management practices such as order quantities that are controlled for where appropriate. The next section details which variables are included in each equation and the reasons for their inclusion.

4.3.3 Inventory Equation

The inventory equation is based on previous models that have examined how product variety is related to inventory levels. Inventory levels are considered to be a function of sales, stock out rates, order quantities, and product variety (Dubelaar et al., 2001; Dong et al., 2014; Sweeney et al., 2015). Past sales should have a positive influence on inventory levels, as a store that has sold more in the recent past is likely to carry more inventory to support those higher sales. Likewise, stores that have experienced higher stock out rates in the recent past are likely to carry more inventory in an attempt to lower their stock out rates (Dong et al., 2014). Inventory levels are a function of both what a retailer sells (outflows) and how much it orders (inflows). In the long run we would expect average order and sales quantities to equilibrate, however, we expect short term fluctuations and differences in retailer order quantities relative to retailer sales. Because of this, the sole inclusion of sales would leave a key component of the dynamic inventory system absent from the equations. Thus, past order quantities are also included in the regression model as a measurement of this short term flow into the retailer's dynamic inventory system.

The variables of interest in the inventory equation are brand variety, size variety, product line variety, and total variety. A measurement of total product variety (in terms of numbers of SKUs offered in the product category) is included in the inventory equation to help differentiate the effects of the composition of the product assortment from the size of the product assortment. The composition of the product assortment is measured by three variables: brand variety, size variety and product line variety. These three product assortment composition variables allow the model to distinguish between the different types of product variety that are being added to the store's product assortment. While it is possible that a store can add an SKU to their assortment without adding a unique brand, size, or line, any addition to the retailer's product assortment that does increase the number of brands, sizes, or product lines also adds an additional SKU to the retailer. In other words, the total number of SKUs provides a base measure for the level of product variety while the brand, size and product line variables measure the composition of that product variety (in terms of the number of brands, sizes, or lines offered).

Store, week, and category dummies are included to control for store, week, and category fixed effects for inventory levels. For example, a specific retailer might carry larger or smaller amounts of inventory due to store manager preference or other space constraints. The week dummy variables allow for inventory differences from week to week due to seasonal effects, such as holidays. Finally, category fixed effects are included to account for the fact that different product categories might have different levels of safety stock or different inventory management policies. As a side note, because of the use of two different product categories in the analysis, inventory levels are measured in monetary terms (Chinese Yuan) rather than units of product.

To help control for potential endogentiy of order quantities, stock out rates and sales, the order quantity, stock out rate, and sales are calculated as four week moving averages of the previous weeks' order quantity, stock out rate, and sales respectively. For a more detailed description of how the variables in the model are operationalized, please see section 4.3.6. The specification of the inventory equation is presented as equation (1) below.

$$\begin{aligned} InventoryValue_{itp} &= \alpha_0 + \alpha_1 ProductVariety_{itp} + \alpha_2 BrandVariety_{itp} \\ &+ \alpha_3 SizeVariety_{itp} + \alpha_4 ProductLineVariety_{itp} \\ &+ \sum_{i=1}^{78} \alpha_5 StoreDum_i + \sum_{t=1}^{30} \alpha_6 WeekDum_t + \alpha_7 CategoryDum_p \\ &+ \alpha_8 OrderQuantity_{itp} + \alpha_9 AverageStockoutRate_{itp} \\ &+ \alpha_{10} SalesForecast_{itp} \\ &+ \omega_{itp} \qquad (1) \end{aligned}$$

4.3.4 Stock Out Rate Equation

In accordance with previous literature, stock out rates are used as a measurement of retailer operational performance (Ton and Raman, 2010; Sweeney et al., 2015). Other recent papers have used fill rates as a product availability metric in the brand manufacturer context, which is analogous to the stock out rate in the retail context (Wan et al., 2014). This paper utilizes the fill rate equation in Wan et al.,

(2014) and the stock out rate equation in Sweeney et al. (2015) as a basis for the stock out rate equation. Stock out rates are considered to be a function of product variety, inventory levels, order quantities, positive sales surprise, and store sales (Dong et al., 2014; Sweeney et al., 2015). Higher inventory levels should be associated with lower stock out rates, as retailers with more inventory should experience fewer stock outs. Recent order quantities and sales are included to account for inflows and outflows in the inventory system which can impact the retailer's current stock out rate. The last control variable included in the stock out rate equation is sales surprise. While the inflows and outflows in the inventory system are measured using order quantities and sales, a sales surprise occurs when sales are larger than would be expected (using a four week moving average of past sales as a base forecast of expected sales). In weeks where sales surprise is positive, sales are larger than would have been expected based on the previous four weeks performance regardless of how large sales were in absolute terms. While the absolute size of the surprise can be important, more important to the retailer is how large the sales surprise is related to expectations. Thus, this variable is constructed using a percentage surprise rather than the absolute values used for the retailer's sales and order quantities.

Brand variety, size variety, and product line variety are included in the stock out rate equation as the variables of interest in this study. Again, as in the inventory equation, the total number of SKUs carried in the product category by the retailer is included to differentiate the effects of assortment size from assortment composition on store stock out rates. The inventory level included in this equation is the fitted inventory value estimate from equation (1). This variable is included because stores with more inventory should have lower stock out rates. The store, week, and product category dummies control for store, week, or product category fixed effects with respect to the weekly stock out rate. For example, certain stores might face different stock out rates due to the inventory and replenishment policies of the managers of that particular store. Week fixed effects are included to control for seasonality that might impact stock out rates. Finally, category fixed effects are included because some categories might have a higher base stock out rate than others due to characteristics inherent in that particular category. An example of such a characteristic is the hedonic or utilitarian nature of the product category. Hedonic product categories are products that are consumed typically for fun or for the experience of consumption, while utilitarian product categories are those that are typically purchased for their practical utility. Because of this, utilitarian product categories tend to be more substitutable than utilitarian product categories which can lead to higher stock out rates in the utilitarian product category as demand for out of stock products is funneled into other products in the category that are in stock at a much higher rate than in hedonic product categories (Sweeney et al., 2015). Because this research uses two product categories (one considered hedonic, and the other considered utilitarian), the potential differences in base stock out rate must be controlled for (Sloot et al., 2005). The specification for the stock out rate is provided below as equation (2).

$$StockOutRate_{itp}$$
$$= \beta_0 + \beta_1 ProductVariety_{itp} + \beta_2 BrandVariety_{itp} + \beta_3 SizeVariety_{itp}$$
$$+ \beta_4 ProductLineVariety_{itp} + \beta_5 InventoryValue^e_{itp} + \sum_{i=1}^{78} \beta_6 StoreDum_i$$
$$+ \sum_{t=1}^{30} \beta_7 WeekDum_t + \beta_8 CategoryDum_p + \beta_9 OrderQuantity_{itp}$$
$$+ \beta_{10} PositiveSalesSurprise_{itp} + \beta_{11} SalesForecast_{itp}$$
$$+ \varepsilon_{itp} \qquad (2)$$

In equations (1) and (2), brand variety is expected to have a larger coefficient than both size variety and product line variety according to hypotheses 1 and 2. This would indicate that brand variety has a larger impact on retailer inventory levels and stock out rates than other types of variety after controlling for the total size of the product assortment offered by that retailer in that product category.

4.3.5 Sales Equation

The last equation included in the system of equations is a sales equation. This equation estimates average daily sales for a week using the estimated stock out rates from equation (2), and includes variables identified from previous research (Wan et al., 2014; Sweeney et al., 2015). Product category sales are considered to be a function of stock out rates, product variety, order quantities and price. The estimated stock out rate from equation (2) is included in the sales equation because periods of higher stock outs should be associated with lower sales. Two different measures for price are included in the model: average price and price change. Average price is included to account for differences in product assortment across retailers since sales are measured in monetary terms rather than physical units. Price changes are included to control for the impact of weekly price changes (in the case of promotions or price cuts) on demand. This variable includes price changes only for items that have been sold during both the current week and the previous week to provide a consistent measure of price changes that potentially impact sales. Details of the calculation are presented in the data appendix.

Similar to the previous two equations, brand variety, size variety and product line variety are included as variables of interest. A squared term for the number of SKUs is included because the relationship between a retailer's product assortment size and sales has been found to be non-linear (Boatwright and Nunes, 2001; Wan et al., 2012; Sweeney et al., 2015).

Previous research suggests the relationship between the different types of product variety and sales may be linear or non-linear. Thus, two versions of the sales equation are estimated. The first uses a linear and squared term for the size of the product assortment, but only linear terms for the composition of product assortment variables: brand variety, size variety, and line variety. The second model includes both linear and squared terms for the size of the product assortment, as well as the composition of product assortment variables. This inclusion is made because results from previous studies have supported both linear and non-linear specifications for the effect of different types of product variety on retailer sales.

The final variables included are the store, week, and category dummy variables. These control for store, week, and category fixed effects on sales. For example, certain stores may have more sales than others due to store location. The week fixed effect variables help control for spikes or drops in demand due to seasonality. The category dummy variable controls for the fact that sales are measured in dollars, and one category may sell more in monetary terms than the other category. One last variable of special note is the interaction term between the category dummy variable and the stock out rate. This is included because previous research suggests that the stock out rate can have a different impact on sales in different product categories. In particular, the stock out rate has a larger negative effect on sales in hedonic product categories rather than utilitarian product categories due to the lower substitutability of products in hedonic product categories compared to utilitarian product categories. Because they are less substitutable, out of stock SKUs are more likely to decrease sales in hedonic product categories than in utilitarian product categories as it is less likely a customer will buy another product when their intended product is out of stock. Potato chips are considered a more hedonic product category than juice (Sloot et al., 2005; Sweeney et al., 2015). Category is a dummy variable which takes the value of 1 for juice (the utilitarian product category) and 0 for potato chips (the hedonic product category), thus the expected coefficient on this term is positive. The specification of the sales equation is presented as equation (3) below.

$$Sales_{itp} = \gamma_0 + \gamma_1 StockOutRate^e_{itp} + \gamma_2 ProductVariety_{itp}$$
$$+ \gamma_3 ProductVariety^2_{itp} + \gamma_4 BrandVariety_{itp}$$
$$+ \gamma_5 BrandVariety^2_{itp} + \gamma_6 SizeVariety_{itp} + \gamma_7 SizeVariety^2_{itp}$$
$$+ \gamma_8 ProductLineVariety_{itp} + \gamma_9 ProductLineVariety^2_{itp}$$
$$+ \gamma_{10} CategoryDum_p \; x \; StockOutRate_{itp} + \sum_{j=1}^{78} \gamma_{11} StoreDum_i$$
$$+ \sum_{k=1}^{30} \gamma_{12} WeekDum_t + \gamma_{13} CategoryDum_p + \gamma_{14} LongRunPrice_{ip}$$
$$+ \gamma_{15} PriceChange_{itp} + \delta_{itp} \qquad (3)$$

4.3.6 Variable Definitions

Because this research uses data from two separate product categories, inventory levels, order quantities, and sales are all calculated in Chinese Yuan (¥). Table 8 below summarizes the definitions of the variables included in the simultaneous equation model.

One variable that needs further explanation is the weekly stock out rate variable. This variable is a weighted average of the stock out rates for each individual SKU in a product category calculated on a weekly basis. The stock out rate for each SKU is computed as the percentage of days in the week that the individual SKU is out of stock. The overall stock out rate for that product category is the weighted average of all the SKUs carried by the retailer in that product category where the weights are based on the overall sales of each SKU at that retailer. Because of the presence of right skewness of some variables included in the regression, such as product variety, average daily sales, average daily inventory levels, and average daily quantities, the natural log is used for all continuous non-percentage variables that are included in the equations in the regression model. The final step of the data cleaning process was to remove items that sold at a rate of less than one unit per day for the duration of the data or experienced stock outs lasting longer than 10 days. Items that sell less than a unit per day are unlikely to add significant complications to the ordering or inventory management processes of a retailer, and because the focus of this paper is on how different types of product variety impact retailer operational performance these items are excluded from the analysis. The exclusion of stock outs lasting longer than 10 days prevents the inclusion of products that were potentially removed from the store's assortment for an extended period of time and items that did not get properly removed from the data base after being removed from the store's product assortment.

There were originally 78 retail stores in the data set. The elimination of SKUs with sales of less than one unit per day resulted in the elimination of three stores. These stores had no SKUs in our two product categories that sold more than one unit per day on average. The remaining 75 stores each had 27 weeks of data, with the exception of two stores. These two stores had 20 weeks and 12 weeks of store data respectively. Both of these were included in the final analysis. It is unknown if the stores opened during this time period or simply did not begin data collection until a later date than the other stores.

Table 8 Variable Definitions

Variable	Description
$InventoryValue_{itp}$	The average daily inventory value in (¥) in product category p at retailer i during week t.
$ProductVariety_{itp}$	The number of different SKUs offered in product category p at retailer i during week t.
$BrandVariety_{itp}$	The number of different brands offered in product category p at retailer i during week t.
$SizeVariety_{itp}$	The number of different pack sizes offered in product category p at retailer i during week t.
$ProductLineVariety_{itp}$	The number of different product lines or flavors offered in product category p at retailer i during week t.
$UtilitarianDum_{itp}$	A dummy variable coded 1 when the product category is utilitarian (juice), and 0 otherwise (potato chips).
$StoreDum_{itp}$	A dummy variable coded 1 if store = i, and 0 otherwise to capture store fixed effects.
$WeekDum_{itp}$	A dummy variable coded 1 if week = t and 0 otherwise to capture week fixed effects.
$OrderQuantity_{itp}$	The 4 week moving average {t-4, …, t-1} of order value of the last 4 weeks in Chinese Yuan in product category p at retailer i.
$AverageStockoutRate_{itp}$	The 4 week moving average {t-4, …, t-1} of the stock out rate of the last 4 weeks in product category p at retailer i.
$SalesForecast_{itp}$	The 4 week moving average {t-4, …, t-1} of average daily sales of the last 4 weeks in Chinese Yuan in product category p at retailer i.
$PositiveSalesSurprise_{itp}$	The percentage of average daily sales in product category p at retailer i during week t that are above the sales forecast.
$StockOutRate_{itp}$	The stock out rate in product category p for retailer i during week t.
$LongRunPrice_{ip}$	The average price for a single unit in product category p at retailer i over the entire data.
$PriceChange_{itp}$	The percentage change in average price for a single unit in product category p at retailer i from week t-1 to week t.

The first four weeks for each store are not included in the final regression analysis, but are instead used to start the calculation of the four week moving averages for order quantities, sales, and stock out rates used in the regression analysis. Finally, some observations were removed due to missing or incomplete data. For example, a few stores only had collected data on a single product category for their orders but both product categories for sales. This resulted in a final sample size of 3,260 observations. The summary statistics for the variables used in the regression analysis are presented in Table 9 on the next page.

The average daily order quantity is 456¥. The average daily sales total is 608¥. The differential is due to the fact that the order quantity is calculated using the internal price of the SKU (wholesale price), while average daily sales are calculated using the price that the customer pays for the product (retail price). Thus, the difference between the two can be seen as the markup, which is about 33%. The total amount of product variety offered in a product category varies from 1 SKU to 60 SKUs. The total amount of brand variety present in a product category varies from 1 to 18 brands. The total amount of size variety varies from 1 to 26 sizes, and the total amount of product line variety varies from 1 to 16 lines. The reason for the higher level of size variety is that different brand manufacturers offer similar products that have slight variations in size from their competitors (for example, a 100 gram bag of potato chips versus a 110 gram bag of potato chips). The alternative to listing each type of size variety separately would be to create binned categories from actual sizes. However, there are some problems associated with this approach. In particular, some sizes fall directly between the majority of sizes provided in the category and two products with a similar volume of product can have very different packaging (for example, a 200 gram bag of potato chips versus a package with 4 bags of 50 grams of potato chips).

Table 9 Descriptive Statistics of Regression Variables prior to Natural Log

Variable	Min	Max	Mean	Std. Dev.
Inventory Value (yuan)	171.00	218588	23506	26594
Sales (yuan)	10.81	7393	608.20	696.96
Order Quantity (yuan)	0	7936.74	455.79	729.14
Product Variety	1	60	22.66	11.25
Brand Variety	1	18	6.69	3.63
Size Variety	1	26	9.83	5.74
Line Variety	1	16	9.77	2.72
Stock Out Rate (%)	0	0.30	0.01	0.03
Positive Sales Surprise (%)	0	0.89	0.09	0.14
Long Run Price (yuan)	2.16	7.99	4.71	1.31
Price Change (%)	-0.88	5.33	0.02	0.21

The size variety variable was left as an unadjusted count variable because each SKU is separately tracked and monitored in the database as well as by the retail managers, even if the SKUs are of similar sizes.

The correlation table for the variables used in this study is presented in Table 10 below.

Table 10 Correlation Table of Regression Variables

Variable	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
Inventory Value [1]	1.00										
Sales [2]	0.76*	1.00									
Order Quantity [3]	0.77*	0.73*	1.00								
Product Variety [4]	0.69*	0.80*	0.64*	1.00							
Brand Variety [5]	0.68*	0.69*	0.60*	0.76*	1.00						
Size Variety [6]	0.71*	0.76*	0.63*	0.85*	0.91*	1.00					
Line Variety [7]	0.47*	0.56*	0.40*	0.83*	0.52*	0.60*	1.00				
Stock Out Rate [8]	-0.15*	-0.09*	-0.11*	-0.05*	-0.15*	-0.12*	0.02	1.00			
Sales Surprise [9]	0.04	0.23*	0.03	-0.01	0.02	0.01	-0.02*	-0.04	1.00		
Long Run Price [10]	0.51*	0.55*	0.46*	0.51*	0.56*	0.64*	0.27*	-0.06	-0.02	1.00	
Price Change [11]	0.02	0.04*	0.05*	-0.01	0.01	0.02	-0.03	0.00	0.04	0.01	1.00

where * indicates $p < 0.05$

Size and line variety are the two types of variety that most closely correlate to the total number of SKUs present in the category. Brand variety is also positively correlated with product variety, but the correlation is slightly weaker than that between product variety, size variety, and product line variety. Order quantities, sales, and inventory value are also fairly highly correlated with each other, as would be expected in a retail setting since products must first be ordered and placed into inventory before they can be sold. Because of the correlation between certain variables in the data set, a variance inflation factor test (VIF test) is conducted on the variables included in the model to determine if the level of multicollinearity present might be an issue for the regression analysis. The results of the VIF test are presented in Table 11.

Table 11 VIF for Regression Variables

Variable	[1]
Inventory Value	3.81
Sales	5.28
Order Quantity	3.10
Product Variety	12.47
Brand Variety	7.24
Size Variety	12.94
Line Variety	4.24
Stock Out Rate	1.05
Positive Sales Surprise	1.23
Long Run Price	1.96
Price Change	1.01
Mean VIF	4.94

While the variance inflation factor for some of the variables are slightly above the typically used threshold of 10 for VIFs, there is research that suggests that this heuristic is not appropriate in situations where there is an inherent correlation among predictor variables (O'brien, 2007). Furthermore, the mean VIF for all of the variables included in the analysis is below the typically accepted threshold of 6.

4.4 Results

The estimation results are presented in Table 10. Two models are estimated, one with only first order terms for the different types of product variety (Model 1), and a second with the squared terms included (Model 2). While the majority of previous literature suggests that the relationship between the number of SKUs, operational performance, and sales is non-linear (e.g. Boatwright and Nunes, 2001; Wan et al., 2012; Sweeney et al., 2015), there is less consensus on whether the relationship between the different types of variety (brand, size, and product line), operational performance, and sales is also non-linear (Boatwright and Nunes, 2001; Wan et al., 2014). Thus, a model with only a linear term (Model 1) and a model with both linear and non-linear terms (Model 2) are estimated in Table 12.

The results are fairly consistent across models, with a few notable exceptions. In equation (1), the coefficients for product variety, order quantity, and sales forecast are positive and statistically significant. These coefficients conform to expectations, as retailers with more product variety, larger average order quantities, and higher sales should carry higher levels of inventory (Dubelaar et al., 2001; Sweeney et al., 2015).

The only major difference between the two models with respect to equation (1) is the sign and significance of the average stock out rate variable. In model 1, this variable is positive and statistically significant, while in model 2 this variable is negative and not statistically significant. The rationale behind the inclusion of this variable is that managers might base their inventory decisions in the present week on their stock out rates of the previous weeks, and that higher stock out rates in the previous weeks might lead managers to decide to carry more inventory in the current week.

Table 12 Regression Results

Variable	Non-squared Terms Sales Equation			Squared Terms Sales Equation		
	Model 1.1 Log Inventory	Model 1.2 Stock Out	Model 1.3 Log Sales	Model 2.1 Log Inventory	Model 2.2 Stock Out	Model 2.3 Log Sales
Log ProductVariety$_{itp}$	1.9156***	0.8921***	2.2376***	1.8956***	0.5377***	2.6939***
	(0.0769)	(0.02812)	(0.3511)	(0.0770)	(0.0192)	(0.5313)
Log ProductVariety$^2_{itp}$			-0.2131***			-0.2914***
			(0.0518)			(0.0873)
Log BrandVariety$_{itp}$	0.2788***	0.1206***	-0.1362*	0.2698***	0.0657***	0.1108
	(0.0509)	(0.0131)	(0.0780)	(0.0510)	(0.0086)	(0.1851)
Log BrandVariety$^2_{itp}$						-0.0710
						(0.0506)
Log SizeVariety$_{itp}$	-0.5501***	-0.2567***	0.2216**	-0.5418***	-0.1446***	-0.4061
	(0.0686)	(0.0183)	(0.0988)	(0.0687)	(0.0121)	(0.3434)
Log SizeVariety$^2_{itp}$						0.1638**
						(0.0810)
Log ProductLineVariety$_{itp}$	-0.8263***	-0.3698***	-0.0547	-0.8057***	-0.2153***	-0.5701
	(0.0832)	(0.0225)	(0.1198)	(0.0833)	(0.0150)	(0.6698)
Log ProductLineVariety$^2_{itp}$						0.1106
						(0.1474)
Log OrderQuantity$_{itp}$	0.1324***	0.0625***	0.0012	0.1302***	0.0372***	-0.0012
	(0.0077)	(0.0024)	(0.0105)	(0.0077)	(0.0016)	(0.0104)
CategoryDum$_{itp}$	0.2547***	0.1196***	0.3433***	0.2562***	0.0780***	0.3586***
	(0.0578)	(0.0145)	(0.0847)	(0.0578)	(0.0095)	(0.0869)
AverageStockoutRate$_{itp}$	0.3989***			-0.1703		
	(0.1511)			(0.1943)		
Log SalesForecast$_{itp}$	0.3881***	0.2029***		0.3880***	0.1097***	
	(0.0251)	(0.0086)		(0.0252)	(0.0058)	
Log InventoryValue$^e_{itp}$		-0.4897***			-0.2938***	
		(0.0117)			(0.0083)	
PositiveSalesSurprise$_{itp}$		0.1275***			0.0466***	
		(0.0089)			(0.0066)	
StockOutRate$^e_{itp}$			-16.9651***			-16.6788***
			(2.3060)			(2.1986)
StockOutRate$^e_{itp}$ x CategoryDum$_{itp}$			14.7383***			11.0823***
			(2.3478)			(2.2346)
Log LongRunPrice$_{ip}$			0.5785***			0.4952***
			(0.0976)			(0.0935)
PriceChange$_{itp}$			0.0164			0.0106
			(0.0399)			(0.0373)
StoreDummies	Included but not shown.					
WeekDummies	Included but not shown.					
X^2 Test Statistic	21,273.07***	3,827.00***	11,557.55***	21,270.80***	3,024.91***	11,799.31***
Observations	3260	3260	3260	3260	3260	3260

The results for equation (2) are identical in terms of significance across model 1 and model 2, but with model 2 coefficients uniformly smaller in magnitude than model 1 coefficients. The product variety, order quantity, sales forecast, and positive sales surprise variables are all positively related to product category stock out rates. Product variety has long been empirically associated with operational complexity and higher stock out rates (Wan et al., 2012; Sweeney et al., 2015), and previous order quantities and past sales can affect the dynamic inventory system in the short term, causing higher operational complexity and higher stock out rates. Because sales surprise indicates the percentage that actual sales exceeded expected sales for the week, the coefficient of this variable being positive also meets expectations. Finally, the fact that the inventory value variable is negative and statistically significant indicates that higher inventory levels seem to lead to lower stock out rates and is also in line with expectations based on the findings of previous research.

The results for equation (3) are similar across model 1 and model 2 for the product variety, order quantity, stock out rate and long run average price variables. Product variety is positively associated with sales but at a decreasing rate which agrees with previous research on the impact of product variety on sales (Wan et al., 2012; Sweeney et al., 2015). The order quantity coefficient is not significantly related to average weekly sales. The category stock out rate is significantly negatively related to product category sales. This relationship is mediated by the product category under consideration, which also agrees with previous findings (Sweeney et al., 2015). Finally, higher average prices (which separate out higher priced assortments from lower priced product assortments) are associated with higher weekly sales.

The results for brand variety, size variety, and product line variety may appear different at first glance, but the two models are not necessarily conflicting. While the Chi-squared test statistic for model 2 is larger for equation (3) than model 1 (in part due to the inclusion of more three variables for model 2), there is only one variable of the brand, size or product line varieties that is statistically significant ($SizeVariety^2_{itp}$) in model 2. In model 1 the coefficient of brand and size variety are statistically significant, while the product line coefficient is not. Something to notice from model 2 is that while the coefficients are not statistically significant, the coefficient of the linear term for brand, size, and product line variety have the opposite sign of the associated non-linear term, which is in line with some results from previous literature (Boatwright and Nunes, 2001). The total model fit (as measured by a sum of the Chi-squared test statistic across all three equations) is better for model 1 than model 2 while model 1 contains fewer estimated parameters, and more control variables have their expected sign in model 1 than in model 2, particularly for equation (1). Furthermore, the interpretation for the brand, size and product line variety variables from model 1 are more intuitive compared to the results from model 2.

For these reasons, model 1 will be used for all interpretation unless otherwise noted. For robustness, tables comparing the results of model 1 to model 2 appear at the end of section 4.4.1.

4.4.1 Interpretation

In order to fully evaluate the impact of a retailer adding an additional brand, size, or product line to their existing product assortment, the individual effects of adding a SKU are isolated to provide a baseline for the expected changes of adding a single SKU that does not affect product assortment composition. This can then be compared to what happens when a retailer adds an SKU that also adds an additional brand, size, or product line to the retailer's product assortment. This analysis can then be extended to scenarios where a retailer adds multiple SKUs of a single new brand, size, or product line.

The results of the regression indicate that the effect of product variety (the number of SKUs) on inventory levels is positive and significant in equation (1). The effect of product variety on stock out rates in equation (2) is more complicated. While the coefficient of product variety in equation (2) is positive and significant, there is also an indirect effect of product variety on stock out rates through inventory levels as the effect of inventory levels on stock out rates is negative in equation (2). Using a non-linear combination procedure (Sobel, 1982; Preacher and Hayes, 2008), we can estimate the total effect of product variety on stock out rates. A similar procedure can be used to determine the total effect of product variety on sales, as there is both a direct effect of product variety on sales and an indirect effect of product variety on sales through the stock out rate. The computations and results for this analysis are provided in Table 13.

As can be seen from Table 13, the total number of SKUs offered seems to positively effect a retailer's inventory levels, while the total effect of product variety on the stock out rate is negative and statistically significant due to the increased inventory that typically accompanies product variety.

Table 13 Total Effect of Product Variety on Inventory Levels, Stock Out Rates, and Sales

Effect	Calculation	Mean (Std. Error)	95% Confidence Interval
Product Variety on Inventory Levels	α_1	1.916 (0.0769)	(1.765, 2.067)
Product Variety on Stock Out Rates	$(\alpha_1 * \beta_5) + \beta_1$	-0.046 (0.0208)	(-0.087, -0.005)
Product Variety on Sales	$((\alpha_1 * \beta_5) + \beta_1)*\gamma_1 + \gamma_2 + 2\gamma_3$ProductVariety	3.020 – 0.426*ProductVariety (0.5200)	(2.001, 4.039)

Because of the presence of a squared term in the regression equation, the total effect of product variety on sales depends on the level of product variety. The largest amount of product variety in this data set for a retailer during a week is 60 SKUs, which using the results from Table 12 gives a coefficient of 1.276 for the expected total effect of product variety on sales, which is still positive. Thus, for the range of SKUs covered by the data set, product variety has a positive total effect on a retailer sales. This means that, in general, a store can expect to have increased inventory levels and sales by simply adding SKUs to their product assortment even if those SKUs do not add additional brands, sizes, or product lines to their existing assortment, and that they can also expect a small decrease in their stock out rate as well due to the increased inventory levels generated by more SKUs. These findings are consistent with previous studies on the impact of product variety on inventory levels, stock out rates, and sales (Sweeney et al., 2015).

While the number of SKUs offered by the retailer has a profound effect on the retailer's inventory levels, stock out rates, and sales, these are also impacted by the composition of the retailer’s product assortment. In other words, changing the product composition of a retailer while adding (or subtracting) SKUs from the retailer’s product assortment alters the impact of adding or removing those SKUs based on how the retailer’s product composition changes. This section now looks to evaluate the potential effects of additions to a retailer’s product assortment both in number of SKUs and changes in product composition.

In equation (1), brand variety has a positive and statistically significant relationship with inventory value, while size variety and product line variety have negative and statistically significant relationships with inventory value. However, the coefficients of the regression model only tell part of the story when a firm adds product variety. In order to add additional brands, sizes, or product lines to their product assortment, a retailer will also have to add additional SKUs to their product assortment unless the retailer changes only the composition of their product offering. Hypothesis 1 states that adding brand variety to a retailer’s product assortment increases inventory to a greater extent than adding size or product line variety, while hypothesis 2 suggests that adding brand variety to a retailer’s product assortment increases stock out rates. Finally, hypothesis 3 suggests that more brand variety should be associated with higher sales than increases in size variety or product line variety. This research first examines these hypotheses by investigating the marginal effect of adding brand, size, or product line variety to a retailer. The marginal effect tests the impact on retail inventory levels, stock out rates, and sales of adding an additional brand, size, or product line to the existing product assortment while adding only the bare minimum number of SKUs necessary. In effect, this involves increasing the appropriate product assortment variable by one as well as increasing the total number of SKUs offered by the retailer in that product category by one.

Table 14 shows the marginal effect of an increase in brand variety, size variety, and product line variety on inventory levels, stock out rates, and sales for the average retailer (all other regression variables are set equal to their average value). For comparison, the effect of adding a single SKU without changing the product assortment offered by the retailer is also provided in the table.

Table 14 Effect of an Increase in Brand, Size, or Product Line Variety on Inventory Levels, Stock Out Rates, and Sales

	Change in Average Daily Inventory Value (in Chinese Yuan)	Change in Stock Out Rate	Change in Average Daily Sales (In Chinese Yuan)
Single SKU	1,593.77	-0.002	57.48
Brand Variety	2,378.09	-0.005	72.23
Size Variety	473.12	0.000	57.92
Product Line Variety	241.08	0.001	15.17

As can be seen in Table 15, the model suggests that adding a single SKU of a new brand would lead to higher inventory levels for the retailer when compared to size variety and product line variety. Because of the negative relationship between inventory value and a retailer's stock out rate, brand variety actually lowers the predicted stock out rate for a retailer while size and product line variety marginally increase a store's stock out rate. Furthermore, under the marginal effect, brand variety has a larger positive effect on a retailer's sales than size variety or product line variety. These results seem to indicate that while the main impact of product variety on sales comes from having another SKU offered in the store, there are subtle differences in how adding an additional brand, size, or product line can effect a retailer's inventory levels and sales. According to the results, the addition of a single brand seems to lead to higher sales than expected of adding a single SKU, the impact on average daily sales by the addition of a size doesn't seem to have additional impact beyond that of adding an additional SKU, and the addition of a single product line seems to lower the expected sales for adding an additional SKU to the retailer's current product assortment. Furthermore, introducing a new brand with a single SKU has a much higher impact on inventory levels than introducing either a size or a product line with a single SKU, which may indicate that the retailer anticipates more inventory management difficulties for the addition of a brand than with the addition of a size or product line.

When compared to simply adding another SKU that does not change the retailer's product assortment, adding a new brand adds multiple new challenges with respect to managing that product, particularly since that product is likely to come from a new supply chain partner. The potential new ordering, shipping, or inventory management processes and policies that come with carrying an additional brand might lead retailers to feel compelled to order more inventory to ensure they are not surprised or caught off guard by these new inventory management challenges or potential demand surges. On the other hand, since new sizes or product lines are likely to come through existing channels for the retailer and are somewhat less likely to introduce completely new processes in ordering or processing retailers may decide that less inventory is needed in these circumstances.

These results have some interesting implications for the retailer's profits. While the marginal effect of brand variety leads to higher sales than does the marginal effect of size or product line variety, it also leads to higher inventory levels for the retailer as well. Because the empirical model simultaneously models the inventory value, stock out rate, and sales as a function of not only the number of SKUs featured by a retailer but by the shape of a retailer's product assortment, we can analyze how revenues and costs for a retailer might be simultaneously impacted by the product assortment changes a retailer makes.

Most previous research has put the carrying cost for retail inventory to be between 20 and 40% per year (Ballou, 1989; Ganeshan, 1999). Carrying cost accounts for the total cost of carrying inventory, which includes warehousing costs such as rent, salaries, and utilities, as well as financial costs such as opportunity costs and insurance, as well as costs of perishability, theft, and inventory shrinkage (Russell and Taylor, 2006). Thus, using the marginal effects from the previous section, we can calculate the potential impact of an increase in brand variety, size variety, or product line variety on profits. However since carrying costs only approximate the costs of holding inventory, we can only estimate how these different types of product variety impact inventory costs using the inventory equation (1).

While not an exact value, we have an approximate estimate for the average markup for the retailers in this firm. If we assume that the retailer typically sells the vast majority of the products they order, then the ratio of the average retailer weekly sales to the average retailer weekly order quantity would give an approximate value for retailer markup, which can be used to calculate a firm's costs of goods sold. The formula for calculating a retailer's costs of goods sold using their markup is the following:

$$CoGS = \frac{Sales}{(Markup + 1)}$$

where markup is a percentage from 0 to 1, and sales is the average daily sales for a week. Using this equation the non-administrative costs associated with offering more product variety can be estimated and compared with the additional expected revenue resulting from an increase in product variety, giving a simple estimate of the overall impact of an increase in product variety (and in different types of product variety) on expected store profits.

Table 15 shows the impact of the marginal effect on inventory costs and profits for an assumed 20% annual carrying cost of inventory as well as a costs of goods sold. The costs of goods sold for the average retailer is given by the ratio of the mean of average daily sales to the mean of average daily order quantities, which can be found from the descriptive statistics in Table 9. Using this information, the markup is estimated to be 33%, which is within reasonable markup percentages for grocery retailers (Crowe, 2011). Furthermore, this research uses a 20% annual Figure for carrying costs, as most information on retail carrying costs put the typical retailer carrying cost on the lower end of the spectrum, somewhere between 20 – 25% (Hurlbut, 2004).

Table 15 Effect of an Increase in Brand, Size, or Product Line Variety on Profits (20% Carrying Cost)

	Average Daily Inventory Value (In Chinese Yuan)	Average Daily Carrying Cost (in Chinese Yuan)	Average Daily Profit (in Chinese Yuan)
Single SKU	1,593.91	0.87	13.39
Brand Variety	2,378.31	1.30	16.62
Size Variety	473.22	0.26	14.11
Product Line Variety	241.07	0.13	3.63

Again, according to the results of Table 14, brand variety has the largest impact on sales for the average retailer when considering the marginal effect (an increase by one of either brand, size, or product line variety as well as the one SKU necessary to make that happen). According to Table 15, the effect of an increase of brand variety on inventory costs is much larger than the effect of an increase in either size or product line variety due to the large increase in inventory generated by carrying a new brand. However, this cost is not enough to prevent brand variety from being the most profitable to the retailer when considering only the additional carrying costs generated by adding that brand. This result assumes that all other costs faced by the retailer not included in carrying costs of inventory remain constant. This may not be the case given the potential for new inventory and ordering processes, as well as the effort and attention that is potentially required to bring a new brand to a retailer. As a robustness check, Table 16 below presents the results of the same analysis assuming a larger annual carrying cost of 40%, which is near the maximum value seen in industry and well above the typical retail carrying costs of 20 – 25%. As can be seen from the table, the results don't vary significantly even with this higher carrying cost.

Table 16 Effect of an Increase in Brand, Size, or Product Line Variety on Profits (40% Carrying Cost)

	Average Daily Inventory Value (In Chinese Yuan)	Average Daily Carrying Cost (in Chinese Yuan)	Average Daily Profit (in Chinese Yuan)
Single SKU	1,593.91	1.75	12.52
Brand Variety	2,378.31	2.61	15.32
Size Variety	473.22	0.52	13.85
Product Line Variety	241.07	0.26	3.50

There results provide support for hypotheses 1 and 3 that brand variety leads to higher inventory levels and sales when considering the marginal effect (the addition of a single SKU required to add a new brand or size to the retailer's product assortment). However, the typical brand, size, or product line increase may not be a single SKU. A new brand would generally involve a multiple increase in SKUs. Size and product line increases may also be greater than an increase of one SKU since when one brand adds a new size or product line other brands may follow. Thus, another way to analyze the impact of increasing different types of product variety is to examine the impact of a retailer adding an average brand, size, or product line to their existing product assortment offering. For this analysis, we look at the product variety assortment carried by a typical (median) retailer and examine how changes to that assortment impact the inventory levels, stock out rates, sales, inventory costs, and profits of that retailer. Because most retailers offer fewer brands than sizes or product lines, the average brand has more SKUs than the average size or flavor available at most retailers. Examining the data, the median store has average sales of around 354 Chinese Yuan per day and offers 20 different SKUs consisting of 6 different brands, 8 different sizes, and 10 different product lines. For the median retailer, this indicates around 3.33 SKUs per brand offered, 2.5 SKUs per size offered, and 2 SKUs per product line offered.

Table 17 shows the change in inventory value, stock out rates, average daily sales, and average daily profit (assuming a 20% annual carrying cost) due to adding an average brand, size or product line to the existing product assortment of the median retailer while holding the other types of product variety constant. In the case of adding a new brand, this would mean adding a new brand within the sizes and product lines already present at the retailer. In the case of adding a size, this would mean adding a new size within the brands and product lines already present at the retailer (for example, adding a new 200 gram bag of potato chips in brands and flavors already available at the retailer). In the case of adding a product line, this would mean adding a new line within the brands and sizes already available (for example, adding a line of pineapple juice to the juice product category under existing brands and sizes).

Table 17 Effect of Adding a Typical Brand, Size, or Product Line to the Median Retailer

	Inventory Value (in Chinese Yuan)	Stock Out Rate	Sales (In Chinese Yuan)	Profit (In Chinese Yuan)
Brand Variety	6486.34	-0.01	212.80	49.08
Size Variety	2838.38	-0.004	146.90	33.27
Product Line Variety	1780.35	-0.001	56.12	15.53

As can be seen from the table, in this case the profits of the median retailer are increased the most by adding an average brand to their existing product assortment rather than by adding an average size or average product line (as long as other types of variety are held constant). The result that brand variety contributes more to a retailer's inventory levels and sales is consistent whether the retailer is adding a new brand with one SKU or a new brand of typical size. Furthermore, the effect of brand variety on stock out rates is smaller (leads to a lower stock out rate) than the addition of size variety or product line variety due to the large amount of inventory that a retailer commits to when adding an additional brand to their product assortment.

As a final robustness check, Table 18 below presents the results of the marginal analysis (adding a single brand, size, or product line as well as the one SKU required to make that happen) performed in Table 12 using model 2 instead of model 1.

Table 18 Effect of an Increase in Brand, Size, or Product Line Variety on Inventory Levels, Stock Out Rates, and Sales (Model 2 Results)

	Inventory Value (in Chinese Yuan)	Stock Out Rate	Sales (In Chinese Yuan)
Single SKU	1578.99	0.001	32.78
Brand Variety	2338.21	-0.003	39.20
Size Variety	473.98	-0.001	36.19
Product Line Variety	257.69	-0.001	10.77

Finally, Table 19 presents the analysis using model 2 of adding an average brand, size, or product line to the median retailer.

Table 19 Effect of Adding a Typical Brand, Size, or Product Line to the Median Retailer (Model 2 Results)

	Inventory Value (in Chinese Yuan)	Stock Out Rate	Sales (In Chinese Yuan)	Profit (In Chinese Yuan)
Brand Variety	6381.57	-0.005	126.85	27.98
Size Variety	2810.68	0.000	86.80	20.00
Product Line Variety	1779.78	0.000	46.66	10.60

The results from Tables 18 and 19 show that the key relationships between brand, size, and product line variety remain the same under both models. However, there are some differences between these results from model 1 and model 2. While the inventory levels and stock out rate predictions remain relatively stable, the sales increases estimated by model 2 are in general lower than the sales estimated by model 1.

In summary, these results provide some interesting insights into how the amount of variety as well as the composition of variety can impact retailer operational performance and sales. The effect of increasing or decreasing the number of SKUs in a retailer's product assortment seems to be the primary driver of a store's inventory levels, stock out rates, and sales. However, these effects are moderated by the addition or subtraction of an additional brand, size, or product line to the retailer's existing product mix. Furthermore, while brand variety leads to higher sales and higher inventory levels than size variety or product line variety (supporting hypotheses 1 and 3), the increased inventory levels associated with the addition of another brand actually lead to lower stock out rates for brand variety when compared to size variety or product line variety.

4.5 Managerial Discussions and Implications

These results shed some light on the interesting trade-offs that retailers face when considering an expansion of their product assortment offering. Not only does the number of SKUs being added impact the costs and sales (and therefore profits of the retailer), but so does the retailer's product assortment shape in terms of brand, size, and product line offerings.

In accordance with expectations, the results of this analysis indicate that adding more brand variety to a retailer's existing product assortment leads to more inventory (and thus more inventory costs) than adding a single SKU that does not change the retailer's product assortment or an increase in either size variety or product line variety. Furthermore, brand variety has a larger impact on retailer sales than size variety or product line variety. Contrary to expectations, more brand variety seems to lead to lower stock out rates for retailers because of the higher level of inventory encouraged by brand variety.

When considering an expansion (or retraction) to their product assortment, retailer managers need to take into account not only how large or small their product assortment will be after the change but also how the composition of their product offering would be changing as well. This research has shown that adding brand variety has the potential to add higher costs as well as higher sales to a retailer. Conversely, if a retailer wants to cut their inventory levels, a reasonable approach might be to remove an unimportant brand from their product offering rather than removing individual SKUs.

Chapter 5: Conclusions

The purpose of this dissertation was to investigate the relationship between product variety, inventory levels, stock out rates, and sales for retail firms. This dissertation presented two studies designed to examine how different aspects of product variety could simultaneously impact retailer operational performance and sales.

The third chapter examined how the number of SKUs a retailer carried in their product assortment for a particular product category affected category inventory levels, stock out rates, and sales. The third chapter also examined how the impact of product variety on inventory levels, stock out rates, and sales could be moderated by the hedonic or utilitarian nature of the product category under consideration. This was hypothesized to have a potential impact because the degree of substitutability between products in hedonic product categories is lower than the substitutability between products in utilitarian product categories. This could potentially lead to different inventory management practices by the retailer and purchasing choices by customers. Using a three stage least squares regression methodology, the results of this chapter found that product variety did have a positive impact on retailer inventory levels, a negative impact on retailer stock out rates, and a positive impact on retailer sales. However, the direct negative impact of product variety on the stock out rate was completely mitigated out by the corresponding increase in inventory levels that came along with that increase in product variety, which is a finding that expands upon our previous knowledge of how product variety can effect operational performance (Wan et al., 2012). Furthermore, the relationship between product variety and the stock out rate were found to not be mediated by the hedonic or utilitarian nature of the product category under consideration. However, the hedonic or utilitarian nature of the product category did mediate the relationship between a product category's stock out rate and product category sales. In accordance with the hypothesis laid out in chapter 3, the stock out rate had a larger negative impact on sales in the hedonic product category than it did in the utilitarian product category, most likely due to the higher substitutability between products in the utilitarian product category as consumers appear more willing to substitute another product for their intend out of stock purchase, leading to a smaller decrease in sales in the utilitarian product category when a stock out does occur. Finally, while higher amounts of product variety had a net positive effect on product category sales, the effect on inventory levels was found to be of greater magnitude than the effect on sales. In other words, inventory costs increased faster than sales as product variety increased for both product categories, leading to smaller profit margins for the retailer as product variety increased. While this finding is incomplete due to the lack of information about other aspects of retailer operations relevant to profit margins (such as overhead costs, potential price premiums, or other factors not included in the regression analysis), it provides an interesting basis for future research in the field of product variety.

The fourth chapter of this dissertation examined how different types of product variety (or product assortment composition) might impact retailer inventory levels, stock out rates, and sales. Previous literature had investigated whether different types of product variety had a larger effect on distribution center operations or retailer sales (Boatwright and Nunes, 2001; Wan et al., 2014), but no research had yet investigated the simultaneous impact of different types of product variety on retailer operational performance and sales. Chapter 4 segmented product variety along three different dimensions: brand, size, and product line. It was hypothesized that brand variety would have a larger effect on inventory levels and stock out rates than size variety or product line variety due to the additional complications in inventory management processes caused by adding new brands to the existing product assortment of the store. The addition of a new brand can also introduce complications in the ordering and forecasting processes of a retailer.

Using a three stage least squares regression methodology, chapter 4 found that the impact of adding or subtracting different types of product variety from a product assortment dependent was fairly consistent across different magnitudes of product variety increases. For a marginal addition to a retailer's product assortment, where a retailer added a new brand, size, or product line and the one SKU required to make that happen, an increase in brand variety led to higher inventory levels and sales as well as lower stock out rates than an increase in both size variety and product line variety. Extending the analysis to the addition of an average new brand also shows that the addition of an average new brand leads to higher inventory levels and sales as well as lower stock out rates than size or product line variety. Because increases in brand variety led to higher inventory levels as well as higher sales than increases in size variety or product line variety, chapter 4 also investigated the total effect of an increase in brand, size or product line variety on store profits. This analysis showed that an increase in brand variety led to larger increases in profits than both size and product line variety.

By allowing for the modeling of inventory levels simultaneously with stock out rates and sales, this dissertation was able to not only investigate how the size and composition of a product assortment can impact a retailer's sales, but how they also might impact the costs that are faced by the retailer. Because retailers are often balancing the trade-offs between sales and costs when making decisions about their product assortment, modeling these relationships simultaneously allows for modeling product variety in a way more closely corresponds to the methods used by managers making these decisions for retail stores.

The results of this dissertation have many implications for retail managers. The results of chapter 3 indicate that retailers should probably focus more of their attention on the inventory management of hedonic product categories rather than utilitarian product categories, as stock outs in hedonic categories seem to have a larger negative impact on product category sales in hedonic categories. Furthermore, while product variety increases can have a direct negative impact on stock out rates, the resulting inventory increase that comes with more product variety can help mitigate the direct negative impact of more product variety on the stock out rate.

The results of chapter 4 indicate that brand variety is more profitable to add than size variety or product line variety. Furthermore, the three different types of variety (brand variety, size variety, and product line variety) studied in this chapter have different effects on the inventory operations of retailers as indicated by their differing impacts on inventory levels and stock out rates. Thus, retailers should not only account for the total amount of product variety they offer, but also the composition of that offering, when making inventory management and new product decisions.

The final takeaway from this dissertation is that product variety does have a large impact on the operations, costs, and sales of a retail firm, both through the size of the product assortment offering (number of SKUs) and the composition of the product assortment (number of brands, sizes, and product lines). Furthermore, the negative impact of stock out rates on sales was shown to be smaller for utilitarian product categories than hedonic product categories, hinting that a different approach for managing inventory and operations of the two different types of product categories may be optimal.

Data Appendix

Both essays in this dissertation use the same data from the same firm. In order to develop the data used in empirical models in both essays, a significant amount of data manipulation and preparatory analysis was required. This appendix presents a detailed description of all of the data provided by the firm, the necessary cleaning and manipulation required to construct the variables used in the regression analysis, as well as a preliminary data analysis.

This appendix is organized as follows: the first section describes in detail the raw data included in each data set provided by the retail firm as well as how the variables used in the regression analysis in the models provided in this dissertation were formed. The second section presents some descriptive statistics, data plots, and histograms that influenced the choice of functional form for the models in both essays of this dissertation.

A.1 Data Provided by the Firm

The data used in this dissertation was provided by a Chinese retail firm located in the Shanghai metropolitan area. The firm operates three different types of stores: large department stores, medium sized grocery stores, and smaller convenience stores. These stores offer many different types of products, including appliances, clothing, books, and food. The retail firm has many distribution centers in their overall network in and around the Shanghai area. The data provided by this retail firm was collected from the large department store chain controlled by the firm. The data was gathered at two stages in the supply chain for the retail firm: the retail stores and the distribution center used to replenish these retail stores. While the retail firm has many different distribution centers in their network, the SKUs included in the provided database were controlled by a single distribution center where the data was gathered.

The firm provided access to 6 different data sets (all part of a single larger database) for purposes of this dissertation. The first data set includes daily information about the inventory levels of various SKUs at the retail stores and at the distribution center. The list of fields included in this inventory data set and their description are provided in Table 20. This data set contains daily data for a subset of SKUs carried by that retailer (those that are supplied by the focal distribution center of the data base), and contains a placeholder during a period that an item is out of stock rather than removing that item from the data base.

Table 20 Inventory Data Set Variables and Description

Store	The store's ID number
Dept	The product category of the SKU
Item	The SKU ID number
Vendor	The supplier of the product
Inventory	The quantity of product in inventory
Inventory Net Amount	The total value of the inventory post taxes
Inventory Amount	The total value of the inventory before taxes
Date	The date the inventory record was recorded

The second data set provides information on the replenishment orders placed by the retailers to the distribution center. The list of fields included in the retailer order data set and their description are provided in Table 21 on the next page. There are a few differences between this data set and the inventory data set. First, Free Quantity is always zero in this data set (there is no record of any free or gift quantity for any SKU). Second, this data set does not have an entry for each day, but rather only contains entries for days that an order is placed by the retailer.

Table 21 Retailer Order Data Variables and Description

Store	The store's ID number
Dist No.	The unique order ID number
Billtype	The type of order (5 for normal, 6 for return)
Date	The date the order was placed
Dept	The product category of the SKU
Item	The SKU ID number
Quantity	The quantity ordered
Free Quantity	The free quantity provided with the order
Net Price	The internal price of the product post taxes
Price	The internal price of the product before taxes
Net Amount	The total value of the order post taxes
Amount	The total value of the order pre taxes

The third data set provides information on the shipments sent out by the distribution centers to the retail stores. The list of fields included in the retailer shipment data set and their description are provided in Table 22. The variable Po No. in this data set corresponds with the variable Dist No. from the retailer order data set.

Table 22 Distribution Center to Retailer Shipment Variables and Description

Store	The store's ID number
Grn No.	The unique shipment ID number
Billtype	The type of shipment (0 for normal, 2 for return)
Po No.	The unique order ID number (same as Dist No.)
Date	The date the shipment was made
Dept	The product category of the SKU
Item	The SKU ID number
Shipment Quantity	The quantity shipped
Net Price	The internal price of the product post taxes
Price	The internal price of the product before taxes
Net Amount	The total value of the shipment post taxes
Amount	The total value of the shipment pre taxes

Similar to the retailer order data set, this data does not have an entry for each day but rather an entry whenever the distribution center ships items to the supplier.

The fourth data set provides information on the orders placed by the distribution center to the suppliers of the retail firm. The list of fields included in the distribution center order data set and their descriptions are provided in Table 23. As in the retailer order data set, there are no records of free quantities being shipped to the distribution center by the retailers. This data set is not daily, but rather records an entry only when the distribution center places an order with their individual suppliers.

Table 23 Distribution Center Orders to Suppliers Variables and Description

Store	The store's ID number (always the DC in this case)
Po No.	The unique order ID number
Vendor	The supplier of the product
Billtype	The type of order (2 for normal, 4 for return)
Dept	The product category of the SKU
Item	The SKU ID number
Quantity	The quantity ordered
Free Quantity	The free quantity ordered
Net Price	The internal price of the product post taxes
Price	The internal price of the product before taxes
Net Amount	The total value of the order post taxes
Amount	The total value of the order before taxes

The fifth data set provides information on the shipments made by the retail firm's suppliers to the distribution center. The list of fields included in the supplier shipment data set and their descriptions are provided in Table 24 on the next page. Additionally, because the data set was collected from the point of view of the retail firm, the date recorded is the date the shipment was received, not the day that the shipment was dispatched by the supplier. Similarly to the other order and shipment data sets, this data set doesn't contain daily data but instead only records whenever a shipment is received by suppliers.

Table 24 Shipments by Suppliers to Distribution Center Data Variables and Description

Store	The store's ID number (always the DC in this case)
Grn No.	The unique shipment ID number
Vendor	The supplier of the product
Billtype	The type of shipment (0 for normal, 1 for return)
Po No.	The unique order ID number
Date	The date the shipment arrived at the DC
Dept	The product category of the SKU
Item	The SKU ID number
Quantity	The quantity received by the supplier
Free Quantity	The free quantity received
Net Price	The internal price of the product post taxes
Price	The internal price of the product before taxes
Net Amount	The total value of the shipment post taxes
Amount	The total value of the shipment before taxes

The sixth and final data set provided by the retail firm was a sales data set for the retail stores in the firm. The unit of observation for this data set was at the individual SKU level. The list of fields included in the retailer sales data set and their descriptions are provided in Table 25. This data set contains information on each item purchased from certain product categories in the store during a certain time period. The price paid by customers might be lower than the sale price of the item due to promotions, coupons, or other sales being put on by the retailer.

Table 25 Retail Store Sales Data Variables and Description

Store	The store's ID number
POS No.	The unique Point of Sale ID number
Dept	The product category of the SKU
Item	The SKU ID number
Quantity	The quantity sold of that SKU
Price	The regular selling price of that SKU
Paid	The price paid by the customer during that transaction
Date	The date of the purchase

A.2 Data Cleaning and Preparation

Because of the large size of this data base (which was slightly more than 50 million total observations across all 6 data sets), and to allow for a more appropriate test of the hypotheses presented in this dissertation, the data was subject to a rigorous and extended data cleaning phase described in the following section.

Each of these data sets contained different sets of products and different time windows to which they applied. The first step was to identify the products that were common across all of the data sets. The inventory database contained 1656 unique SKUs, the order database contained 714 unique SKUs, the shipment database contained 1626 unique SKUs, and the sales database has 1653 unique SKUs. All of the SKUs in the order data set were present in the other data sets, so the SKUs from the order database were kept while all the SKUs not present in the order data set were dropped. The remaining SKUs belonged to three product categories in the data base: potato chips, juice, and haircare products. These 714 SKUs covered the entirety of the assortment offered by the firm in these three product categories.

The next step was to remove stores from the data base that weren't recorded as making sales during the period of the order data set. The inventory database contained information regarding 105 stores, the order and shipment databases contained 83 stores, and the sales database contained 80 stores. However, two of the stores in the sales database didn't appear in the inventory database, so they were dropped from the sample as well. This left 78 stores with records in all of the databases for the analysis.

Additionally, the different data sets had different time scales. While the order and shipment data bases contained information from January 1st to to November 11th, 2011 (a period of around 10 full months), the inventory and sales databases only covered from April 1st to October 31st (a period of 7 months). The data from the first 3 months was used to generate some variables (which will be elaborated on later), but not was used in the regression models.

The second step was to focus the analysis on items that had steadier sales as well as remove potentially confounding stock out occurrences from the data set. The step of removing items with low amounts of sales was taken because the main premises of this dissertation is that more product variety is harder to manage, and while items with low amounts of sales may add some difficulty in the initial ordering process, they do not contribute as much difficulty to a retailer's inventory management. Two different data sets was generated: one that contained information on all of the items that sold less than 1 unit per day (less than 224 in total quantity over the sales data set) and a second data set that contained the store and item code for items that had stock out events that lasted longer than 10 days in the data set. The items and stores that fit these criteria were then removed from all 6 data sets prior to variable operationalization. This was to help mitigate the possibility of inventory record inaccuracies or items that were no longer on sale at the store but not removed from the inventory data base from biasing the regression analysis.

A.3 Variable Operationalization

This section details the formulation of each of the variables used in the regression analysis. This section does not detail why each of these variables was included, but will rather describe the mechanics by which the variables were created from the existing data. The unit of analysis for this dissertation is the store – product category – week, or an individual week for a product category for each store. This means that for each store and each week in the data set, there are two observations: one for the potato chip category, and one for the juice product category.

Both of the essays in this dissertation use a weighted stock out rate as one of the operational metrics of interest. The weighted stock out rate is weighted for each SKU within specific product category by proportion of sales for that product in that product category for each retailer over the entire duration of the data set. The reason for weighting the stock out rate by sales proportion is to represent the potential value of a stock out to the retailer. For example, a retailer would experience a higher effective stock out rate if they had a stock out of a single SKU that was normally 50% of a product category's sales rather than 5% of a product category's sales. In order to generate this weight, the first step is to generate the proportion of each SKU's sales for each store. The revenues (in Chinese Yuan, or ¥) are first aggregated across each SKU by store for the entire duration of the sales data set, which generates the total sales of a particular SKU within a store. These totals are then aggregated by store and product category, which provides a total sales revenue for both product categories in each store. Finally, the sales proportion for each item at each store is generated by taking the total sales of a particular SKU within the store and dividing it by the total sales of the product category of that SKU within that store.

The next step was to generate a variety measure, a stock out measure, a weighting stock out measure, and the value of the inventory for each store - product category - week. The first step in this process was to count the total number of items carried in a product category at a particular store during a week; this generated the variety measure used in the data analysis. One important thing to note is that this variety count includes items that are currently out of stock, as the inventory data included those items. In order to calculate a weekly stock out measure, the total number of inventory days for store for a week is calculated. The total number of inventory days is defined as the number of items carried by a store during each day of the week. For example, if a store has 20 items listed in its inventory each day of a week, then the total number of inventory days would be 140. If that store removes two items from their product assortment on the last day of the week, then the total number of inventory days would then be 138. Then, the total number of stock out days for a product category for a particular store for the week is calculated the same way. Linking with the previous example, if the store in the numerical example was out of stock of two items per day, then the total stock out days for the week would be 14. If only one item is out of stock each day, then the stock out days would be 7. The stock out rate for each week and each store and each product category is calculated by dividing the number of stock out days by the total number of inventory days for that product category in that store during that week. In order to calculate the weighted stock out rate, the procedure is slightly different. Instead of aggregating the stock outs in a binary fashion, the stock out is multiplied by the proportional sales weight generated in the previous step. These are then aggregated and divided by 7 to generate an average daily weighted stock out rate for that week.

Average daily sales for each week by product category and store was calculated by using the sales data. The total sales (in ¥) for the week in each product category and store was aggregated, and then divided by 7 to generate an average daily total for sales.

The next step is to generate the average daily order quantity for each week by product category and store. This is significantly more difficult than previous variables, because not every store orders every week in the data set. The first thing is to match orders made with shipments made via the unique order number, and remove any shipments that aren't received by the store. In this way, the order quantity variable is more representative of orders that have been received by the store. The reason for removing these undelivered orders from the data set is because undelivered orders can generate more orders by the store until that retailer gets the items they wanted, so the final amount delivered is more indicative of the true order quantity desired by the store. First, the order data (in ¥) is aggregated by each week for each store and product category. This total is divided by 7 to generate a daily average for the week. The order quantity data is then grouped by product category and by store, then sorted by week. Whenever a week is missing the from data base, an entry is created for that week with an order quantity equal to 0.

To construct the final order quantity variable used in the regression analysis for both essays, order quantity was generated as a 4 week moving average of the previous week's order quantities. For example, the forecast order quantity (in ¥) for week 20 in the potato chip category in store 1003 is calculated as a 4 week moving average of the actual (not 4 week moving average) order quantity (in ¥) in the potato chip category in store 1003 for weeks 16, 17, 18, and 19. This was done to account for potential differences in ordering behavior between stores.

The next two generated variables are the price change and average price variables. These are used to control for the typical product assortment (in the case of average price) and the changing of the assortment price from week to week. These are generated using the sales data. The average price variable is generated by taking the total sales (in ¥) for each store / product category combination during the duration of the sales data, and dividing by the total quantity sold in each store and product category for the duration of the data set. This generates an average price per unit for that product category at that specific retailer.

The price change variable is generated by aggregating the total sales (in ¥) by week for each store and product category, and dividing it by the total quantity sold for the week in that product category at that store. Next, the result from the previous week (by store and product category) is subtracted from the result for the current week, leaving the price increase from last week to this week. Finally, this result is divided by average price from the previous week, giving a final variable that is the percentage price increase or decrease in sales of the store's assortment from the previous week to the current week. The calculation for this variable was limited only to SKUs that were carried both in the week in question and the previous week to better reflect price changes from week to week rather than assortment changes.

The final variable needed for the regression analysis is the positive sales surprise variable. This variable is created by generating an expected sales for each week and subtracting it from the actual sales. The expected sales for each week is generated by taking a 4 week moving average of the sales (in ¥) in that same product category over the previous 4 weeks. The resulting "forecast" sales is then subtracted from the sales that week. If the sales are greater than the forecast, then the difference is kept as the positive sales surprise. If the sales were less than the forecast, then the positive sales surprise for that week is defined as 0. Only positive sales surprises are kept because they are likely to be a cause of a stock out, while a negative sales surprise is unlikely to contribute to stock out rates. Then, the sales surprise variable is divided by the total sales for the previous week to generate a percentage sales surprise variable.

A.4 List of Brands, Sizes, and Product Lines in the Potato Chip and Juice Product Categories

Essay two uses the number of distinct brands, sizes, and product lines in a product category as measurement for brand, size, and product lines variety respectively. This section provides a list of the different brands, sizes, and product lines in each category for the purpose of operationalizing brand variety, size variety, and product line variety. Abbreviations are used for brands with no English name.

Juice Brands:

1. BH
2. BL
3. Coconut Palm
4. DH
5. DP
6. HB
7. Huiyuan
8. JE
9. KH
10. LH
11. LL

12. LY
13. LZ
14. PY
15. QL
16. SD
17. SK
18. Tingyi
19. TZ
20. Want Want
21. WZ
22. XG
23. YB
24. YZ
25. ZG

Potato chip brands:

1. BL
2. Bugles
3. HuaYuan
4. Lays
5. Pringles
6. QiaQia
7. Snoopy
8. XiangMei

Juice Sizes:

1. 1.25 L
2. 1.5 L
3. 1.88 L
4. 1.88 L x 2
5. 1 L
6. 1066 mL
7. 125 mL
8. 125 mL x 20
9. 125 mL x 24
10. 125 mL x 4
11. 145 mL x 4
12. 180 mL
13. 2.5 L
14. 200 mL
15. 200 mL x 12
16. 218 mL
17. 240 mL

18. 245 mL
19. 245 mL x 12
20. 245 mL x 6
21. 250 mL
22. 250 mL x 12
23. 2 L
24. 300 mL
25. 318 mL
26. 350 mL
27. 375 mL
28. 450 mL
29. 450 mL x 4
30. 500 mL
31. 750 mL

Potato Chip Sizes:

1. 100 g
2. 110 g
3. 170 g
4. 30 g x 2
5. 40 g
6. 45 g
7. 50 g
8. 50 g x 4
9. 518 g
10. 60 g
11. 65 g
12. 68 g
13. 70 g
14. 80 g
15. 80 g x 4

Juice Product Lines:

1. Coconut
2. Lemon
3. Orange
4. Pear
5. Prune
6. Peach
7. Guava
8. Flower
9. Milk
10. Strawberry
11. Grape

12. Litchi
13. Kiwi
14. Pineapple
15. Tomato
16. Carrot
17. Apple
18. Almond
19. Corn

Potato Chip Product Lines:

1. Sweet
2. Original
3. BBQ
4. Italy Stew
5. Tomato
6. Fish Soup
7. Cucumber
8. Mustard
9. Nori
10. Korean
11. Chicken
12. Steak
13. Curry
14. Cheese
15. Crab
16. Sour Cream and Onion
17. Spicy
18. Japanese

A.5 Figures

This section presents a list of tables and figures that show information about the variables formed using the steps described in the previous section. This analysis formed the basis for using a log-log model specification in the regression analysis in both papers presented in this dissertation.

Figures 7, 8, and 9 (which begin appearing below) show the histograms of retailer order quantities, inventory levels, and sales respectively. As can be seen from the figures, all three of these variables have a right skewed distribution which would violate the assumptions of a three stage least squares regression model. Figures 10, 11, and 12 follow figures 7, 8, and 9 for average daily order quantity, average daily inventory levels, and average daily sales and show the histogram of the natural log of retailer order quantity, inventory levels, and sales respectively.

Figure 7 Histogram of Average Daily Order Quantity

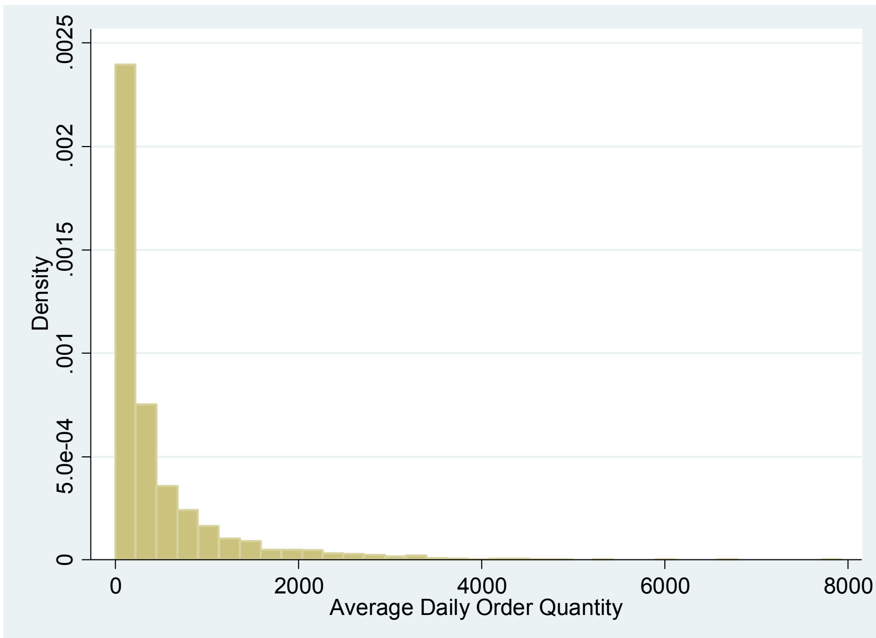


Figure 8 Histogram of Average Daily Inventory Levels

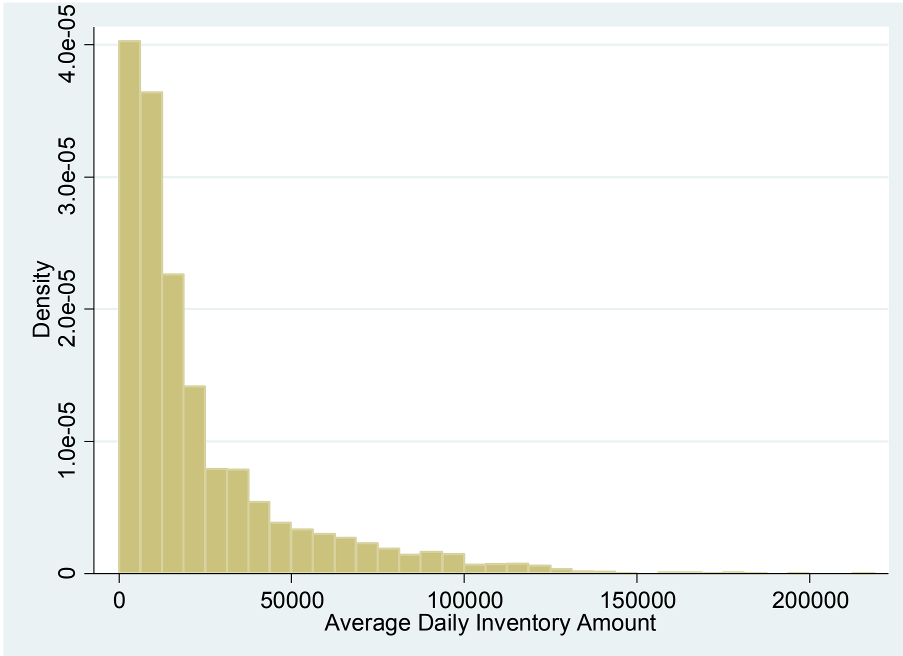


Figure 9 Histogram of Average Daily Sales

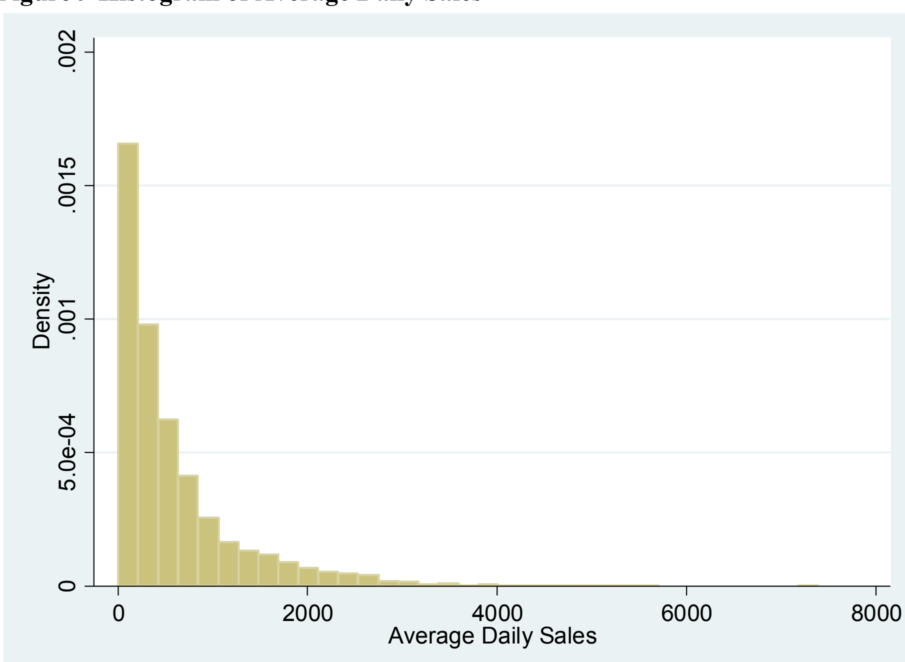


Figure 10 Histogram for the Natural Log of Average Daily Order Quantity

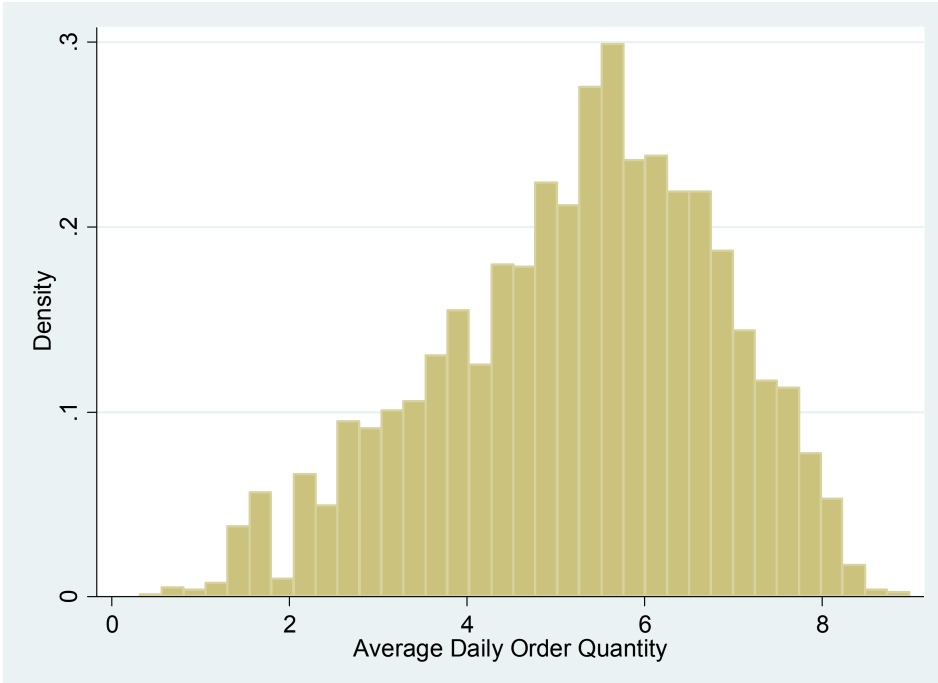


Figure 11 Histogram for the Natural Log of Average Daily Inventory Levels

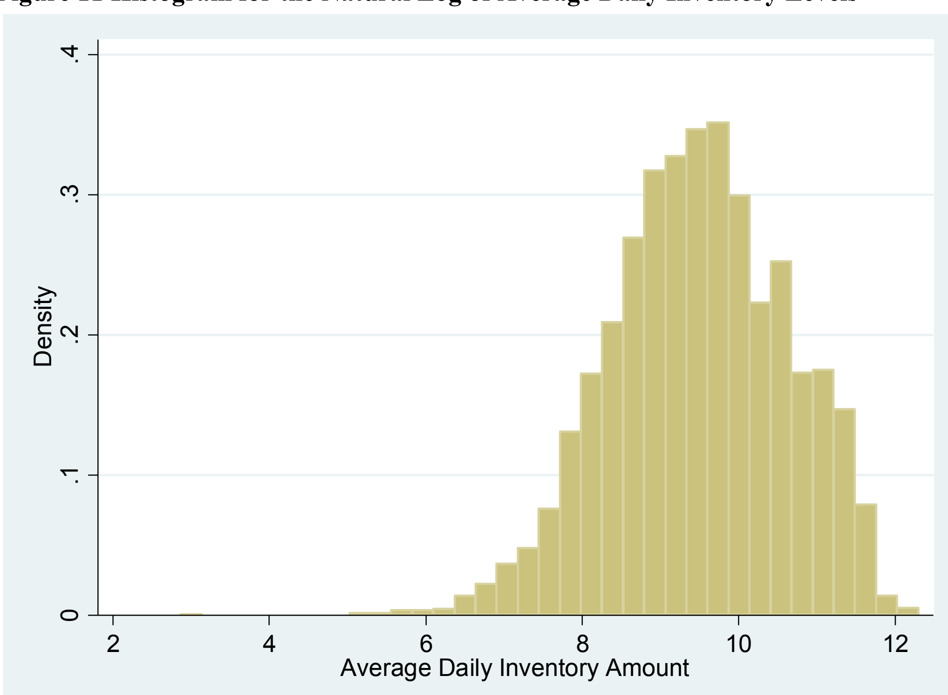
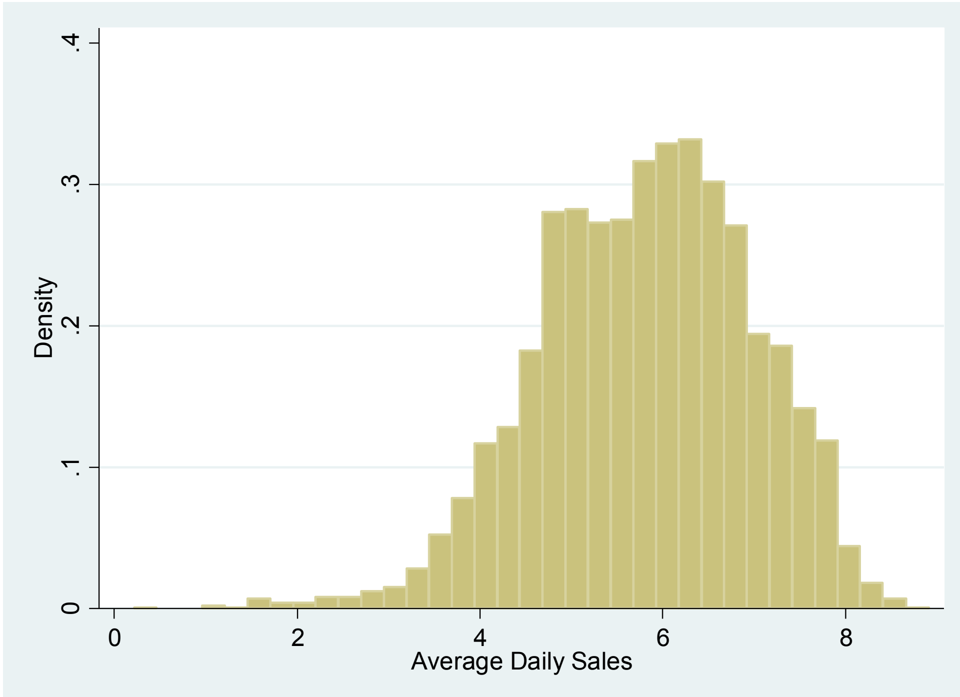


Figure 12 Histogram for the Natural Log of Average Daily Sales



As can be seen from the histograms, the natural log of order quantities, inventory levels, and sales fit the assumptions of the three stage least squares models much more closely than that of the untransformed variables. The log-log model also fits with the findings of previous literature that show a diminishing impact of product variety on operational performance and sales as product variety increases (Wan et al., 2012).

Some additional histograms are provided here for other variables constructed during the variable creation process. Figure 13 (on the next page) shows the histogram for the number of SKUs provided by the retailer. Figures 14, 15, and 16 show the distribution of brand variety, size variety, and product line variety respectively for each store – product category – week combination. Finally, Figure 17 shows a histogram of the long run average price across stores.

Figure 13 Histogram of Number of SKUs Offered

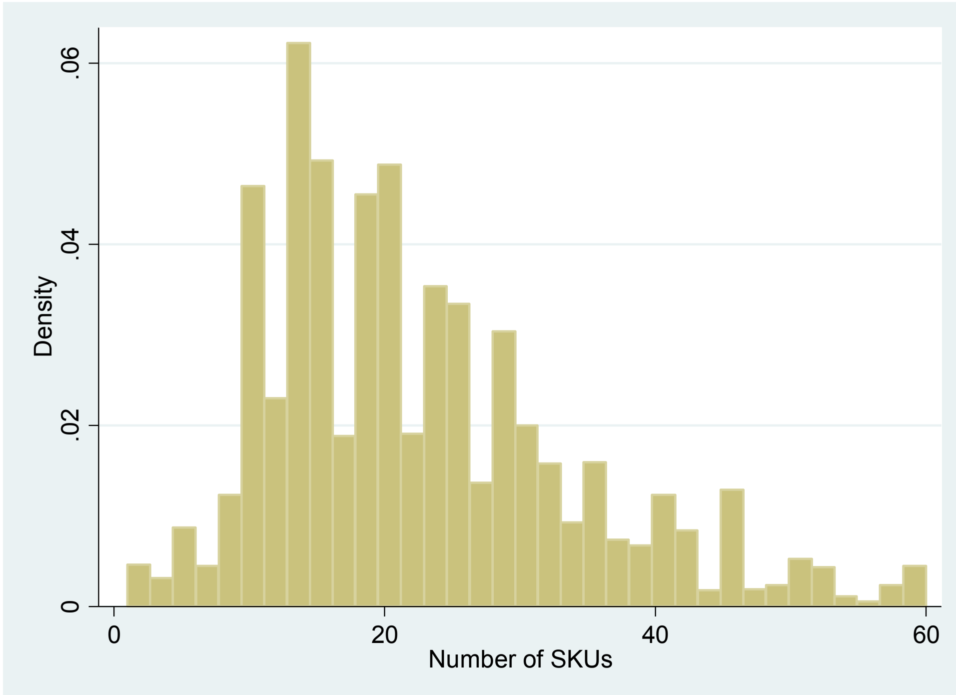


Figure 14 Histogram for the Number of Brands Offered

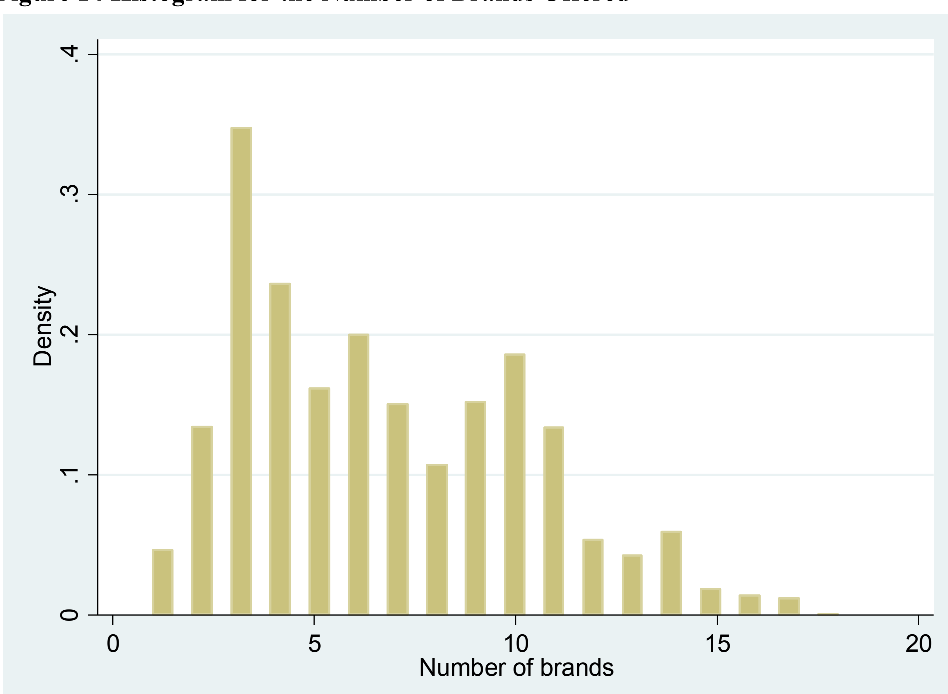


Figure 15 Histogram for the Number of Sizes Offered

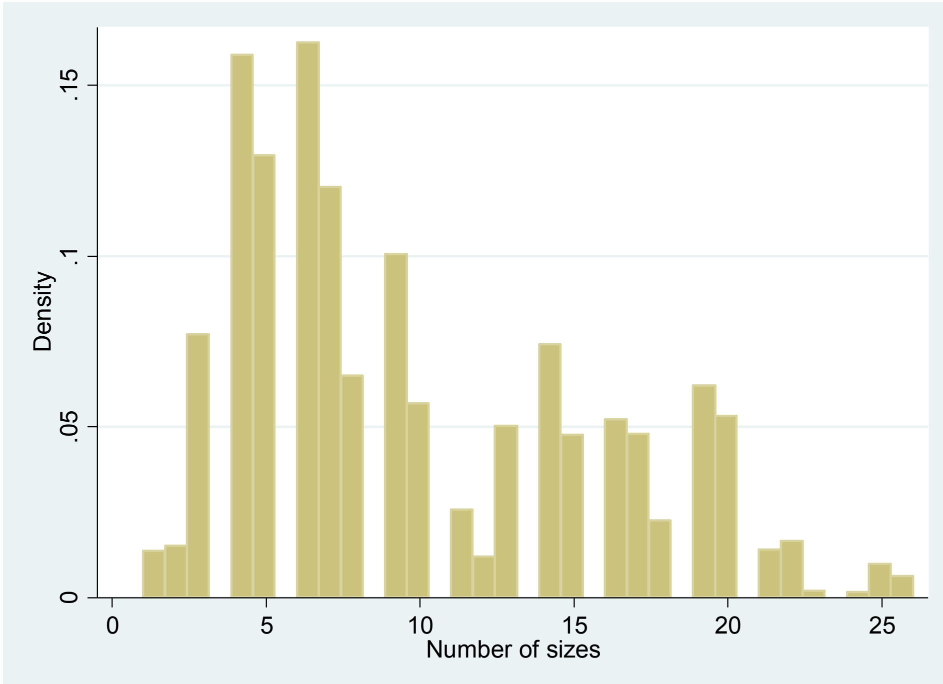


Figure 16 Histogram for the Number of Product Lines Offered

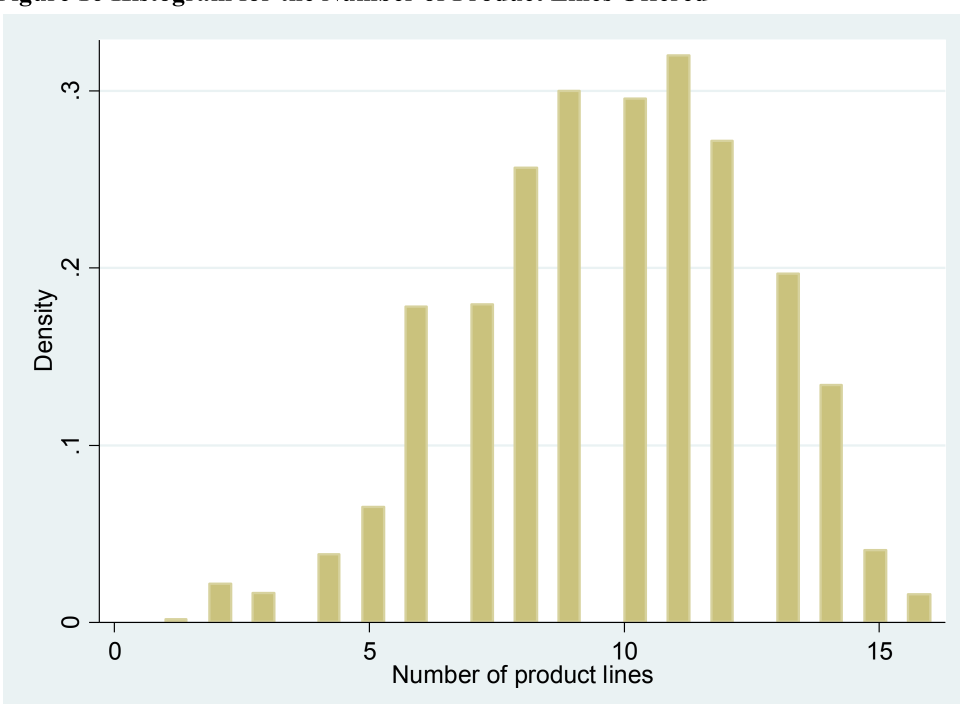
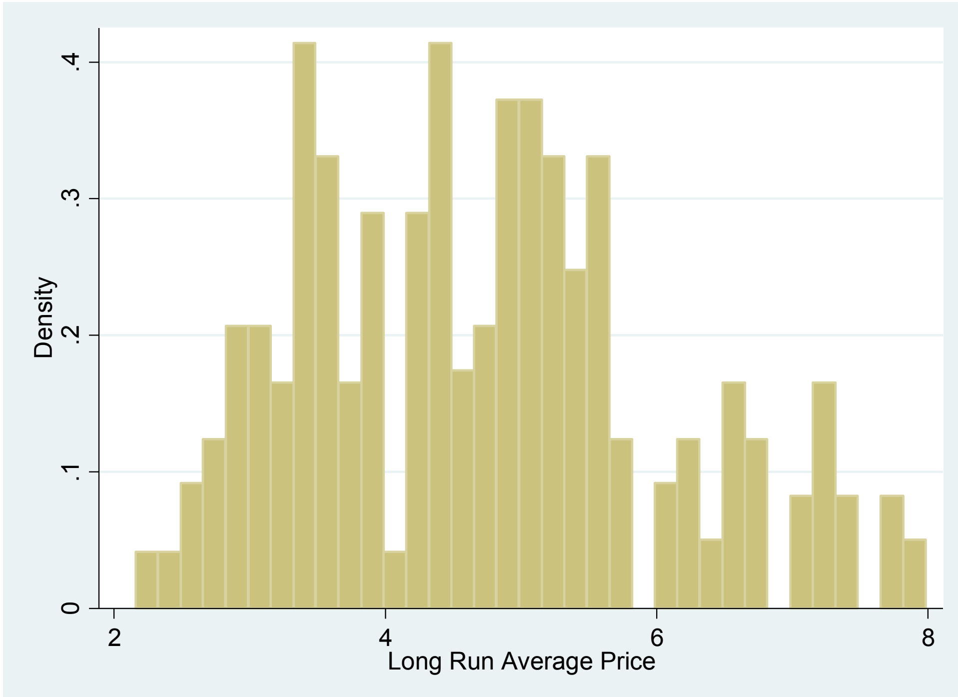


Figure 17 Histogram of Average Unit Price for the Duration of the Data Set



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