PRODUCT QUALITY IN THE DISTRIBUTION CHANNEL
FOR RETAIL FOOD PRODUCTS

A Dissertation in
Agricultural, Environmental and Regional Economics

by

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Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Doctor of Philosophy

August 2011
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ABSTRACT

This study investigates the relationship between the manufacturer and the retailer in the distribution channel. The primary focus is the use of product quality as a strategic tool for the manufacturer to improve his overall and relative performance inside the channel. The base model discusses one manufacturer and one retailer interacting in various conditions. First, we look at the variation of the manufacturer’s control of quality in the distribution channel under the single product scenario. In the static setting, the impacts of quality on the manufacturer and retailer’s pricing decisions and their relative performances depend on the quality cost function specifications. The linear cost schedule for quality produces the more profitable situation for the retailer. On the other hand, the manufacturer performs better in the convex cost specification, suggesting the increasing difficulty in modifying the product quality benefits the manufacturer. The simulations for the static models show that an increase in the quality cost hurts the manufacturer more than the retailer; whereas an increase in elasticity positively affects the manufacturer in larger magnitude than the retailer. The multi-period model for the single product quality addresses quality as an investment-like aspect. In our setup, the consumer demand is influenced by the stock of quality, which can be the reputation or the accumulated brand name generated by the quality flow in each period. The optimal quality decisions indicate the existence of the optimal quality stock level, where, using the quality flow, the manufacturer adjusts his quality stock gradually to the optimal long-run level regardless of whether the initial stock is above or below the optimal level. Despite the constant unit cost of quality, the solution for the optimal path recommends the gradual adjustment instead of the rapid approach.

Next, we consider a more competitive setting between the manufacturer and the retailer in the distribution channel through the use of the private label product. The retailer offers a similar
product to the national brand product. We derive a demand specification from the reservation price schedule and the consumer distribution. From the simulation results, we find that the national brand manufacturer generally tries to differentiate his product from the private label through the use of product quality. The increase in the national brand product quality benefits the retailer to a greater extent since the improved national brand product allows the retailer to increase the private label retail price without having to improve its characteristics as consumers switch from the national brand to the private label products. Our simulation results indicate that both the increase in the quality cost and the private label quality improvement produce similar outcomes for prices, product quality and market shares. Both the increase in quality cost and the improvement in the private label quality increase the quality differentiation, raise all retail prices and reduce the demand for the national brand product. Because of the high increase in the national brand price, the retailer can gain higher profit through the increase in the private label price and the expansion of its demand.

We extend our distribution channel model to address the situation where the national brand manufacturer supplies the private label product to the retailer. Again, the optimization specification influences the outcomes. We modify the demand to allow for non-purchase customers who may decide to start purchasing later. When the retailer chooses both the national brand and the private label retail prices, we find that the optimal supply and pricing decisions for each product depend entirely on the cost and quality parameters for each of the products. The parameters of the national brand production do not affect the decisions for the private label production. On the other hand, when the retailer imposes a fixed markup for the manufacturer’s retail pricing, we observe the connections between the parameters of the two products in all of the optimal outcomes. The decision of the national brand manufacturer to supply the private
label product depends on the production costs and the product quality levels of both products, as well as the relative quality between the national brand and the private label products.

Using the Dominick’s Finer Food scanner database, we investigate the theoretical results empirically. Because of the lack in the direct quality information, we use proxies and indicators instead of the actual product quality level. We identify the products with improvements and the national brand and private label pairings for the empirical tests for the single product model and the national brand and private label competition model, respectively. We use the price difference as the primary proxy for the quality difference and quality level, as well as considering the elasticity influences on the quality and other market outcomes for the case of product improvement. We find that the theoretical results from the single product model are generally supported by the empirical evidences. The products with higher price difference or higher elasticity are of higher quality and exhibit greater quality improvement. The high quality product is also more profitable to the retailer than the low quality product. We use similar quality proxy for the empirical tests of the national brand and private label model. Although the empirical results on the national brand and private label products are less consistent with the results in some regressions vary from one product category to another, the overall results are relatively similar to the theoretical findings. The product pair with a large quality difference produces a higher profit margin for the retailer than a pair with a close quality. The empirical results transfer from the overall pair group to the individual brand type, confirming the general results are consistent throughout the brands. However, some tests reveal the variations in results across product categories, suggesting the results may depend on the characteristics, such as the degree of competitions, the extent of main national brand market power, and the substitutability of the national brand and private label products, in various product categories. Due to the
sensitivity of the materials discussed in the topic of the national brand manufacturer supplying private label product to the retailer, we omit the empirical tests on the topic.
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### Glossary of Variables

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<thead>
<tr>
<th>Symbol</th>
<th>Variable Name</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>Retail Price</td>
<td>The product retail price</td>
</tr>
<tr>
<td>Q</td>
<td>Demand</td>
<td>The quantity of demand</td>
</tr>
<tr>
<td>w</td>
<td>Wholesale Price</td>
<td>The wholesale price as set by the manufacturer</td>
</tr>
<tr>
<td>C</td>
<td>Cost</td>
<td>The cost function</td>
</tr>
<tr>
<td>c</td>
<td>Manufacturing Cost</td>
<td>The manufacturing or the non-quality manufacturing cost</td>
</tr>
<tr>
<td>r</td>
<td>Retail Operating Cost</td>
<td>The cost of retail operation per unit of product</td>
</tr>
<tr>
<td>$\varepsilon_P$, $\eta$</td>
<td>Price Elasticity</td>
<td>The elasticity of price</td>
</tr>
<tr>
<td>$k$, $K$</td>
<td>Demand Coefficient</td>
<td>The constant parameter in front of a demand function</td>
</tr>
<tr>
<td>m</td>
<td>Retail Markup</td>
<td>The constant percentage charged on the wholesale price by the retailer which determines the final retail price</td>
</tr>
<tr>
<td>$\theta$</td>
<td>Product Quality</td>
<td>The product quality level</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>Quality Elasticity</td>
<td>The elasticity of quality</td>
</tr>
<tr>
<td>h, q</td>
<td>Quality Cost</td>
<td>The unit cost of quality</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>Quality Cost Parameter</td>
<td>The parameter in the increasing quality cost function</td>
</tr>
<tr>
<td>$\psi$</td>
<td>Quality Value Function</td>
<td>The consumer-perception-of-quality function</td>
</tr>
<tr>
<td>A</td>
<td>Quality Stock</td>
<td>The stock of quality or the accumulated quality level</td>
</tr>
<tr>
<td>a</td>
<td>Current Quality</td>
<td>The current period product quality level contributing to the quality stock</td>
</tr>
<tr>
<td>$\rho$</td>
<td>Deterioration Rate</td>
<td>The deterioration rate of the quality stock (A)</td>
</tr>
<tr>
<td>$g$</td>
<td>Quality Contribution Function</td>
<td>The function determining the contribution of the current quality level to the stock of quality</td>
</tr>
<tr>
<td>R</td>
<td>Reservation Price</td>
<td>The reservation price schedule</td>
</tr>
<tr>
<td>$\delta$</td>
<td>Consumer Characteristic</td>
<td>The consumer characteristics, such as income or education</td>
</tr>
<tr>
<td>$R_0$</td>
<td>Intercept of Reservation Price</td>
<td>The minimum willingness to pay of the person with minimum consumer characteristic level</td>
</tr>
<tr>
<td>a</td>
<td>National Brand Quality</td>
<td>The quality level of the national brand product as appeared in the reservation price schedule</td>
</tr>
<tr>
<td>b</td>
<td>Private Label Quality</td>
<td>The quality level of the private label product as appeared in the reservation price schedule</td>
</tr>
<tr>
<td>NITEM</td>
<td>NITEM Codes</td>
<td>A coding system used in Dominick’s data set to determine whether different UPC products are in fact same product of different versions</td>
</tr>
</tbody>
</table>
Acknowledgement

I would like to express my gratitude to the Thai government and the Department of Agricultural Economics and Rural Sociology at Pennsylvania State University for providing funding throughout my doctoral education. I also would like to acknowledge the generosity of James M. Kilts Center, University of Chicago Booth School of Business in granting free access to the data sets used in the study. I am grateful to the comments and suggestions provided by Professor Ted Jaenicke, Professor Alessandro Bonanno and Professor Susan Xu, which help improve the contents of the dissertation as well as shaping its future directions. Lastly, I am in debt to Professor Stefanou, my dear advisor and mentor, for all he has done throughout my years at Penn State. I am and will always be truly grateful.
Chapter 1: Introduction and Literature Review

The role of a producer in the traditional economic models is usually an all-in-one role, meaning that the production firm does everything from acquiring the inputs down to sending the finished product to the market. Hence, the decision making process constituting the supply side economics is naturally in the control of a single firm. Because they are under a common objective, the decision making steps can be merged or combined. Understandably, we do not need to consider the individual decision steps within a firm. However, the economic model specifications we traditionally use have become increasingly questionable under the recent business environment. The tasks on the supply side are broken down into several steps and carried out by independently-own firms. Similarly, the task of distributing the product requires more thorough consideration. The distributor and the retailer become more aggressive in participating in the pricing and other strategies. The supply side of the market is no longer dominated by a do-it-all manufacturing firm. Consequently, the modeling of the supply side entails a different set up, providing more insights into the complexity of multiple steps.

Now that the supply side is not under the management of single firm, the traditional model with the one producer firm becomes inadequate in explaining the nature of the supply side economy. We must acknowledge the existence and the decision making steps of firms that constitute the production section to accurately explain the economics of the supply side. The separation of tasks within the supply side of economy is recognized as a supply chain or a distribution channel problem. The distribution channel framework focuses on the movement of goods and services along various production (manufacturing) and distribution firms onto the market place. From the economic viewpoint, we are interested in individual firms, who make up the chain of production, and the channel outcomes generated from those firms’ interactions. The
traditional production model is broken down into several steps, with an individual firm taking responsibility for completing the job in each step. The distribution channel framework recognizes the production linkages generated within the production section, as well as the distinct objectives from several firms that make up the supply side. A simple distribution channel is described using Figure 1.1.

Figure 1.1: A Map of the Distribution Channel

Instead of focusing on every aspect of the supply chain linkages, we concentrate on the most crucial ones, namely the linkages from the manufacturer to the retailer to the consumers. We assume implicitly that the procurement of raw materials is done through a competitive market or through a collection of suppliers that does not have market power. We also simplify the manufacturing process and assume that it is done by a single firm. Consequently, the
activities in the supply side are dictated by two players: the manufacturer who produces the product and the retailer who sells the product to consumers.

Figure 1.2: The Simplified Distribution Channel

In addition to the connection between the manufacturer and the retailer, we also consider the connection between the retailer and the consumers. The overall channel outcomes (such as prices, quantity and profits) do not only depend on the relationship of and the decisions generated in the manufacturer-retailer framework, but also in the relationships that the retailer and manufacturer have with the consumer market. By considering the link between the retailer and the consumers, we obtain a more complete picture of economic transactions than by concentrating on the manufacturer-retailer relationship alone.

The distribution channel we want to emphasize in this study corresponds generally to products sold in the supermarkets. The supermarket and its supply chain provide an interesting case to investigate the relationship between the manufacturer and the retailer. First, the supermarket generally sells branded products, in which case the one-manufacturer setup is acceptable. Second, the manufacturer interacts closely with the supermarket retailer and the two firms constantly make contact. The pass-through in pricing decisions is also prevalent in supermarket retailing. In addition, the ownership of manufacturer and retailer in the supermarket setting is usually separated. Lastly, there are several strategic interactions between the
manufacturer and the supermarket, which presents a context to further study the interactions and the influences of one firm’s decisions on another’s decisions.

1.1 Specific Issues and Motivations

The independence and interdependence of the firms constituting the supply side economy contribute to the complexity of the traditional production problem. The decisions of firms within a distribution channel are linked inevitably and the optimal outcomes of one firm can be influenced by the decisions of others. Firms need to acknowledge the connection and understand the relationships that arise among firms and their choices. Understanding the underlying interactions and the mechanisms inside the distribution channel model can clarify the transmission of a change from one firm to another. Knowing how one firm’s decision impacts the decisions of others, the firm decision maker can use this knowledge to his advantage by influencing and manipulating the outcomes in such a way that increases firm’s profit (or revenue, depending on his objective) or strengthen his performance.

Although we usually think of a firm’s decision as determining price or quantity of the product, price and quantity are no longer the only choice variables firms encounter in the market. More often than not, firms are capable of controlling the other strategic variables related to the production and/or the demand. Having more strategic tools usually implies that the firm has more flexibility in influencing or manipulating the other firms’ decisions and the distribution channel outcomes. The additional choice variables can be the variables for either the demand side and/or the variable for the supply sides. The variables for the demand side primarily impact or influence the consumer demand by changing consumer’s perception, altering tastes and
preferences and modifying the demand specification. The variables associated with the supply side are those influencing the production function or its associated cost. In our study, we focus on product quality, which has the potential to influence both the demand and the supply sides of the market. Product quality changes the consumer demand through its real physical change in the product. Also, product quality relates directly to the cost of production; hence, it impacts the production side. We may consider product quality as a supply-side oriented strategic variable that influences the consumer demand.

Product quality is an interesting choice for the study in the distribution channel because it induces demand as well as changes the cost for all firms interacting within the distribution channel. Hence it opens up many possibilities for the study of interactions of firms (and consumers) in the channel. Product quality improves the demand and is beneficial for both the manufacturer and the retailer; although the cost is paid directly by the manufacturer during the production process. Quality changes the characteristic of the product and normally requires a change in the production process. Since the quality improvement is most often done during the manufacturing process, the product quality is primarily considered the manufacturer’s choice rather than the retailer’s. Nonetheless, the retailer may persuade the manufacturer to change the quality of the product through various strategic incentives. Product quality represents an example of choice variables that are traditionally restricted to one firm within the channel. Even if the benefit of the choice variable is felt throughout the channel, only one firm can choose its level.

There are several specifications we can identify and model product quality in the production. We begin by introducing the static model of the distribution channel where the manufacturer chooses the level of product quality. The product quality impacts the costs and demand for the current period. However, using a static model to explain the firm’s decisions on
quality choice has limitations. Most importantly, a single period decision does not support the situation where the choices have impacts lasting into future periods. The static model ignores the fact that firms may be selling the same branded product to the same set of customers for an extended period of time. In the real world, product quality tends to impact consumers’ perception of a product for several periods. If the quality information stays with consumers for multiple periods, a static model is incapable of conveying this property into the firm’s decision making process. We investigate this issue using the multi-period model. We build a model that considers quality as a path-dependent variable.

In addition to the single product market setup, we will consider the two-product setup. Most commonly, products do not exist individually and independently, but there are several related or substitutable products offered within the same market. When making purchasing decisions, consumers usually consider comparable and competing products and choose the product that most fits their interest. This is true for the case of product quality as well. Hence, firms make pricing decision taking into account the characteristics of the products and their positions in comparison to competitors. We consider the distribution channel with the manufacturing firm choosing the product quality when an alternative, competing product is present in the market. The manufacturer’s ability to choose quality allows the manufacturer to position the product on the platform of consumer’s preference. We are interested in the quality positioning decision as well as the impacts of the determining factors (such as manufacturing cost and quality cost) on the manufacturer’s quality decision.

To emphasize the scenario of the distribution channel, we focus on the private label product as competition for the national brand product. In the distribution channel model, the retailer is generally considered a distributor of the product, and seldom has a chance to control
the production or to alter the product. However, in the recent market movement, the retailers enter into brand competition with the national manufacturers by offering store brand products, which are also known as the private label products. The practice of retailers offering a competing product with similar characteristics as the manufacturing brands has become increasingly common, especially in the supermarket retail business. The store brand or private label products are increasingly prominent and gain competitive market shares from the national brand.

Moreover, the retailer’s use of private label as strategic variables provides an interesting case for the understanding of the firms’ interaction inside the channel. The private label products are usually direct competitors of the branded products produced by the manufacturers. The private label product, then, weakens the influence of the branded product on consumers, hence reducing the profit generated by the brand. The interactions of the manufacturer and the retailer in the distribution channel with a presence of the private label can be quite complex because of the trade-off between the loss in the main brand and the gain in the private label and the change in the consumer demand due to the competition between the two products. With product quality being one of the main characteristics shaping the relationship between the national brand product and the private label product, private label is an ideal addition to the single product study.

1.2 Objectives

The connections of optimal decisions and equilibrium outcomes provide insight into how the firms are connected. With such information, a firm should be able to manipulate the channel outcomes through the use of choice variables, improving its performance in the channel. We
intend to look at these connections through the prism of quality choice. We focus on how the product quality links the manufacturer to the retailer and how the manufacturer’s choice of quality manifests in other choices and the channel outcomes, as well as firms’ relative performance.

In this study, we aim to

1. Propose various models of the distribution channel with one manufacturer and one retailer that allow a flexible integration of the choice of product quality.
2. Analyze the relationships between the manufacturer and the retailer that generate from the use of quality. A strong emphasis is given to the “market power” variables, which identify the relative performance of the manufacturer and the retailer.
3. Extend the quality choice in distribution channel model to incorporate the competition between the national brand manufacturer and the retailer providing private label product and provide the analysis of relative performance and market outcomes under this setting.
4. Test various theoretical and simulation findings using econometric models that apply to a scanner data, as well as expand the empirical search to related topics extended from the existing models.
5. Investigate the empirical results and the appropriateness of empirical models in response to the corresponding theoretical models. Identify the theoretical model(s) that are suitable for and match with the empirical data.
The Progression of the Paper

Building on the framework of a distribution channel, we first develop a theoretical model focusing on the relationship between the manufacturer and the retailer. Following the traditional decision choice, we begin by focusing on the pricing decisions for the manufacturer and the retailer and study how a choice of one firm relates to the choice of another. Then, we look at the distribution channel model when the product quality choice is included. We investigate the quality choice models in both static and dynamic settings. The competition between the manufacturer and the retailer due to the presence of the private label product in the market is also investigated. We consider the situation where the private label product is manufactured by the outside manufacturer and the situation where the national brand manufacturer supplies the private label products for the retailer. Lastly, we present an empirical study that confronts the evidence of our theoretical findings using a supermarket dataset.

The study proceeds as the follows. In Chapter 2, we develop a base model that displays the connections and links across the manufacturer, the retailer and consumers, as well as describes the inter-dependence of firms in the channel. The model developed in this chapter is used as the basis for the further modifications in later chapters. We introduce the quality choice into the model in Chapter 3, starting with models of a single product. The several quality specifications are applied to the models, leading to different optimal solutions. The models are divided into the single period model and the multi-period model, with more emphasize on the former. In Chapter 4, we extend the quality choice model into a two-product setting. We motivate our theoretical models in this chapter using the story of national brand and private label products. The model setup and assumptions are built around the nature of competition between the national brand and the private label. For the theoretical model, we concentrate on the
manufacturer’s optimal quality choice; although the problem can be expanded to include the optimal choice of private label quality. Building on the setup from Chapter 4, Chapter 5 considers a related problem with the national brand manufacturer producing the private label product for the retailer. We address how the additional role of the national brand manufacturer may affect the decisions regarding the production of the national brand products and how the overall outcomes change following the alterations from the original setup in earlier chapter.

Throughout Chapters 2 through 5, we focus our analysis on the optimal relations among parameters and choice variables. We provide analysis of the optimal conditions and illustrate the optimal choices, as well as the related market outcomes. We pay particular interest to the market power related variables such as profit margin, profit ratio and price ratio. The simulations are employed to illustrate the optimal outcomes where the explicit solutions are difficult to address analytically. Further discussions on the theoretical findings are motivated by the simulation results.

Chapters 6 and 7 address ideas and discussion of empirical studies focusing on the findings from Chapter 3 and 4. We use the empirical chapter to illustrate various findings from the earlier theoretical chapters. The empirical studies are aimed at supporting and testing the results from simulations by using scanner data from Dominick’s Finest Food available through University of Chicago Booth School of Business. Each chapter begins with the description of the related data sets and the overview analysis of their summary statistics. Then, the theoretical results summary is presented. The theoretical results provide suggestions regarding the directions and topics for empirical tests, which are the major components of Chapters 6 and 7. The empirical results are discussed for similarity, consistency and contradictory evidence vis-à-vis the theoretical results. The study concludes with Chapter 8, where we discuss the overall findings.
of the dissertation, the shortfalls, the possible improvements and the future directions we intend to undertake after this study.

1.3 Literature Review

Historically, studies looking at firms operating along a production chain or a distribution channel have been done through several disciplines, resulting in distinct differences in styles and directions of research. Various disciplines are interested in the connection and relationship of firms along the channel; however, they have different concerns and different research questions on which they focus. We discuss the overall questions concerning the research in this area with the emphasis on the topics related to the product quality. In addition, due to the framework of distribution channel, we are particular interested in the literature on pricing and other strategic choices, as well as the discussions on the market power within the distribution channel.

1.3.1 The Role of Product Quality in Distribution Channel

The quality of the product and services can be contributed by one or many (if not all) firms within the distribution channel and impact all firms in the channel. Product quality influences the final demand, which in turn is also the demand for intermediate firms. The intermediate firms (or retailer, for our study) are interested in the product quality because it improves demand and increases consumer’s willingness to pay. Since the product quality is a demand-inducing variable, we assume that the control of product quality leads to a higher power or a better performance of the firm. Betancourt and Gautschi (1998) confirm this assumption. They find the firm (either the manufacturer or the retailer) that controls the level of services has an improvement in channel performance, in this case, an increase marginal profit. However,
Sutton (1986) warns that the benefit of quality, specifically in the case of pure vertical differentiation, depends on the consumer preference and reaction toward quality change, as well as the cost of quality.

If many firms along the channel can contribute to the level of product or service quality, firms must focus on the efficiency and effectiveness in the contribution of individual firms and discuss the optimal methods that individual firms may approach to obtain the optimal quality level. Quite commonly, the better managed and better coordinated supply chain is more likely to achieve a better quality when the quality can be contributed from several links in the chain. The retailer, although not producing the product, may be reliable to contributing services associated to the sale of the product. As a result, the overall “quality” of the product (which includes consumers’ perception of brand) depends on the retailer’s effectiveness in adding satisfactory services to consumers. Huang et al (2008) suggest that the dependency between the value of quality (mostly evaluated as brand equity) and the performance of retailer is more apparent in the market where retailers are not accountable or not associated with the manufacturer, such as in the grey market (market with unauthorized or unaffiliated retailers). In such a case, the manufacturer relies on the retailer to add value to the product, effectively causing the retailer to become a part of production process. The contribution of the retailer services becomes more complicated in the case where the manufacturer sells to multiple, differentiated retailers. Iyer (1998) considers the market where the manufacturer can induce different behaviors from differentiated retailers through the use of menu-based contracts. This author suggests that without substantial differentiation in consumers’ location (from a location model) the manufacturer is better off inducing retail differentiation. The preference in the price-service combination from the manufacturer’s point of view also depends on the relative price level of the
product. For products of high price, the manufacturer prefers the retailer to focus on the price competition rather than the service competition. The reverse is true for the product at a low price level.

The issue of information becomes crucial when we consider the optimal choice for the product quality. Since quality is usually incorporated into the product during the production process, the downstream firms do not necessarily know the exact quality of the products produced by the upstream firm. Communication regarding the quality of the product may occur across the channel but the downstream firms may not believe in the information passed through; or, they may not trust the upstream firm to provide an accurate description of the product quality. This is most common for the case where the quality of products is difficult to observe by the downstream firms or the product is new so the quality is still unknown to the downstream firms and the consumers. In such a situation, the market faces an imperfect information problem; hence, the prices and the product quality are not optimized. The lack of apparent information or an appropriate measurement on the level of the product quality creates uncertainty within the distribution channel. Chen and Seshadri (2006) show that the degree of the retailer’s risk preference is crucial in determining the optimal pricing decision of the manufacturer. By trying to account for the imperfect information and the characteristics of the firms, firms will be able to make better decisions regarding pricing and quantity outcomes. In response to the issue of uncertainty, firms within the channel have to come up with methods to reduce risks associated with the lack of information. One possibility is to initiate some kind of insurance programs allowing firms to share the uncertainty. Another frequently used option is to ask the upstream firms to make payments to account for the unknown quality information and is known as a Stocking-Fee.
Because the information of product quality is not known to all firms in this case, both the upstream and the downstream firms may choose to do something to correct the imperfect information problem. This occurs most commonly during the new product introduction. Not having sold the product, the retailer does not know the exact response of demand; also, the retailer may believe that the manufacturer withholds some vital information regarding the new product. The upstream firms could transmit the quality information to the downstream firms to reduce the uncertainty regarding quality of the product. Alternatively, the downstream firms may require actions from the upstream firms that will imply their knowledge on the quality of the product. Chu (1992) considers several techniques used by firms in the distribution channel and concludes that the retailer prefers an application of the slotting fee for the new product whereas the manufacturer prefers to use advance advertising and to set a high wholesale price. The author analyzes the welfare implications and suggests that a slotting fee is a better strategy for overall channel profit; however, it can pose as an entry barrier for firms with small capital reserves.

There are several cases of signaling related to the insurance measures. Kirmani and Rao (2000) investigate the signaling behavior of manufacturing firm as a measure to reduce adverse selection problem where the quality of product does not change over time but the manufacturer may claim the quality he does not produce. The signals are price setting, advertising, brand name and branding, a slotting fee, and warranties. The first three methods act primarily as an indication or a proxy of product quality; whereas, the last two methods can be considered as insurance measures.

Consumers also face similar problem as the retailer when it comes to evaluating the product quality. For a not-yet-purchased product, consumers do not know for certain the quality of the product and need to use a proxy to approximate the level of quality before making the
purchase. Rao and Monroe (1989) indicate that both price and brand are positively correlated to the perceived quality level. Consumers regard product with a high price as a product of a high quality level. In this case, the price becomes a proxy for the quality of the product. Milgrom and Robert (1989) find a similar result for price and uninformative advertising in the multi-period setting. Advertising and brand name are also closely related to quality in term of consumers’ perception toward the quality. Good quality will reinforce the strong brand, improve brand image and increase brand equity. On the other hand, a positive brand presence encourages consumers to purchase or to try the product.

1.3.2 Product Quality in Multi-Period Setting

When the time frame of the problem changes to the multiple-period setting, the product quality takes a different role and impacts demand differently. For a problem to fit a multi-period setup, some element is linking the optimization problems across periods. With quality embedded in consumer demand, it is natural to have quality taking the role of this linkage. The impact of quality may persist on demand for several periods, most likely with decreasing effects as time goes by. The product quality can be considered an investment from the manufacturer’s (and possibly retailer’s) perspective. The stock and flow concept of the product quality comes into play. Previous investment on quality may persist for some periods of production, constituting the stock of quality; whereas, the level of quality (or resource used in creating product quality) inserting into the production in each period is the flow. Taking stock and flow into consideration, product quality becomes an investment, which requires careful planning into the future.

We have discussed the issue of price acting as a signaling tool for the product quality. This role of product quality is even more prominent in the multi-period setting. Considering a
horizontal market, Milgrom and Roberts (1986) formalize the signaling model where the price and uninformative advertising are used to signal the product quality in a repeated purchase setting. In the world of imperfect information, consumers infer the quality of the product from the price the firm sets and the amount of uninformative advertising seen by consumers. Milgrom and Roberts find that firms with a higher quality product would rather set an initial price low to attract more consumers in anticipation of repeated purchases rather than setting it high to signal high quality of the product. The combination of uninformative ads and pricing strategy depends strongly on the cost structures of both the advertising and the manufacturing process. On the other hand, Bagwell and Riordan (1991) suggest that the firm with a high quality product will initially set the price above the optimal profit pricing level to signal consumers of its high quality and gradually lower the price to the optimal level as the time goes on and consumers learn about the true quality of the product. The difference between the two opposing strategies lies in the nature of competition in the industry. If there are competing firms that also produce a similar product of the same quality, the high quality firm should use a lower-than-optimal price to encourage more consumers before gradually increasing the price up to the optimal level. However, if the firm is in a single firm market, the higher-than-optimal price will serve as signal to consumers of the product’s high quality.

Consumer’s perception is a crucial element in firms’ quality investment decisions. Since the quality is intended to impact consumer demand, the consumer’s realization of product quality is generally what the manufacturer aims for when deciding on the appropriate quality level. It is important from the firms’ perspective that the resources they put in are recognized by consumers and stimulate demand. Consequently, consumer’s perception and understanding of quality will influence the manufacturer’s optimal decision and timing for quality. Shapiro (1982) investigates
the situation where consumers cannot evaluate the exact quality level of the product before purchase. The purchase decision is made based on the consumers’ expectation of quality. The firm’s optimal quality decisions are lower than the level when consumers know the exact quality before purchase – for both the one-and-for-all quality decision and the quality over time decision. It is better for the firm to set a lower quality when information is imperfect.

Instead of having quality act directly upon consumer demand, the manufacturer may use quality through the influence of the brand name or brand equity. Product brand has direct impact on consumer demand, in both quantity and willingness to pay. Branding generates the concept of brand loyalty, which is an inter-temporal consumer preference for that specific product. Fruchter et al (2006) consider the impact of country-image on the manufacturer’s decision to locate a production of a branded product. The country-image is a proxy of the quality of product that particular country can produce, as perceived by consumers. The authors find that the production decision, which is set in the multi-period, dynamic framework, depends on the relative position to the stationary level. Their results also suggest that the manufacturer should use prices as signaling of the quality of the product.

1.3.3 Quality Choice in Product Competition

A significant portion of the marketing and consumer behavior literature is devoted to the situations involving two or more products competing in the same market. Our study investigates the case of two competing products and the optimal quality choice resulting from the competition. We are particularly interested in the story of the private label product, which is controlled by the retailing firms. For the purpose of our study, we focus the literature review on the subject of two-product competition, especially national brand and private label competition.
Since the private label is a product designed to reduce the influence of the national brand product and its manufacturer, we consider the literature on the methods that the national brand manufacturer may use to reduce the impact of the competition from or counteract the strength of the private label product. We investigate the role of the product quality in the competition in the two-product setting.

Because the competition is generally believed to lead to a reduction of power of individual firms, the retailer often uses private label product as a primary means to reduce the manufacturer’s power in the distribution channel. The private label weakens the market power of the existing brand and at the same time offers an additional source of income to the retailer. There are several reasons why the retailer should supply private label in the store. The literature in the area shows how the private label product affects the national brand standing and its profit share in the market. Several studies also discuss how the retailer can use private label and its pricing schedule to (partially) control a part of the market. The private label product is considered a tool for the retailer to compete with the manufacturer in the distribution channel. Most literature in the area focus on the two aspects, which are closely intertwine; namely, the brand positioning and the pricing strategy. The brand positioning usually corresponds to the pricing strategy and vice-versa. Literature also shows that the retailer and the manufacturer decisions in these matters are connected closely and we can think of them as strategic responses between the two linkages in the distribution channel.

The retailer always looks for a way to improve his retail gross margin of the national brand, measured by the difference between product’s wholesale price and its retail price, which is achieved through an increase in control of the channel or an increase in retailer’s bargaining power. The presence of the private label product is a direct threat to the manufacturer’s ability to
control the channel profit. The retailer gets a higher retail gross margin from selling the private label product than from selling the national brand (Steiner, 1993), suggesting the retailer may act strategically in favor of the private label product. The private label product competes directly with the national brand, causing the latter to lose its market share and market power, which weakens the position of the manufacturer in the distribution channel. Bontemps et al. (2005) demonstrates that movement of the private label product significantly impacts the national brand price and strategy. The national brand reacts to the change in the market share and characteristics compositions of the store brand product, indicating, again, the importance of consumer reactions and the degree of product substitutability. Steiner (2004) reports that the entry of the private label product drives down the price of the national brand as well as its retail gross margin. Private label, as an alternative product, also provides leverage to the retailer when he negotiates for the wholesale price of national brand. Scott Morton and Zettelmeyer (2000) find that the presence of private label improves the retailer’s bargaining power when discussing the terms of the national brand with its manufacturer. In Putsis (1997), the manufacturer, who only produces the national brand product, will use price strategy to control or to reduce the private label penetration into the market. In such a case, the pricing strategy depends on the brand dispersion, making pricing strategy related to substitutability between the national brand and store brand. As a result, national brand pricing is limited in the presence of private label in comparison to the situation with no private label. Private label also increases the goodwill and loyalty of consumers on retail stores; hence, weakening the national brand loyalty as suggested in Bonfrer and Chintagunta (2004). In this case, private label helps strengthen the retailer’s market power by changing the preference of consumers for the national brand products.
The price competition between national brand and private label intensifies when the national brand and private label products are close substitutes. Bontems et al (1999) shows that the optimal pricing strategy of the national brand product corresponds more closely to the private label quality. However, a non-linear quality dependent cost schedule may lead to the optimal wholesale price not decreasing when the private label quality approaches the quality of national brand. Shaked and Sutton (1982) suggest that products that are positioned close to one another, as in the case of national brand and private label products, are prone to fierce price competition. Since the product differentiation is found to help weaken the price competition (hence, improving the profit of manufacturer), the presence of private label product directly targeting and positioning close to the national brand product creates a strong price competition, which lessens the impact of the national brand product in the market. However, Bonanno and Lopez (2005) find that the competition between the national brand and the private label products in the milk product does not lead to a price cut of BOTH products. Rather, the national brand milk price increases as the private label price decreases and the private label product share expands. The strategic pricing of the retailer is possibly responsible to such a bizarre pricing behavior. Since the retailer decides on the final pricing of products sold in his store, it is a threat that the retailer may price in a way that harms the sale of national brand and benefits the sale of private label. It is possible (although generally not very likely) that the retailer may opt out of providing national brands altogether and sell only private label products. In practice, it is more likely that the retailer opts out of lesser national brands but still remains the seller of leading national brand (Berlinski, 1997). There is overwhelming evidence that the private label is harmful to the national brand. Consequently, there is a strong argument against the national brand manufacturer supplying the retailer with private label products.
Although the private label product is primarily designed to target and compete with the national brand counterpart, it is not necessarily that the quality of private label product approaches the quality of the national brand. Several times, the private label product has the quality level that is distinctively lower than the national brand quality. The low quality private label is generally intended for the lower segment of consumers’ distribution and possibly covers the consumers that would otherwise not purchase any products. However, Gabrielsen and Sorgard (2007) discover that the existence of lower quality private label may lead to a reduction in welfare due to consumers’ substitution from the higher quality national brand product to the lower quality national brand product.

Although it is more customary to assume that the private label supply comes from the outside manufacturer, it is possible that the national brand manufacturer is asked to supply the private label product for the retailer. Although a prevalent portion of literature presents a concrete case why the national brand manufacturer should not supply the retailer with private label, there are some studies attempting to describe when the manufacturer does produce private label products. Several studies and reports (Sutton, 1991, Hoch et al., 2002, and Steiner, 2004, among others) show that the share of private label is increasing in many sectors, which reduces the profit of national brand manufacturer. If the growth in private label sale is unavoidable, the manufacturer should get into this business and use private label production to offset the loss in national brand sales. The situation is even more so in the case of medium size, non-leading national brand manufacturers, who find themselves going out of business because their national brand products being driven off of shelf to make room for private label products. Galizzi et al. (1997) study the Italian food industry and suggest that the national brand manufacturer’s decision to supply private label to the retailer changes according to the stage of private label
growth within the industry. The more advance the development of private label in the industry leads to a more likely decision of national brand manufacturers to supply private label. Alternatively, some national brand manufacturers find their plant idle and want to produce private label products to limit their excess capacity. In addition, being a supplier for the private label may give the national brand manufacturer some bargaining power in the competition between national brand and private label products. Wu and Wang (2005) propose that private label can be used as a strategic tool for duopoly manufacturers with competing national brands to lessen the degree of competition. The authors claim that private label is a credible commitment showing that one national brand manufacturer will not promote his product, an action that can lead to a promotion war between the two manufacturers. Nevertheless, we model the manufacturer’s decision choices allowing for the case when there is no duopolistic competition going on between manufacturers. Our study aims for a more flexible explanation to justify manufacturer’s supply of store brand.

In addition to the product competition and the quality involvement in the competition, we are interested in designing and setting up the demand specification suitable for this scenario. Identifying the nature and specification of demand is an important part of our study, particularly in the two-product competition model. With the two products setup, it is crucial how we deal with the demand specification, which displays the competition between the two products. The choice of demand specification has been a concern, and likely a source of divergence in results, in the distribution channel studies. Choi (1991) finds that the results for optimizing prices and profits depend “critically” on the choice of the demand specifications, as a change in demand specification leads to a drastic change in findings and conclusions. Demand in the distribution channel models can be aggregated into a single equation with some parameters indicating degree
of consumer responsiveness or it can be disaggregated to include the heterogeneity of consumers. A more disaggregated version of demand is often used in the situation where several products or several sellers are concerned since it provides a detailed description of market allocation. A breakdown of demand into groups with different parameters is suitable for the situation where different prices are set for different groups (Gerstner et al., 1994). Another concern for appropriate demand relates to demand uncertainty issues where a vast literature exists, especially in the supply chain studies. Uncertainty in demand and asymmetric information call for strategies that help the manufacturer and the retailer communicate more effectively (Chu, 1992).

The product competition opens up the consideration of multi-firm setting for the distribution channel. So far, our study has ignored the possibility that there is more than one firm in each level of the channel. Several researchers investigate the situation where multiple firms constitute the distribution channel. There are distinction among the cases of multiple manufacturers with single retailer (Choi, 1991), multiple retailers with a single manufacturer (Chen et al., 2001) and multiple of both manufacturers and retailers (Richard and Patterson, 2005). Multiple firms offer a model setup more applicable to a game theoretic scenario. When there is more than one firm, the interactions among firms are important. The decision of a single firm should incorporate the information and anticipation regarding choices of other firms. The setting becomes complicated for games with multiple players in each link of the distribution chain. This is because the game happens in two directions: within each link and between links. Multiple firms within individual link also introduce a scenario for multiple pricing for directly competing products. Richard and Patterson (2005) argue that the complexity of coordination efforts required for retailers to collude on prices is too great; but various reasons such as menu
costs, search costs and consumers’ preference of stable prices lead to tacit, non-cooperation collusion in prices BOTH in the retailer level and the manufacturer level.

1.3.4 Power and Decision in the Distribution Channel

The studies of distribution channel often involve questions about power, profit distribution, pricing theory and market manipulation. Many studies, especially in the earlier history of studies of distribution channel, investigate the issue of “power” in the distribution channel. Discussion of power in the distribution channel may refer to several aspects within the framework of the channel. Researchers can focus on the profit share as a measurement of the power of firms, as well as the allocation of profit that goes into each firm along the channel. Hunt and Nevin (1974) focuses on the ability of firm to influence or change the behavior and decisions of other firms along the distribution channel, which is the concept we will apply for our study. Although the minor details may differ, most literature agrees upon the main point in definition of power. Power is defined as an ability of one firm to influence another firm to do what he otherwise would not (for a thorough survey of the definition, see Gaski, 1984). Although many papers discuss and analyze multiple scenarios of power in the channel, not many papers present an empirical measurement of this topic. Because of various definitions of power are available, it is difficult to settle for a single measure of power and the integrated measure may provoke concerns regarding which measure should be precedent. Early studies such as El-Ansary and Stern (1972) and Hunt and Nevin (1974) provide the first attempts at measuring “power” using some integrated index. However, their attempt relies on qualitative measures rather than quantitative measures such as profits or prices (Frazier, 1983). Gaski (1984) acknowledges the shortcoming of empirical studies in the past as too specific, unreliable and rely heavily on survey data. However, studies following, mostly in the business literature, still largely rely on
qualitative measures to reach analytical results. In the economics literature, the concept of power is measured in a more qualitative aspect. Price-cost margin, which measures the closeness between the marginal cost of product and its price, is used in determining the pricing power and the control in the distribution channel. Villas-Boas (2007) applies the price cost margin to the Yogurt industry and discovers that the retailer has a higher price cost margin, implying that the retailer has a better control in prices within the channel. The paper presents an alternative empirical method to measure the price cost margin when the wholesale price data is unavailable and the individual firm marginal costs are difficult to measure. Although the price-cost margin offers a definite, quantitative measure for the power in the distribution, it is restrictive when compared to qualitative measurements.

In our study, we are more interested in power in distribution from the stand point that one firm may influence the optimal decision of another firm, resulting in outcomes that differ from the case when each firm stand alone with no linkages. In general, studies of distribution channel focus on strategic choices of firms which influence the outcomes of the channel. Depending on a setup and a focus of study, firms may choose various factors that impact the decision of consumers or other firms in the channel. The most basic choice for firms on the supply side is the product price. In the distribution channel setup, the manufacturer chooses a wholesale price and the retailer chooses a retail price; whereas, only the retail price directly affects consumer final demand. Although the manufacturer does not choose the retail price directly, it is shown in most research that the wholesale price influences the retail price. Hence, the manufacturer may influence the demand indirectly through the manipulation of prices (Gerstner and Hess, 1991). As an alternative to the nominal price levels, some studies concentrate on the retail markup, defined as a charge applied in percentage from the wholesale price, which the retailer uses for
specifying the final retail price instead of choosing the nominal retail price directly. Gerstner et al. (1994) look at the impact of retail markup on the manufacturer’s price discrimination decision. They find a negative relationship between the level of markup and the use of coupons for price discrimination. Aguirregabiria (1999) considers the markups levels’ relationship with the optimal inventory and sale promotion decisions. In fact, the study considers both the nominal price changes and the markup decisions although the markup appears to take the center stage as it is fitting to the sale promotions analysis.

Other strategic variables can be used by the manufacturer and/or the retailer to influence the outcomes in the distribution channel. The most notable factors are brand-name, advertising, services and quality. A presence of additional choice variables provides flexibility for firms when deciding the pricing strategy. Promotional methods such as coupons, rebates and slotting allowance are also prominently discussed as alternative strategies to improve firms’ profit share. Betancourt and Gautschi (1998) consider the situation where there is an additional demand-inducing choice variable for either the manufacturer or the retailer. Although the authors motivate the theoretical model using distribution services story, the model is applicable to many kinds of demand inducing variables. The result shows the firm that controls the services level earns a higher marginal profit and provides a higher level of services in comparison to the integrated channel situation. Their result supports general intuition that additional choices will improve performance of an individual firm in the distribution channel.

The magnitude of change in price resulting from actions of manufacturer and/or retailer offers another kind of indicator for relative importance and power in the channel. Nakamura (2008) looks at this issue empirically by measuring the movement of prices across market as the manufacturer or the retailer experience shocks. The author finds that there are more movements
in retail prices as a result of shocks in retail level. The result implies that the retailer shocks pass through easier than the manufacturer shocks and they affect the consumer demand more strongly. This may imply a stronger influence the retailer may have in the channel. Besanko et al. (2005) look at the pass-through rate of trade promotion by considering both own-brand and cross-brand pass-through effects. They discover that the pass-through rates measured from empirical data are much higher than the rates believed (or reported to believe) by the manufacturers. Since a higher degree of pass-through in trade promotion may signal the strength of distribution channel power of the manufacturers, the results implies that the position of the manufacturers is generally better than what they believe. In addition, the paper finds that the retailer responses asymmetrically to the pass-through depending on the brand size. The larger national brands have more favorable rates of pass-through when compared to smaller brands, supporting the idea that a bigger national brand has a stronger channel presence than the smaller ones.

1.4 Concluding Comments

Our study focuses on a slightly different topic than the literature discussed above. We intend to focus on the impact of quality as a tool to create “power” in the distribution channel. More specifically, we are interested in the possible changes in behavior of downstream firms as a result of the quality changes done by the upstream firm. The study concentrates on the medium- or long-term adjustment of firms rather than a short term sale strategy. Our study differs from previous studies in this subject because we focus on product quality or an improvement of existing product rather than services quality or new product introduction. The physical quality incurs to every unit of product and changes the production cost for the manufacturer. We will
look at the pricing and quality decisions made by the retailer in response to the quality change done by the manufacturer in the single period setting, the multiple-period setting and the competitive product setting. In addition, we look at the change in profit share and marginal cost to price ratio as the measures for power within the distribution channel. We aim at studying the impact that quality has in improving the power of the manufacturer.
Chapter 2: The Distribution Channel Modeling

We begin our study with the standard setup model, which addresses the distribution channel where the consumer preference depends on the retail price. Working backward, we form a model corresponding to the decision making system of the manufacturer and the retailer in the distribution channel. We are interested in the optimal pricing and quantity decision as well as optimal profits. In addition, we focus our analysis on the effects of one firm’s decisions on the decisions and outcomes of another firm. In later chapters, we extend this basic setup to incorporate the decision for product quality.

2.1 The Base Model for the Distribution Channel

In this section, we establish the basic setup of the distribution channel model, which is the basis of the other models throughout the paper. We present a system with the manufacturer, the retailer and the consumers. Although multiple-manufacturer, multiple-retailer models are possible, we decide to model initially the distribution channel system with only one manufacturer and one retailer, which is not as restrictive as it first appears. A single manufacturer model is reasonable in the context of branded products. A branded product is singular from the market/consumer standpoint with normally one firm producing a specific brand. Some demand specifications allow for the substitution effects to other products to appear in the demand even though the other products (and other firms) are not explicitly present in the model. Consequently, modeling the distribution channel using the single-manufacturer feature is both acceptable and reasonable. The single-retailer setup is also plausible. Although there are usually many retailers in the same area, we usually think of large supermarket retailer as a large buyer in the market.
They can set prices for products in stores and usually engage in price wars with other retailers in the same area.

We assume that the manufacturer acquires the inputs from a perfectly competitive, open market, which implies the manufacturer’s decisions are not related to any firms upstream from the manufacturer. Upon focusing on the link between the manufacturer and the retailer first in this chapter, we assume the demand function is in a predetermined specification and only the retail price matters. The optimal decisions for firms in the distribution channel are linked through the stream and are interconnected where the product passes from the upstream firms to the downstream firms. The interdependence of the decision making process is described in figure 2.1.

![Figure 2.1: The Decision Process in the Distribution Channel](image)

A change in production factors, production technology or costs in one firm can be felt by all firms in the channel because of this interdependence. Consequently, a firm’s optimal decisions take in account decisions from other firms in the channel. Modeling the decision
making in the distribution channel then requires a backward looking approach as the upstream firm takes the optimal decisions of the downstream firm into the objective function.

For the initial, standard model, the problem contains only price and quantity variables. The manufacturer produces a product, which is sold to a retailer under a wholesale price, \( w \). The retailer then sells the product to consumers at a retail price, \( P \). We assume that all goods bought by the retailer are sold to the consumer with no waste and no uncertainty in the demand. The objective functions of the manufacturer and the retailer are described as follows:

**Manufacturer’s Optimization Problem:**

\[
\Pi_M = w \cdot Q(P) - C_M(Q(P))
\]  
(2.1)

**Retailer’s Optimization Problem:**

\[
\Pi_R = P \cdot Q(P) - C_R(Q(P))
\]  
(2.2)

Generally, firms may choose prices \((P, w)\) or quantity \((Q)\) to optimize the profits. Although we can use either price or quantity as the firm’s choice variable in the other firm’s optimization models, we are interested mainly in the price variables in the distribution channel setting. The optimization problems of the two firms are linked through prices under a common quantity. Such a problem is solved by working backward, solving the retailer’s optimization problem for the optimal retail price, \( P \), and bearing in mind it is a function of the manufacturer’s price, \( w \). Then, we substitute the function of retail price, \( P(w) \), in the manufacturer’s objective function and solve for the optimal wholesale price, \( w \), as a function of exogenous parameters. The solution for \( w \) is then substituted back into the optimal retail price for its corresponding solution.
In addition to solving for the optimal decisions for prices, we pay particular attention to the first order conditions. Next, we analyze the optimal conditions derived from the first order conditions and interpret those conditions in terms of marginal cost and the marginal benefit.

2.1.1 The Retailer’s Optimization Problem

The first order condition with respect to the retail price, $P$, can be rearranged into

$$ Q + P \frac{\partial Q}{\partial P} = \frac{\partial C_R}{\partial Q} \frac{\partial Q}{\partial P} \quad \text{where} \quad \frac{\partial Q}{\partial P} < 0 \quad (\text{demand}) \quad (2.3) $$

The left hand side is the marginal revenue, which is a combination of quantity sold less a loss (gain) from sale decrease (increase) due to price increase (decrease). Although the second term is negative when the price increases, we categorize it as “revenue” since it is the component emerging from the revenue contribution. The right hand side is the marginal cost and reflects a reduction in cost due to a decrease in quantity demand caused by the price increase. It is presented as a “cost”, even though it positively contributes to the profit when the price increases, since it is derived from the cost component.

We can further rearrange the first order condition to get the optimal retail price function as:

$$ P = \left( \frac{\epsilon_p}{1+\epsilon_p} \right) \frac{\partial C_R}{\partial Q} \quad (2.4) $$
The effect of retailer’s cost change on the retail price depends on the magnitude of price elasticity, \( \varepsilon_p = \frac{\partial P}{\partial Q} \). With the absolute value of the elasticity greater than one (\( \varepsilon_p < -1 \)), a unit change in the cost results in the larger-than-unit change in the retail price\(^1\).

We apply a log-linear (multiplicative) demand function, which has elasticity embedded in the functional form, taking the form:

\[
D(P) = k \cdot P^{-\eta}
\]

where \( P \) is the retail price and \( \eta \) is the parameter for the price elasticity. The associated price elasticity is constant:

\[
-\eta = \frac{\partial D}{\partial P} \cdot \frac{P}{D} = \varepsilon_p.
\]

The wholesale price is assumed to be constant for all units and the retailer faces a constant retail operating cost, \( r \). The marginal cost for the retailer is \( \frac{\partial C_R}{\partial Q} = c_R = w + r \). Consequently, the optimal retail price function can be written in terms of the wholesale price as:

\[
P^* = \left( \frac{-\eta}{1-\eta} \right) \cdot (w + r)
\]

The solution for the retail price depends on the magnitude of the price elasticity, \( \eta \). With the elasticity greater than one in absolute value, the retail price is always positive.

\(^1\) The case of smaller magnitude value is not particularly relevant here because the products at the brand level generally have elasticity larger than one in absolute value.
2.1.2 The Manufacturer’s Optimization Problem

Taking the optimal retail price schedule, the manufacturer optimizes profit, which results in the following first order condition:

\[ Q + w \cdot \frac{\partial Q}{\partial P} \cdot \frac{\partial P}{\partial w} = \frac{\partial C_M}{\partial Q} \cdot \frac{\partial Q}{\partial P} \cdot \frac{\partial P}{\partial w} \]  

(2.8)

We observe a similarity between the first order condition of the manufacturer and that of the retailer. The marginal change in wholesale price brings additional income equal to the total number of quantity sold (the first term on the left hand side). This benefit is adjusted with a reduction in the revenue due to a change in retail price, which incorporates a change in the wholesale price in the second term \( w \cdot \frac{\partial Q}{\partial P} \cdot \frac{\partial P}{\partial w} \). On the right hand side, we have a straightforward change in cost, which is the marginal cost of production times the change in quantity produced due to the change in the wholesale price.

With demand responding directly to the retail price, not the wholesale price, the manufacturer can influence the final demand via the pass through from the wholesale price to the retail price. Since an increase in the retail price will reduce demand, the manufacturer ideally wants a relatively small pass through when he increases the wholesale price. With a relatively small pass through, an increase in wholesale price results in a higher overall profit return because an increase in price will not induce a large reduction in demand.

Assuming the manufacturer incurs a constant marginal cost of producing one unit of the product, \( \frac{\partial C_M}{\partial Q} = c \), the first order condition leads to
Substituting in the optimal price solution from retailer’s optimization decision, we derive the optimal solution for wholesale price:

$$Q \cdot \frac{\partial P}{\partial Q} + w \cdot \frac{\partial P}{\partial w} = c_m \cdot \frac{\partial P}{\partial w}$$

$$P \cdot \frac{1}{\epsilon_p} + w \cdot \left(\frac{-\eta}{1-\eta}\right) = c_m \cdot \left(\frac{-\eta}{1-\eta}\right)$$

(2.9)

Substituting in the optimal price solution from retailer’s optimization decision, we derive the optimal solution for wholesale price:

$$w^* = \left(\frac{-1}{1-\eta}\right) \cdot (\eta \cdot c + r) = \left(\frac{-\eta}{1-\eta}\right) \cdot c_m + \left(\frac{-1}{1-\eta}\right) \cdot r$$

(2.10)

We evaluate how the wholesale price adjusts to a change in the production cost or the operating cost. The associated derivatives are

$$\frac{\partial w}{\partial c} = \frac{-\eta}{(1-\eta)} \quad \text{and} \quad \frac{\partial w}{\partial r} = \frac{-1}{(1-\eta)}$$

With $\eta > 1$, the marginal change in the wholesale price due to a marginal increase in the production cost is larger than the cost increases. When the manufacturer faces a change in the production cost, he will make an even larger change in the wholesale price, which can be considered compensation from the demand loss. For the manufacturer trying to maintain his profit level, he would need to increase the price even further than the increase in cost to increase the per-unit-profit.

The ability of the manufacturer to acquire compensation from the loss in demand is apparent from the derivative with respect to the retail operating cost. The manufacturer will react to any change in retail operating cost since the change in retail cost impacts the retailer price. The retailer increases the retail price, which causes the demand to fall. The reduction in demand
also affects the manufacturer’s profit, who will increase the wholesale price to recover some of the loss.

As expected, the impacts of the two cost changes on the wholesale price are not the same. Naturally, we expect the direct impact of the manufacturing cost to be greater than the indirect impact of the retail operating price. The comparative static results indicate that the relative differences in the impacts depend on the magnitude of the price elasticity.

2.1.3 The Optimal Market Outcomes

The optimal wholesale price leads to the following solution for the optimal retail price,

\[ P^* = \eta^2 \frac{(r + c)}{(1 - \eta)^2} \]  \hspace{1cm} (2.11)

The optimal decision indicates two sources of cost changes impacting the retail price: the retail operating cost \( r \) and the manufacturing cost \( c \). We investigate the magnitude of their impacts by taking the first derivative of retail price with respect to the cost variables:

\[ \frac{\partial P}{\partial c} = \frac{\partial P}{\partial r} = \eta^2 \left( \frac{1 - \eta}{(1 - \eta)^2} \right) \]  \hspace{1cm} (2.12)

Unlike the first order conditions produced from the optimal wholesale price, the marginal impacts of both the manufacturing cost and the retail operating cost are the same for the optimal retail price. The result suggests that, from retailer’s point of view, both costs are identical. This is interesting since the manufacturing cost is an indirect cost (since it is paid by manufacturer) whereas retail operating cost is a direct cost from the retailer’s perspective. If both costs yield the same impact, this suggests that the retailer is impacted by the manufacturing cost as strongly as
he is impacted by the change in the retail operating cost. The change in the manufacturing cost passes through in the form of the wholesale price adjustment, which the retailer must pay to the manufacturer. The results suggest that the increase in the manufacturing cost is passed through to the retailer, causing the same change as it would be for the retail operating cost.

Since \( \frac{\eta^2}{(1-\eta)^2} > 1 \), the optimal retail price suggests that retailer will increase the retail price more than the change in cost incurred to retailer. Again, this counteracts the reduction in demand due to the price increase. Comparing across the results, we also observe that the change in retail price is higher than the change in wholesale price given an equal change in cost.

Given the above retail price result, we can compute the demand quantity. The corresponding quantity outcome for the distribution channel is

\[
Q^* = k \cdot \left( \frac{-\eta}{1-\eta} \right)^{-2\eta} \cdot (r + c)^{-\eta}.
\]  

(2.13)

The optimal quantity is a non-linear function of the manufacturing and the operating costs. Since each cost enters the quantity function in the same manner, the derivatives from both cost parameters are identical:

\[
\frac{\partial Q}{\partial c} = \frac{\partial Q}{\partial r} = (1-\eta) \cdot k \cdot \left( \frac{-\eta}{1-\eta} \right)^{-2\eta} \cdot (c + r)^{-\eta}
\]

(2.14)

Since the first derivative is always negative, it tells us that the optimal quantity is always decreasing as the cost increases. This is reasonable (and expected) given that the increase in cost leads to an increase in prices. For consumers, an increase in price discourages purchase. Hence,
the quantity demanded decreases. Consequently, the optimally supplied quantity is also reduced to meet the decreasing demand. The second derivative indicates that the rate of quantity reduction is decreasing in absolute value (since the second derivatives are always positive). In total, the absolute change in quantity is falling when the cost increases:

\[
\frac{\partial^2 Q}{\partial c^2} = \frac{\partial^2 Q}{\partial r^2} = (-\eta) (1 - \eta) \cdot k \cdot \left(\frac{-\eta}{1-\eta}\right)^{-2\eta} \cdot (c + r)^{-\eta-1}
\] (2.15)

The resulting second derivatives are positive but less than the absolute value of the first derivative. Consequently, the graph of quantity with respect to either cost presents a convex nature as shown in Figure 2.2. Since the second derivative becomes small quite quickly, it suggests that the quantity slope is likely to converge to non-negative value as well.

![Graph 2: Optimal Quantity](image)

**Figure 2.2: The Characteristic of the Optimal Quantity**

In addition to the usual market outcomes (prices and quantity), we are interested in the outcomes regarding firms’ performance such as revenues and profits. The revenue of the
manufacturer and the retailer can be computed directly from the price and quantity information above\(^2\).

Manufacturer’s Revenue:

\[
\text{Rev}_M = w \cdot Q = k \cdot \frac{1}{\eta - 1} \cdot \left(\frac{\eta - 1}{\eta}\right)^{2\eta} \cdot (\eta \cdot c + r) \cdot (c + r)^{-\eta}
\]  

(2.16)

Retailer’s Revenue:

\[
\text{Rev}_R = P \cdot Q = k \cdot \left(\frac{\eta - 1}{\eta}\right)^{2\eta - 2} \cdot (c + r)^{1-\eta}
\]  

(2.17)

The resulting profits for the manufacturer and the retailer according to the optimal prices and quantity are

\[
\Pi_M = k \cdot \frac{-1}{1-\eta} \cdot \left(\frac{-\eta}{1-\eta}\right)^{-2\eta} \cdot (c + r)^{1-\eta}
\]  

(2.18)

and

\[
\Pi_R = k \cdot \frac{\eta}{(1-\eta)^2} \cdot \left(\frac{-\eta}{1-\eta}\right)^{-2\eta} \cdot (c + r)^{-\eta}
\]  

(2.19)

Notice that in each profit function, the production cost and the retail operating cost enter in the same argument, which leads to the first derivatives of profits with respect to the change in costs being identical. We conclude that the impacts of both cost changes on the profits are the same. We derive the first derivatives of profits with respect to the manufacturing and the operating costs as

\(^2\) We can further derive the profit margin by finding the profit to revenue ratio. The profit margin is an indicator of how much power the firm has in the market or the industry. The profit margin is sometimes used for identifying the nature of market the firm operates. Generally, the higher margin indicates a greater industry concentration or greater control a firm has in the market.
\[
\frac{\partial \Pi_R}{\partial c} = \frac{\partial \Pi_R}{\partial r} = -\eta \cdot k \cdot \frac{\eta}{(1-\eta)^2} \cdot \frac{-\eta}{1-\eta}^{\cdot \cdot 2\eta} \cdot (c+r)^{-(\eta+1)} \quad (2.20)
\]

\[
\frac{\partial \Pi_M}{\partial c} = \frac{\partial \Pi_M}{\partial r} = (1-\eta) \cdot k \cdot \frac{-1}{1-\eta} \cdot \frac{-\eta}{1-\eta}^{\cdot \cdot 2\eta} \cdot (c+r)^{-\eta} \quad (2.21)
\]

Profit is decreasing in a non-linear manner and the magnitude for the marginal change in profit with respect to cost changes is also always negative. Moreover, the first derivatives are functions of costs; thus, the magnitude of costs also influences the impact of the cost change on overall firm’s profit.

Figure 2.3: The Manufacturer and Retailer Profits for the Base Model

Since the costs are inversely related to profits, the change in cost at a higher cost is going affects the profit less than when at a low cost. In addition, the manufacturing and the retail operating costs are important in determining the marginal change of profit. In fact, the total marginal cost \((c + r)\) determines the impact of the cost change. If the total cost is high (low), the impact of cost change on profit is low (high).

Besides the manufacturing and retail operating costs, the elasticity of demand is a crucial parameter determining the optimal decisions and the channel outcomes. We use simulations to
explore the character of optimal solutions under the variation of price elasticity. We investigate five outcomes from the distribution channel problem; namely, the wholesale price, the retail price, the supply quantity, the manufacturer’s profit and the retailer’s profit.

2.2 Simulations for the Base Model

We assess the manufacturing cost as it is set arbitrarily at 2.0, and the retail operating cost is set at 0.3. The scale of these costs is to approximate the relative difference in the two firms’ costs. In this case, the retail operating cost is approximated to be 15% of the manufacturing cost. Lastly, the coefficient of the demand function, k, which is the scaling for aggregated demand for the product, is assumed to be 1. The simulation results are shown in Figure 2.4 – 2.6.
Figure 2.6: Base Model - the Manufacturer’s and the Retailer’s Profits

Figure 2.4 presents the optimal wholesale and retail prices as the price elasticity varies. Given everything else equal, the optimal price for a less elastic product is higher than the optimal price of a more elastic product. As consumers become more responsive to the price change the manufacturer and retailer are reluctant to increase the price substantially for fear of losing customers. The drop in optimal prices is substantial as the elasticity approaches 2.5. From that point on, both the wholesale and the retail prices are relatively constant.

The retailer can charge a much higher price than his marginal cost (wholesale price) for a less elastic product. This is indicated as a widening gap between the retail price and the wholesale price when the price elasticity is less than two. Generally, a small magnitude of elasticity implies firms can charge a higher price and to reap more surplus. Figure 2.4 indicates that the retailer gains a relatively greater benefit from the inelasticity compared to the manufacturer.

From Figure 2.4, both the wholesale and retail prices are monotonically decreasing as price elasticity increases in value. Considering that supplied quantity is an inverse function of prices, this may lead us to believe that the optimal quantity supplied in the market is
monotonically decreasing in the elasticity value as well. However, the result displayed in Figure 2.5 tells a different story. As the optimal quantity is initially increasing and then decreasing as the value of price elasticity progresses, the quantity behavior may be explained by the interaction between demand and supply. For the first part where the quantity supplied is increasing, consumer demand expands rapidly in response to a drop in price. Consumers want more product and firms can sell more units. However, as the price elasticity increases to a value close to two, consumers become less responsive to a reduction in price. The price drop is not well compensated by a decrease in demand. With both reduction in demand response and a less willingness to sell from firms, the optimal quantity is gradually decreasing as price elasticity moves to the right.

The manufacturer and the retailer profits are presented in Figure 2.6, which displays differences in shapes of the two profit schedules. The retailer’s profit is always decreasing as the price elasticity increases whereas the manufacturer’s profit is increasing slightly before dropping. This indicates different effects of the combination of prices and quantity on firms. Generally, a continuous decreasing profit implies a drop in price that is not compensated by an increase in consumer demand (possibly because the demand is less responsive). In contrast, the manufacturer must enjoy a relatively small reduction in price compared to an increase in demand corresponding to price reduction. Consequently, the manufacturing profit increases as the wholesale price decreases in the first section of Figure 2.6. However, after a certain point, the reduction in price cannot keep up with the fall in demand and the manufacturer faces the same fate as the retailer.
2.3 The Distribution Channel Model under Common Ownership

It is useful to compare the optimal prices, quantity and profit of our base model to the solutions from the case where both retailer and manufacturer operating under the same ownership. A common ownership model does not only provide a useful discussion for welfare analysis but also provides an overview for the possible results when firms in the distribution channel start to come together and coordinate. The common ownership, implying perfect coordination, is the extreme case of firms’ coordination. Our later chapters address possible involuntary coordination through the use of strategic choice variables. We proceed to discuss the voluntary coordination as a cornerstone for comparisons.

2.3.1 The Optimization Model

In the common ownership model, the retailer and the manufacturer are owned by the same firm and their optimization decisions are jointly made; that is, the parent firm will maximize the sum of profit generated by both the retailer and the manufacturer. The optimization problem of the parent firm then becomes:

$$\Pi^* = \Pi_R + \Pi_M$$  \hspace{1cm} (2.22)

Some of the variables are eliminated from the optimization problem. We know that the retailer’s profit function can be broken down into smaller parts. More specifically, retail cost can be divided into “procurement cost” (cost of obtaining product for sale in store) and retail store’s “operating cost” (general cost of operating store):

$$\Pi_R = P \cdot Q(P) - C_R^{\text{Procurement}}(Q(P)) - C_R^{\text{Operating}}(Q(P))$$  \hspace{1cm} (2.23)
When combined to the manufacturer’s profit function, the procurement cost component of retailer’s profit function disappears (because it cancels out manufacturer’s revenue.) As a result, the overall objective function for the parent firm is:

$$\Pi^* = P \cdot Q(P) - C^\text{Operating}_R(Q(P)) - C_M(Q(P))$$  \hfill (2.24)

The parent firm chooses the retail price to maximize the profit. The corresponding first order condition with respect to the retail price is

$$\frac{\partial \Pi^*}{\partial P} = Q(P) + P \cdot \frac{\partial Q}{\partial P} - \frac{\partial C^\text{Operating}_R}{\partial Q} \cdot \frac{\partial Q}{\partial P} - \frac{\partial C_M}{\partial Q} \cdot \frac{\partial Q}{\partial P}$$

The optimal condition leads to the solution for retail price as:

$$P = \left( \frac{\varepsilon_p}{1 + \varepsilon_p} \right) \cdot \left[ \frac{\partial C^\text{Operating}_R}{\partial Q} + \frac{\partial C_M}{\partial Q} \right]$$  \hfill (2.25)

This is similar to the solution we have for retailer alone, only now the marginal cost of increasing one unit of quantity sold (or produced) accounts for the marginal cost at both retailer and manufacturer levels. Notice that under the common ownership the effect of a change in the cost from either the retailer or the manufacturer impacts the final price in the same way. Since the common ownership does not differentiate where the source of cost comes from, all costs are considered in the same way under the single owner.

Applying the same demand and cost specifications, we derive the optimal retail price for the integrated distribution channel (i.e., the manufacturer and the retailer combined) as:

$$P^* = \left( \frac{-\eta}{1 - \eta} \right) \cdot (r + c), \hfill (2.26)$$
and, the corresponding optimal quantity in the single ownership case is

\[ Q^* = k \cdot \left( \frac{-\eta}{1-\eta} \right)^{-\eta} \cdot (r + c)^{-\eta} \]  \hspace{1cm} (2.27)

From the above prices and quantity, the optimal profit for the integrated firm equals:

\[ \Pi^* = k \cdot \frac{1}{(\eta - 1)} \cdot \left( \frac{\eta - 1}{\eta^2} \right)^{\eta} \cdot (r + c)^{-\eta+1} \]  \hspace{1cm} (2.28)

The marginal profit or the per unit profit can be computed from \([P - c - r]\), which yields

\[
\text{Marginal Profit} = \left( \frac{1}{\eta - 1} \right) \cdot (r + c) \]  \hspace{1cm} (2.29)

2.3.2 The comparison between the two ownership types

Price

When comparing the optimal price under the single ownership to the price in the separated ownership case, we note that the separated ownership has the optimal retail price determined by

\[ P^* = \left( \frac{-\eta}{1-\eta} \right)^2 \cdot (r + c) \]  \hspace{1cm} (2.30)

We are interested in the relative magnitude between the two prices. To help us compare the prices, we rearrange the optimal price for the common ownership in (2.30) into:
Since we can assume that the typical price elasticity is greater than one in absolute value:
\[ \eta > 1, \]
it is easy to see that the coefficient, \( \left( \frac{\eta}{\eta - 1} \right) \), is greater than one as well and the squared coefficient is even larger:
\[
\left( \frac{\eta}{\eta - 1} \right) < \left( \frac{\eta}{\eta - 1} \right)^2
\]  
(2.32)

Thus, the retail price from the single ownership is larger than the retail price from the separate ownership: \( P_{\text{SingleOwner}} > P_{\text{SeparatedOwner}} \). While the separate ownership case for the manufacturer and the retailer do double markup on the price of the product, the total sum of markups charged by those firms is not as large as the one charged by commonly owned firms. This is because the firms in the separate ownership do have the market control to the degree that the single firm in the integrated supply chain.

**Quantity**

The final quantity supplied is also important from both consumers’ and firms’ perspectives. From the results in both cases, we discover that the optimal quantities are:

\[
Q^* = k \cdot \left( \frac{-\eta}{1 - \eta} \right)^{-\eta} \cdot (r + c)^{-\eta}
\]  
(2.33)

\[
Q^* = k \cdot \left( \frac{-\eta}{1 - \eta} \right)^{-2\eta} \cdot (r + c)^{-\eta}
\]  
(2.34)
We need to identify the size of \( \left( \frac{-\eta}{1-\eta} \right)^{-2} \) to judge which quantity is greater. This component is less than one with \( \eta > 1 \), which means the optimal quantity in the separated owner case is smaller than the quantity from the firm with common ownership. Notice that

\[
Q_{\text{Separate}}^* = \left( \frac{-\eta}{1-\eta} \right)^{-2} \cdot Q_{\text{Common}}^* .
\]

Since \( \left( \frac{-\eta}{1-\eta} \right)^{-2} < 1 \), we can that the quantity produced under the common ownership is larger than the quantity produced under the separate ownership: \( Q_{\text{common}}^* > Q_{\text{Separate}}^* \). This is interesting because the single ownership has both the retail price and the quantity larger than those in separate ownership situation. Under the constant cost assumption, it is natural to conclude that the total profit of the firm in common ownership is larger than the sum of profits from separately owned firms. Nonetheless, we will take a closer, more conclusive look at the optimal profits in both cases.

**Profit**

The profit of common ownership can be computed from the information of price and quantity.

\[
\Pi_{\text{Common}}^* = (P - c - r) \cdot Q = k \cdot \frac{1}{(\eta-1)} \cdot \left( \frac{\eta-1}{\eta} \right)^{\eta} \cdot (r + c)^{-\eta+1} \quad (2.35)
\]

This should be compared to the total profit generated by firms in separate ownership case (i.e., the base case). The total profit is the combination of manufacturer’s profit and retailer’s profit under optimal solutions. Nonetheless, notice that:

\[
\Pi_{\text{Separate}}^* = \Pi_M^* + \Pi_R^* = (w-c) \cdot Q + (P-w-r) \cdot Q = (P-c-r) \cdot Q \quad (2.36)
\]
which is the same equation we have for the common ownership. Since the marginal profit \((P - c - r)\) and the optimal quantity are smaller than in the common ownership case, the total profit from the separated firms is smaller than the profit from the integrated firm.\(^3\) The overall optimal results from the two cases are summarized in Table 2.1.

Table 2.1: Optimal Results Summary for the Two Ownership Types

<table>
<thead>
<tr>
<th>Separately Owned Firms</th>
<th>Integrated Firm</th>
<th>Total Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retail Price</td>
<td>Quantity</td>
<td>Total Profit</td>
</tr>
<tr>
<td>(\left(-\frac{\eta}{1-\eta}\right)^2(r+c))</td>
<td>(k \cdot \left(-\frac{\eta}{1-\eta}\right)^{2\eta} (r+c)^{\eta})</td>
<td>(k \left(\frac{2\eta-1}{(1-\eta)^2}\right) \left(-\frac{\eta}{1-\eta}\right)^{2\eta} (r+c)^{\eta+1})</td>
</tr>
</tbody>
</table>

\(^3\) Another way to see this is that the total profit equations are the same for both cases. Since we choose \(P\) to optimize the total profit only in the integrated firm situation, only the result from that case will produce the optimal total profit. Separated ownership firms have different objective functions; so they yield lower profits combined.

2.4 The Alternative Model Specifications

The base model for this chapter focuses on prices as the choice variables. Nonetheless, it is not necessary that all firms must choose prices as their choice variables. In this section, we investigate other model specifications that are plausible in the context of the distribution channel. Specifically, we focus on the choice variables available to the retailer. Instead of the retail price, we explore two alternatives; namely, the quantity and the retail markup. Finally, we purpose that our original specification is plausible and provide the same results as the alternatives.
2.4.1 The Retailer Choosing Quantity

We look into the case where the retailer chooses the quantity to order. This is quite realistic in the real world situation, especially when we consider that the retailer sometimes imposes different prices on the single product, depending on the sales strategy. Multiple pricing for one product suggests that the retailer may first choose the quantity he wants delivered rather than select the price. Then retailer can choose price schedule as sale season progresses.

The retailer’s profit function is written as a function of $Q$:

$$ \Pi_R = P(Q) \cdot Q - C_R(Q) $$

The first order condition with respect to quantity is

$$ \frac{\partial \Pi_R}{\partial Q} = \frac{\partial P}{\partial Q} \cdot Q + P(Q) \frac{\partial C_R}{\partial Q} = 0 $$

Or,

$$ P \left[ 1 + \frac{1}{e_p} \right] = \frac{\partial C_R}{\partial Q} \tag{2.37} $$

We may recall that the optimal condition above is the same as the condition we get from the first order condition with respect to the retail price. Now, we apply the same demand specification as we did in earlier section. This means the inverse demand function can be represented as

$$ P = K \cdot Q^{-\eta} \cdot \frac{1}{\varepsilon} $$

Using the above (inverse) demand and the same cost assumptions introduced earlier, we can solve for $Q$ as a function of manufacturer’s choice variable.
Taking the retailer’s quantity order as given, the manufacturer decides how much to charge for such the order. Recall that quantity is a function of wholesale price, \( w \).

**Manufacturer’s profit function**

\[
\Pi_M = w \cdot Q(w) - C_M(Q(w))
\]

The first order condition with respect to wholesale price is

\[
\frac{\partial \Pi_M}{\partial w} = Q(w) + w \cdot \frac{\partial Q}{\partial w} - \frac{\partial C_M}{\partial Q} \cdot \frac{\partial Q}{\partial w} = 0 \tag{2.40}
\]

From the optimal solution for \( Q \) above, we derive the first order condition with respect to the wholesale price:

\[
\frac{\partial Q}{\partial w} = \frac{-\eta \cdot Q}{w + r}. \text{Hence}, \quad \frac{Q}{w} \cdot \frac{\partial w}{\partial Q} = \frac{-1}{\eta} \cdot \left( \frac{w + r}{w} \right).
\]

Upon substituting relevant parameters, we rearrange the first order condition with respect to the wholesale price and obtain the following optimal solution for \( w \):

\[
w^* = \left( \frac{-1}{1 - \eta} \right) \cdot r + \left( \frac{-\eta}{1 - \eta} \right) \cdot c_m \tag{2.41}
\]

This is exactly the same optimal solution for the wholesale price we achieved when retailer chooses the retail price (see equation (2.10)). Consequently, the optimal solutions for the distribution channel models are the same regardless of the retailer’s choice variables. In other words, it does not matter whether the retailer optimizes his profit by choosing the retail price or
the retail quantity. His solution yields the same outcomes (prices, quantity and profits) either way.

2.4.2 The Retailer Choosing Markup

Instead of the retail price, sometimes the retailer is choosing the markup rate, \( m \), which is the extra charge in addition to the wholesale price; in other words,

\[
P = (1 + m) \cdot w
\]

(2.42)

The profit function of the retailer is transformed into:

\[
\Pi_R = (1 + m) \cdot w \cdot Q((1 + m) \cdot w) - C_M(Q((1 + m) \cdot w))
\]

(2.43)

The first order condition with respect to the mark up, \( m \), is

\[
\frac{\partial \Pi_R}{\partial m} = w \cdot Q + (1 + m) \cdot w \cdot \frac{\partial Q}{\partial P} \cdot w - \frac{\partial C_R}{\partial Q} \cdot \frac{\partial Q}{\partial P} \cdot w
\]

\[
= Q + (1 + m) \cdot w \cdot \frac{\partial Q}{\partial P} - \frac{\partial C_R}{\partial Q} \cdot \frac{\partial Q}{\partial P}
\]

(2.44)

which is equivalent to the first order condition when retailer chooses retail price directly. This is not surprising considering that choosing a markup is equivalent to choosing a retail price. Because the retail price is a function of the markup rate, an optimal choice for the retail price corresponds to an optimal solution for the markup. Consequently, both variables produce the same first order condition. The first order condition implies

\[
P = (1 + m) \cdot w = \frac{\partial C_R}{\partial Q} + \frac{P}{\epsilon_p} \quad \text{where} \quad \epsilon_p = -\frac{P}{Q} \cdot \frac{\partial Q}{\partial P}.
\]

(2.45)
Since the optimal retail price in this case is the same as what we have when the retailer picks the retail price, the solution for manufacturer’s optimal wholesale price should also be the same. Consequently, we continue to use the original model as the base model for our study.

2.5 Concluding Comments

This chapter establishes the base model describing the relationship between the manufacturer and the retailer in the distribution channel. We find the optimal pricing schedules for both the wholesale price and the retail prices. Our findings confirm that the decisions of the manufacturer and the retailer are closely related. We also show that the cost parameters of individual firms influence all of the outcomes, suggesting that individual firm must take into account the parameters of the other firm in the channel. Now that we establish the base model for the distribution channel, we can move to our main interest – the use of the strategic choice variable by firms in the distribution channel. Specifically, we investigate the impact of quality in the distribution channel in the next chapter.
In this chapter, we investigate the role of product quality as a strategic tool influencing the decisions in the distribution channel with one manufacturer setting. Shaping the characteristics of the product, product quality influences the consumer demand and at the same time affects the production process and changes the production cost. Since the quality improvement is generally done during the manufacturing process, the product quality is primarily considered the manufacturer’s choice rather than the retailer’s. Even if the benefit of the choice variable is distributed throughout the channel, only the manufacturer can directly implement a quality level.

We focus our study on the quality level influencing the consumer demand through an application of quality on each unit of the product. We apply a static model where the manufacturer chooses product quality, which impacts the costs and demand for the current period. Most of the issues investigated in this static quality model are similar to the ones we discussed in the basic distribution channel model from Chapter 2.

3.1 The Distribution Channel Model with the Manufacturer Choosing the Product Quality

We begin by examining the basic model for the manufacturer choosing a demand-induced quality choice. We assume only the manufacturer can choose a level of quality for the product sold through a distribution channel. Since product quality influences consumer demand while increasing the manufacturing cost, the respective objective functions for the manufacturer and the retailer are given as:

\[ \Pi_R = P \cdot Q(P, \theta) - C_r(Q(P, \theta)) \]  \hspace{1cm} (3.1)
Manufacturer’s Profit:  
\[ \Pi_M = w \cdot Q(P, \theta) - C_M(Q(P, \theta), \theta) \]  
(3.2)

The product quality, \( \theta \), appears in both the demand and the manufacturing cost functions. Consumers care about the quality of the product they purchase; hence the quality level is an argument of the demand specification. A product with higher quality is more desirable than a product with lower quality, which implies \( \frac{\partial Q}{\partial \theta} > 0 \). The quality is assumed to be costly: \( \frac{\partial C_M}{\partial \theta} > 0 \), and a product with a higher quality level is more costly to produce than a product with a lower quality level.

Starting from the retailer’s problem, we consider the first order condition with respect to the retail price. With no change in the structure of the objective function for the retailer from the previous model, the first order condition is structurally the same as in Chapter 2:

\[ Q + P \cdot \frac{\partial Q}{\partial P} = \frac{\partial C_R}{\partial Q} \cdot \frac{\partial Q}{\partial P} \]  
(3.3)

Although the first order condition is the same as before, the condition is likely not to yield the same numerical results because the partial derivatives are evaluated at different values. The optimal retail price can be solved out as a function of wholesale price and quality if we know the demand function.

Taking into account that the retail price is a function of wholesale price and product quality, the first order conditions for the wholesale price is:

\[ Q - \frac{\partial C_M}{\partial Q} \cdot \frac{\partial Q}{\partial P} \cdot \frac{\partial P}{\partial w} = -w \cdot \frac{\partial Q}{\partial P} \cdot \frac{\partial P}{\partial w} \]  
(3.4)

The optimal condition with respect to the wholesale price provides a similar condition as the first order condition of the retail price. The only difference is that the change in the wholesale price indirectly impacts the demand through its influence on the retail price. Equation (3.4) states
that an increase in revenue in all units (shown as Q) plus a reduction in the production cost on the left hand side must equal a revenue reduction from a decreased sale on the right hand side for the optimal production. When the manufacturer optimizes his profit under the product quality (θ), the first order condition can be rearranged into:

\[ w \cdot \frac{\partial Q}{\partial \theta} - \frac{\partial C_M}{\partial Q} \cdot \frac{\partial Q}{\partial \theta} \cdot \frac{\partial P}{\partial \theta} = -w \cdot \frac{\partial Q}{\partial P} \cdot \frac{\partial P}{\partial \theta} + \frac{\partial C_M}{\partial Q} \cdot \frac{\partial Q}{\partial \theta} + \frac{\partial C_M}{\partial \theta} \]  

(3.5)

This condition arranges the positive impacts are on the left hand side and the negative impacts are on the right hand side. An increase in the quality persuades consumers to buy more of the product: \( \frac{\partial Q}{\partial \theta} > 0 \). This increase in demand also contributes negatively to the profit due to an increase in the manufacturing cost (the second term on the right hand side). On the other hand, an increase in the cost of production translates into an increase in prices: \( \frac{\partial P}{\partial \theta} > 0 \). With the increase in the retail price, the demand for the product decreases: \( \frac{\partial Q}{\partial P} > 0 \). The reduction in demand appears in two opposing terms. The first term on the right hand side is the negative impact, which is a reduction in revenue due to a lower demand. As the retail price increases, consumers adversely demand fewer products, suggesting that the quality improvement weakens the sale of products through an increase in retail price. The second term on the left hand side represents the positive contribution of the reduction in demand, which is a reduction in the manufacturing cost. Moreover, a product of higher quality should cost more to produce: \( \frac{\partial C_M}{\partial \theta} > 0 \). This is the only direct cost effect of an improvement in product quality, which is shown in the last term on the right hand side.
3.2 The Model Specifications and the Explicit Solutions

The Demand Specifications

In keeping with the previous chapter, we apply a similar specification for the demand and costs. The log-linear demand is assumed to take the following multiplicative form:

\[ Q = k \cdot P^{-\eta} \cdot \theta^\alpha \]  \hspace{1cm} (3.6)

where the constant price elasticity is equal to \( \eta \) and the constant quality elasticity is equal to \( \alpha \).

The demand equation (3.6) is not a definite form for quality influenced demand. There are several specifications one may apply depending on the underlying quality story and how quality impacts demand. As an alternative, the product quality may impact the demand through the price elasticity. The consumer’s reaction toward a change in price may depend on the quality of the product. This is a plausible assumption considering that the consumers may be more reluctant to switch from a higher quality product to other substitutes. Structurally, the price elasticity should be decreasing in the product quality value. The corresponding demand specification for the situation is written as

\[ Q = k \cdot P^{-\eta \theta} \]  \hspace{1cm} (3.7)

We rearrange the first order condition to achieve an expression of the price elasticity:

\[ \varepsilon_p = \frac{\partial Q}{\partial P} \frac{P}{Q} = -\eta \cdot \theta \]  \hspace{1cm} (3.8)

The change in price elasticity due to an improvement in product quality is linear. The price elasticity (\( \varepsilon_p \)) decreases when the quality of product (\( \theta \)) increases. In our initial setup, we retain the demand specification in (3.6). The changing price elasticity demand in (3.7) can be a subject of further study.
The Explicit Solutions for the Constant Marginal Cost of Quality Model

Since only the manufacturer can choose the level of product quality, the modification in this chapter applies directly to the manufacturer’s optimal problem. The retailer’s objective function remains the same and his implicit first order condition is unchanged. The optimal retail price is a function of the wholesale price, which is determined simultaneously with the product quality:

\[ P^* = \left( \frac{\eta}{\eta - 1} \right) \cdot (w_{optimal} + r) \]  

(3.9)

An assumption about the cost of product quality has to be made before the manufacturer’s optimization problem can be discussed. The quality improvement we address in this study is an improvement that happens to an individual unit. If the production presents a constant return to scale (CRS) characteristic, a constant additional cost due to the product improvement is reasonable. Let the cost of an additional unit of quality to the product be equal to \( h \). The resulting per-unit manufacturing cost is equal to \( c + \theta \cdot h \). The manufacturer’s profit function is

\[ \Pi_M = w \cdot Q(P, \theta) - [c + h \cdot \theta] \cdot Q(P, \theta) \]  

(3.10)

The manufacturer selects the wholesale price and the quality level to maximize profit. The first order condition with respect to wholesale price provides the following optimal condition

\[ w = \left( \frac{\eta}{\eta - 1} \right) \cdot (c + h\theta) + \left( \frac{1}{\eta - 1} \right) \cdot r \]  

(3.11)

Known to the firms, the parameters \( c, h, r \) and \( \eta \) are all positive. Equation (3.11) describes the relationship between the optimal wholesale price and the cost variables. To solve for the optimal wholesale price and discuss its static analysis, we need information from the first order condition for the product quality, which is
\begin{equation}
\begin{aligned}
w &= c + h\theta + h\theta \cdot \left( \frac{Q}{\theta} \frac{\partial \theta}{\partial Q} \right)
\end{aligned}
\tag{3.12}
\end{equation}

The last term on the right hand side is the inverse of the quality elasticity. Equation (3.12) can be rearranged into:

\begin{equation}
\begin{aligned}
w &= c + \left(1 + \frac{1}{\alpha}\right) \cdot h \cdot \theta
\end{aligned}
\tag{3.13}
\end{equation}

The two optimal conditions for the manufacturer, (3.11) and (3.13), provide sufficient information to solve for the optimal wholesale price and product quality. The resulting optimal wholesale price is

\begin{equation}
\begin{aligned}
w^* &= \left(\frac{1}{h - (1 + \alpha)}\right) \cdot \left[ h \cdot c + r \right]
\end{aligned}
\tag{3.14}
\end{equation}

The corresponding marginal analysis provides that

\begin{equation}
\begin{aligned}
\frac{\partial w^*}{\partial c} &= \left(\frac{h}{h - (1 + \alpha)}\right) \quad \text{and} \quad \frac{\partial w^*}{\partial r} &= \left(\frac{1}{h - (1 + \alpha)}\right)
\end{aligned}
\tag{3.15}
\end{equation}

Since the wholesale price should be an increasing function of costs, we impose the restriction: \( h > 1 + \alpha \). As a result, the static analysis suggests that the effect of the manufacturing cost is greater than the effect of the retail operating cost on the optimal wholesale price. This is reasonable considering that the manufacturing cost is a direct cost for the manufacturer, whereas the retail operating cost is an indirect cost, that should have a lesser impact than the manufacturing cost.

The optimal choice for the product quality can be derived from the manufacturer’s first order conditions as

\begin{equation}
\begin{aligned}
\theta^* &= \frac{1}{h} \left(\frac{\alpha}{h - (1 + \alpha)}\right) \cdot (c + r)
\end{aligned}
\tag{3.16}
\end{equation}
The optimal decision indicates that the essential factor determining the level of quality is the sum of the manufacturing and the operating costs rather than the individual costs. As a result, the impact of the manufacturing cost on the optimal quality is the same as the impact of the retail operating cost, which is

\[
\frac{\partial \theta^*}{\partial c} = \frac{\partial \theta^*}{\partial r} = \frac{1}{h} \left( \frac{\alpha}{h - (1 + \alpha)} \right). \tag{3.17}
\]

With \( h > 1 + \alpha \), the manufacturer chooses to produce a higher quality product when the costs of production or the cost of retail operation increases. An increase in costs leads to an increase in the retail price, which in turns reduces the demand of the product. To counteract this loss in demand, the manufacturer seeks to increase the product quality and to attract more consumers. An increase in product quality will help off-set the reduction in demand due to the increase in the production cost or the retail operating cost.

Our results suggest that a product with higher manufacturing cost will have higher quality. This manufacturing cost is not the quality cost; so it is important to make the distinction straight. The product with a high input cost for the components unrelated to quality improvement should also have high quality. A product that is difficult to make should have better quality than any comparable product of a lower non-quality input costs. A difference in retail operating cost may also lead to a different quality choice. Our finding states that the product with higher retail operating cost should have a higher quality. It suggests that a product that is either difficult to handle, costly to store, or expensive to manage will have higher quality than a comparable product.

From the manufacturer’s optimal decisions, the corresponding optimal retail price decision is
\[ P^* = \left( \frac{\eta}{\eta - 1} \right) \left[ \frac{h}{h - (1 + \alpha)} \cdot c + \frac{h - \alpha}{h - (1 + \alpha)} \cdot r \right] \]  

(3.18)

With \( h > 1 + \alpha \), the retail price increases the costs increases. The first derivatives with respect to costs suggest that the impacts of costs on the retail price differ. Interestingly, the impact of the manufacturing cost is stronger than the impact of the retail operating cost, even though the retail operating cost is the direct cost of the retailer. Also, both elasticity parameters appear in the optimal retail price condition. The retail price depends on the responsiveness of the consumers on both the quality and the retail price.

In addition to the manufacturing cost and the retail operating cost, the optimal decisions depend on the parameters for the cost of quality (h) and the elasticity parameters (\( \eta \) and \( \alpha \)). We will illustrate the characteristics of the optimal decisions under the changes in quality cost and elasticity in the simulations.

### 3.3 Simulations for the Linear Cost Specification in the Single Period Model

This section provides the overview of the optimization results under the variations of quality cost and elasticity.

#### 3.3.1 Variation in the Quality Cost Parameter

We first consider the impact of quality cost \( h \) changes on optimal outcomes. The optimal quality schedule is simulated using the following parameter specifications: the elasticity of quality, \( \alpha \), = 0.5; the elasticity of demand, \( \eta \), = 2; the demand coefficient, \( k \), = 100; the manufacturing cost, \( c \), = 2; and, the retail operating cost, \( r \), = 0.3. These parameter values are similar to the scenarios used for the simulations in Chapter 2.
Figure 3.1 indicates that the manufacturer chooses a lower level of product quality when the quality becomes expensive, which is expected from the theory of demand. When the per-unit quality cost increases, the manufacturer is discouraged from applying quality onto the product. The optimal level of quality is decreasing as a convex function and approaches zero as the
quality cost exceeds 3.5. Due to the nature of the demand specification, the optimal quality is decreasing approaching zero asymptotically.

According to Figure 3.2, the simulations indicate that the wholesale price and the retail price are decreasing as the quality cost increases. The results appear surprising at first. However, when they are considered the results alongside Figure 3.1, the results can be explained using the associated optimal quality level. Because an increase in the quality cost leads to a reduction in the quality usage, the resulting cost of production is actually decreasing. Recall that the manufacturing cost and the retail operating cost are kept constant. Figure 3.2 also suggests that the wholesale price and the retail price are in close proportion of one another and the curvature of both lines resemble one another. Nonetheless, they are not exactly proportional, which can be confirmed by (3.14) and (3.18). Figure 3.3 suggests that the price reducing impact dominates the quality reduction impact on the demand. The retail price reduction leads to an increase in the demanded quantity.

Although the optimal prices and the optimal quality are monotonic, the profit functions, which are shown in Figure 3.4, are not. The profits are increasing for sometime before decreasing. The results indicate that the firms are more profitable as the cost of quality increases, suggesting that the revenue is increasing faster than the cost during this period. After that, the profits are decreasing functions of the quality cost. Figure 3.4 also indicates that the peaks for the manufacturer’s and the retailer’s profits do not occur at the same level of quality cost. The manufacturer does relatively better with at lower level of quality cost, reported at around 1.9 in the graph. The retailer, on the other hand, performs better as the cost moves to about 2.2.

Since the retailer’s profit is always higher than the manufacturer’s profit, the profit ratio is always less than one, as shown in Figure 3.5. The resulting profit ratio is a decreasing function of
the quality cost, indicating that the difference between the manufacturer’s profit and the retailer’s profit is increasing as the quality cost increases. The retailer does relatively better than the manufacturer as the cost of quality increases. The results imply the impact of the increased quality cost is carried relatively more heavily by the manufacturer, suggesting that the manufacturer cannot pass on most of the increase quality cost to the retailer.

3.3.2 The Variation in the Elasticity of Quality

The variation in the optimal decisions as the elasticity of quality changes is addressed next. With the condition that \( h > 1 + \alpha \), we set the quality cost parameter, \( h \), equal to 2.5 and allow the elasticity of quality, \( \alpha \), to range from 0 to 1.5. The other parameters are the same as earlier.

![Graph: Optimal Quality under Variation in Quality Elasticity](image)

**Figure 3.6: Quality Elasticity - the Optimal Quality**

![Graph: Optimal Prices under Variation in Quality Elasticity](image)

**Figure 3.7: Quality Elasticity – the Optimal Prices**
The result from Figure 3.6 suggests that the optimal quality level is increasing as the elasticity of quality increases. The result is intuitive considering that the manufacturer would prefer to add more quality if the consumers are more responsive to the change in quality. The optimal quality schedule is a convex function, indicating a stronger increase in quality as the elasticity approaches 1.5, which is the threshold of the elasticity under this specification. Because the increase in quality combines with the cost of product, the corresponding wholesale and retail prices are also increasing in the elasticity of cost, as shown in Figure 3.7.

With an increasing retail price, we can expect the quantity demanded to be decreasing as the elasticity of quality increases. The results are confirmed in Figure 3.8, where the quantity is a decreasing function. Generally, the quantity is a convex function until the elasticity of quality
reaches 13, and then becomes a concave function. The change in the second derivative occurs at
the point where the price increases rapidly, which should imply a rapid decrease in the quantity
demand.

Figure 3.9 (a) shows that the manufacturer’s and the retailer’s profits are non-monotonic
in the quality elasticity. The firms’ profits are decreasing and then increasing as the elasticity
value increases, implying that the increase in prices induces an increase in revenue at a faster rate
than the reduction in quantity. The profit functions are convex with minimum points at about the
same elasticity value for both the manufacturer and the retailer. Unlike the quality cost, the
effects of the elasticity of cost on profits are similar for both firms, leading to the similar
schedules for the profit functions. The profit ratio, shown in Figure 3.9 (b), indicates that the
retailer does relatively better than the manufacturer, by gaining more benefit from the increase in
the elasticity of quality.

The simulations demonstrate the description on the impact of the cost of quality and the
quality elasticity⁴. Under a linear cost specification, we find that the optimal quality choice is
decreasing in the quality cost. Also, the optimal wholesale and retail prices are decreasing as the
quality cost increases. The quality elasticity appears to have an opposite impact in comparison to
the quality cost on the quality level and the prices. The quality level and the prices are increasing
functions of quality elasticity. A product with higher elasticity has a higher quality level and a
higher retail price.

⁴ The variations in costs and other parameters, beside the elasticity result, in a change in magnitude but
not the shape of graphs describing the optimal decisions and channel outcomes. Hence, we decide to
forgo the presentation of those variations.
3.4 The Optimization Model with a Convex Quality Cost Function

Instead of a constant per unit cost of quality, the manufacturer may experience a convex cost function, implying that the marginal cost per unit of quality is increasing as the level of quality increases. The convex specification suggests that a high level of product quality is marginally more difficult (i.e., more costly) to attain than a low level of quality. This is a plausible assumption considering that the manufacturer may encounter a diseconomy of quality in production or a disutility in the adjustment; hence, it is expensive to produce a high level quality product or increasingly costly to improve the quality level. A convex specification provides a reasonable description of the quality cost characteristic.

Applying the specification to the optimal decisions

Assume the manufacturer pays the cost of a unit quality per unit of product equal to $\frac{1}{2} \gamma \theta^2$. Consequently, the manufacturing cost function takes the following form:

$$ C_M = \left[ c + \frac{1}{2} \gamma \cdot \theta^2 \right] \cdot Q(P, \theta) $$

(3.19)

Similar to the previous specification, the “unit cost” of quality (the bracketed term) is added directly to the constant marginal cost of production. This new specification allows for a non-constant cost of quality per unit of product, which differs from the previous specification where the per-unit cost is constant. For this convex specification, the change in per-unit cost of quality is non-constant and equal to $\gamma \theta$. The corresponding marginal cost of adding one more unit of quality is correlated positively with the level of quality the manufacturer chooses.

$$ \frac{\partial C_M}{\partial \theta} = \left[ c + \frac{1}{2} \gamma \cdot \theta^2 \right] \cdot \frac{\partial Q}{\partial \theta} + \gamma \cdot \theta \cdot Q(P, \theta) $$

(3.20)

When the marginal cost is applied into the original first order conditions, (3.11) and (3.13), the change in the optimal condition for quality can be derived as follows:
\[ \theta^* = \left[ \frac{2\alpha \cdot (w - c)}{\gamma \cdot (2 + \alpha)} \right]^{1/2} \quad (3.21) \]

where \[ w^* = \left[ \frac{(\eta - 1)^2 \cdot (2 + \alpha)}{2\eta^2 - (6 + \alpha) \cdot \eta + 1} \right] \cdot \left[ \left( \frac{2}{2 + \alpha} \right) \cdot c + \left( \frac{\eta}{(\eta - 1)^2} \right) \cdot r \right] \quad (3.22) \]

Unlike the optimal condition for the wholesale price in (3.14), the optimal wholesale price in (3.22) also depends on the elasticity of price, meaning that the optimal wholesale price depends on the sensitivity of the demand when the price changes. Since the price elasticity enters the optimal condition in a non-linear way, we use simulation to address the static analysis. In addition, the cost parameter for quality is not a part of the optimal wholesale price, which differs from the linear cost case. It appears that only the manufacturing cost, the operating cost and the elasticity parameters (but not the quality cost parameter, \( \gamma \)) are factors in the optimal wholesale price. The quality cost parameter shows up in the optimal quality equation (3.21) and its first derivative, which is always negative, indicates that the manufacturer will apply less quality when its price goes up.

The above optimal conditions require some restrictions for the parameter values in order for the wholesale price to be an increasing function in the production cost (c) and the retail operating cost (r). The denominator of the first term must be positive, which requires

\[ \eta \geq \frac{(6 + \alpha) + \sqrt{(6 + \alpha)^2 - 8}}{4} \quad (3.23) \]

If equation 3.23 holds, an increase in the manufacturing cost and/or an increase in the retail operating cost will lead to an increase in the wholesale price. We can show that this condition is also a requirement for positive optimal wholesale prices. Because the solutions are difficult to understand from the explicit solution equations, (3.21) and (3.22), the graphical
representations derived from simulations will offer better descriptions of the optimal decisions. We next present the simulations of the firms’ decision and the channel outcomes.

3.5 The Simulation for the Convex Cost Structure in the Single Period Model

In this section, we present the simulations for optimal solutions resulting from variations in price and quality elasticity. The simulations start with the finding of the optimal prices, the optimal quality and the corresponding quantity. Then, we discuss the profits of both firms in the distribution channel, their profit ratio and the markup (prices ratio).

3.5.1 The Variation in the Price Elasticity

The simulation applies the following arbitrary parameter values. The elasticity of quality is equal to 0.5. The cost of quality is 0.4 per unit of quality. The retail operating cost per unit is 0.1 and the manufacturing cost for each unit of product is 1.5. The demand parameter, k, takes the value of 100. Corresponding to the above set of parameters, the starting point of price elasticity (η) is equal to 3.0881. We focus on the range of price elasticity that is higher than 3.0881.

The optimal quality falls steeply as the price elasticity moves away from the threshold value, suggesting that the more sensitive consumers are to price, the less the manufacturer is willing to invest in quality. To understand why this is the case, we should also look at the optimal pricing schedules from Figure 3.11. The figure indicates that the prices decrease substantially when we move from a relatively low elasticity to higher elasticity. Both the wholesale and retail prices drop in the same manner and approach zero as the price elasticity becomes larger than 3.5. The steep drop in wholesale price is associated with the sharp drop in quality. The sharp drop in prices comes about from a strong drop in the cost, which reasonably
comes from a reduction in quality (hence, its cost of production). It is arguable that the high elasticity of price persuades the manufacturer to reduce its price to avoid a reduction in quantity (and as a result, a reduction in profit).

Figure 3.10: Price Elasticity – the Optimal Quality

Figure 3.11: Price Elasticity – the Optimal Prices

Since the pricing schedules for both prices appear to be very close in the above graph, we present the price ratio of the wholesale price to the retail price in Figure 3.12 as an indicator of relative size of the two prices.
We observe that the ratio is increasing as the price elasticity increases, starting from 0.68 and reaching 0.78 as the price elasticity moves from 3.1 to 5, which indicates that the manufacturer price increases in a relatively larger magnitude than the retailer price. As the price elasticity increases, the manufacturer increases price faster than the retailer. We address later in this section whether this increase in price ratio translates into an increase in profit ratio, which indicates the relative strength in distribution channel.

The patterns of optimal quantity and profit help explain the optimal prices and quality level. Consider the optimal quantity. Despite a rapid drop in quality shown in Figure 3.10, the overall quantity in Figure 3.13 is increasing in a slightly S-Shape curve as the price elasticity
increases, indicating that the effect of the price reduction dominates the decreasing quality effect.

The optimal quantity appears to reach a plateau as the price elasticity hits the value 5, which is reasonable considering that the optimal prices at that point are relatively flat.

Knowing that prices increase, the cost decreases and the demand increases, we are interested in the net effect on the firms’ profits.

Figure 3.14: Price Elasticity – the Manufacturer’s and Retailer’s Profits

Interestingly, the manufacturer’s profit shown in Figure 3.14 is always greater than the retailer’s profit. This result differs from the results under the linear marginal quality cost specification. Under a convex marginal cost assumption, the manufacturer always performs relatively better than the retailer. To make the comparison easier to read, we present two measures: first, the absolute difference in profit and second, the profit ratio between the two firms.

In terms of the absolute difference shown in Figure 3.15 (a), we observe that the manufacturer does increasingly better at first as price elasticity increases. The profit difference reaches its peak at 0.8059 when $\eta = 3.75$. Then the difference in profit decreases gradually. In comparison, the manufacturer earns more profit than the retailer at any given value of price elasticity as shown in figure 3.15(b). The manufacturer’s performance, when measured in terms
of nominal profit, is improving at first as $\eta$ moves from 3.1 to 3.7. This indicates that the manufacturer is gaining relatively more profit from the changes in optimal prices and quality due to an increase in price elasticity. Interestingly, as the consumers become more sensitive to price change, the manufacturer’s profit is decreasing in comparison to the retailer’s profit. The result suggests that the manufacturer has less power as the consumers become more sensitive to prices.

3.5.2 The Variation in Quality Elasticity

Next we consider the changes in optimal decisions and market outcomes as a result of variation in the elasticity of quality. In this simulation, the parameters are kept similar to the previous simulations for the comparison. We set price elasticity, $\eta = 3.5$, the marginal cost of quality, $h = 0.4$, the retail operating cost, $r = 0.1$ per unit, the manufacturing cost, $c = 1.5$ per unit and the constant for demand, $k = 100$. 

Figure 3.15: Price Elasticity – the Firms Profit Difference and Profit Ratio
As expected, the optimal quality is increasing as the quality elasticity increases. The graph shows a very slight S-shape, starting with a concave shape and gradually changes into a slightly convex curve. This indicates that the manufacturer is more willing to increase the level of quality as the level of responsiveness to quality is relatively large, which is reasonable and expected.

Figure 3.17: Quality Elasticity – the Optimal Wholesale and Retail Prices.
As shown in Figure 3.17 (a) and (b), the optimal prices for both the manufacturer and the retailer are increasing as the elasticity of quality increases. This is expected since an increase in elasticity induces higher level of quality of product, which means a higher per unit cost of production. Consequently, the optimal prices must increase in a similar manner. Figure 3.18 indicates a reduction in the gap between the wholesale price and the retail price, which implies an improvement in the performance of manufacturer. The retailer can pass the cost through to consumer to a smaller degree when the elasticity increases. The retail markup is decreasing, indicating that the retailer is losing “power” in the channel when consumers are more responsive to the quality.

Figure 3.18: Quality Elasticity – the Wholesale and Retail Price ratio

Figure 3.19: Quality Elasticity – the Optimal Quantity
Figure 3.20: Quality Elasticity – the Firms’ Profits

Figure 3.19 shows that the optimal quantity is decreasing as the elasticity increases. Although we observe an increase in price and quality, the resulting equilibrium leads to overall reduction in the total demand of the product, suggesting that the increase in price actually kicks in with a greater effect. An increase in price may dissuade consumers from buying the product even if they are more positively responsive to quality.

The profits outcomes in Figure 3.20 indicate that the impact of quantity dominates the increase in prices in sales contribution. As a result, the profits for both the manufacturer and the retailer are decreasing as the quality elasticity increases. The impact of price increases is stronger in consumer’s response than the impact of quality improvement.

Earlier, profit margin shows that the manufacturer is performing relatively better under an increase in quality elasticity. The depictions of profit and the profit ratio from Figure 3.21 indicate otherwise. Figure 3.21 (a) shows that the nominal difference in profit between the manufacturer and the retailer is decreasing, suggesting the manufacturer does relatively poorly with high quality elasticity. The profit ratio in Figure 3.21 (b) confirms the result although the graph indicates a reversal in the profit ratio at much higher level of elasticity. This suggests the relative profit can improve for the manufacturer with even higher level of quality elasticity.
For the convex cost function section, most of the findings discuss the same issues as the linear quality cost specification. Interestingly, the convex quality cost case offers a comparison between the impact of the price elasticity and the quality elasticity on the optimal quality and price levels. The elasticity of quality in the convex case is approximately similar to the result from the linear cost case, with differences in the magnitude and the marginal effects. Moreover, the results suggest that the linear and the convex quality cost schedules lead to the same trends in optimal choices and outcomes. However, the elasticity of price appears to have an opposite impact on quality and price levels.

Some may argue that product quality is more appropriate to investigating multiple-period framework due to its investment-like nature and delayed consumer’ response. This issue of product quality in a multi-period model is addressed in the next section.

3.6 The Quality Choice for the Multi-Period Models

Up to this point, all models we discuss are single period, static models where all decisions impact only the current period outcomes. Using a static model to explain the firm’s decisions on quality choice has limitations. Most importantly, a single period decision does not support the
situation where the choices have impacts lasting into future periods. The static model ignores the fact that firms may be selling the same branded product to the same set of customers for an extended period of time. Often, product quality tends to impact consumers’ perception of a product for several periods. If the quality information stays with consumers for multiple periods, a static model is incapable of conveying this property into the firm’s decision making process.

In this section, we build a model that considers quality as a path-dependent variable. According to the model, consumers look at quality of product not just in this period but in previous periods as well. Consumers regard the term “quality” as a sum of performance of the product. We assume consumers consider all past history of quality variables and calculate a quality measure as the discounted sum of all past performances.

Another aspect of multi-period model requires consideration is the cost of quality. The quality cost may depend on the actual quality level, as seen in previous section, or alternatively, depend on the relative measure with respect to the past quality. The reasoning supporting the first condition is straight-forward. Different levels of quality should require different production costs, especially when materials of different costs are used in the production. On the other hand, the quality cost can be considered as a function of relative quality (improvement or reduction) in comparison to the previous quality levels. In this scenario, the manufacturer pays an additional cost if the level of quality he chooses for this period differs from the quality in the last periods. The general idea behind this specification is that sometimes the quality cost comes from a change in technique or technology used in manufacturing. Moreover, a change in quality may require the manufacturer to adjust his production, which is costly to the manufacturer. The cost structure applying the actual quality level condition looks similar to the cost structure we have in
the static models. We choose the actual quality level cost structure for the multi-period model constructed in this section.

### 3.6.1 Variation in the multi-period model specifications

Before we get into the multi-period model we propose using as a comparison to the single period model, we discuss some specifications for the multi-period models. We address the general setups, which can be made specific given the demand and cost functions. The discussions into the various specifications of the multi-period problems reinforce the complexity of the issue and suggest that a single model setup is likely not to account for all the factors included in the multi-period product quality optimization problem.

Assuming a simplest form of the quality perception, only the quality of the last period and the quality of this period matter to the consumers. Under this specification, we can write the objective functions for the manufacturer and the retailer as:

**Retailer’s Profit:**  
\[ \Pi_R = P_t \cdot Q_t(P_t, \hat{\theta}) - C_t^R(Q_t(P_t, \hat{\theta})) \]  
(3.24)

**Manufacturer’s Profit:**  
\[ \Pi_M = w_T \cdot Q_T(P_T, \hat{\theta}) - C_T^m(Q_T(P_T, \hat{\theta}), \theta_t) \]  
where \[ \hat{\theta} = \psi(\theta_{t-1}, \theta_t) \]  
(3.25)

The quality function, \( \psi \), represents the consumer’s perception regarding the product quality. It is a function of the past period quality and this period quality. The relative importance between the last period and this period quality is arguable. It is possible that the quality of the last period product matters more to consumers because the consumers have observed and tested the change of the last period, whereas the quality of this period is still unknown to them. On the other hand, the quality of this period can matter more because it is relevant to the current purchase. The relative importance must be specified for the explicit solution section.
Instead of the actual level of quality, the difference in quality may play a role in determining the cost of quality. Assuming the two-period relation, the distribution channel objectives are described as

\[
\text{Retailer’s Profit: } \Pi_R = P_t \cdot Q_t(P_t, \hat{\theta}) - C^R_t(Q_t(P_t, \hat{\theta}))
\]

\[
\text{Manufacturer’s Profit: } \Pi_M = w_t \cdot Q_t(P_t, \hat{\theta}) - C^m_t(Q_t(P_t, \hat{\theta}), \tilde{\theta})
\]

where \( \hat{\theta} = \psi(\theta_{t-1}, \theta_t) \)

and \( \tilde{\theta} = \varphi(\theta_t - \theta_{t-1}) \) \quad (3.26)

In this setting, the consumer’s perception is still described in the absolute quality levels. However, instead of the current period quality, the manufacturer’s cost depends on \( \tilde{\theta} \), which is a function of the relative difference between the past period quality and this period quality. This cost specification focuses on the quality change or “improvement” rather than the actual level of quality. The simplest case assumes that if there is no change in the quality level from the last period, the cost of quality change is equal to zero.

We may expand this specification to consider the actual level of quality as well as the change in quality. The specification for the manufacturer’s profit becomes

\[
\text{Manufacturer’s Profit: } \Pi_M = w_t \cdot Q_t(P_t, \hat{\theta}) - C^m_t(Q_t(P_t, \hat{\theta}), \tilde{\theta}, \theta_t) \quad (3.27)
\]

where other specifications remain the same as in (3.26).

Similarly, the consumer’s perception can be expanded to include the relative level of quality as well. In this case, the consumers display a habit persistence nature, where they grow accustomed to the product and do not like change. The term representing the relative quality appears in the consumer’s quality perception function, \( \psi \). The model is similar to (3.26), with a minor adjustment in the consumer’s perception function: \( \hat{\theta} = \psi(\theta_{t-1}, \theta_t, \theta_t - \theta_{t-1}) \).
To find the solutions of the multi-period problems, we start by solving backward from the retailer’s optimization. This is going to be the same as the static model because retailer only has retail price, which is a one period variable, as a choice variable. This first step provides us with the retail price as a function of wholesale price and quality. Note that the quality variables appeared in the retail price function come from two periods: the current quality and the last period quality. Now, the manufacturer optimizes the total stream of profit by choosing the current period wholesale price and the current period quality. With quality of this period linking to the next period profit, manufacturer chooses quality that maximizes profits of the two periods. Lastly, given an initial value of quality, we solve for the sequences of the optimal quality levels and the optimal wholesale prices.

Even if the firm optimization problem spans multiple periods, the problem remains similar to that of single period problem if there is no connections across periods. The characteristics of the optimization problem depend largely on the specification of inter-period connection. We propose one possible setup of the problem in this section; although we acknowledge that several specifications are plausible depending on which quality story we want to emphasize.

3.6.1 The Multi-Period Quality Stock Model

The static model ignores the fact that firms may be selling the same branded product to the same set of customers for an extended period of time. In such case, product quality may impact consumers’ perception of a product for several periods. If the quality information stays with consumers for multiple periods, the multi-period model is more appropriate in describing the firm’s decision making process. We build a model that considers quality as a path-dependent variable. Consumers regard the term “quality” as a sum of product performance. At one extreme, we may assume consumers consider the entire past history of quality variables and calculate
“quality measure” in some kind of discounted sum of all past performances. Alternatively, the quality associated with a finite number of past periods matters to the consumers. In this section, we consider the optimization problem where the manufacturer chooses quality in a non-channel setup. We later extend the discussion into the distribution channel setup. We start by outlining the setup of the firm’s optimization problem in a multiple period setting. Then, we introduce the product quality component into the setup.

The model is modified slightly and a concept of “quality stock”, or more appropriately “stock of goodwill”, is introduced into the model. We assume that the consumer demand depends on a stock of goodwill toward the product, denoted as $A$, which is accumulated through the previous product quality (or product “performance”). In each period, the firm may invest in a quality variable (a flow variable), namely $a$, that will increase the level of the perceived quality stock. This is very similar to the brand name concept since the current level of quality perceived by consumers relies on the past performance of the same product. We assume the change in the quality stock follows the form:

$$ A_{t+1} = A_t + g(a_t) - \rho(A_t) $$  (3.28)

Note that the current product quality, $a$, contributes to the perceived quality stock in a functional form, $g$, which is assumed to be monotonic (decreasing) and its inverse exists. We normally assume the first derivative of $g$ is smaller than unity, indicating one unit of the flow variable $a$ leads to a smaller impact on the quality stock. The quality stock also deteriorates every period at the rate $\delta$, which depends on the current level of stock.

Another possible specification for quality linking through time is the situation when the current quality level is a function of quality from the past purchase units.

$$ A_{t+1} = \Psi(A_t, A_{t-1}, ...) $$  (3.29)
The function can be a weighted average of the previous quality levels for finite or infinite periods. We normally believe that the more recent purchase is more crucial to the consumer’s perception than the older purchase; hence, the more recent quality has more weight toward the overall quality conception.

For now, we focus on the quality specification represented by equation (3.28). A single period problem for firm’s optimization problem when demand depends on quality stock is assumed to be

$$\Pi_i = P_i \cdot D_i(P_i, A_i) - C_i(D_i) - \gamma_i(a_i)$$  \hspace{1cm} (3.30)

which implies that the cost of quality is separable from the other input cost. Under an assumption of discrete time setting, the optimization problem is written as

$$\text{Max}_{P,a} \sum_{t=0}^{T} \left( \frac{1}{1+r} \right)^t \left[ P_i \cdot D_i(P_i, A_i) - C_i(D_i) - \gamma_i(a_i) \right]$$  \hspace{1cm} (3.31)

Subject to \( A_{t+1} = A_t + g_t(a_t) - \rho_t(A_t) \) for \( t \in \{0,1,\ldots,T\} \)

3.6.2 Solving the Optimization: Discrete-Time Case

Now, we proceed to solving the optimization problem with product quality in infinite time setup. The optimization problem in this case is described as:

$$\text{Max}_{P,a} \sum_{t=1}^{\infty} \left( \frac{1}{1+r} \right)^t \left[ P_i \cdot D_i(P_i, A_i) - C_i(D_i) - \gamma_i(a_i) \right]$$  \hspace{1cm} (3.32)

Subject to \( A_{t+1} = A_t + g_t(a_t) - \rho_t(A_t) \) for \( t \in \{0,1,\ldots,T\} \)

and \( A_{t=1} = A_0 \).

We may reasonably assume that the constraints are binding. The corresponding Lagrangian equation is written as
The firm chooses the series of $P_t$ and $a_t$ to maximize the profit. The corresponding first order conditions are of $P_t$ and $a_t$ as well as the multipliers $\mu_t$ and $\nu$.

The Optimal Condition from Price

The first derivative for $P_t$ is

$$
\left( \frac{1}{1+r} \right)^t \left[ D_t + P_t \cdot \frac{\partial D_t}{\partial P_t} - \frac{\partial C_t}{\partial D_t} \cdot \frac{\partial D_t}{\partial P_t} \right] = 0
$$

(3.34)

which is equivalent to stating that

$$
\left( \frac{1}{1+r} \right)^t \cdot \frac{\partial \Pi}{\partial P_t} = 0
$$

The optimal condition suggests the static nature for the solution of $P_t$. The optimal prices depend on the same optimal condition in every period. In the case of a constant elasticity of demand: $D_t = kP^\varepsilon A^\alpha$, the optimal price for period $i$ is equal to

$$
P_i = c_i \cdot \left( \frac{\varepsilon}{1+\varepsilon} \right)
$$

(3.35)

Under this special case of constant elasticity demand, the optimal price is proportional to the unit cost. If we further impose a constant marginal cost assumption, the above proportion is constant throughout all periods and depends only on the magnitude of the price elasticity. Since $\varepsilon$ is generally considered to be less than -1, the ratio $\left( \frac{\varepsilon}{1+\varepsilon} \right)$ is greater than one, which confirms that retail price is always larger than the unit cost. This is effectively the same result as in the previous chapters.
The Optimal Condition from Flow of Quality

The first order condition with respect to $a_t$ is:

$$
\left( \frac{1}{1+r} \right)^t \left( -\frac{\partial \gamma_i}{\partial a_t} \right) + \mu_t \left( -\frac{\partial g_t}{\partial a_t} \right) = 0 \quad (3.36)
$$

which involves the value of multiplier $\mu_t$, or the shadow value of quality stock. Assuming a constant cost of $a, \gamma$, we may compare the optimal decisions between period $t$ and $t+1$:

$$
\frac{\mu_t}{\mu_{t+1}} = (1+r) \cdot \frac{\left( \frac{\partial g_{t+1}}{\partial a_{t+1}} \right)}{\left( \frac{\partial g_t}{\partial a_t} \right)} \quad (3.37)
$$

The ratio on the right hand side is the ratio of the marginal changes in $A$ with respect to the changes in $a$. The marginal change in quality stock with respect to a change in quality flow is the consumer’s perception of current level product quality that contributes to the consumer’s stock of goodwill and brand name of the product. From the equation of $A$, this is the marginal contribution that $a$ has on the stock of $A$ in the next period through the function $g$:

$$
\frac{\partial A_t}{\partial a_t} = \frac{\partial g_t}{\partial a_t}. \quad \text{The optimal condition for } a \text{ then states that the ratio of shadow prices across period is a discounted ratio of the marginal contribution of } a. \text{ The ratio of the marginal contribution of } a \text{ is equal to the discounted shadow price ratio.}
$$

The assumption for the cost and contribution of $a$ may impose a certain outcome for this problem. For example, if the cost of $a$ is constant, there is no incentive to invest in the stock of $A$ and build it up in earlier periods to gradually reach the optimal, long-run level of quality stock.

---

5 Assuming a constant cost of quality may sound too restrictive. We will attempt to ease up this restriction through the use of quality transformation function $g$. By reducing the impact of quality flow, $a$, we effectively produce similar (but not the same) effect as having increasing cost of quality.
The firm may choose to invest right away to adjust the initial stock level to reach the optimal level and spend the remaining time maintaining the stock of A to its optimal level by replenishing the depleted portion, suggesting that \( g(a_t) = \rho(A_t) \).

Noticeably, the optimal condition of \( a \) does not provide the further interpretation for the optimal choice of \( a \). We will need more explicit solution to achieve a more in-depth discussion of the optimal quality flow, by solving the optimization problem given functional specifications. We first consider the problem for the two-period case then we extend the solutions into a general, infinite-period situation.

### 3.6.3 The two-period Model

For the simplest case, the manufacturer chooses prices for two periods. The demand depends on the price and stock of perceived quality. In addition to the prices, the manufacturer chooses a level of first period quality, \( a \), which contributes to the stock of quality in the second period. After the second period, the production concludes and the firm computes the profits.

The two-period optimization problem is written as

\[
\max_{P_1, P_2, a_1} \left[ P_1 \cdot D_1 - C_1(D_1) - \gamma(a_1) \right] + \left( \frac{1}{1+r} \right) [P_2 \cdot D_2 - C_2(D_2)]
\]

Such that \( A_2 = A_1 + g(s) - \rho(A_1) \) \hspace{1cm} (3.38)

The constraint shown above is binding so we can substitute in \( A_2 \) for the optimization equation. Similar to the original setup, the first order conditions for prices over the two periods are structurally the same. Assuming the constant elasticity of demand specification\(^6\), the optimal

---

\(^6\) This is not quite necessary because the optimal relation with elasticity is still correct even in the case where the elasticity is not constant. However, by assuming constant elasticity, the right hand side of the optimal condition contains only fixed and known parameters.
price of each period is independent from the information in another period. The optimal price for both periods are shown as

\[ P_i = c_i \cdot \left( \frac{\epsilon}{1+\epsilon} \right) \quad \text{for } i = 1,2 \quad (3.39) \]

There is a slight change in the first order condition of quality flow, \( a \), when compared to the original multi-period setup. With the constraint is substituted into the maximization problem, the derivative with respect to \( a \) involves the derivative of demand:

\[ -\frac{\partial \gamma}{\partial a_1} + \left( \frac{1}{1+r} \right) \left[ P_2 \cdot \frac{\partial D_2}{\partial A_2} \frac{\partial A_2}{\partial a_1} - c_2 \cdot \frac{\partial D_2}{\partial A_2} \frac{\partial A_2}{\partial a_1} \right] = 0 \quad (3.40) \]

The optimal choice of \( a \) depends on its functional form, \( g \). If \( a \) enters into \( A \) in constant proportion or linearly, the optimal \( a \) is just the argument inside the bracket times the relevant coefficient. Note that the condition of the optimal flow of \( a \) is going to depend on the current price because of the derivative of demand with respect to \( a \) involves the price variable.

In addition to the usual constant cost assumption, we need to settle for a function of \( g(a) \), which is the contribution of quality flow on the perceived quality stock. The function \( g(a) \) is assumed to be increasing in \( a \) at a decreasing rate \((0 < \frac{\partial g}{\partial a} < 1 \text{ and } \frac{\partial^2 g}{\partial a^2} < 0)\), implying a weakening contributing effect of quality flow on quality stock\(^7\). We choose the function for \( g \) to be \( g(a) = 2 \cdot a^{1/2} \). In association with the constant elasticity demand assumption, the corresponding optimal decision translates into

\[ \left( \frac{1}{\gamma} \right) \left( \frac{P_2 - c_2}{1+r} \right) (\alpha \cdot k \cdot P_2 \epsilon) = \left( (1-\delta) \cdot A_1 + 2 \cdot a^{1/2} \right)^{(l-a)} \cdot a^{1/2} \quad (3.41) \]

\(^7\) This assumption is not necessary. We may try other assumptions base on the story motivated the quality variable.
Given the marginal cost and other parameters are constant and known, the left hand side of the above equation is just a constant. The right hand side contains a non-linear multiplication of the quality flow variable. Further simplification of the optimal quality may require greater computational power.

The above solution relies on the assumption that the before-discounted cost of \( a \) (denoted by \( \gamma \)) is constant. The constant marginal cost assumption arguably voids the firm of the reality of any possible adjustment cost effects. However, we argue that since the contribution of \( a \) on \( A \) is non-linear, the adjustment cost effects can appear through the contribution rather than on the cost. With a decreasing effect, it will be costly for firm to invest in a significantly large level of quality in one period to substantially improve the quality stock. A major change in the perceived quality stock level may optimally require several periods of sustained investment in quality flow.

### 3.6.4 The extension to the multi-period model

When we extend the solution to the infinite period problem (with initial conditions), the optimal conditions are similar to that found in the two-period setting. In the case of constant elasticity demand, the optimal price depends only on the manufacturing cost of the current period:

\[
P_t = c_t \cdot \left( \frac{\varepsilon}{1+\varepsilon} \right)
\]

(3.42)

The ratio between the price and the cost is constant for all period, indicating that the optimal price adjusts according to the growth in cost. If the manufacturing cost is assumed constant (before discounting), the optimal price is the same for all periods. It is clear that the optimal pricing corresponds to the manufacturing cost structure. If the manufacturing cost does not change, there is no change in the pricing schedule.
The solution for the flow of quality is similar to what we find earlier, having the optimal flow depends on the current period stock of A. As the problem is solved sequentially, the current level of A is solved from the past level of A so on. The resulting optimal condition for $a$ at period $t$ is given by

$$
\left(\frac{1}{\gamma}\right) \left(\frac{P_{t+1} - c}{1 + r}\right) \left(\alpha \cdot k \cdot P_{t+1}^\varepsilon\right) = \left[(1 - \rho) \cdot A_t + 2 \cdot a_t^{1/2}\right]^{1-\alpha} \cdot a_t^{1/2} \quad (3.43)
$$

where $P_{t+1}$ follows the optimal condition stated earlier. Although the optimal condition of quality, $a$, requires the knowledge of the next period optimal prices, it is not problematic because the optimal path of price is known at any given time. In addition, the stock of quality, $A$, at time $t$ is also known to the firm at time $t$. Consequently, the entire optimal path of quality flow, $a$, can be solved using the above optimal relation. We rely on the simulation to solve for the path of optimal flow.

We focus on finding the optimal quality stock and the quality level paths when the costs are known to be fixed over time. We assume the price elasticity, $\varepsilon = -2$, the quality elasticity, $\alpha = 1.2$, the discount rate $= 0.1$, the quality stock depreciation rate, $\rho = 0.2$, the demand constant, $k = 1$, the non-quality cost, $c = 1$ and the quality elasticity, $\gamma = 0.2$. We simulate the quality paths for different starting points of the quality stock, $A$. The results for the optimal levels for quality application given different level of $A$ are shown in Figure 3.22, with the corresponding optimal quality stock level shown in Figure 3.23.
The X-Axis represents time period and the Y-Axis is the unit of quality for both figures. Figures 3.22 and 3.23 indicate that there are steady state levels for the optimal quality stock and the quality application. Given the parameter values, the manufacturer’s long-run optimal quality stock settles around 26.1 and the optimal quality application is at approximately 6.86. If the manufacturer starts with the quality stock lower than 26, he will choose the quality per period (a)
to be smaller than 6.86 initially and gradually increase the quality application per period until it reaches 6.86 as the quality stock reaches the steady state level. In the other direction, if the manufacturer starts with the quality stock higher than 26, the quality per period input is selected initially to be larger than 6.86. Then it is gradually decreased each period, which effectively lowers the quality stock until it reaches the steady state level. The manufacturer chooses to decrease or increase the stock gradually instead of quick adjustment, which can be done by inserting a large volume of quality flow if the stock is too low or inserting a small volume if the stock is too high. The quick adjustment would bring the manufacturer to the optimal steady state stock level quickly but it may be too costly for the manufacturer. Notice that the quality cost per unit (γ) is assumed to be constant overtime; yet, the optimal paths all exhibit gradual changes. This optimal behavior suggests the large magnitude adjustment is too costly for the manufacturer. The gradual adjustment can come about even with the constant unit cost. In addition, the reason for gradual changes may as well come from the concave-shape contribution function, g(a). Because the quality flow contribution rate to the quality stock weakens as the size of the flow increases, the quality flow becomes less effective at a high level. It is more effective to apply a gradual change for the stock adjustment. For the starting quality stock level above the steady state level, the gradual incline in the quality stock may result from the manufacturer’s decision not to keep the quality stock at the high level. Although the high quality stock is generally good for the manufacturer, it is costly to maintain at the high level. If the starting quality stock is higher than the optimal level, the optimal quality input from the manufacturer will not be high enough to maintain the high level quality stock. The depreciation is larger than the new flow and the overall stock gradually drops toward the steady state level. The simulations
indicate that regardless of the starting stock positions, the manufacturer uses a gradual change in
the quality per period flow to adjust the overall quality stock over time.

When the parameters for the optimization problem change, we have different solutions for
the optimal steady state quality stock level. Figure 3.22 and 3.23 indicate that the manufacturer
will need time to adjust to the optimal steady state level unless the initial stock is at the optimal
long-run level. However, if the change in a parameter value happens frequently, the
manufacturer may not have enough time to adjust to the steady state level. Instead, the
manufacturer will aim at a moving target, with the quality flow per period being optimally
adjusted for the next period. But he never reaches any permanent steady because the target
steady state keeps changing. In such a case, we observe changes in the optimal path every time
the parameter changes value.

Extension to the Distribution Channel Model

Up to this point, we focus on the case of a single firm optimization. We now extend the
result into the distribution channel setting. Because quality is a choice variable usually reserved
to the manufacturer of the product, the firm presented in the earlier multi-period setting setup
corresponds more appropriately to the manufacturer in the distribution channel setting. The
retailer is assumed to behave under the same condition as in the earlier distribution channel
setup.

Because there is no change in the problem setup of the retailer, the resulting optimal
decision of the retailer remains the same. The retailer chooses only the optimal retail price in
each period, given the wholesale price and the product quality. Under the constant elasticity of
demand assumption, the optimal retail price is described by

$$P^*_t = \left(\frac{\varepsilon}{1+\varepsilon}\right) \cdot (w_t + r_t)$$  \hspace{1cm} (3.44)
The optimal pricing decision feeds into the optimization problem of the manufacturer. The corresponding optimal pricing decision for the manufacturer in the multi-period setup is similar to that of before:

\[
 w_i^* = \left( \frac{\varepsilon}{1 + \varepsilon} \right) \left( c_i + \frac{1}{\varepsilon} r_i \right) 
\]

(3.45)

The pricing schedule again suggests that the manufacturer is concerned about the parameters of the current period; namely, the manufacturing cost and the retail operating cost. Consequently, if the costs remain constant throughout, the optimal prices stay constant for all periods as well. The optimal retail price schedule is not related to the choice of the flow variable \(a\). The flow of quality, \(a\), enters into the argument of the manufacturer directly through the demand, not through the retail price. This implies no change in the optimal condition regarding the flow of \(a\). For the initial demand setup, the corresponding optimal quality follows the optimal relation below:

\[
 -\gamma + \left( \frac{1}{1 + r} \right) \left( w_{i+1} - c \right) \left[ \frac{\partial D_{i+1}}{\partial A_{i+1}} \frac{\partial A_{i+1}}{\partial a_i} \right] = 0 
\]

(3.46)

The result is similar to equation (3.36) except now the optimal condition also contains the (deterministic) wholesale price.

### 3.6.4 An Alternative Specification of Demands

The optimal solution relies on the specification of demand and how the product quality enters into the consumer demand. In this section, we offer an alternative specification for the demand, which offers a different story on how the quality impacts demand. We propose that an alternative demand take the form \( D_i = k \cdot P_i^{\varepsilon + \beta A} \). This new demand specification implies the stock of quality alters the elasticity of demand rather than being a multiplicative component as before. The change in elasticity due to \(A\) may arise through a change in perception of the brand.
over time and the change in consumer loyalty to the brand. The coefficient $\beta$ is assumed positive, implying that the overall price elasticity increases (in absolute terms) as the stock of A grows.

Consumers become more inelastic about the change in the price when their perceived quality stock increases. Besides the alteration in the demand specification, we assume everything else remains under the same assumptions as the previous setup.

To keep the narrative compact, we skip the setup and the derivatives of the implicit first order conditions (which are nearly identical to these previously, except for the shape of demand) and move straight toward the results. The corresponding optimal pricing decision is

$$P_t = c_t \left( \frac{\varepsilon + \alpha \cdot A_t}{1 + \varepsilon + \alpha \cdot A_t} \right)$$

(3.47)

We can see that the optimal condition for price follows the same implicit relationship as the one we implied in the original demand specification. It is still the multiplication of manufacturing cost and some ratio related to the price elasticity. However, we know that in this case the elasticity is not constant as before. More specifically, the elasticity depends on the current value of quality stock, implying non-constant optimal prices for all periods. As we know, the current stock of A is an accumulation, less the depreciation, of the flow of $a$, which occurs in all previous periods. Hence, the pricing decision in this case relies on the past decisions on the flow variable, $a$.

The optimal condition for quality flow is given as

$$- \frac{\partial \gamma}{\partial a_t} + \left( \frac{1}{1 + r} \right) \left[ P_{t+1} \frac{\partial D_{t+1}}{\partial A_{t+1}} \frac{\partial A_{t+1}}{\partial a_t} - c_{t+1} \frac{\partial D_{t+1}}{\partial A_{t+1}} \frac{\partial A_{t+1}}{\partial a_t} \right] = 0$$

(3.48)

We impose the functional forms and cost assumptions to solve for the optimal flow of $a$.

Leaving the assumption for $g(a)$ unspecified, the optimal condition above provides the following optimal relationship:
(g(a_i)) \cdot \ln P_{t+1} + \ln(g'(a_i)) = \\
\ln \left( (1 + r) \cdot \left( \frac{1 + \varepsilon + \alpha A_t}{-c \cdot k \cdot \alpha \cdot \ln P_{t+1}} \right) \right) \cdot \gamma_i - (\alpha \cdot (1 - \rho) \cdot A_t + \varepsilon) \cdot \ln P_{t+1} \quad (3.49)

Since the terms P_{t+1} and A_t are known at the decision making time, the right hand side is known (as constant) at period t. The only variable present is the flow variable, a_i on the left hand side. If the transformation function g follows the form \( g(a) = 2 \cdot a^{1/2} \), the left hand side is modified into:

\((g(a_i)) \cdot \ln P_{t+1} + \ln(g'(a_i)) = 2 \cdot (\ln P_{t+1}) \cdot a_i^{1/2} - \frac{1}{2} \cdot \ln a_i \quad (3.50)\)

Similar to equation (3.43), the optimal solutions can be solved out numerically.

3.8 Model Extensions: The Product Quality as a Cost Reducing Variable

The purpose of quality in this model is to stimulate the consumer demand and to increase sales for both the retailer and the manufacturer. Naturally, we expect the product with quality improvement to have a higher production cost. The manufacturer’s decision to insert quality entails a higher production cost for the firm. However, product quality can have another function besides inducing the demand. Instead of the product quality improving the characteristic of the product, an improvement in quality may be a change on the product in such a way that it lowers production costs. Unlike the model discussed previously, the quality is assumed not to impact demand directly but rather to influence the firm’s costs. The cost reduction benefit of quality may impact either the retailer or the manufacturer. In addition to a reduction in manufacturing cost, the quality increase can be an improvement that reduces the retail cost (such as transportation, storage or shelving costs). We will discuss both possibilities starting from the manufacturer’s cost saving benefit.
Manufacturer Cost Saving

In this scenario, the quality improvement aims to reduce the production cost. In a simple way, we may look at this quality as a permanent technological improvement with continual cost in applying the technology (as opposed to one-time, R&D investment in prior periods). If the manufacturer wants to have this quality improvement, he has to pay some cost to acquire it per unit of product being produced. Incorporating this scenario into the model, we modify the objective functions slightly. The profit functions for the retailer and the manufacturer can be represented in equations (3.1) and (3.2).

Because the quality does not directly induce demand, the quality variable will not appear as an argument in the demand function. In this case, the product quality variable appears only in the manufacturing cost function. Now, the retail price is a function of the wholesale price and the product quality (from manufacturer’s point of view) but the demand is not a direct function of quality. Consequently, the general forms of the first order conditions are similar to those presented in Section 3.1, except for the optimal condition with respect to quality. Several terms appearing in the previous manufacturer’s first order condition with respect to product quality are dropped to the following first order condition with respect to the quality variable:

\[ \frac{\partial \theta}{\partial P} \cdot \frac{\partial P}{\partial \theta} - \frac{\partial C_M}{\partial \theta} = \frac{\partial C_M}{\partial Q} \cdot \frac{\partial Q}{\partial P} \cdot \frac{\partial P}{\partial \theta} \]  

(3.51)

The marginal gains are collected on the left hand side and the marginal costs are collected on the right hand side. Since quality in this case is assumed to reduce the manufacturing cost, the first derivative of the manufacturing cost with respect to quality \( \frac{\partial C_M}{\partial \theta} \) is negative and should be considered as a marginal benefit. Another term represents an increase in revenue due to an increase in product sold. We rationalize that, since quality improvement reduces manufacturing
cost, the quality should negatively impact the retail price: \( \frac{\partial P}{\partial \theta} < 0 \). Hence, an increase in quality leads to a decrease in retail price and an increase in quantity being sold. As a result, the revenue of manufacturer increases. The marginal benefit must equal to marginal cost, which is an increase in the manufacturing cost due to the expanded demand. In general, the optimal conditions of firms in this setup are similar to the result we have in the previous model, except that quality has a relatively straight-forward impact on the manufacturer’s profit due to the lack of quality impact on the consumer demand.

**Retailer Cost Saving**

As shown above, the model where cost saving occurs to the manufacturer is straightforward. Because the manufacturer is deciding on the quality level, the direct benefit of quality on cost saving is easily utilized. If the benefit of cost saving falls onto the retailer rather than the manufacturer, it is interesting to see how much quality will be applied by the manufacturer for the benefit of the retailer. Rationally, the cost saving benefit on the retailer must indirectly and partially return to the manufacturer to motivate the manufacturer to pay for the quality in the production process. However, we suspect that the amount of quality applied by the manufacturer in this case will not be at the efficient level since the benefit is felt by the retailer rather than the cost-bearer manufacturer. Quite possibly, the retailer must find a method to encourage the manufacturer to increase his quality level.

To understand the problem, we return to the objective functions for the manufacturer and the retailer shown in (3.1) and (3.2). Because the retailer cannot choose quality level, the first order condition of the retailer stays implicitly the same.

\[
Q - \frac{\partial C_R}{\partial Q} \cdot \frac{\partial Q}{\partial P} = -P \cdot \frac{\partial Q}{\partial P}
\]  

(3.52)
Nonetheless, the retailer cost function has quality variable embedded into it. The resulting explicit solution for the retail price as a function of wholesale price and quality will be different from the earlier condition in (3.3).

For the manufacturer, the optimal condition with respect to the wholesale price is the same as before. However, the optimal condition with respect to quality differs:

\[
\frac{\partial Q}{\partial P} \cdot \frac{\partial P}{\partial \theta} = \frac{\partial C_M}{\partial Q} \cdot \frac{\partial Q}{\partial P} \cdot \frac{\partial P}{\partial \theta} \quad (3.53)
\]

Comparing to the previous case, the direct benefit term, \( \frac{\partial C_M}{\partial \theta} \), vanishes from the optimal condition. Further manipulation of the above condition tells us that the manufacturer chooses the production such that

\[
w = \frac{\partial C_M}{\partial Q}. \quad (3.54)
\]

Since the manufacturer’s cost function does not have a quality variable as an argument, the first order condition with respect to quality does not provide insight into the optimal quality level. We must look at the first order condition with respect to the wholesale price to see whether the manufacturer wants to invest in quality. According to the objective function above, the manufacturer’s first order condition with respect to price can be computed as:

\[
Q + w \cdot \frac{\partial Q}{\partial P} \cdot \frac{\partial P}{\partial w} = \frac{\partial C_M}{\partial Q} \cdot \frac{\partial Q}{\partial P} \cdot \frac{\partial P}{\partial w} \quad (3.55)
\]

At first glance, the optimal condition does not provide information for the optimal quality. However, this is not correct. The product quality is embedded inside the demand function and would show up when we specify the functional forms. We should be able to solve for the explicit solution and compare the results between the manufacturers cost saving and the retailer cost saving if the demand and cost functions are specified.
3.9 Concluding Comments

In this chapter, we investigate the impact of product quality on the channel outcomes and performance of firms. We focus our study on the quality of product that can be controlled by the manufacturer and the improvement is per unit improvement rather than overall brand improvement. Although the general perception is that the additional control the manufacturer has on quality variable (which is a demand-stimulating variable) should improve the firm performance and increase its power in the channel, our results suggest that it is not necessarily true. The overall results depend heavily on the specification of demand and costs as well as the magnitude of parameters associated in the optimization problem. In many cases of parameters, the manufacturer controls on quality can become a burden rather than a blessing since it incurs higher cost per unit of production, which the manufacturer cannot recover due to smaller returns in price or fewer responses in demand. Product quality may become a bane to the distribution channel if it is not properly compensated.

We present the distribution channel model where the manufacturer picks the wholesale price and the product quality level. In the static setting, we find that, depending on the specification of the quality cost, the manufacturer’s profit relative to the retailer’s profit can be either higher or lower. Simulations for the quality cost and the elasticity suggest that the manufacturer generally tries to differentiate his product through the use of quality. The application of quality is relatively greater for the high price product. However, the product quality may cause the reduction in the demand if the use of quality drives the cost up to an undesirable level.

We also consider the quality choice in the multi-period setting. Realizing the variety in the specifications for the multi-period models, we choose to discuss the model with the stock of
quality. According to our specification, there exists an optimal long-run quality stock which the manufacturer would target for. The paths of the quality build-up from different starting quality stock level are similar. Regardless of whether the initial stock is higher or lower than the optimal level, the manufacturer would choose a gradual adjustment in the quality stock until it reaches the optimal long-run level, from where he continue to apply quality flow to sustain the optimal level.
Chapter 4: The Quality Choice for National Brand and Private Label Products

Generally, it is more likely that a product faces direct competition from comparable products. We modify our single product model to accommodate this scenario. In the new setup, the manufacturer produces a single product, which is on sale by the retailer alongside another competing product. Consumers are assumed to choose products based on prices, which reflect product quality. We focus now on the distribution channel with the manufacturing firm choosing product quality as well as its wholesale price when an alternative, competing product is present in the market. The manufacturer’s ability to choose quality allows the manufacturer to position the product on the platform of consumer’s preference. We are interested in the quality positioning decision as well as the impacts of other determining factors (such as manufacturing cost and quality cost) on the manufacturer’s quality decision.

Since we intend to limit our competition to two products, there are several scenarios we can investigate. In this study, we focus on the competition and the consumer’s choice between the national brand and the private label products. There are several reasons for this concentration. First, since we are focusing on the two-product setup, it is reasonable to choose products that are directly competitive. It is easily observed that many private label products are designed to compete with the leading national brand, whether from the close imitation of products and packaging material or their shelving position in the supermarket. In addition, private labels are gaining a larger share in supermarket sales and becoming a more threatening competitor to many leading national brand manufacturers. The leading national brand and its private label rival
counterpart are a more reasonable paring for direct competition than the leading national brand and the second national brand.

Second, we focus primarily on the production’s decision throughout the study; consequently, by allowing only one national brand, we imply that there is one manufacturer controlling a product. This allows for a more concise and precise scope of study, which centers at the production stage; namely, the manufacturer’s quality decision. Because private label products are normally designed to imitate the leading national brand, the relative quality measure and the relative consumer’s “quality” preference, which includes brand loyalty and brand presence, are also relevant for the quality discussion. This allows us to investigate the quality choice model focusing on the difference in quality without the complication of the horizontal product characteristics. By focusing on the direct paring between the national brand and private label product, we can assume that the only difference between the two products is their quality.

In this chapter, we attempt to learn about manufacturer side of story when dealing with the competition from private label. We start by modeling the demand function which is modified to incorporate both products via the use of consumer’s preference and the distribution of consumer characteristic. Next, we list the assumptions and modifications to the demand and the supply sides that help characterize the distribution model. The modified demand is then included into the distribution channel model of one national brand manufacturer and one retailer to derive the pricing and quantity decisions. Some alterations in model assumptions which deviate from the earlier models are discussed and explained. We then apply simulations to the optimal conditions to illustrate the optimal solutions to the distribution channel problem.
4.1 Model Setup for the Demand Side

This section presents a modification of the consumer demand to incorporate two products and their quality at the same time. The demand function is a result of consumers deciding on NB and PL using their prices and quality as determining factors. We emphasize the importance of quality in the consumer preference and derive the demand from the preference as well as the consumer’s distribution. By fundamentally deriving the demand from consumer preference and consumer distribution, we can observe how the two products interact, which help us better understand the interplay between the two products. In addition, we have more flexibility in adjusting the components of demand that can incorporate more stories. The demand derived in this section is used in the objectives of the manufacturer and retailer in the next section.

4.1.1 A Modified Consumer Location Model

Motivated by the consumer location model, this section develops a model of the consumer demand, which incorporates consumers choosing between the national brand product and the private label product. We assume consumers are distributed along a [0, 1] segment representing the normalized consumer characteristic, \( \theta \), which is assumed to be a continuous variable. There is a corresponding reservation price that a consumer of a given characteristic level is willing to pay for either the national brand product or the private label. The reservation schedule provides the willingness to pay information of consumers based on their characteristic levels. We assume the characteristic, \( \theta \), affects the reservation price, \( r \), of consumers such that

\[
r'(\theta) > 0 \quad \text{and} \quad r''(\theta) \leq 0.
\]

The reservation price is increasing at a non-increasing rate as the value of consumer characteristic increases. Consumers with a higher characteristic level are willing to pay more for the product than consumers with a lower characteristic level. The corresponding characteristic
can be demographic variables, such as disposable income, or preference variables, such as brand
loyalty. The assumption implies that the consumers can be arranged along a normalized zero-one
line using their reservation price values and consumer’s characteristics. In addition, since the
consumer’s satisfaction depends on the product quality, \( \lambda \), which is assumed to be pre-
determined, the reservation price is a function corresponding to a specific value of the quality
parameter.

With the above setup, the utility function of a consumer located at point \( x \) of the
characteristic line is defined as:

\[
U_x = \begin{cases} 
    r_{NB}(x) - p_{NB} & \text{if she buys national brand, } NB \\
    r_{PL}(x) - p_{PL} & \text{if she buys private label, } PL \\
    0 & \text{if she chooses neither}
\end{cases}
\]

(4.1)

We further assume that the reservation price of the national brand is always at least as
great as the reservation price of the private label: \( r_{NB}(\theta) \geq r_{PL}(\theta) \ \forall \ \theta \). The consumers of any
given level of characteristic are willing to pay for the national brand at least as much as they
want to pay for the private label. This is the result of two influencing factors. First, the national
brand is assumed to be (generally) of a better quality. Secondly, the national brand usually is
associated with a higher level of brand loyalty, encouraging consumers to pay more for the
product.

The first derivatives of the reservation price schedules determine the difference in the
willingness to pay for the two brands. If \( r'_{NB}(\theta) > r'_{PL}(\theta) \ \forall \ \theta \), the difference between NB and PL
reservation prices is gradually increasing as the consumer characteristic increases. This implies
that consumers prefer the national brand relatively more and more as their characteristic
increases. It is more difficult to substitute the national brand product with private label as
consumer’s income grows.
Given the above specifications, the retail price of the private label never exceeds the retail price of the national brand, since any arbitrary consumer always values national brand more than the private label. If the private label price is higher, no consumers will buy the private label product. This situation implies that the private label is inferior to the national brand and the difference between the two is likely vertical rather than horizontal.

Throughout the chapter, the linear specification is primarily used as the specification of the reservation price schedule. The functional form of the reservation price for the national brand product is given as:

\[ r_i(\theta) = r_{i,0} + r_{i,1} \cdot \theta \quad \text{where} \quad i \in \{\text{NB, PL}\} \]  

The term \( r_{i,0} \) is the intercept of the reservation price indicating the minimum reservation price for consumers with the zero normalized value of characteristics. We assume that the minimum reservation price constant \( r_{i,0} \) is high enough to guarantee a purchase from consumers at any given level of \( \delta \). The slope of the reservation schedule is equal to \( r_{i,1} \), which indicates the change in the reservation price due to the change in the consumer’s characteristic. The linear specification implies that the degree of reservation price change, which comes from the change in characteristic, is always constant. Consequently, the degree of response is constant throughout all characteristic levels. We assume initially that the intercepts for the national brand and the private label are identical and allows only the slopes to vary. Figure 4.1 illustrates the reservation price functions for the national brand and private label products.
4.1.2 The Indifferent Consumer

Using the reservation price schedules, we identify the segments of consumers buying each of the products. The demand segments are separated by the indifferent consumers who gain equal utility by buying the national brand or the private label products. Since the reservation price functions are increasing in \( \theta \), we find the indifferent consumer by solving for \( \theta^* \) that satisfies

\[
 r_{NB}(\theta^*) - P_{NB} = r_{PL}(\theta^*) - P_{PL}. \tag{4.3}
\]

The condition can be shown graphically in Figure 4.2.
The bold two-way arrows indicate the utilities of the indifferent consumer: the top arrow is for when she buys national brand and the bottom arrow for private label. For the consumer to feel indifferent, the lengths of both arrows are identical, indicating that either choice return the same utility.

Given the linear specification for the reservation schedule, the two reservation prices are

\[
\text{National Brand Reservation Price: } r_{NB}(\theta) = r_0 + a \cdot \theta \quad (4.4)
\]

\[
\text{Private Label Reservation Price: } r_{PL}(\theta) = r_0 + b \cdot \theta \quad (4.5)
\]

Using the linear specification for reservation prices, we solve for \( \theta^* \).

\[
\theta^* = \frac{P_{NB} - P_{PL}}{a - b} \quad (4.6)
\]

The last person choosing the national brand is not the person who gains zero utility consuming the national brand product but rather the person, whose utility of consuming the national brand is the same as the utility of consuming the private label. Since the consumers have a lower price alternative, the national brand cannot fully charge the consumer her reservation price and leave her with zero utility. Consumers are better off switching to the private label to obtain some positive utility rather than sticking with the national brand.

For the initial setup, we assume that the consumers always purchase either of the products. This is done by assuming that the lowest reservation price is always high enough to persuade the last consumers to buy something. Consequently, the consumers are divided into two groups: the national brand consumers and the private label consumers, with the indifferent consumer location indicating the dividing point between the two groups. Consumers locating on the right side of \( \theta^* \) will purchase national brand product and consumers to the left of \( \theta^* \) will buy private label product.
4.1.3 The Distribution of the Consumer along the [0, 1] Consumer Characteristic Segment

To derive the consumer demand for either the national brand or the private label, we must identify the consumer distribution along the [0, 1] interval. The location of indifferent consumers is used in determining the range of consumers purchasing a specific brand; while the distribution of consumers reveals how many consumers are associated with each segment of the consumers. Different distribution functions yield different aggregated demand for the product even though the indifferent consumer’s locations remain unchanged. Because the reservation price schedules and the indifferent consumer locations are independent of the distribution form, the conditions determining the line segment are the same for all the distributions. The ranges for two groups of consumers are:

1. Consumers of private label: $[0, \theta^*]$

Assume for generality that the consumer distribution function takes the form $f(\theta)$ and the corresponding cumulative distribution is $F(\theta)$. The consumer demand for each product is categorized by the following intervals:

1. Demand for PL: $F(\theta^*)$
2. Demand for NB: $1 - F(\theta^*)$

Given a specification of the distribution function, the intervals can be used directly to derive the aggregated demand for national brand and private label.

4.1.4 Deriving Aggregated Demand

For the initial setup, we assume that the consumers are distributed uniformly across the [0, 1] interval. The assumption implies that there is an equal number of consumers at any given level of the consumer characteristics. According to the uniform distribution, the aggregated demand
for the nation brand product is $[1 - \theta^*]$. The aggregated demand for private label is as simple as $\theta^*$ for the uniform distribution. The segments of consumers corresponding to different product choices are shown below in Figure 4.3.

![Figure 4.3: Consumer Line and Demand Segments](image)

The aggregated consumer mass buying of NB is $[\theta^*, 1]$, which can be written in terms of prices as

$$D_{NB} = 1 - \left(\frac{1}{a-b}\right)\left[P_{NB} - P_{PL}\right].$$

(4.7)

The aggregated consumer mass buying PL is in $[0, \theta^*]$ interval, which is translated into

$$D_{PL} = \frac{1}{(a-b)}\left[P_{NB} - P_{PL}\right].$$

(4.8)

These aggregated demands can be used to compute the retailer’s and the manufacturer’s profits.

Up to this point, the focus has been on continuous distributions. Nonetheless, step functions and discrete distributions can be used in describing consumer’s distribution as well. Since the locations of indifferent consumers are independent of the distribution of consumer, we may derive the aggregated demand in a similar way.
4.2 The optimal Product Quality in the Two Products Setting

We focus on the role of product quality in determining the prices and other outcomes of distribution channel when there are two competing products offered to the consumer. We start by establishing assumptions regarding the supply side.

4.2.1 Additional Assumptions

Supply Productions

The source of private label supply is assumed to be “outside” manufacturers, meaning firms who do not own any brands of the same or similar products in the market. Since he does not have any brand associated to the product sold to the retailer, the outside option manufacturer can be assumed to behave like firms in a perfectly competitive market. We further assume that the retailer can always find a substitute for the outside option so the supply of private label is guaranteed. The price of the private label products supplied by the outside option is then equal to the marginal cost of production.\(^8\)

Product Characteristics

The national brand and private label products are assumed to differ in only one dimension: their quality. This is a vertical differentiation rather than the horizontal differentiation. Although we state that quality is a one dimensional measure, product quality can be an integrated measure of several characteristics such as physical quality, brand equity and advertisement impact. We restrict consumers to always prefer the product of a higher “quality”\(^8\)

---

8 This condition about the outside option manufacturer is similar to assuming the retailer owns a manufacturing plant. When the retailer owns a manufacturing plant, the “internal price” he pays for the supply of the private label is equal to the marginal production cost of private label.
to the product of a lower quality, if they are at the same price. We further assume the national brand product is generally of a higher quality than its private label counterpart.⁹

**Production Cost**

The cost of production depends on the product quality. A product with higher quality is more costly to produce than a product with lower quality. We assume the national brand manufacturer possesses skill and experience superior to the outside manufacturer; hence the cost of producing a product of the same quality is higher for the outside manufacturer than for the national brand manufacturer. We assume for now that the quality variable is exogenously determined by the retailer prior to this stage of the optimization problem. Only the manufacturer chooses the level of product quality taking into account the known level of private label quality.

**Cost Specification**

We continue to use the constant marginal cost assumption for both the manufacturing cost and the retail operating cost. In addition, we further assume that the operating costs for NB and PL are equal: $r_{NB} = r_{PL}$. This is reasonable enough considering that both products should require similar (if not the same) handling and management process.

**4.2.2 The Derivatives of Demand**

We establish in the earlier section the demand structure we use in this chapter. They are

\[
D_{NB} = 1 - \left( \frac{1}{a-b} \right) [P_{NB} - P_{PL}] \quad \text{for National Brand (NB) product and}
\]

\[
D_{PL} = \frac{1}{b \cdot (a-b)} \left[ b \cdot P_{NB} - a \cdot P_{PL} + (a-b) \cdot r_0 \right] \quad \text{for Private Label (PL) product.}
\]

---

⁹ This is not necessarily true in the actual practice. The private label products for higher-end supermarket chain can be of higher quality than the national brand counterparts.
As expected, demand of a single product depends on prices of both products. Both the NB demand and the PL demand are functions of NB and PL retail prices. A change in either of the retail prices results in a change in the demand of both products. We also note that the demand of one product depends on the quality of both products. The impact of quality comes through the parameters a and b, where a is the assigned quality of NB and b is the quality of PL.\(^{10}\)

The magnitudes of demand changes in response to a change in price can be shown through the first derivatives of demand functions with respect to retail prices:

**National Brand Demand:**

\[
\frac{\partial D_{NB}}{\partial P_{NB}} = -\frac{1}{a-b}, \quad \frac{\partial D_{NB}}{\partial P_{PL}} = \frac{1}{a-b}
\]

**Private Label Demand:**

\[
\frac{\partial D_{PL}}{\partial P_{NB}} = \frac{1}{a-b}, \quad \frac{\partial D_{PL}}{\partial P_{PL}} = \frac{-a}{b \cdot (a-b)}
\]

The first derivatives have the expected signs. The own-price derivatives are negative, indicating that the demand is decreasing when own-price increases. On the other hand, the cross-price effects are positive because an increase in the price of the rival product should lead to an increase in own-demand. Interestingly, the NB demand is affected by changes in the NB price and the PL price in equal magnitude. A unit increase in NB price brings about an equal impact on demand as a unit decrease in PL price.

\(^{10}\) The quality parameters, a and b, are the slopes of consumers’ reservation price schedules for the linear price schedule case. Generally speaking, the quality parameters should show up in the reservation price schedule as a determinant of consumer’s valuation of product. Since demand is derived from the information of reservation price schedule, demand will always be a function of quality parameter(s).
We solve the optimization problem back ward to solve for the optimal prices and quality, starting from the retailer optimization problem, then the manufacturer optimal pricing and finally optimal quality problems.

4.3 The Optimization Framework

4.3.1 The Retailer Optimization Problem

The retailer sells two products: NB and PL. We assume that the retailer manages PL brand; however, we maintain that the retailer does not own production plants and must contract out the production of PL to outside manufacturers. The retailer obtains PL products at the outside manufacturer’s production cost, which is assumed to be a constant marginal cost. The manufacturing cost depends on the quality level of the product; hence, the NB and PL manufacturing costs, \(c_{NB}\) and \(c_{PL}\), are functions of quality.

We further assume that for the same quality, the NB manufacturer is able to produce the product at a lower cost than the outside manufacturers. The NB manufacturer is assumed to have more experience and/or a better manufacturing process, which allows him to manufacture products at a lower cost than the contract manufacturer, given the same level of product quality. This condition manifests in the manufacturing cost of the national brand manufacturer is proportionally lower than that of the outside option manufacturer.

We assume the retailer applies a pre-determined constant markup, \(m\), when he sets the NB retail price. The resulting retail price for NB product can be described as

\[
P_{NB} = (1 + m) \cdot w_{NB}
\]  

(4.9)

The retailer freely chooses the retail price of the private label product. The resulting profit function for the retailer is given as
\[ \Pi_r = \left[ (1+m) \cdot w_{NB} \right] \cdot D_{NB} + P_{PL} \cdot D_{PL} - \left[ w_{NB} + r \right] \cdot D_{NB} - \left[ w_{PL} + r \right] \cdot D_{PL} \]

\[ = m \cdot w_{NB} \cdot D_{NB} + P_{PL} \cdot D_{PL} - w_{PL} \cdot D_{PL} + r \quad (4.10) \]

The retail operating cost \( r \) is constant for all units of product and is assumed to be identical for both NB and PL. The retailer chooses the retail PL price, \( P_{PL} \). The corresponding first order condition is

\[ \frac{\partial \Pi_r}{\partial P_{PL}} = m \cdot w_{NB} \cdot \frac{\partial D_{NB}}{\partial P_{PL}} + D_{PL} + P_{PL} \cdot \frac{\partial D_{PL}}{\partial P_{PL}} - w_{PL} \cdot \frac{\partial D_{PL}}{\partial P_{PL}} \quad (4.11) \]

The second-order derivative is negative guaranteeing the solution is the maximum. After taking into account the derivatives of demands, we rewrite the first order condition into the optimal condition for the retail price of PL.

\[ P_{PL} = \frac{1}{2} \left[ (1+2m) \cdot w_{NB} + w_{PL} \right] \quad (4.12) \]

The retail price for PL depends on the wholesale prices for both NB and PL. This is different from the retail price for NB that depends only on the wholesale price of NB. Both the NB wholesale price and the PL wholesale price affect the PL retail price in the same direction (positive), which means an increase in either of the wholesale prices will lead to an increase in the retail price of PL. Considering that \( (1+2m) > 1 \), the marginal effect of NB wholesale price on the retail price is bigger than the marginal effect of PL wholesale price.

**Demand**

Given the price schedules for NB and PL, we can write the demand as functions of wholesale prices. They are presented here as:

\[ D_{NB} = 1 - \left( \frac{1}{2} \right) \left( \frac{1}{a-b} \right) \left( w_{NB} - w_{PL} \right) \quad (4.13) \]
\[ D_{PL} = \left( \frac{1}{2} \right) \left( \frac{1}{a-b} \right) (w_{NB} - w_{PL}) \]  

(4.14)

Note the difference in the retail prices, given the price equations above, is equal to half of the difference in the wholesale prices of the two products.

\[ P_{NB} - P_{PL} = \frac{1}{2} [w_{NB} - w_{PL}] \]  

(4.15)

**4.3.2 The Manufacturer’s Pricing Decision**

Now, we focus on the pricing decision of the manufacturer. We concentrate on the national brand manufacturer who only supplies the national brand product. To keep the assumptions similar to previous chapters, we assume the following cost structure for each unit of product,

\[ C_{NB} = c + q \cdot a \quad \text{where } a \text{ is a per-unit quality level of NB.} \]  

(4.16)

A similar structure is also imposed on the cost structure of PL. The profit function of the NB manufacturer is similar to what we have previously, except in this case the demand takes a different form (as shown above).

The general profit function is written as

\[ \Pi_M = w_{NB} \cdot D_{NB} - C_{NB} \cdot D_{NB} \]  

(4.17)

Substituting in the demand as a function of wholesale prices, we have

\[ \Pi_M = (w_{NB} - C_{NB}) \left[ 1 - \left( \frac{1}{2} \right) \left( \frac{1}{a-b} \right) (w_{NB} - w_{PL}) \right] \]  

(4.18)

The national brand manufacturer may potentially choose the wholesale price and the quality of the product. We first focus on the optimal condition for the wholesale price. The first order condition with respect to the NB wholesale price is
\[
\frac{\partial \Pi_M}{\partial w_{NB}} = D_{NB} + w_{NB} \left[ \frac{\partial D_{NB}}{\partial w_{NB}} \right] - C_{NB} \left[ \frac{\partial D_{NB}}{\partial w_{NB}} \right] = 0
\]

\[
= 2(a - b) - 2w_{NB} + w_{PL} + C_{NB} \quad (4.19)
\]

After substituting in the marginal cost of NB product, the optimal wholesale price for NB is given as

\[
w_{NB} = \left(1 + \frac{q}{2}\right) \cdot a + \frac{w_{PL}}{2} + \frac{c}{2} - b \quad (4.20)
\]

If the wholesale price is the only choice variable of the NB manufacturer, the above equation is the final optimal value for the NB wholesale price. The wholesale price is a function of product quality, the non-quality cost, the wholesale price of PL (which is the manufacturing cost of PL product) and the NB and PL quality. The optimal wholesale price suggests that the marginal impact of product quality is the strongest among the parameters determining the wholesale price. We also notice from the optimal wholesale price that all parameters, except PL quality, have a positive impact on the wholesale price. This result follows from the assumption that the wholesale price (or the manufacturing cost of PL quality) is unrelated to the quality level of PL product.

Nonetheless, this is the case where the national manufacturer can choose the quality of the national brand product. Consequently, the final optimal solution for the NB wholesale price has to combine the optimal condition for the NB quality level. We will also add the information on the manufacturing cost of private label product to clarify the relationship between the quality level and the production cost. We assume that the private label production cost depends on the quality of PL in a similar form as the national brand production cost. We assume that the PL manufacturer can produce a product of the same quality at a higher cost than the national brand manufacturer. Let’s specify the marginal cost function for a unit of PL product as
\[ C_{PL} = k \cdot \left[ c + q \cdot b \right] \] (4.21)

where \( k \) is a proxy for technical difference and is greater than 1. This guarantees that the manufacturing cost of PL is always higher than the manufacturing cost of NB, for a given quality level. When substituting in this cost specification, the optimal wholesale price can be rearranged into

\[ w_{NB} = \left( 1 + \frac{q}{2} \right) a + \left( \frac{k}{2} + \frac{1}{2} \right) c + \left( \frac{1}{2} kq - 1 \right) b \] (4.22)

Similar to the previous result, the NB quality appears to have the greatest marginal impact on the wholesale price of NB. However, this is not a definite result because a very high relative value of quality cost (\( q \)) or technical difference (\( k \)) may lead to quality of PL having a higher impact on the wholesale price. Nonetheless, we should be able to generally state that the effect of NB quality (direct quality) dominates the other term.

The effect of private label quality on the wholesale price of national brand can also be ambiguous. Depending on the parameter values of \( k \) and \( q \), the direction of \( b \) on \( w_{NB} \) is indeterminate. With relatively small values of \( k \) and \( q \), the impact will be negative, indicating that an increase in quality of private label leads to a reduction in the wholesale price of the national brand product. This is probably more reasonable considering that NB and PL are competing products. When the quality of PL increases, the PL becomes more appealing to consumers. The manufacturer of NB adjusts the wholesale price to be competitive with the change in PL quality.

We can find the retail prices for both NB and PL from the optimal wholesale price.

**The Optimal Quality for National Brand**

The quality decision is assumed to be made at the same time as the pricing decision and help determine the optimal value of the national brand wholesale price. In addition to the first
order condition for the wholesale price, we find the first order condition for the NB quality, which is

$$\frac{\partial \Pi_M}{\partial a} = - D_{NB} \cdot \frac{\partial C_{NB}}{\partial a} + w_{NB} \left( \frac{\partial D_{NB}}{\partial a} \right) - C_{NB} \cdot \left( \frac{\partial D_{NB}}{\partial a} \right)$$

$$= w_{NB} \cdot (w_{NB} - w_{PL}) - q \left[ 2(a-b)^2 - (a-b)(w_{NB} - w_{PL}) \right] - (c + qa)(w_{NB} - w_{PL})$$

(4.23)

By inserting in the optimal wholesale price condition for NB and the specified wholesale price for PL, we can rearrange the first order condition of NB quality to find that the optimal condition for $a$ as a quadratic form. The solution to optimal $a$ is difficult to analyze from the stated condition; consequently, we employ MATLAB to produce the result for $a$ for further analytical discussion.

4.4 The Simulations for the National Brand and Private Label Competition Model

4.4.1 Simulations for the Variations in Quality Cost

Using the optimal solutions for national brand wholesale price and quality from the previous section, we use simulations to illustrate the optimal decisions as well as the market outcomes for the competing products model. We focus our simulation on the situation where the quality cost ($q$) varies and other parameters are fixed.

Assuming that the level of private label quality remains constant, the parameter values are $c = 1.5$, $k = 0.2$, $m = 0.3$ and $b = 0.5$. 

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Because of the quadratic form, there are two sets of solutions for NB quality. Given our initial parameters, we choose the larger number set as the solution as it produces a reasonable set of solutions for the remaining outcomes. NB quality, a, is increasing with the cost of quality increases. Interestingly, the choice of quality from the NB manufacturer’s perspective is to increase the quality level even it costs higher to produce. The figure 4.5 shows the two cost schedules for NB and PL products.

The unit cost of NB is progressing at a relatively much faster rate than the PL product, which is a natural result from the increase in quality unit applied to each NB unit during the increase in quality cost. The resulting wholesale price for NB follows a similar direction and curvature as the quality choice and the unit cost.
The national brand wholesale price is increasing in a slight S-shape curve, which is translated into a similar direction and curvature for the national brand retail price. Figure 4.7 shows the retail prices for both NB and PL being increasing as the quality cost increases. We observe that the increase in the price of national brand is slightly faster than the increase of PL price, which is confirmed in Figure 4.8. Nonetheless, the price ratio is increasing at a decreasing rate and appears to reach a plateau toward the peak of both prices, suggesting the price ratio becomes stable toward the right end of quality cost.

Figure 4.7: Quality Cost – the Retail Prices

Figure 4.8: Quality Cost – the Price Ratio

Although the prices of both products are increasing, the demand shown in Figure 4.9 and 4.10 suggest that the increase in price has a stronger negative impact on the demand for national brand as the consumers switch more and more from NB to PL due to the price increase. The increasing price ratio suggests that the faster increase in NB price in relative to PL price may be responsible to this decrease in demand. The higher the price of NB is, the more consumers switch to PL products. Since we establish earlier that the increase in quality cost actually accompanies a higher quality level, we deduce that the impact of price on consumer’s choice is stronger than the impact of quality. An increase in quality cannot persuade consumers to switch to NB products if it induces high price adjustment.
When we consider the change in the prices and demands for national brand and private label products, we may predict (correctly) that the manufacturer’s profit should be decreasing as the quality cost increases due to the sharp decline in demand. The retailer on the other hand
should be enjoying the increase in demand for the private label products. It is true that the retailer also earns partial profit from selling the declining national brand product but it is already established that the retailer earns relatively more by selling private label products than by selling national brand product. Figure 4.11 confirms this fact regarding profits. It also suggests that the profit for NB manufacturer almost reaches zero by the point where the quality cost peaks. Moreover, the figure indicates that the profit of NB manufacturer is lower than that of the retailer, which is interesting to compare to real-world evidence.

![Graph: Profit Ratio](image1)

**Figure 4.12: Quality Cost – the Profit Ratio**

![Graph: Difference in Profit](image2)

**Figure 4.13: Quality Cost – the Difference in Profit**

The relative profits between the manufacturer and the retailer are presented in two ways in Figure 4.12 and Figure 4.13. Considering the retailer’s profit as the base, the absolute difference
is increasing in a slight S-shape whereas the profit ratio is a monotonically increasing, convex function.

4.4.2 Simulations for the Variations in Private Label Quality Level

We are also interested in the variation in the private quality level, which reflects different quality choices chosen by the retailer. We focus on how the other market variables change in response to the variable quality level of the private label product. The simulations use similar parameters as the previous simulation, with an addition of quality cost (q) equals 0.7.

The simulation begins by considering the optimal quality levels. Figure 4.14 illustrates the national brand manufacturer’s quality choice as the private label quality increases. The result indicates that the national brand quality keeps increasing in response to the rise of private label quality. Figure 4.15 further suggests that the national brand quality improves at a greater magnitude than the private label quality expansion, resulting in an increasing quality difference between NB quality and PL quality.

Figure 4.14: PL Quality – the NB Quality Level
The simulation results imply that the national brand manufacturer reacts to the increase in quality competition by increasing his product quality at an even larger magnitude and pushes the difference in quality further away. The results may also indicate that the optimal quality difference from the national brand manufacturer’s standpoint is relatively larger when the quality of private label product is high than when the quality level is low. There is an even greater need to distinguish the national brand product quality from its competitor if the competitor’s quality level increases.

An increase in the quality level for both products suggests the production cost and the prices; both are confirmed in the simulations. Figure 4.16 shows patterns of unit cost increases for both the national brand and the private label products. The NB cost line is steeper than the PL cost line, indicating a relatively higher cost rise for the national brand product, which is reasonable considering NB is experiencing a larger improvement in quality. The subsequent wholesale price for national brand product is also increasing as presented in Figure 4.17. The difference between the wholesale price and the production cost appears to be increasing as well, judging from the larger increase in the wholesale price than the NB cost as PL quality increases.
Consequently, the manufacturer earns higher profit per unit of product as he decides to improve NB quality to compete with PL quality expansion.

Figure 4.16: PL Quality – the NB and PL Unit Cost

Figure 4.17: PL Quality – the NB Wholesale Price

With the increases in the unit costs, we expect both products to have higher retail prices, which are confirmed in Figure 4.18. The figure also indicates that the national brand retail price is increasing at a steeper rate, which is also reasonable considering its steeper increase in quality level. The price ratio from Figure 4.19 shows an increasing price ratio between the national brand retail price and the private label retail price, confirming that the national brand price is increasing at a steeper rate.
Figure 4.18: PL Quality – the NB and PL Retail Prices

Figure 4.19: PL Quality – the Retail Price Ratio

Figure 4.20: PL Quality – the NB and PL Quantity
Figure 4.21: PL Quality – the Quantity Ratio (DPL/DNB)

The increases in quality levels accompanying the increase in price make it difficult to speculate on the relative quantity. The relatively high quality of national brand product leads it to be appealing to consumers. However, the larger increase in the retail price will discourage consumers from purchasing the national brand product and switch to the private label product. The simulation results shown in Figure 4.20 suggest that the consumers are more discouraged by the high price than tempted by high quality level, resulting in the drop of the overall national brand demand. The consumers switch to the private label product, which has a relatively lower price. Considering Figure 4.16 and 4.18, we may speculate that the switching purchase comes mainly from the consumers not willing (or not able) to afford the national brand product rather than because the private label product offers a better deal for quality. We observe from Figure 4.16 and 4.18 that the increase in the retail price for the private label product is relatively much higher than its relative increase in quality. The gap between the retail price and the unit cost for the private label product is much larger than that of the national brand product. Also, the retail price ratio is also smaller than the unit cost ratio. The results indicate that the retailer can charge a relatively much higher price than its quality level due to the high price of the national brand.
product, leading the retailer to earn higher per unit profit from selling the product as he pushes the PL quality level up.

Figure 4.22: PL Quality – the NB and PL Profits

Figure 4.23: PL Quality – the PL/NB Profit Ratio

Figure 4.22 supports our analysis on profits. It shows both the national brand manufacturer and the retailer profits increasing as the PL quality increases, with the retailer profit always higher in magnitude. The figure also illustrates a steeper increase in profit for the retailer at any given point, confirming that the profit growth is higher for the retailer as he increases his product quality level. It is also clear that the profit difference (or profit gap) is increasing as the quality levels of the two products increase. The profit ratio shown in Figure 4.23 indicates that, although the retailer always has higher profit, the profit ratio is reducing as
the quality level increases. The national brand manufacturer performance improves as he decides to improve the NB product relative quality level even though he is relatively less well off with the quality improvement than the retailer.

The simulations in this section illustrate how the firms and the consumers react toward a change in the quality level for private label product. The simulation results suggest that the higher level of private label quality will influence the national brand manufacturer to increase his product quality even higher relatively. Although it is good that the consumers may choose from both higher quality products, the consumers have to pay higher for the quality improvement and some need to switch from a much higher quality national brand to a relatively low quality private label. Specifically for our simulations, the private label quality is never at the same level of any previous national brand version, suggesting that the switching in brands leaves the consumers worse off in terms of overall product quality.

It is possible that the consumers may be better off with the increase in private label quality if the scenario leads to the switching has the consumers buying a high quality private label with relatively lower price. In such a case, the private label product must offer a cheaper quality per unit to the consumers, which is an unlikely scenario if the national brand manufacturer has an expertise in the production process. Our simulations also suggest that the retailer gains a much larger per unit profit from selling the private label product. This large profit ratio reduces consumer benefit and possibly leads to the quality improvement benefiting the retailer rather than the consumers overall.
4.5 Extensions to the Current Models

4.5.1 Non-Linear Reservation Price Schedules

Our original demand specification assumes that the marginal increase in satisfaction from quality level is identical for consumers of all characteristic levels. In case of our general assumption of characteristics being income, the constant slope of linear reservation price schedule implies that consumers with higher income react marginally the same as the consumers with lower incomes in their willingness to pay for quality as their income increases. This is not necessarily the case. It is possible that consumers of higher income will be willing to pay more marginally for quality product than the consumers of lower income. We may use a convex reservation price schedule to represent consumers’ willingness to pay to accommodate such situation. The reservation price schedule is assumed to take a general form of \( R(\theta) \) where \( \theta \) denotes a consumer’s characteristic with \( \frac{\partial R}{\partial \theta} > 0 \). For a convex reservation price case, we have \( \frac{\partial^2 R}{\partial \theta^2} > 0 \).

To illustrate how the change in reservation price schedule affects the optimization problems, we derive the location for indifferent consumer for the convex reservation price schedule. To obtain the indifferent consumer’s location, we equate the utilities of consumer coming from two different alternatives (NB and PL):

\[
R_{NB}(\theta) - P_{NB} = R_{PL}(\theta) - P_{PL}, \quad \text{or,} \\
R_{NB}(\theta) - R_{PL}(\theta) = P_{NB} - P_{PL}.
\]

We need to specify the functional form of \( R_{NB} \) to solve for \( \theta \). As a generalization, we have \( R_{NB}(\theta) - R_{PL}(\theta) = R(\theta) \). Hence, assuming R is invertible, we can derive the general solution for \( \theta \) equals to \( R^{-1}(P_{NB} - P_{PL}) \). This general solution does not help us solve the problem any further because it does not allow us to find aggregated demand for each product. We need to specify
some functional form for reservation price functions to advance further in the optimization problem.

We look into the quadratic specification for convex and concave reservation price functions. We apply the basic quadratic formula to the reservation price schedule. The reservation price schedule with quadratic specification is given as:

\[ R_i(x) = a_i \cdot x^2 + b_i \cdot x + c_i. \]

The indifferent consumer is the person such that

\[ R_{NB}(\theta) - P_{NB} = R_{PL}(\theta) - P_{PL} \]

\[ a_{NB} \cdot x^2 + b_{NB} \cdot x + c_0 - P_{NB} = a_{PL} \cdot x^2 + b_{PL} \cdot x + c_0 - P_{PL} \]

\[ (a_{NB} - a_{PL}) \cdot x^2 + (b_{NB} - b_{PL}) \cdot x - (P_{NB} - P_{PL}) = 0 \]

The quadratic form implies the solution for \( x \) as

\[ x^* = \frac{- (b_{NB} - b_{PL}) \pm \sqrt{(b_{NB} - b_{PL})^2 + 4 \cdot (a_{NB} - a_{PL}) \cdot (P_{NB} - P_{PL})}}{2 \cdot (a_{NB} - a_{PL})} \]

We consider two special cases:

1. When \( a_{NB} = a_{PL} \), this is the case when the second derivatives of the two reservation prices differ. In this case, the location for indifferent consumer is \( x^* = \frac{P_{NB} - P_{PL}}{b_{NB} - b_{PL}} \).

This is the same solution for indifference consumer as the case of linear reservation price, which implies that this special case leads to the same aggregate demand as the linear case we discussed in equation 4.6.
2. When $b_{NB} = b_{PL}$, both first and second derivatives of the reservation prices differ. Here,

the location for indifference consumer, $x$, is $x^* = \left(\frac{P_{NB} - P_{PL}}{a_{NB} - a_{PL}}\right)^{\frac{1}{2}}$. The square-root may pose as a complication; however, the solution for $x$ is straight-forward enough and can be used for deriving aggregated demand and solving optimal prices.

4.5.2 The Variation in the Consumer Distribution

The derived demand, which is the basis of the firms’ optimization problems, relies upon how the consumers react to products (in form of the reservation price schedule) and how the overall consumer characteristic preferences look like in the market (as reflected by the consumer distribution function). Previously, we show that the change in the reservation can have a significant impact on how the demand function changes. Similarly, the different forms for the consumer distribution along the characteristic line can influence the outcomes of the optimization problems through the changes in the demand for products with specific quality levels. We offer some alternatives to the original uniform distribution and discuss how the solutions may change corresponding to the changes in the distribution function.

High-Low Groups

We first consider a discrete distribution for consumers when the consumers are located only at two points of the characteristic line. The consumers can be divided into the LOW group and the HIGH group on the consumer characteristic line. The consumers are segmented by some characteristics. For example, we may deal with consumers who have high awareness for quality and those who have low awareness. Alternatively, we may encounter the consumers who care about brand name and those who do not. In any case, each consumer group has a specific reservation price that the group members are willing to pay. The reservation prices reflect the
characteristics of the group and depend on the locations of groups on the characteristic line. A sample distribution of consumers in this case is shown in Figure 4.25.

![Figure 4.25: Two-Group Consumer Distribution](image)

With the consumers divided into two portions, the firms will be concentrating on capturing the demand of either or both groups. Depending on the reservation price levels and the manufacturing costs, the national brand product and the private label product position themselves to capture the consumers according to their effective returns. The consumer reservation price for the group must be higher than the retail price for the group to make any purchase. In identifying which product to buy, the group will pick the product with the greatest difference between the retail price and the reservation price. We generally assume that the consumers have higher reservation price for national brand product due to its higher quality level. In addition, with the national brand manufacturer being able to produce with technological advantage, the cost of products with the same quality is lower for the national brand. Consequently, the national brand manufacturer may choose first to produce a product for the group with the highest return. This may be the HIGH group if the members are willing to pay high price or it can be a LOW group if the quantity expected to be sold is large enough to counteract smaller profit margins. The retailer can then choose to position the private label quality to capture the other group or cease to produce altogether. Since the national brand manufacturer has the cost advantage, the double
marginalization will come into play in determining the difference in the reservation price and the retail price. The technological advantage that the national brand manufacturer may have can be undermined by the markup set by the retailer.

There are several possible scenarios for the firms supply decisions. First, the national brand manufacturer sells to both groups and the retailer earns profit from the markup. This is a likely scenario if the technological advancement of the national brand manufacturer is so high that the cost difference between the two product costs is significantly large such that the production of private label to capture the HIGH group would not be cost-effective. Second, the private label products are sold to both groups, which is possible if the cost difference is so small that the retailer decides to produce private label very close to national brand characteristics and set markup discriminately to push the national brand out of the market. In this situation, the returns that the retailer gets from selling the private label products must be higher than his returns from selling national brand. And also the combined markups charged by the national brand manufacturer and the retailer are higher than the single markup the retailer charge for the private label product.

The third scenario is when the national brand products are sold to HIGH group and the private label products are sold to LOW group, which is a mixture of the two situations previously described. The situation implies the cost differences must not be too far apart such that one firm gains market advantage over the other. The fourth scenario is when neither group makes a purchase, which is possible if the reservation price is too low for any given quality level. We also would like to point out that, under some specific circumstances, it is possible that the retailer chooses to supply a high quality private label product to the HIGH group when the national brand focuses on the larger population LOW group. The reservation price for the HIGH group
must be significantly high for the retailer to cater for the HIGH group using product quality as a discrimination criterion.

**The Normal Distribution**

In contrast to the two-group situation, we may have more consumers concentrated in the middle portion of the characteristic lines. The most basic form would be the normal distribution (although other variations are applicable as well). In such situations, the consumers are more likely to be of the middle characteristics as a large proportion of consumers do not deviate far from the mean characteristic value. Figure 4.26 depicts an example of the consumer distribution similar to a normal distribution.

**Figure 4.26: The Normal Distribution based on Consumer Characteristics**

![Population Density](image)

When the consumers are distributed normally or close to normal distribution, the demand is also concentrated in the middle characteristic area. Assuming the same reservation price schedule as used in the NB-PL model, the magnitude of demand for each product as identified by the location of indifference consumers relies on the density of the area divided by the indifference consumers. The accumulation of consumers toward the middle of the characteristic line drives the firms to focus more on the middle characteristic group. The normal distribution suggests that the cumulative demand specified for each product group is a function of the distribution’s mean and standard deviation. Recall that the indifferent consumer is located at
The resulting demand for private label and national brand products can be specified as

\[
Q_{\text{National Brand}} = 1 - \frac{1}{\sqrt{2\pi}\sigma^2} \int_{-\infty}^{P_{\text{NB}} - P_{\text{PL}} / (a - b)} e^{-(t - \mu)^2 / (2\sigma^2)} \cdot dt
\]

\[
Q_{\text{Private Label}} = \frac{1}{\sqrt{2\pi}\sigma^2} \int_{-\infty}^{P_{\text{NB}} - P_{\text{PL}} / (a - b)} e^{-(t - \mu)^2 / (2\sigma^2)} \cdot dt
\]

If we know the mean and the standard deviation of the consumer distribution, we can derive the explicit demand functions for the national brand and private label products in term of \(P_{\text{NB}}, P_{\text{PL}}, a, b, \mu, \sigma\). The explicit demands are used in the optimization problems to solve for the optimal quantities and prices given the distribution and cost parameters.

4.6 Concluding Comments

In this chapter, we consider the product quality in the competition between two products. Realizing that the products are very closely related, we focus our interest to the competition between the national brand and private label products, which should heighten our investigation on the connections within the distribution channel. With the retailer taking a more active role in the private label product than in the national brand product, considering the competition between national brand and private label provides insights into the interactions and responses of firms in the channel. We build a flexible demand specification allowing for adjustments in consumers’ characteristics and preferences. The optimization problems follow where the manufacturer controls the national brand product and the retailer controls the private label product, which is supplied by the outside, inactive manufacturer; also, both brands are sold by the same retailer. The national brand has a quality advantage in the form of cheaper manufacturing cost. The
private label has an advantage with the absence of double-marginalization. Given the private label’s quality, the manufacturer chooses the optimal quality level for the national brand product.

Using the simulations, we find the characterizations of the optimal quality, prices, quantities and profits. The simulations on the quality cost variations show that an increase in quality cost surprisingly leads to an increase in the national brand quality level and a widening gap between national brand and private label quality. The increase in quality cost (and also the optimal quality level) drives up both the wholesale and retail prices for national brand product, making it less attractive to the consumers. Although the retailer also faces an increase in the quality cost, the impacts are not as great as that faced by the national brand manufacturer, which results in the retailer becoming relatively better off when the quality cost increases.

The quality rise from the private label product affects the optimal choices in severally similar ways. A higher level of private label quality is best responded with an even larger improvement in the national brand quality. The gap between the national brand quality and the private label quality expands as the private label quality increases. The increases in quality lead to increases in prices for both the national brand and the private label products. Interestingly, the marginal, per unit profit becomes larger for both national brand and private label. Even though the quantity demand for national brand reduces due to the consumers switching to the cheaper private label product, the overall profit level for the national manufacturer increases with the increase in private label quality.

The national brand and private label competition reinforces the crucial role the product quality plays in the dynamic of the distribution channel. The quality level can be used by the firms to influence the other firm’s decisions as well as improve their relative performance within the distribution channel. The quality control for any of the firms allows firms to be more flexible
in the production choices and to have a better control for the market outcomes. More specifically, the retailer may use the private label quality to influence how the national brand product and the manufacturer perform in the market. The quality choice presented in the private label framework strengthens the need of the retailer to explore his potentials in offering the private labels in competition to the national brand products.
Chapter 5:
The National Brand Manufacturer Supply of the Private Label Product

5.1 Introduction

From the distribution channel model perspective, the retailer’s use of private label as strategic variables provides an interesting case for understanding of the firms’ interaction within the channel. The private label products are often direct competitors of the branded products produced by the manufacturers. The private label product, then, weakens the influence of the branded product on consumers; hence, reducing the profit generated by the brand. In addition to the competition effect between the national brand and private label, the national brand manufacturer may be reluctant to supply private label for brand-value and technical reasons. Some manufacturers believe that supplying private label will dilute their brand values because consumers, knowing that national brand and private label products are produced by the same producer, will perceive no difference in the product quality and devalue the national brand. The manufacturer may also need to provide production information to the retailer for the private label production, leading to the retailer being able to approximate the production information for the national brand production. The decision to supply private label product can lead to a reduction in the brand value or technical advantage the national brand manufacturer has.

Even though there are several reasons why the national brand manufacturer may not want to facilitate in the production of the private label product, the question regarding the national brand manufacturer’s decision to supply the private label product is often arisen. Generally, the origin of private label products is largely set aside as coming from independent, competitive market manufacturers. However, this is not necessarily the case for many products. With an
increasing market size of private label, it is only natural that more national brand manufacturers, who have expertise and capability, will be asked to supply private label products for retailers. Being directly beneficial to the retailer, the private label product can be beneficial to the manufacturer as well if he participates in the production of the private label. In this case, the manufacturer can regain some revenue to off-set the loss created when the private label takes away the market share of the manufacturer’s brand. The manufacturer must consider the tradeoff between income earned through private label product supply and the profit gained through sales of its national brand. The private label product supplied to the retailer can increase the manufacturer income but (partially) draw away the market share of national brand and reduce its revenue. Given the private label product position relative to the manufacturer’s national brand, manufacturer has to decide how much to charge the retailer for its product to maximize his overall profit.

The interactions of the manufacturer and the retailer in the distribution channel with a presence of private label can be quite complex because of the trade-off between the loss in the main brand and the gain in the private label, and the change in the consumer demand due to the competition between the two products. In this chapter, we address the manufacturer side of story when dealing with the competition from private label and, at the same time, supplying the retailer’s private label product. The model of one national brand manufacturer and one retailer is used to study the firm decisions. The demand function is modified to incorporate both products via the use of consumer’s preference and the characteristic distribution. The newly modified demand is then used in the distribution channel model to explain the decisions of the manufacturer and the retailer. Primarily, the model focuses on the pricing decisions rather than the quality decision as in the previous chapters. We are interested in the price and the quantity
schedule of the private label product the manufacturer sells to the retailer, as well as the role of product quality in determining the prices and quantities of the national brand and private label products in this setting.

5.2 The Theoretical Optimization Problems

We begin by considering the general specification of the problem and the resulting optimization conditions. The theoretical model in this section relies on several assumptions. First, the national manufacturer does not have capacity constraints, so he can supply both national brand and private label as much as he wants to. Second, the manufacturing cost of private label done by the national manufacturer is always lower, given a specification, than the manufacturing cost of the outside option. Hence, if the national manufacturer decides to supply private label, the wholesale price must not be higher than the outside option. Third, the retailer can only choose to buy private label supply from one manufacturer. No mixing contracts are allowed.

Because the outside option manufacturer acts passively to the optimization problem, we may consider only the national manufacturer and the retailer. Consequently, the term “manufacturer” mentioned in this section corresponds to the national manufacturer. The model of the distribution channel still consists of the manufacturer and the retailer, with two brands (national brand and private label) being offered to the consumers.

5.2.1 The Retailer Optimization Problem

Retailer takes wholesale prices for national brand and private label $w_{NB}$ and $w_{PL}$ respectively, as given when deciding the retail prices, $P_{PL}$ and $P_{NB}$. The consumer demand of each product is a function of both retail prices. The retailer’s profit function takes the following form:
\[ \Pi_R = P_{NB} D_{NB}(P_{NB}, P_{PL}) + P_{PL} D_{PL}(P_{NB}, P_{PL}) \]

\[ - C_{R,NB}(D_{NB}) - C_{R,PL}(D_{PL}) \quad (5.1) \]

The setup assumes the cost structure for each product is separable from the demand of another product. Consequently, the retailer cost function can be separated into two terms: the cost for national brand and the cost for private label.

The first order conditions from the retailer’s optimization are

NB Retail Price:

\[ D_{NB} + P_{NB} \frac{\partial D_{NB}}{\partial P_{NB}} + P_{PL} \frac{\partial D_{PL}}{\partial P_{NB}} = \frac{\partial C_{R,NB}}{\partial D_{NB}} \frac{\partial D_{NB}}{\partial P_{NB}} + \frac{\partial C_{R,PL}}{\partial D_{PL}} \frac{\partial D_{PL}}{\partial P_{NB}} \quad (5.2) \]

PL Retail Price:

\[ D_{PL} + P_{PL} \frac{\partial D_{PL}}{\partial P_{PL}} + P_{NB} \frac{\partial D_{NB}}{\partial P_{PL}} = \frac{\partial C_{R,NB}}{\partial D_{NB}} \frac{\partial D_{NB}}{\partial P_{PL}} + \frac{\partial C_{R,PL}}{\partial D_{PL}} \frac{\partial D_{PL}}{\partial P_{PL}} \quad (5.3) \]

The first order conditions are mirror images of one another. The conditions are comparable to the optimal condition of retail price in the case where the retailer only sells the national brand product. The difference lies in the impact of one product retail price on the demand of another product, which appears in the last terms on both sides. For example, in the case of the national brand retail price, the change in the private label demand caused by the change in the national brand price, \( P_{PL} \frac{\partial D_{PL}}{\partial P_{NB}} \), is added to the marginal revenue consideration.

The retailer’s revenue from sale of the private label product changes because of the change in the national brand price. When the national brand price increases, some consumers switch from the national brand product to the private label product, hence increases the retailer’s revenue generated from private label. The increase in the private label demand induces a marginal
increase in the retailer’s cost of private label represented by \( \frac{\partial C_{R,PL}}{\partial D_{PL}} \cdot \frac{\partial D_{PL}}{\partial P_{NB}} \), which is added to the cost consideration on the right hand side of the optimal condition.

### 5.2.2 The Manufacturer Optimization Problem

Although there are two manufacturers in the market, we only need to consider the optimal decision of the national manufacturer. The outside option manufacturer supplies private label product at a specific price always equals to its marginal manufacturing cost. On the other hand, the national manufacturer, whose manufacturing cost for the private label product is assumed to be lower than that of the outside option, can choose to provide the private label product at a lower price. Optimizing his profit, the retail is assumed to buy the supply of private label from the manufacturer that offers the lowest price. Consequently, the national manufacturer cannot set the wholesale price of private label higher than the manufacturing cost of the outside manufacturer, \( \bar{c} \). The corresponding profit function of the national manufacturer is described as

\[
\Pi_M = w_{NB} \cdot D_{NB} + w_{PL} \cdot D_{PL} - C_{M,NB}(D_{NB}) - C_{M,PL}(D_{PL}) \tag{5.4}
\]

where \( w_{PL} \leq \bar{c} \) for \( S_{PL} = D_{PL} \), otherwise \( S_{PL} = 0 \).

We focus on the case where the national manufacturer supplies private label to the retailer. The optimal profit in this case is compared to the optimal profit when the outside source supplies private label to decide whether the national manufacturer provides private label to the retailer.

Realizing that the retail prices are influenced by the wholesale price decisions, the manufacturer’s optimization problem results in the following first order conditions:
**NB Wholesale Price**

\[
D_{NB} + w_{NB} \left[ \frac{\partial D_{NB}}{\partial P_{NB}} \frac{\partial P_{NB}}{\partial W_{NB}} + \frac{\partial D_{NB}}{\partial P_{PL}} \frac{\partial P_{PL}}{\partial W_{NB}} \right] + w_{PL} \left[ \frac{\partial D_{PL}}{\partial P_{NB}} \frac{\partial P_{NB}}{\partial W_{NB}} + \frac{\partial D_{PL}}{\partial P_{PL}} \frac{\partial P_{PL}}{\partial W_{NB}} \right] = \frac{\partial C_{M.NB}}{\partial D_{NB}} \left[ \frac{\partial D_{NB}}{\partial P_{NB}} \frac{\partial P_{NB}}{\partial W_{NB}} + \frac{\partial D_{NB}}{\partial P_{PL}} \frac{\partial P_{PL}}{\partial W_{NB}} \right] + \frac{\partial C_{M.PL}}{\partial D_{PL}} \left[ \frac{\partial D_{PL}}{\partial P_{NB}} \frac{\partial P_{NB}}{\partial W_{NB}} + \frac{\partial D_{PL}}{\partial P_{PL}} \frac{\partial P_{PL}}{\partial W_{NB}} \right]
\]

or, equivalently,

\[
D_{NB} + \left( w_{NB} - \frac{\partial C_{M.NB}}{\partial D_{NB}} \right) \left[ \frac{\partial D_{NB}}{\partial P_{NB}} \frac{\partial P_{NB}}{\partial W_{NB}} + \frac{\partial D_{NB}}{\partial P_{PL}} \frac{\partial P_{PL}}{\partial W_{NB}} \right] + \left( w_{PL} - \frac{\partial C_{M.PL}}{\partial D_{PL}} \right) \left[ \frac{\partial D_{PL}}{\partial P_{NB}} \frac{\partial P_{NB}}{\partial W_{NB}} + \frac{\partial D_{PL}}{\partial P_{PL}} \frac{\partial P_{PL}}{\partial W_{NB}} \right] = 0 \quad (5.5)
\]

The first order condition relies on two important facts. First, the demands of both products depend on both retail prices. Second, each retail price is influenced by the wholesale prices of both products. The marginal effect coming from each demand must account for the changes in both the national brand retail price and the private label retail price, which is manifested in the terms: \[ \left[ \frac{\partial D_i}{\partial P_{NB}} \frac{\partial P_{NB}}{\partial W_{NB}} + \frac{\partial D_i}{\partial P_{PL}} \frac{\partial P_{PL}}{\partial W_{NB}} \right] \] where \( i \in \{NB, PL\} \) in equation (5.5). The optimal condition for the national brand wholesale price takes into account the impacts of the national brand wholesale price on both retail prices, which in-turn influence the demands for both products.

Intuitively, an increase in the wholesale price of national brand directly leads to an increase in the retail price for the national brand, which reduces the demand for national brand. A reduction in the demand of national brand should accompany an increase in the private label demand, which can be used as a substitute. The increase in demand for private label as a substitution for the national brand allows the sellers to increase the price of private label. As a result, we should expect an increase in the national brand retail price as well as a rise in the
national brand wholesale price. Nonetheless, the change that happens to private label product is considered an indirect impact and should be confirmed through the explicit solutions of the optimization problem.

The first order condition for the private label wholesale price is a mirror image of equation (5.5). The analysis regarding the first order condition is also the same, which we present below for completeness.

\[
D_{PL} + \left( w_{NB} \frac{\partial C_{M,NB}}{\partial D_{NB}} \right) \left[ \frac{\partial D_{NB}}{\partial P_{NB}} \frac{\partial P_{NB}}{\partial W_{PL}} + \frac{\partial D_{NB}}{\partial P_{PL}} \frac{\partial P_{PL}}{\partial W_{PL}} \right] \\
+ \left( w_{PL} \frac{\partial C_{M,PL}}{\partial D_{PL}} \right) \left[ \frac{\partial D_{PL}}{\partial P_{NB}} \frac{\partial P_{NB}}{\partial W_{PL}} + \frac{\partial D_{PL}}{\partial P_{PL}} \frac{\partial P_{PL}}{\partial W_{PL}} \right] = 0 \quad (5.6)
\]

As mentioned earlier, the optimal conditions presented in this sub-section correspond to the situation when the national manufacturer decides to supply the retailer the private label product. The optimal profit under this situation has to be compared to the profit when the retailer gets the supply from the outside manufacturer. We briefly discuss the optimization problem when the retailer is assumed to obtain private label supply from the outside option. In this case, the wholesale price for PL is fixed at $\bar{c}$. There is no change in the optimization problem of retailer; hence, the optimal conditions for the national brand and private label retail prices remain structurally the same. The national manufacturer only chooses the wholesale price for the national brand product and the optimization problem appears identical to the basic setup for the manufacturer in Chapter 2. More information on functional specifications is required before we can make further analysis regarding the optimal outcomes in the case where the retailer gets private label supply from the outside manufacturer.

Although it is not quite apparent from the optimal conditions in this section, the manufacturer’s optimal decision on private label supply relies on the trade-off between the
marginal benefits and the marginal costs of reducing (increasing) the wholesale price.

Considering the situation where the wholesale price of private label is reduced, the retail price of private label decreases and the private label demand increases. The demand expansion is broken down into two parts. First, some of the previous national brand customers switch to private label. This portion of demand change results in a loss of the national brand manufacturer’s profit. The price reduction also brings in new customers for private label.

On the other hand, a reduction in the wholesale price of private label indirectly leads to a reduction in the retail price of national brand. The price reduction increases demand, which can partially off-set the loss in demand due to the reduction in the private label price. Generally, the reduction in price and the increase in demand may lead to either a net loss or gain. Additional information about demand is needed before we can explicitly conclude the direction and magnitude of demand change.

In addition, the national manufacturer also incurs changes in the production cost due to the changes in demands for both products. The marginal changes in the costs are incorporated in the optimization as well. A reduction in national brand demand results in a reduction in the production cost for the national brand. On the contrary, an increase in the demand for private label translates into an increase in its production cost. Under a constant marginal cost assumption, the marginal cost change is equal to the product of the constant unit cost and the change in demand.

5.3 General Analysis of the Supply Decision and Price Setting

Although the general setup in Section 5.2 require further assumptions on demand and cost specifications to derive the explicit solutions, the setup of the problem and the prior assumptions
provide some insights into the characteristics of the solutions. In this section, we discuss the general characteristics of the optimal supply and pricing decisions resulting from the setup in the previous section.

5.3.1 The Range for National Manufacturer’s Supply of Private label

The national manufacturer only prefers to supply the private label products within a limited price range. The manufacturer will not supply at any price lower than its manufacturing cost ($c_{PL}$) because the sale would yield a deficit. On the other hand, the retailer will not buy private label product from the national manufacturer if the wholesale price is higher than the price of an outside option ($\bar{c}$). Consequently, the feasible optimal private label wholesale price from the national manufacturer is capped between $c_{PL}$ and $\bar{c}$: $c_{PL,A} \leq w_{PL} \leq c_{PL,B}$.

![Figure 5.1: Range of Private Label Supplied by National Brand Manufacturer](image)

From Figure 5.1, the national brand manufacturer only offers the private label product under a limited range of the private label wholesale price (the red line in the graph). Consequently, the actionable supply curve is only the segment highlighted in blue. Any other prices or quantities outside this supply segment are either unprofitable or non-existent.
In fact, the structure of the problem creates the restricted supply range for the national manufacturer, who has no incentive to offer the price outside this range because any lower price only contributes negatively to the total profit. This is because manufacturer’s decision on the private label supply cannot positively impact profit generated through national brand sales. For the situation where the market cannot be expanded and there are no new consumers that may begin buying the private label product (such as in the Chapter 4 setting), a decrease in the private label retail price only leads to reduction in the national brand demand, hence reducing profit generated from selling the national brand. Moreover, the profit margin the manufacturer earns from each unit of the national brand is larger than that he earns from the private label. One unit increase in the private label sold is not a profitable trade off when compared to one unit decrease in the national brand sold. Given that the profit margin is likely a decreasing function in quantity sold, it is impractical for the manufacturer to reduce the national brand sales and increase the private label sales.

5.3.2 The Optimal Supply Decisions

From the manufacturer’s objective function, there are two parts of profits: profit generated from NB ($\pi_{NB}$) and profit generated from PL ($\pi_{PL}$). The optimal conditions can be considered as the trade-off conditions between the two portions of profits. At the optimum, a marginal reduction in one portion must be met with an equal increase in marginal profit of another portion. When the wholesale price of the private label product decreases, the private label retail price decreases, causing the private label demand to increase, given the national brand retail price stays constant. Since national brand and private label are substitutes and consumers buy one unit of either the national brand or private label product, an increase in the private label demand translates into an equal decrease in the national brand demand. The decision to decrease
wholesale price for private label may increase the profit generated from the private label sale (subject to the sensitivity of demand change with respect to price change) however it will certainly reduce the profit earned in the national brand sales. Consequently, for the national brand manufacturer earning extra profit from selling private label, he sacrifices some portion of profit from selling the national brand product.

The extent to which manufacturer trades off the profit from the national brand sale with profit from the private label sale depends on the responsiveness of demand with respect to price change. Holding the price of national brand constant, the change in the private label wholesale price leads to change in demand in private label, which is converted into more profit for the manufacturer if the change in demand covers the lost in price reduction. In addition, the manufacturer loses some portion of the national brand demand and the profit associated with it. In equilibrium, the marginal loss from decrease in national brand sales and decrease the private label price must be equal to the marginal gain from increase private label sale.

\[
\text{Profit Loss from } D_{NB} \text{ Reduction} + \text{Profit Loss from } W_{PL} \text{ Decrease} = \text{Profit Gain in } D_{PL} \text{ expansion} \quad (5.7)
\]

With no new consumers, the profit loss from \(D_{NB}\) Reduction is most likely always larger than the profit gain from \(D_{PL}\) expansion. The national brand manufacturer should be able to extract higher rent per unit from selling national brand product than from selling private label. In fact, the national brand manufacturer would prefer the retailer not to sell the private label product because the private label sales will reduce the profit that the national brand manufacturer gains from selling the national brand product. However, the retailer can get an outside manufacturer to
supply the private label product. So, the national brand manufacturer cannot force the retailer to not sell private label by refusing to supply it. If retailer is going to sell private label anyway, it is better for the national brand manufacturer to supply private label himself. In addition, the national brand manufacturer does not have any incentive to offer private label supply to the retailer at the price lower than the outside alternative. Because the benefit per unit of private label is going to be lower than benefit per unit of the national brand product at any given level of the private label product supplied, it is in the national brand manufacturer’s interest to charge the highest price possible for the private label.

Figure 5.2: The Optimal Supply Decision

Because the manufacturing cost per unit of private label product is lower than the wholesale price, manufacturer’s revenue from supplying private label is always positive. Although the indirect cost of supplying additional unit of private label is most likely overshadow the marginal manufacturing profit, the indirect cost is unavoidable and can be considered “fixed” from the national brand manufacturer’s perspective. Consequently, it is most profitable for the national brand manufacturer to supply private label as much as is demanded and his capacity.
allows. The optimal wholesale price, which is shown in Figure 5.1, is the highest price the manufacturer can possibly charge, which is equal to the marginal cost of the outside manufacturer. The result suggests that the retailer makes decision on how many units of the private label product he wants to supply, taking into account the wholesale prices of the national brand and private label products. The national brand manufacturer behaves passively in the private label market, using only the national brand wholesale price to address the private label market invasion.

The optimal decisions for the manufacturer described here depend largely on the assumption that no new consumers may be generated through the use of private label prices. We find that the restrictions on the demand as used in Chapter 4 is not as desirable when discussing the situation where the national brand manufacturer supplies the private label product to the retailer. For this chapter, we will modify the demand formerly used in Chapter 4 to allow for a broader setup and a wider range of solutions, possibly from the expansion of the consumers.

5.4 The Modifications to the Model Setup

Due to the similarity between the theoretical problem in this chapter and the theoretical problem in Chapter 4, we use a similar setup of the problem as in the last chapter. The supply side assumptions remain the same as the ones in Chapter 4. For the demand side, we propose some changes in the demand setup allowing for a wider range of possible outcomes. Instead of assuming all consumers must choose between the national brand and private label products as in Chapter 4, we assume the consumers may choose not to purchase any product. The utility function of a consumer located at point x of the characteristic line is defined as:
We assume that the non-buying option generates zero utility\(^{11}\). The assumption implies that the consumers will purchase the product unless the retail prices are higher than their reservation prices. We apply the linear reservation price schedule identical to the setup in Chapter 4. The reservation prices for the national brand and the retailer products are

\[
U_x = \begin{cases} 
R_{NB}(x) - p_{NB} & \text{if she buys national brand, NB} \\
R_{PL}(x) - p_{PL} & \text{if she buys private label, PL} \\
0 & \text{if she chooses neither}
\end{cases}
\quad (5.8)
\]

National brand Reservation Price: 
\[ R_{NB}(\delta) = R_0 + a \cdot \delta \quad (5.9) \]

Private label Reservation Price: 
\[ R_{PL}(\delta) = R_0 + b \cdot \delta \quad (5.10) \]

The last person that chooses national brand product, as assumed to be located at \(\delta^*\), is not the person who gains zero utility consuming the national brand product but rather the person whose utility of consuming national brand is the same as the utility of consuming private label. Since the consumers have a lower price alternative, the national brand cannot fully charge consumer their reservation price and leave them with zero utility. Consumers are better off switching to private label to get some positive utility than sticking with national brand.

Similarly, the consumers also have an option of not buying either product. The indifferent consumer at this location, \(\delta_{LOW}\), is also the last consumer that makes a purchase. Since the private label does not have competitors on the left end of the consumer line, the price charge for the last consumer is equal to her reservation price. The location for the last consumer of PL, \(\delta_{LOW}\), is the \(\delta\) such that \(P_{PL} = R(\delta_{LOW})\), or equivalently, \(\delta_{LOW} = R^{-1}(P_{PL})\).

\(^{11}\) It is possible to use different assumption. Since the income not spent on either product can be used for buying products outside of the model, another possibility is to have a minimum utility, \(u_0\), representing the utility of the out-of-the-model option.
The positions of indifferent consumers, $\delta^*$ and $\delta_{LOW}$, indicate the border lines of purchasing decisions. Consumers locating on the left side of $\delta^*$ will purchase private label, consumers between $\delta_{LOW}$ and $\delta^*$ will buy national brand; and consumers to the left of $\delta_{LOW}$ will buy neither of the products. The division of consumers is described in Figure 5.3.

![Consumer Line and Demand Segments](image)

Figure 5.3: Consumer Line and Demand Segments

In keeping with the assumption in Chapter 4, we assume the consumer distribution is a uniform distribution. The assumption implies that there is an equal number of consumers at any given level of the consumer characteristics. The number of consumers is distributed evenly along the interval. We identify the positions of consumers determining the cuts in the consumer segments. First, we consider the indifferent consumer for the national brand and private label products. This is the same as in Chapter 4, which is

$$\delta^* = \frac{P_{NB} - P_{PL}}{a - b} \quad (5.11)$$

Given the linear reservation price schedule, the location of the private label’s last consumer is categorized as $\delta_{LOW} = \frac{1}{b}[P_{PL} - R_o]$. The aggregated consumer mass buying the national brand product is $[1 - \delta^*]$, which can be written in term of $P$’s as
\[ D_{NB} = 1 - \left( \frac{1}{a-b} \right) [P_{NB} - P_{PL}] \]  \hspace{1cm} (5.12) 

The aggregated consumer mass buying the private label is in \([\delta^* - \delta_{Low}]\) interval, which is translated into

\[ D_{PL} = \frac{1}{b \cdot (a-b)} [b \cdot P_{NB} - a \cdot P_{PL} + (a-b) \cdot R_0] \]  \hspace{1cm} (5.13) 

These aggregated demands are used in computing the retailer’s and the manufacturer’s profits.

### 5.5 The National Brand Manufacturer Optimization Problem

Now, the modified demand specification described in Section 5.4 is applied to the theoretical model developed in 5.2. We focus on the situation where the retailer obtains the private label from the national manufacturer, leading to the national manufacturer selling two products simultaneously.

#### The Derivatives of Demand

Recall the demand function shown in (5.12) and (5.13). Both the national brand demand and the private label demand are functions of the national brand and private label retail prices. A change in either of the retail prices results in a change in the demand of both products. The magnitudes of changes can be shown through the first derivatives of demand functions with respect to retail prices.

\[ a \cdot (w_{NB} - w_{PL}) + (1 + 2m)(a-b)w_{NB} \leq (2a + R_o)(a-b) \]

\[ \text{To guarantee non-negative demand for NB, we require } P_{NB} - P_{PL} \leq a-b. \text{ Plugging in the optimal conditions for } P_{NB} \text{ and } P_{PL}, \text{ we derive a necessary condition for non-negative NB demand as:} \]

\[ a \cdot (w_{NB} - w_{PL}) + (1 + 2m)(a-b)w_{NB} \leq (2a + R_o)(a-b) \]
National Brand Demand:
\[
\frac{\partial D_{NB}}{\partial P_{NB}} = -\frac{1}{a-b}, \quad \frac{\partial D_{NB}}{\partial P_{PL}} = \frac{1}{a-b}
\]

Private Label Demand:
\[
\frac{\partial D_{PL}}{\partial P_{NB}} = \frac{1}{a-b}, \quad \frac{\partial D_{PL}}{\partial P_{PL}} = \frac{-a}{b \cdot (a-b)}
\]

The first derivatives have the expected signs. The own-price derivatives are negative, indicating that the demand is decreasing when own-price increases. On the other hand, the cross-price effects are positive because an increase in price of rival product should lead to an increase in own-demand. Interestingly, the national brand demand is affected by changes in the national brand price and the private label price in equal magnitude. A unit increase in the national brand price brings about an equal impact on demand as a unit decrease in PL price.

5.5.1 The Optimal Decisions for the Retailer

We apply the information on costs and demand into the first order conditions found in 5.5.1. The retailer’s first order conditions result in the following optimal conditions for retail prices.

Retail Price of National Brand:
\[
P_{NB} = \frac{1}{2} \left[w_{NB} + a + R_0 + r \right] \quad (5.14)
\]

Retail Price of Private Label:
\[
P_{PL} = \frac{1}{2} \left[w_{PL} + b + R_0 + r \right] \quad (5.15)
\]

The optimal conditions of the retail prices offer several interesting points worth discussing. First, the retail price of either product only depends on its wholesale price, not the wholesale price of the competing product. The condition suggests that the retailer is only concerned about the direct wholesale price and does not use the information about the wholesale price of the competing product when determining the optimal retail price. However, the result
does not necessarily imply that the existence of the competing product has no impact on the optimal retail price, since the wholesale price of the own product is determined in conjunction with the wholesale price of the competing product during the manufacturer’s optimal decision making process. The absence of the private label wholesale price in the optimal national brand retail price equation (and vice-versa) may imply that the retailer does not need to account for the rivalry between the two products since it is accounted for during the manufacturer’s decision making process.

The structures of the optimal retail price decisions of the two products also mirror one another. The marginal impacts of the wholesale price on the retail price are also the same (both are equal to one-half.) Moreover, only the information regarding the reservation schedule of own-product is important in determining its optimal retail price.

**5.5.2 The Optimal Decisions for the Manufacturer**

With the above optimal retail price conditions, the optimal wholesale price decisions are derived as follows:

Wholesale Price of National Brand: \( w_{NB} = \frac{1}{2} \cdot [c_{NB} + a + R_0 - r] \) (5.16)

Wholesale Price of Private Label: \( w_{PL} = \frac{1}{2} \cdot [c_{PL} + b + R_0 - r] \) (5.17)

Surprisingly, the optimal conditions for the wholesale prices have almost identical structure as the optimal retail prices. Notably, the wholesale price of the national brand only depends on its marginal cost (and vice-versa). The impact of the marginal manufacturing cost on the wholesale price is also identical for both products. While the manufacturing cost positively impacts the wholesale price, the retail operating cost has a negative impact on the price. This is reasonable since an increase in retail operating cost will discourage the retailer from selling the
product. Consequently, the manufacturer may reduce the price to boost the demand of the retailer.

The rest of the optimal conditions are similar in analysis as the optimal retail price condition. They contain the information regarding the own-reservation price schedule, which acts positively on the wholesale price. The impact of reservation price coefficients on the wholesale prices is identical to the impacts on the retail price. This information implicitly infers that a change in the parameter value of the reservation price coefficient has greater impact on the retail price than on the wholesale price. The change appears in two parts for the retail price; directly through the coefficient level and indirectly through the wholesale price. On the other hand, the change only appears directly through the coefficient parameter in the optimal wholesale price condition. Hence, a change in reservation price parameters (which indicate the consumer preference) results in a larger change in the retailer prices than in the wholesale price.

The optimal wholesale prices and retail prices solutions from equations (5.14) through (5.17) imply that the optimal course of action when the manufacturer deciding about producing national brand and private label products are independent. The manufacturer can consider an individual product separately and the decision to produce one product does not impact the decision to produce another. The result implies the national brand manufacturer’s decision to supply private label is independent of national brand sales, suggesting that, if the solution is feasible, the national brand manufacturer should always supply the retailer with private label product at its optimal cost. We do require that the optimal wholesale price should be lower than the marginal cost of producing PL for the outside manufacturer.
5.5.3 Introducing the Quality Decisions

From section 5.5.2, the optimal solutions for wholesale and retail prices show no relationship between the national brand and private label decision making. Since there is no direct relationship except from the demand. The national brand manufacturer can decide on the two products separately because the decision on one side of production does not influence the optimal prices on the other side. As a result, the national brand manufacturer is relatively unresponsive toward the supply of private label products.

The initial model implicitly assumes that the quality levels of both products are independent and exogenously determined by the firms ahead of the pricing decision and the production process. Arguably, the exogenous cost assumptions take away some crucial elements in the modeling for the national manufacturer supplying private label products. A general argument is that quality is crucial in the competition between national brand and private label, and firms use the quality level to counteract the competitions and strengthen their products. The decisions on quality level should be important especially from the national brand manufacturer’s standpoint. Specifically, the quality of private label can influence the perception of the consumers toward the national brand product. Brand erosion may occur if the national brand manufacturer decides to supply private label product with the quality level close to that of the national brand level. The interconnection in quality levels between the national brand and private label products connect the pricing decisions, resulting in the national brand manufacturer having to consider the supply of private label in conjunction with the production of his national brand product.
5.6 The Optimization Problem when the Retailer Uses a Constant Markup

Now, we consider the problem in a slightly different setup than in Section 5.5. Instead of the retailer choosing both the national brand and private label retail prices, we assume that the retailer uses a predetermined markup to set the national brand price and chooses the private label retail price. This setting is similar to the optimization problem investigated in Chapter 4.

5.6.1 The Retailer’s Optimization

Assume that the retailer applies a fixed, pre-determined markup, \( m \), on the national brand product. The national brand retail price is proportional to its wholesale price and can be specified as follows:

\[
P_{NB} = (1 + m) \cdot w_{NB} \quad (5.17)
\]

The retailer chooses the private label retail price. The source of income for retailer arises from two products: national brand and private label. The profit generated from national brand product is \( m \cdot w_{NB} \cdot D_{NB} \) and the profit generated from the private label product is \( (P_{pl} - w_{pl}) \cdot D_{pl} \). Consequently, the retailer profit function is described as:

\[
\Pi_R = m \cdot w_{NB} \cdot D_{NB} + (P_{pl} - w_{pl}) \cdot D_{pl} \quad (5.18)
\]

We substitute in the integrated demand segments in the profit function, yielding

\[
\Pi_R = m \cdot w_{NB} \left[ 1 - \left( \frac{1}{a-b} \right) (P_{NB} - P_{PL}) \right] + \nonumber
\]

\[
(P_{pl} - w_{pl}) \cdot \left[ \frac{1}{b(a-b)} (b \cdot P_{NB} - a \cdot P_{PL} + (a-b) \cdot R_o) \right] \quad (5.19)
\]

The retailer has only one choice variable in this problem: the private label retail price. The first order condition for \( P_{PL} \) yields the following optimal condition for the private label price.
Note that the private label pricing only corresponds to half of the private label wholesale price with the remainder contributed by constant term and wholesale price. Further, $P_{PL}$ is not equal to $R_o$, implying there will be some segment of demand not buying either product. Also, with positive wholesale prices, we can guarantee that retail prices are always positive.

### 5.6.2 The Manufacturer’s Optimization Problem

Given retailer’s optimal decisions, manufacturer solves for the optimal price schedules that manufacturer A should charge for the national brand and the store brand. The price schedules will determine how much manufacturer A supplies of the national brand and how much he supplies the store brand. The manufacturer A’s profit function appears as

$$
\Pi_A = (w_N^A - C_N) \cdot N + (w_S^A - C_S^A(\theta)) \cdot S_A
$$

Manufacturer A decides how much to charge for wholesale prices of national brand and private label. Although it appears as if the production decisions for the two products are independent, this is not actually the case. The quantity supplied must be the result of demand, where both products are linked through retail prices and substitution.

We look at the case where the national brand manufacturer also supplies private label product to the retailer. This is the situation when the wholesale price charged by the national brand manufacturer for the private label supply is lower than or equal to the outside company. Consequently, the condition $w_{A,PL} \leq c_{B,PL}$ applies throughout the problem. Moreover, the national brand manufacturer has no incentive to supply the private label product when the wholesale price is lower than the manufacturing cost. So, it is necessary that the national brand wholesale price is at least as large as its production cost: $w_{PL} \geq c_{PL}$.
Similar to the retailer, the manufacturer also gains profit from two segments: the national brand and private label demands. The profit from the national brand demand is
\((w_{NB} - c_{NB}) \cdot D_{NB}\) and the profit from the private label demand is \((w_{PL} - c_{PL}) \cdot D_{PL}\). Substituting in the aggregated demands, the total profit function for national brand manufacturer (henceforth called manufacturer A) can be described as:

\[
\Pi_M = (w_{NB} - c_{NB}) \left[ 1 - \left( \frac{1}{a-b} \right) (P_{NB} - P_{PL}) \right] \\
+ (w_{PL} - c_{PL}) \left[ \frac{1}{b(a-b)} (b \cdot P_{NB} - a \cdot P_{PL} + (a-b) \cdot r_o) \right].
\] (5.22)

subject to

\[
P_{NB} = (1+m) \cdot w_{NB}
\]
\[
P_{PL} = \left( \frac{b \cdot (1+2m)}{2a} \right) \cdot w_{NB} + \left( \frac{1}{2} \right) \cdot w_{PL} + \left( \frac{a-b}{2a} \right) \cdot r_o
\]

\[0 < w_{A,PL} \leq c_{B,PL}, \quad w_{PL} > 0, \quad P_{NB} \geq P_{PL}\]

\[D_{NB} + D_{PL} \leq 1, \quad D_{NB} \geq 0 \quad \text{and} \quad D_{PL} \geq 0\]

Although it does not appear explicitly in the optimization problem, we are required to have the total profit when manufacturer A decides to supply both the national brand and private label products to be higher than the profit when he supplies only the national brand product and the retailer acquires the private label product from manufacturer B (outside alternative.) Otherwise, manufacturer A will produce only the national brand and choose only the national brand wholesale price.
The manufacturer chooses the wholesale prices for both the national brand and private label products. The first derivative with respect to national brand’s wholesale price, \( w_{NB} \), yields the following optimal condition.

\[
\begin{align*}
\frac{d}{dw_{NB}} &= \frac{2(a - r_o)(a - b)}{2b(1 + 2m)} + \left[ \frac{1}{2} - \left( \frac{a \cdot (1 + m)}{b(1 + 2m)} \right) \right] \cdot c_{NB} \\
&- \left( \frac{a \cdot m}{b(1 + 2m)} \right) \cdot c_{PL} - \left( \frac{a \cdot (1 - 2m)}{2b(1 + 2m)} \right) \cdot w_{PL}^*.
\end{align*}
\]

Then, rearranging the first derivative with respect to PL wholesale price, \( w_{PL} \), leads to

\[
\begin{align*}
\frac{d}{dw_{NB}} &= \frac{1}{2} c_{NB} + \left( \frac{a}{2b(a - b)} \right) \cdot c_{PL} \\
&+ \left[ \frac{a(a - b - 1)}{2b(a - b)} \right] \cdot w_{PL}^* - \left( \frac{a - b}{2b} \right) \cdot r_o
\end{align*}
\]

Given these two optimal conditions, we can solve the manufacturer’s optimal decisions for national brand and private label wholesale prices: \( w_{NB} \) and \( w_{PL} \), which can be written as functions of manufacturing costs for the national brand and private label products: \( c_{NB} \) and \( c_{PL} \), and parameters \( a, b \) and \( m \). This leads to

\[
\begin{align*}
\frac{d}{dw_{NB}} &= \left[ \frac{1}{2} + \left( \frac{a^2 - ab - a)(1 + m)}{b \cdot (1 + 2(m - a + b))} \right) \right] \cdot c_{NB} \\
&+ \frac{a}{2b \cdot (a - b)} \left[ 1 + \frac{(a - b - 1) \cdot (1 + 2m \cdot (1 + a - b))}{1 + 2(m - a + b)} \right] \cdot c_{PL} \\
&+ \left[ \frac{(a - b - 1)(a + mr_o)(a - b)}{b(1 + 2(m - a + b))} \right] - \left( \frac{r_o \cdot (a - b)}{2b} \right)
\end{align*}
\]
and
\[
\begin{align*}
\hat{w}_{PL}^* &= \left( \frac{2(a-b)(1+m)}{1+2(m-a+b)} \right) \cdot c_{NB} \\
&\quad + \left( \frac{1+2m(1+a-b)}{1+2(m-a+b)} \right) \cdot c_{PL} \\
&\quad - \left( \frac{2(a+mr_p)(a-b)^2}{a(1+2(m-a+b))} \right).
\end{align*}
\] (5.26)

After solving for the optimal wholesale prices, we can derive the optimal retail price for both the national brand and the private label products by plugging the wholesale prices in the optimal retail price equations. Because the solutions to optimal retail prices are quite lengthy and offer no further insight to the solutions, we decide not to explicitly state them here, and we must rely on numerical solutions for some insight of these theoretical solutions.

Nonetheless, we can draw some results from the optimal solutions. Considering the wholesale prices, we know that the wholesale price of national brand (private label) is supposed to be positively related to the manufacturing cost of national brand (private label) and negatively related to the manufacturing cost of private label (national brand). Hence, we have the following requirements:

1. \[
\left[ \frac{1}{2} + \left( \frac{(a^2-ab-a)(1+m)}{b \cdot (1+2(m-a+b))} \right) \right] > 0
\] (5.27)

2. \[
\frac{a}{2b \cdot (a-b)} \left[ 1 + \frac{(a-b-1) \cdot (1+2m \cdot (1+a-b))}{1+2(m-a+b)} \right] \leq 0
\] (5.28)
The conditions are a bit different in the private label wholesale price. We naturally expect the wholesale price of private label to be increasing in its manufacturing cost. Nonetheless, we may also expect the private label wholesale price to be increasing in the national brand manufacturing cost as well. This makes sense from national brand manufacturing’s profit maximization point. Since private label product competes with national brand product, which is the direct product of the manufacturer, national brand manufacturer prefers to increase the wholesale price of private label when wholesale price of national brand increases to counteract the reduction in the national brand demand. We derive the following conditions:

3. \[ \left( \frac{2(a - b)(1 + m)}{1+ 2(m - a + b)} \right) \leq 0 \]  
   \[ (5.29) \]

4. \[ \left( \frac{1 + 2m(1 + a - b)}{1 + 2(m - a + b)} \right) > 0 \]  
   \[ (5.30) \]

The last condition translates into \[ a - b < \frac{1}{2} + m \], implying that the difference in maximum consumer’s willingness to pay cannot be greater than the markup plus one-half. The maximum willingness to pay reflects the degree of substitutability between the products. It appears that for wholesale price of private label to increase with respect to an increase in its manufacturing cost we require the private label to be within some substitution range that is close enough to the national brand product.

The optimal conditions for the wholesale prices in (5.25) and (5.26) display the interconnection between the national brand supply and the private label supply. Unlike the previous setup in Section 5.5, the optimal wholesale prices of the national brand and private label products depend on parameters related to both products. More specifically, both wholesale prices are functions of the national brand quality, the private label quality, the national brand
manufacturing cost, the private label manufacturing cost and the markup. The national brand manufacturer’s decision to supply private label product is not independent of factors related to the demand and supply of the national brand product. The results imply that the national brand manufacturer has to put into consideration the characteristics of the national brand product (i.e., the quality level) as well as its cost in determining the optimal price and supply of the private label product that he should produce.

5.7 Concluding Comments

This chapter considers an extension from the national brand and private label competition model first discussed in Chapter 4. We focus on the situation where the manufacturer supplies the private label product to the retailer as well as producing his own national brand. Since the private label product is a direct competitor of the national brand product, the national brand manufacturer generally has a disincentive not to supply the product to the retailer. With technology and cost advantages that the national brand manufacturer usually possesses, the private label supply from the manufacturer can increase the advantage of the private label product relative to the national brand product, which hurts the sale of the national brand product and possibly the overall profit earning of the national brand manufacturer. We present two theoretical models for the national brand supplying private label products. Depending on the assumption regarding the retailer’s pricing strategy, we discover the solutions lead to different conclusions on the issue. When the retailer picks the national brand and private label retail prices, our theoretical model shows that the national brand manufacturer’s decision to provide the private label product is independent of any factors related to the national brand demand and production. However, if the retailer uses a pre-specified markup for setting the national brand
retail price, the optimal pricing decisions are influenced by the quality and cost parameters from both products. We propose introducing the relationship of the two products’ quality levels into the optimization with two retail prices in order to allow for a connection between the two productions in the manufacturer’s level. If the production of the private label products influences the characteristics of the national brand manufacturer, such as reducing the brand value or the consumer’s perception of the national brand quality, the supply decisions for the two products by the national brand manufacturer will be linked. We also discuss the trading off rules between the profit from the national brand sale and the profit from selling an increasing-demand private label. The national brand manufacturer must identify how the demand would change in relation to his decisions to supply a cheaper-than-outside-source private label product to the retailer.
Chapter 6: The Empirical Tests for the Single Product Models

We now turn our attention to the empirical investigations on topics related to the theoretical results developed in Chapters 3 and 4. We address the results from the single product model in this chapter and move to the national brand and private label competition model in the next chapter. The theoretical results are tested empirically on data sets for packaged food product categories collected of Dominick’s Finer Food supermarket chain. For this chapter, we apply a unique item coding system used in the data set to identify products with improvements. In addition to the presentation of the data set, we summarize the findings from the theoretical chapters that are the focus of our empirical studies. Findings in Chapters 3 are tasted on several issues to find the consistency between the theoretical findings and the empirical results. Using various measurements as indicators for quality, we test the theoretical findings on the purchasing data. The chapter begins with the overview of the data set and the discussions of techniques and modifications applied to the data set to accommodate our empirical tests. Then, we consider the summary results from the single-product model that are suitable for empirical studies. We consider several product categories and discuss the variations in the empirical results across groups. We conclude the chapter by connecting the objectives of various empirical tests and discussing how they help unify the overall concept of the study.

6.1 The Discussion of the Data Set: Dominick’s Finer Food

The proposed data set is the Dominick’s database from the James M. Kilts Center, University of Chicago Booth School of Business, which is available to the public via the website of Kilts Center for Marketing. Dominick’s database covers the 6-year period of 1989 to 1994.
during the partnership between Chicago business school and Dominick’s Finer Foods. The database encompasses 400 weeks and over 100 stores. It is a collection of products and purchasing information from the Dominick’s Finer Food supermarket chain. The data contains products under 3500 different UPCs, which are divided into 29 categories. The database contains four types of data files, which are not limited to only the scanner data. First data group contains data sets with information generally obtained from supermarket scanners. This includes a set of movement data files, which records weekly information per store on sale volumes, prices and retail gross margin for individual products. There are also separate UPC files, which have the descriptions and additional codes for each product. The second group of data files is considered general files, containing the customer counts file and the store-level demographic file. The customer count files provide store specific daily information regarding in-store traffic. This includes the number of customers, category-specific sales volumes and number of coupons redeemed. The store-level demographics have the census information for the locations where stores are located. The information in this file includes, but not limit to, age range, ethic, college education, household sizes, median incomes and income distribution for any given store.

The overall product-related data are divided into 29 product categories, which allow us to focus on relatively comparable products. By concentrating on products from specific categories, we reduce various differentiating factors contributing to that make products differ so we can concentrate on the differences across products more closely and relate them to specific characteristics within the same category. Running empirical studies of quality focusing on products in the same categories is more appealing as the products are more comparable.

The product categories available in the scanner data are divided into the food products and the non-food products. We are interested in the empirical tests on the food product categories and
we focus the empirical tests in selected categories suitable for a specific set of regressions. The priority is given to the categories containing a greater concentration of products; namely, products with improvements or the national brand and private label products paring. Table 6.1 lists the available food product categories with initial information such as the numbers of observations, the numbers of products and the numbers of weeks.

Table 6.1: The List of Product Categories

<table>
<thead>
<tr>
<th>Category</th>
<th>Acronym</th>
<th>No. Obs.</th>
<th>Weeks</th>
<th>No. UPCs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottled Juices</td>
<td>bjc</td>
<td>6,016,137</td>
<td>1-399</td>
<td>511</td>
</tr>
<tr>
<td>Cereals</td>
<td>cer</td>
<td>6,417,055</td>
<td>1-399</td>
<td>490</td>
</tr>
<tr>
<td>Cheese</td>
<td>che</td>
<td>9,175,101</td>
<td>1-399</td>
<td>667</td>
</tr>
<tr>
<td>Cookies</td>
<td>coo</td>
<td>13,021,115</td>
<td>1-399</td>
<td>960</td>
</tr>
<tr>
<td>Crackers</td>
<td>cra</td>
<td>3,506,239</td>
<td>1-399</td>
<td>330</td>
</tr>
<tr>
<td>Canned Soup</td>
<td>cso</td>
<td>7,011,243</td>
<td>1-399</td>
<td>445</td>
</tr>
<tr>
<td>Front-end-candies</td>
<td>fec</td>
<td>6,561,190</td>
<td>1-399</td>
<td>505</td>
</tr>
<tr>
<td>Frozen Dinners</td>
<td>frd</td>
<td>2,597,193</td>
<td>142-399</td>
<td>283</td>
</tr>
<tr>
<td>Frozen Entrees</td>
<td>fre</td>
<td>11,347,587</td>
<td>1-399</td>
<td>900</td>
</tr>
<tr>
<td>Frozen Juices</td>
<td>frj</td>
<td>3,085,057</td>
<td>1-399</td>
<td>175</td>
</tr>
<tr>
<td>Oatmeal</td>
<td>oat</td>
<td>1,301,870</td>
<td>91-399</td>
<td>96</td>
</tr>
<tr>
<td>Soft Drinks</td>
<td>sdr</td>
<td>17,069,092</td>
<td>1-399</td>
<td>1746</td>
</tr>
<tr>
<td>Snack Crackers</td>
<td>sna</td>
<td>5,310,005</td>
<td>1-399</td>
<td>425</td>
</tr>
<tr>
<td>Tuna</td>
<td>tna</td>
<td>3,763,229</td>
<td>1-399</td>
<td>278</td>
</tr>
</tbody>
</table>

The Dominick’s data set offers a wide range of packaged food products as presented in Table 6.1. There are products with relatively short shelf life such as cheeses and cookies, in contrast to long shelf-life products like canned soup and canned tuna. Some products require
special storage such as frozen items, which are more expensive to stock. There is also a wide range of product numbers available in each category. The numbers of UPCs range from as high as 1,746 items in Soft Drinks category and as low as 96 in Oatmeal. These numbers imply the feasibility for empirical tests in each product category. We prefer the category with many enough UPCs but not too many to make the data management (such as identifying the private label and national brand pairing) difficult. More detailed discussions on the categories chosen for the empirical studies are presented in Section 6.2 for the Single Product model and in the next chapter for the National Brand and Private Label model. Additional discussion on products summary statistics is presented after we specify the reduced data sets for the products with improvements and the national brand and private label pairs.

6.2 NITEM Coding Clarification

The Dominick’s Database has one unique feature that helps us identify the quality change within a product. An improved quality product may show up in a new UPC code, which appears as if the old quality product is discontinued and is replaced by the new quality one. The Dominick’s data contains a numerical coding called “nitem” which will help identify a switch of product from one UPC to another during the survey period. The variable “nitem” is Dominick’s own item code tracking individual product through various UPCs. In the case of our interest, when a product changes to a newer version, it may come in a new UPC; but it will be under the same nitem number.

Although it is not explicitly confirmed in the data set that the newer version product is always of higher quality than the older version, we assume that the newer version is the one that
the manufacturer believes is better than the older version. The nitem numbering system does not necessarily identify which product is the newer product but this fact can be clarified by observing the date of sale. We will assume that the newer version is of a higher quality, or at least of the same quality.

One draw-back to the nitem coding system is that it is incomplete. It is possible that newer versions of products that are listed under new UPCs are also given different nitem codes. The nitem system does not include all the “improved” products on sale in the supermarket chain. We do not expect that this incompleteness should impact our empirical tests as long as the inconsistency in data entering is random. By using the products identified by nitem coding, we only randomly select the products from the data set. Moreover, we can manually detect the changed version of a product by investigating the description accompanying UPC codes. If the products have the same description and are of the same size, it is quite reasonable to suspect them to be the same product. This can be further verified by checking the sale dates for any coinciding intervals. Generally, if one product is offered exclusively prior to the other product, we may deduce that the pair of products is possibly older-newer version of the same product. Nonetheless, this is only a possible course of action as we first focus on the nitem coding system.

Table 6.2: Numbers of Products with Repeated NITEM Codes

<table>
<thead>
<tr>
<th>Category</th>
<th>Bottled Juices</th>
<th>Cereals</th>
<th>Cheese</th>
<th>Cookies</th>
<th>Crackers</th>
<th>Canned Soup</th>
<th>Front-end Candies</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. NITEM Products</td>
<td>62</td>
<td>77</td>
<td>78</td>
<td>132</td>
<td>24</td>
<td>12</td>
<td>66</td>
</tr>
<tr>
<td>Category</td>
<td>Frozen Dinners</td>
<td>Frozen Entrees</td>
<td>Frozen Juices</td>
<td>Oatmeal</td>
<td>Soft Drinks</td>
<td>Snack Crackers</td>
<td>Tuna</td>
</tr>
<tr>
<td>----------------</td>
<td>----------------</td>
<td>----------------</td>
<td>---------------</td>
<td>---------</td>
<td>-------------</td>
<td>----------------</td>
<td>------</td>
</tr>
<tr>
<td>No. NITEM Products</td>
<td>2</td>
<td>71</td>
<td>3</td>
<td>3</td>
<td>207</td>
<td>13</td>
<td>53</td>
</tr>
</tbody>
</table>

Depending on category, the numbers of products with improvement as defined by repeated NITEM codes rank from as few as two (in Frozen Dinners) to 207 (in Soft Drinks). The proportion of improved products identified by NITEM also varies substantially across categories. The Canned Tuna category has almost 20% of its products with some recorded changes in versions; while the Canned Soup category has 3%. The variation in the number of product improvements may imply some key differences across the category and the characteristics of the specific product markets. Nonetheless, we need to keep in mind that the NITEM indicates only the products with new versions introduced rather than the newly introduced products. Consequently, the implication of new versions differs from the new product introduction. From the numbers of repeated NITEM product, we decide to use five product categories in the empirical tests for the Single Product model. They are Bottled Juices, Cereals, Cheese, Cookies and Frozen Entrees. These categories are chosen mainly for the large number of repeated NITEM observations presented. They also vary by market characteristics, which allow us to further identify the differences and possible causes for deviation in the results.
6.3 Data Description for NITEM Groups

Initial investigation into the prices and profits provides the primary information regarding prices and profits, as well as their relationship. The summary data sets contain information on the mean prices, the mean profit ratio and the total quantity for each NITEM group for all five product categories we address in our empirical study. Table 6.3 presents the general data summary for all five product categories.

Table 6.3: The Summary Statistics for NITEM Groups

<table>
<thead>
<tr>
<th>Means Statistics</th>
<th>Product Category</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bottled Juices</td>
</tr>
<tr>
<td>Retail Price</td>
<td>0.997</td>
</tr>
<tr>
<td>Profit Ratio</td>
<td>13.63</td>
</tr>
<tr>
<td>Quantity</td>
<td>123,212.50</td>
</tr>
<tr>
<td>Number of</td>
<td>62</td>
</tr>
</tbody>
</table>

Table 6.3 shows quite a variation in summary statistics across product categories. The mean retail prices range from $0.185 in Frozen Entrees to $1.90 in Cereals. The highest average profit ratio is for Cheese at 18.89% whereas the Cereals category has the lowest average of 10.49%. In general, the mean statistics do not appear to show any patterns or relationships across variables. To obtain a further detailed description of the data, we consider the category plots for

---

13 We compute the mean for each NITEM group by first computing the mean for each UPC product, then we find the mean of all UPCs in the same NITEM group.
the statistics summarized in Table 6.3. Aiming at providing a general overview of the variables of interest, we reorder the data set for each product category by quantity before plotting the retail price and the profit ratio against the total quantity. Figure 6.1 displays the set of scatter plots for the retail prices.

With the ordering of the quantity demand, Figure 6.1 shows that generally the products with low prices are also those of low quantity volumes. Interestingly, this characteristic is not generally expected. One explanation may be that the low price products are the introductory products, which are available during the promotional periods. However, they are products with changes in versions; so they are likely to be on market for some extent. The evidence of low price products with low volumes is particularly apparent in the Frozen Entrees group with 17 out of 71 products are of low prices (less than $0.10) and low quantities (fewer than one thousand units). The plots also suggest that products with high prices are that of high volumes. They are most likely the market leaders or well-established products that are in market for an extended period. The high volume implies the product is popular, causing it being able to have high price.

Figure 6.1: The Scatter Plots for the Retail Prices
We extend the plots into the profit ratio as shown in Figure 6.2, representing the profit ratio plots after the data set is ordered by sales volume. Although the degrees of correlations vary, the general trends for the profit ratio are also similar to those observed in the plots for the retail prices. The products with low demand are the ones with the low profit ratios. If considering only the quantity and profit ratio, we may draw a conclusion that the retailer determines the rate for the profit ratio using the quantity level. Nonetheless, we also have a positive trend between the retail price and the profit ratio, which may suggest that the high profit ratio is associated with products of high costs (i.e., the high retail price is a direct indication of the high wholesale price.)
Figure 6.2: The Scatter Plots for the Profit Ratio
6.4 Theoretical Findings Summary

The optimization problem framework in Chapter 3 focuses on an optimal quality choice when one product is concerned. The chapter presents the basic setup of the distribution channel model when quality is a choice variable. The problem is posed in a single period framework, with quality being an instantaneous choice variable where the choice of this period and it impacts the consumers right away. There is no delay in consumers obtaining information about product information. Since it is a single period model, the findings, which are shown in Table 6.4, constitute of a series of singular optimal choices (wholesale price, retail price, quality) and their corresponding channel outcomes (quantity and profits).

Table 6.4: Simulation Results for Linear Quality Cost Function

<table>
<thead>
<tr>
<th>Cost Specification</th>
<th>Variable Parameter</th>
<th>Optimal Quality</th>
<th>Optimal Prices</th>
<th>Optimal Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality Cost h</td>
<td>Decreasing Convex</td>
<td>Decreasing Convex</td>
<td>Increasing Concave</td>
<td></td>
</tr>
<tr>
<td>Convex</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear Cost</td>
<td>Quality Elasticity α</td>
<td>Increasing convex</td>
<td>increasing convex</td>
<td>Decreasing convex</td>
</tr>
<tr>
<td>Concave</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost Specification</td>
<td>Variable Parameter</td>
<td>Manufacturer Profit</td>
<td>Retailer Profit</td>
<td>Profit Ratio PiM/PiR</td>
</tr>
<tr>
<td>Quality Cost h</td>
<td>Increasing then Decreasing</td>
<td>Increasing then Decreasing</td>
<td>Decreasing concave</td>
<td></td>
</tr>
<tr>
<td>Convex</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear Cost</td>
<td>Quality Elasticity α</td>
<td>slight U-Shape Sharp increase at high elasticity</td>
<td>slight U-Shape Sharp increase at high elasticity</td>
<td>Decreasing almost straight line very small change</td>
</tr>
<tr>
<td>Sharp increase</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
We find that the optimal quality choice is decreasing in the quality cost. Also, the optimal wholesale and retail prices are decreasing as the quality cost increases. The quality elasticity appears to have an opposite impact compared to the quality cost on the quality level and the prices. The quality level and the prices are increasing functions of the quality elasticity. A product with a higher elasticity has a higher quality level and a higher retail price. The relative market power between the retailer and the manufacturer is shown traditionally through the profit ratio; although the price ratio is also another interesting indicator. Empirically, the profit ratio may be more difficult to obtain whereas the price ratio is relatively easier to infer from the data set. Another set of simulations is done under the convex cost specification and the results are shown in Table 6.5.

For the convex cost function section, most of the findings as shown in Table 6.5 address the same issues as the linear quality cost specification. Interestingly, the convex quality cost case offers a comparison between the impact of the price elasticity and the quality elasticity on the optimal quality and price levels. The elasticity of quality in the convex case is approximately similar to the result from the linear cost case, with differences in the magnitude and the marginal effects. The linear and the convex quality cost schedules also lead to the same trends in optimal choices and outcomes (in direction, at least). However, the elasticity of price appears to have an opposite impact on quality and price levels. The empirical tests may shed some light on which assumption is consistent with the empirical data.
Table 6.5: Simulation Results for the Convex Quality Cost Function

<table>
<thead>
<tr>
<th>Cost Specification</th>
<th>Variable Parameter</th>
<th>Optimal Quality</th>
<th>Optimal Prices</th>
<th>Price Ratio W/P</th>
<th>Optimal Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convex Cost</td>
<td>Price Elasticity</td>
<td>Decreasing Convex</td>
<td>Decreasing Sharper convex</td>
<td>Increasing almost straight</td>
<td>Increasing S-Shape</td>
</tr>
<tr>
<td></td>
<td>Quality Elasticity</td>
<td>Increasing saddle shape</td>
<td>Increasing slightly convex</td>
<td>increasing Almost straight</td>
<td>Decreasing slightly convex</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost Specification</th>
<th>Variable Parameter</th>
<th>Manufacturer Profit</th>
<th>Retailer Profit</th>
<th>Profit Ratio PiM/PiR</th>
<th>Difference in Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convex Cost</td>
<td>Price Elasticity (\eta)</td>
<td>Increasing then Decreasing Convex</td>
<td>Increasing then Decreasing Convex</td>
<td>(&gt;) one Increasing almost straight line</td>
<td>Inverted-U-Shape</td>
</tr>
<tr>
<td></td>
<td>Quality Elasticity (\alpha)</td>
<td>Decreasing slightly convex</td>
<td>Decreasing slightly convex</td>
<td>U-Shape</td>
<td>decreasing slightly convex</td>
</tr>
</tbody>
</table>

6.5 The Empirical Tests for the Single Product Model

Our theoretical section in the single-product model focuses on the issues of quality, prices and market power variables. We focus on these issues when we identify the empirical tests for particular data sets. We propose using the price level and the price difference as indicators for quality and quality difference. The impacts of quality and elasticity are tested in various market outcomes.
Using Price as Quality indicator

Our study focuses on the quality change or quality improvement of a particular product rather than the qualitative quality difference across product. Theoretically, we consider the situation where a product is improved in quality and is changed into a better product. The idea suggests that the lower quality version of the product does not exist in the market at the time when the improved quality product is on sale. This may not be the normal case for many products we encounter in the market, whose higher quality versions are often offered alongside the lower quality ones through the product line extensions. The co-existence of lower and higher quality versions, some may suggest, should be considered as two available products rather than one. We need to clearly identify this issue in our empirical section and suggest methods in dealing with these differences.

A direct correspondence to the Single Product models presented in Chapter 3 is a product that has a change in quality and the improved quality completely replaces the former version of the product. This improved level of quality in the product may come from several sources. First, there can be a change in production technology, which improves quality without requiring a change in inputs. A change in formulation or the input combination can lead to an improved quality product, especially in the presence of a higher percentage of higher quality input in the formula. The increasing portion of better quality ingredient would generally result in a higher cost of product as we anticipate in the theoretical model. There can also be a change in an individual input itself but not in the composition. This is the case where individual input quality increases leads to an increase in the final product quality without a change in input combination.
The change in the quality of existing product, leading to an improved version of the product is more closely aligned to the idea we have for quality improvement in our single-product theoretical section. However, this is generally more difficult to detect in the scanner data than the competing product scenario because the scanner data do not necessarily contain detailed information of product quality or quality change. The Dominick’s Finer Food data set offers a unique opportunity for testing this type of model; since the products with changes in versions are recorded using the NITEM coding system. With the multiple versions originating from the same product, it is easier to assume that the change in versions is mainly associated with the change in quality or perceived quality. By considering the difference in prices set for different versions, we should be able to capture the difference in quality between versions. In addition to the price difference, we also consider the price level, which should be a broader indicator of the quality cost.

6.5.1 Testing the Impact of Quality Cost on Market Outcomes

We investigate the impact of quality on the retailer’s profit through the relation of prices and profit ratio. Since the quality information is not directly available from the main data set, we use the product price as an indicator for the product quality. More specifically, we employ the unique feature of the data set and use the price difference as a proxy for a quality related measure. For the first part of the empirical investigation, we focus on the market outcomes and movements in relation to the level of product quality cost. The difference in price levels across versions should help approximate the change in production costs from an old version to a new version, which can be associated to the change in quality of the products. We look at the empirical results in comparison to the theoretical results in determining the appropriateness of price difference as a proxy for either the quality cost or the product quality level.
The initial data set contains weekly sale data for individual UPC product per store location. Due to the nature of supermarket pricing strategy, the weekly sale data can be too volatile to accurately represent the pricing for the questions we pose. Since we are more interested in a medium to long-term adjustment of the product due to the change in quality, we address these issues at a more aggregated level of sale movements. Consequently, we primarily address the relationship between quality and market outcomes in the most aggregated data set; namely, NITEM aggregate data. The NITEM aggregate data set provides the average level of price for each NITEM product group. This is the average price for all product versions, which include older and newer versions of the product with the same NITEM code. The data set presents the average of weekly price instead of the average of individual version’s price average. This type of mean value implies that prices from all sale periods will be given importance equally. The mean price in this case represents the average price for each NITEM and conveys the overall mean quality cost.

The price difference is calculated as the difference between the older and the newer versions of a given product. In majority of NITEM groups, there are only two versions of the product leaving a computing of the price difference straight-forward. For when there are more than two versions, we use the largest range of price for measuring the price difference. Because the differences are those of versions, we compute the difference using UPC aggregated data as the starting data set. The difference data records the changes in prices from one UPC version to another within the same NITEM group.

\[^{14}\text{We should also check the aggregation done through the UPC group integration. In such case, the average NITEM price comes from the average of the mean price for each UPC product.}\]
We claim that the price difference between the aggregated price levels reflects how the production cost changes from one product to another. When addressing the difference between versions of the same product, the price difference should be closely related to the change in the cost of production. It is also possible that the price difference implies the quality level of the product. The different versions of the same product are assumed have the majority of the change coming from an improvement in quality (or consumers-perceived quality). Consequently, the price difference across versions can be an indicator for the level of quality cost of the product. The products with high price differences can be products of high quality level since it costs more to improve.

**Price Deviation on Profit Ratio**

We begin with an investigation into the relationship between the price difference and the retailer profit ratio. We run least squares estimates for linear, quadratic and log functional forms. Tables 6.6 and 6.7 present the regression results for all five product groups. We do not present the coefficients from the regressions with negligible adjusted-$R^2$.

### Table 6.6: The Quadratic Relationship between Price Deviation and Profit Ratio

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Explanatory Variables</th>
<th>Cookies</th>
<th>Frozen Entrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profit Ratio</td>
<td>Intercept</td>
<td>9.296</td>
<td>19.683</td>
</tr>
<tr>
<td></td>
<td>PriceDev</td>
<td>15.089</td>
<td>-4.138</td>
</tr>
<tr>
<td></td>
<td>PriceDevSQ</td>
<td>-7.519</td>
<td>0.434</td>
</tr>
<tr>
<td>$R^2$</td>
<td></td>
<td>0.101</td>
<td>0.068</td>
</tr>
<tr>
<td>Number of Observations</td>
<td></td>
<td>132</td>
<td>71</td>
</tr>
</tbody>
</table>

Note: Bottled Juices, Cereals and Cheese regressions are not reported due to its negligible explanatory power.
Table 6.7: The Log Relationship between Price Deviation and Profit Ratio

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Explanatory Variables</th>
<th>Cereals</th>
<th>Cookies</th>
</tr>
</thead>
<tbody>
<tr>
<td>LnProfitRatio</td>
<td>Intercept</td>
<td>2.176</td>
<td>2.712</td>
</tr>
<tr>
<td></td>
<td>LnPriceDev</td>
<td>0.064⁹</td>
<td>0.206</td>
</tr>
<tr>
<td>(R^2)</td>
<td></td>
<td>0.021</td>
<td>0.165</td>
</tr>
<tr>
<td>Number of Observations</td>
<td></td>
<td>77</td>
<td>132</td>
</tr>
</tbody>
</table>

Note: Bottled Juices, Cheese and Frozen Entrees regressions are not reported due to its negligible explanatory power. The superscript “a” indicates the coefficient is not significant at 5% confidence level.

The regressions for the relationship between price deviation and profit level offer mixed results. For Table 6.6, two categories indicate no relationship and the two with significant relationship have different signs for coefficients. When considering tables 6.6 and 6.7 together, we observe a result following our theoretical findings for the Cookies category on the relationship between quality improvement and profit change, which is also the category with the relatively strongest explanatory power. We have no evidence to suggest the generalization across product categories. Nonetheless, the observed significant results reinforce the theoretical findings that the higher quality difference brings about higher profit ratio for retailers.

**Price Difference on Profit Ratio Difference**

In addition to using the direct profit ratio, we also consider the difference in profit ratios across product versions. The profit difference indicates the change in markups set by the retailer on profits when it experiences a change in version. With product quality improved, we may expect the retailer to set the markup at a higher rate than the previous versions. The increase in quality benefits the retailer by allowing him to reap greater benefit from selling the products. By
using the profit ratio difference, we focus on the influence of quality change on the profit change rather than the profit level.

The series of regressions of price difference on profit difference are presented in the following set of tables from 6.8 to 6.9. The first two tables use price ranges as a measure for the price difference.

Table 6.8: Price Range on Profit Range in the Quadratic Form

<table>
<thead>
<tr>
<th>Functional Form: Quadratic Form</th>
<th>Bottled Juice</th>
<th>Cereals</th>
<th>Cheese</th>
<th>Cookies</th>
<th>Frozen Entrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent Variable</td>
<td>Explanatory Variables</td>
<td>Profit Ratio Range</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>PriceRange</td>
<td>1.890ᵃ</td>
<td>4.253</td>
<td>2.356ᵃ</td>
<td>1.589ᵃ</td>
</tr>
<tr>
<td>PriceRangeSQ</td>
<td></td>
<td>-3.709</td>
<td>0.660ᵃ</td>
<td>-2.625</td>
<td>-2.812</td>
</tr>
<tr>
<td>R²</td>
<td></td>
<td>0.554</td>
<td>0.313</td>
<td>0.390</td>
<td>0.504</td>
</tr>
<tr>
<td>Number of Observations</td>
<td></td>
<td>54</td>
<td>77</td>
<td>78</td>
<td>132</td>
</tr>
</tbody>
</table>

Note: The superscript “ᵃ” indicates the coefficient is not significant at 5% confidence level.

Table 6.9: Price Range on Profit Ratio Range – Log Form

<table>
<thead>
<tr>
<th>Functional Form: Log Form</th>
<th>Bottled Juice</th>
<th>Cereals</th>
<th>Cheese</th>
<th>Cookies</th>
<th>Frozen Entrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent Variable</td>
<td>Explanatory Variables</td>
<td>LnProfitRatio Range</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>LnPriceRange</td>
<td>2.350</td>
<td>1.924</td>
<td>2.409</td>
<td>2.432</td>
</tr>
<tr>
<td>LnPriceRange</td>
<td></td>
<td>0.450</td>
<td>0.508</td>
<td>0.769</td>
<td>0.815</td>
</tr>
<tr>
<td>R²</td>
<td></td>
<td>0.253</td>
<td>0.495</td>
<td>0.578</td>
<td>0.566</td>
</tr>
<tr>
<td>Number of Observations</td>
<td></td>
<td>54</td>
<td>77</td>
<td>78</td>
<td>132</td>
</tr>
</tbody>
</table>

We present two forms of the regressions: a quadratic form in Table 6.8 and a log form in Table 6.9. Except for Bottled Juices, most of the product categories fit better in the log form.
The regressions results indicate a positive relationship between the price difference and the profit difference. The difference in profit ratio, although is increasing, is increasing at a decreasing rate. Overall, the results suggest that products with larger differences between versions are also associated with the larger gaps in profit ratios between versions. This implies that the quality difference brings about a larger change in profit ratio that the retailer sets for the particular products.

Next, we address the profit deviation, which is a slightly different measure for differences. The results are closely similar to those we found using the price range measures as presented in Tables 6.10 and 6.11.

Table 6.10: Price Deviation and Profit Deviation in the Quadratic Form

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Explanatory Variables</th>
<th>Bottled Juice</th>
<th>Cereals</th>
<th>Cheese</th>
<th>Cookies</th>
<th>Frozen Entrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profit Ratio</td>
<td>Intercept</td>
<td>1.429(^a)</td>
<td>2.455</td>
<td>1.973(^a)</td>
<td>0.955(^a)</td>
<td>4.921</td>
</tr>
<tr>
<td>Deviation</td>
<td>PriceDev</td>
<td>15.645</td>
<td>4.135(^a)</td>
<td>12.947</td>
<td>15.711</td>
<td>5.851(^a)</td>
</tr>
<tr>
<td></td>
<td>PriceDevSQ</td>
<td>-5.011</td>
<td>-0.197(^a)</td>
<td>-2.995</td>
<td>-5.069</td>
<td>-1.225(^a)</td>
</tr>
<tr>
<td>(R^2)</td>
<td></td>
<td>0.561</td>
<td>0.245</td>
<td>0.361</td>
<td>0.4740</td>
<td>0.148</td>
</tr>
<tr>
<td>Number of Observations</td>
<td></td>
<td>54</td>
<td>77</td>
<td>78</td>
<td>132</td>
<td>71</td>
</tr>
</tbody>
</table>

Note: The superscript “\(^a\)” indicates the coefficient is not significant at 5% confidence level.

Table 6.11: Price Deviation and Profit Deviation in the Log Form

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Explanatory Variables</th>
<th>Bottled Juice</th>
<th>Cereals</th>
<th>Cheese</th>
<th>Cookies</th>
<th>Frozen Entrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>LnProfitRatio</td>
<td>Intercept</td>
<td>2.140</td>
<td>1.729</td>
<td>2.320</td>
<td>2.350</td>
<td>2.010</td>
</tr>
<tr>
<td>Deviation</td>
<td>LnPriceDev</td>
<td>0.443</td>
<td>0.503</td>
<td>0.770</td>
<td>0.808</td>
<td>0.226</td>
</tr>
<tr>
<td>(R^2)</td>
<td></td>
<td>0.248</td>
<td>0.491</td>
<td>0.575</td>
<td>0.557</td>
<td>0.152</td>
</tr>
<tr>
<td>Number of Observations</td>
<td></td>
<td>54</td>
<td>77</td>
<td>78</td>
<td>132</td>
<td>71</td>
</tr>
</tbody>
</table>
The regressions on the deviations produce similar results to the regressions on the ranges, leading us to the same conclusion that the higher price difference leads to a higher profit change. Similar to the price level, the price difference is related positively to the profit ratio difference. We find a stronger connection in the price difference than in the price level as the regressions generally produce better results, especially for the log form as shown in Table 6.11. The price difference regressions suggest that the higher quality differences may have a positive influence on the retailer’s choice of profit ratio. Nonetheless, we may want to account for the relative change instead of absolute change. The weighted price difference can be referred to as a measure for a proportional or a percentage change in price. With the weighted measure, the results will be more standardized and easier to interpret than the nominal case. These results are presented in Tables 6.12 and 6.13.

Table 6.12: Weighted Price Range on Profit Ratio Deviation

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Explanatory Variables</th>
<th>Bottled Juice</th>
<th>Cereals</th>
<th>Cheese</th>
<th>Cookies</th>
<th>Frozen Entrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profit Ratio Deviation</td>
<td>Intercept</td>
<td>2.996</td>
<td>4.624</td>
<td>3.133</td>
<td>2.094</td>
<td>5.418</td>
</tr>
<tr>
<td></td>
<td>WeightedPriceRange</td>
<td>4.951</td>
<td>4.584</td>
<td>6.042</td>
<td>5.705</td>
<td>2.928</td>
</tr>
<tr>
<td>R²</td>
<td></td>
<td>0.385</td>
<td>0.166</td>
<td>0.339</td>
<td>0.313</td>
<td>0.116</td>
</tr>
<tr>
<td>Number of Observations</td>
<td></td>
<td>54</td>
<td>77</td>
<td>78</td>
<td>132</td>
<td>71</td>
</tr>
</tbody>
</table>

Table 6.13: Weighted Price Deviation on Profit Ratio Deviation

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Explanatory Variables</th>
<th>Bottled Juice</th>
<th>Cereals</th>
<th>Cheese</th>
<th>Cookies</th>
<th>Frozen Entrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profit Ratio Deviation</td>
<td>Intercept</td>
<td>2.935</td>
<td>3.377</td>
<td>2.549</td>
<td>1.390</td>
<td>5.418</td>
</tr>
<tr>
<td>R²</td>
<td></td>
<td>0.395</td>
<td>0.146</td>
<td>0.401</td>
<td>0.371</td>
<td>0.116</td>
</tr>
<tr>
<td>Number of Observations</td>
<td></td>
<td>54</td>
<td>77</td>
<td>78</td>
<td>132</td>
<td>71</td>
</tr>
</tbody>
</table>
In terms of fit, the weighted price variables in Table 6.12 and 6.13 fit better than the range variables from Table 6.8 and 6.9, but not as good as the deviation in Table 6.10 and 6.11. Nonetheless, they are better overall for all categories with significant coefficients and relatively strong explanatory power across the board. The results indicate a positive relationship between the proportional change and the profit deviation. The magnitudes for profit deviation changes corresponding to the proportional price change vary greatly from one category to another, with the relationship strongest for Cheese and Cookies. These results confirm the conclusions we draw from the nominal price difference that the larger quality difference between the two versions is associated with higher deviation in profit ratios set for products with improvements.

6.5.2 Additional Regressions Using Fixed Effects and Dummies

The Dominick’s Finer Food data set contains store information that may impact the estimation of quality impact on market outcomes. In this section, we look at the influence of the store-related variable on the regression results. For this set of tests, we use the quarterly purchasing data, which allow us to investigate the influence of store-level variables, which are not presented in the more aggregated data set we used earlier. Because of the broader scope, the quarterly data set contains the categorical information for stores, which can be used for grouping stores together. Such information can also be used as dummy variables in regressions. The original data set contains three group identifications for store locations. Stores can be divided into 15 pricing groups, three price tiers and four clusters. The movement of prices is assumed to be the same for stores in the same pricing group. Since we are interested in the overall pricing of products, we can focus on the purchasing data in the pricing group level instead of the individual store level. Dominick’s Fine Food categorizes stores into three price tiers: Low, Medium and High, which represent the overall price levels of products in
stores. In addition, the stores can be categorized by the store locations using clusters. The clusters represent groups of stores with similar demographics.

Using similar regression forms used in Section 6.5.1, we revisit the quadratic formation for the price deviation regressions. Store information is introduced into the regression model to investigate the impacts of store fixed effects on the profit ratio. Pricing tier dummies are used in the price-profit regression to measure the impact of store types on the amount of profit the retailer realizes.

We use the price deviation, which is a measure for standard deviation of prices within a quarter, rather than the price range as we did in earlier regressions. This is because the range may negate our purpose of using quarterly aggregation to cancel out random sales. Price ranges can be influenced by some temporary sales with extreme values. Hence, we use the standard deviation instead of the range to capture the degree of variation in prices within the quarter to generate a better measure of how the prices differ within the period. The two regressions comparing the basic regressions and the fixed effect regressions are shown in table 6.14 and 6.15.

Table 6.14: The Price Deviation Regression without Store Fixed Effect

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Explanatory Variables</th>
<th>Bottled Juice</th>
<th>Cereals</th>
<th>Cheese</th>
<th>Cookies</th>
<th>Frozen Entrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profit Ratio</td>
<td>Intercept</td>
<td>28.747</td>
<td>17.068</td>
<td>33.711</td>
<td>31.968</td>
<td>31.706</td>
</tr>
<tr>
<td></td>
<td>PriceDev</td>
<td>-7.198</td>
<td>-4.141</td>
<td>-9.466</td>
<td>-14.077</td>
<td>-5.201</td>
</tr>
<tr>
<td>R²</td>
<td></td>
<td>0.137</td>
<td>0.101</td>
<td>0.272</td>
<td>0.345</td>
<td>0.065</td>
</tr>
<tr>
<td>Number of Observations</td>
<td></td>
<td>73867</td>
<td>121453</td>
<td>138701</td>
<td>170183</td>
<td>62885</td>
</tr>
</tbody>
</table>
Table 6.15: The Price Deviation Regression without Store Fixed Effect

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Explanatory Variables</th>
<th>Bottled Juice</th>
<th>Cereals</th>
<th>Cheese</th>
<th>Cookies</th>
<th>Frozen Entrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profit Ratio</td>
<td>Intercept</td>
<td>25.342</td>
<td>14.520</td>
<td>32.850</td>
<td>31.999</td>
<td>30.883</td>
</tr>
<tr>
<td></td>
<td>MediumTier</td>
<td>3.230</td>
<td>2.032</td>
<td>0.745</td>
<td>-0.109 a</td>
<td>0.605</td>
</tr>
<tr>
<td></td>
<td>HighTier</td>
<td>5.407</td>
<td>4.908</td>
<td>1.481</td>
<td>0.137 a</td>
<td>1.832</td>
</tr>
<tr>
<td>R^2</td>
<td></td>
<td>0.159</td>
<td>0.144</td>
<td>0.274</td>
<td>0.345</td>
<td>0.067</td>
</tr>
<tr>
<td>Number of Observations</td>
<td></td>
<td>73867</td>
<td>128291</td>
<td>138701</td>
<td>170183</td>
<td>62885</td>
</tr>
</tbody>
</table>

Note: The superscript “a” indicates the coefficient is not significant at 5% confidence level.

When comparing table 6.14 and 6.15, we observe that the regression results are quite comparable. The resulting coefficients on the price deviation are close to the ones we obtain from the regression without the store tier variables. Adding the store price tier fixed effect does not improve the explanatory power of the regressions; instead, the store price tier information helps identify the components formerly absorbed in the intercept terms. The results suggest that the pricing tier shift the overall profit ratio in a quite uniform way across products within the same store tier. The store price-tier dummies remove some of the intercept magnitude, but leave the regression coefficients relatively similar to the ones from the basic regression without the fixed effects.

The coefficient values are also of expected levels, with the medium tier coefficients less than the high tier coefficients. It is also interesting to note that the resulting coefficients in Cookies category are insignificant, which may suggest that the Cookies category works differently in the store pricing strategy. It is also important to point out that the regressions results in table 6.14 and 6.15 shed new light into the relationship between profit and price difference (as quality differences). In the previous section where we investigate this relationship by aggregated NITEM group means, we observe no strong relationship between profit and price difference.
difference. In contrast, the relationship is apparent in all product categories under the UPC Quarterly data set. We observe a negative relationship between profit and price differences. A high price difference, which implies a relatively large quality difference, is associated with a reduction in the profit ratio set by the retailer. This result suggests that the retailer sets lower profit ratios for products with higher quality improvement. Because we generally expect the profit for product with higher quality improvement to be earning higher profit ratio overall, the reduction in the retailer profit ratios observed in the regressions may imply a higher profit ratio earned by the manufacturer as the product quality increases. However, without the information on the manufacturer profit, we are unable to confirm this implication.

The results lead us to conclude that the price difference works better as an estimator of the quality level. With a negative relationship with the profit ratio, the price difference works as an identification of the quality level by implying how much quality is embodied in the new products, indicating the levels (or relative level) of quality changes as they occur.

6.5.3 Testing the Impact of Elasticity on Market Outcomes

The Regression of the Price Elasticity

Now, we turn our attention to the next variable used in the simulation, namely the elasticity. According to our theoretical model, we consider price elasticity and quality elasticity, due to the flexibility in the demand structure. With the information on quality not directly available, it is not a straight-forward procedure to separate out the elasticity values as we do in the theory section. Consequently, we will first address the overall elasticity value and observe its relationship to the profit ratio. We expect the overall elasticity to yield similar results as findings in the price elasticity simulation.
Because of the wide range of aggregation choices available from the data set, we have many options for the elasticity measures. For our regressions, we want to measure one elasticity value per product. We use the quarterly data as the base data set for the estimation of product elasticity. The elasticity is measured as price elasticity from the log regression between quantity and price:

\[ \ln Q = C + \alpha \cdot \ln P + \varepsilon \]

where \( C \) is a constant and \( \alpha \) is the product elasticity. Since we are aiming to test the impact of elasticity on the profit ratio for overall products categorized as having improvements, we estimate an overall UPC-specific elasticity for every product in all NITEM groups. We observe some elasticity values less than one, which do not correspond to the theoretical model. Consequently, in studying the relationship between elasticity and market outcomes, we focus only on the products with an elasticity level greater than one\(^{15}\).

In keeping with the previous regressions, we focus on the impact of the elasticity on the profit ratio. We consider this relationship across product categories without including additional explanatory variables. This is to focus on the elasticity and profit relation without any other factors. The results are presented in Table 6.16.

\(^{15}\) The products with elasticity less than one are dropped from the data set since they do not correspond to our theoretical models.
Table 6.16: Regressions of Elasticity on Profit Ratio

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Explanatory Variables</th>
<th>Bottled Juice</th>
<th>Cereals</th>
<th>Cheese</th>
<th>Cookies</th>
<th>Frozen Entrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profit</td>
<td>Intercept</td>
<td>-12.59</td>
<td>3.479&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.865</td>
<td>3.278&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.058&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>R&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
<td>0.291</td>
<td>0.102</td>
<td>0.040</td>
<td>0.116</td>
<td>0.092</td>
</tr>
<tr>
<td>Number of Observations</td>
<td></td>
<td>33</td>
<td>77</td>
<td>167</td>
<td>132</td>
<td>74</td>
</tr>
</tbody>
</table>

Note: The superscript “a” indicates the coefficient is not significant at 5% confidence level.

Generally, the results suggest positive impact of elasticity on retailer’s profit. This is in line with the simulation results from Chapter 3. The regressions results are particularly reasonable given the levels of elasticity we encounter are generally low. As seen from the regressions, elasticity is expected to be related positively to the retailer profit ratio for smaller values of elasticity. Only in the higher ranges of the elasticity do we expect this trend to reverse. Nonetheless, we do not have observations within the high elasticity ranges to test for such hypothesis. The regressions of elasticity on profit present a low overall explanatory power. Except for Bottled Juices category, the adjusted R<sup>2</sup> are at around or less than 0.1. We also consider a natural log form (Ln Profit vs. Elasticity) as an alternative specification, which does not improve the regression results from the linear specification shown above.

The Regressions of the Quality Elasticity

In addition to the price elasticity, the simulation results discuss the variation in the quality elasticity, which is not directly available from the data set because of the lack of quality information. Given the purchasing information available from the Dominick’s Finer Food data set, there are several ways to measure a proxy for the quality elasticity. In this study, we propose using the elasticity differences between product versions. We compute the proxy for the quality
elasticity from the difference between the elasticity levels of older and newer UPC products within the same NITEM group. We then use the quality elasticity numbers to investigate the influence of the quality elasticity on firms’ decisions and market outcomes; namely, the retail price, the retailer’s profit ratio, the retail price deviation, and the profit ratio deviation. The tests are done on five product categories: Bottled Juices, Cereals, Cheese, Cookies and Frozen Entrees. According to our theoretical simulation results, the quality elasticity to be positively related to prices and quality level; hence, we may expect to see positive relationship between the quality elasticity and the price and price difference variables. On the other hand, the simulation results suggest a negative relationship between the quality elasticity and the retailer’s profit; so we may expect negative relationships between the quality elasticity and the profit ratio related variables.

The regressions vary from one category to another with most of the regressions showing no significant impacts of the quality elasticity on the focus market variables. Table 6.17 summarizes the regressions resulting in significant coefficients at 5% and 10% confidence levels.

Table 6.17: Regressions of Quality Elasticity on Market Outcomes

<table>
<thead>
<tr>
<th>Product Category</th>
<th>Dependent Variables</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Price</td>
<td>Profit</td>
</tr>
<tr>
<td>Bottled Juices</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Cereals</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cheese</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cookies</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Frozen Entrees</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Note: “+” indicates the coefficient is significant at 10% confidence level.
“++” indicates the coefficient is significant at 5% confidence level.
Table 6.17 shows that most of the regressions produce insignificant coefficients. Nonetheless, in most of product groups (with the exception of Cereals), there is at least one regression indicating a significant relationship between quality elasticity and the market outcomes. Most notably, the quality elasticity is a significant indicator for the degree of price deviation in Bottled Juices and Cookies. Since the price deviation is an indicator for quality difference between versions, the results suggest that the elasticity of quality influences the level to which the product quality adjusts. The actual coefficients are 0.801 for Bottled Juices and -0.193 for Cookies, making it inconclusive to judge the unique direction. A further investigation into the overall elasticity level may help explaining the difference in direction of quality elasticity impacts as we generally expect the reactions to be different for different levels of elasticity.

In addition, the regression results indicate a positive impact of the quality elasticity on price as we predict from the simulation results. The regressions produce significant coefficients in two groups; namely, Bottled Juices and Frozen Entrees. Both coefficients are positive, at 0.848 and 0.828 for Bottled Juices and Frozen Entrees, respectively, suggesting that the quality elasticity positively influences the price levels of products. The empirical results on prices support our theoretical findings for the quality elasticity.

As shown in Table 6.17, we also capture the relationship between profit ratio and quality elasticity in Cheese and Frozen Entrees categories. Although the forms of the relationship differ (one is in linear and another is a semi-log regression), both coefficients are positive, indicating that quality elasticity positively influences the profit ratio set by the retailer on product – the results we do not observe in the theoretical simulations. Nonetheless, further investigation into the difference in profit ratio between versions (shown in the last column of Table 6.17) displays
no significant relationship between the quality elasticity and the profit difference. We conclude that there is no evidence suggesting that the quality elasticity influences the change in profit ratio set for different versions of products.

Although many regressions offer no significant coefficients, the ones that are significant generally are of expected direction. Considering the regression results from all sets, we conclude that there are some evidences supporting the theoretical results found on the impacts of quality elasticity in the single product quality model.

6.6 Concluding Comments

This chapter investigates the empirical tests on the theoretical results from the single product model in Chapter 3. We use Dominick’s Finer Food data set, which is a collection of weekly, store-level purchasing and demographic data set recorded for Dominick’s supermarket chains, for the empirical investigations. The Dominick’s data set contains NITEM coding system that allows us to identify products with improvements in versions. The NITEM system separates out the products that have several versions through time, allowing us to select products with improvements. We focus our tests on the data for Bottled Juices, Cereals, Cheese, Cookies and Frozen Entrees categories.

Following the simulations in Chapter 3, we propose using price differences as an indicator of the quality level and the quality improvement. The quality variable is tested against market outcomes such as profit ratio in explaining the impacts of quality on the firms’ decisions. In addition, we calculate product elasticity as well as estimating quality elasticity for additional tests. The overall regressions results for the Single Product tests follow the results we
discovered in the simulations from Chapter 3. The empirical findings can also be generalized in any aggregation levels. The empirical results generally support our theoretical findings and support the validity of the theoretical models.
Chapter 7: The Empirical Tests for the National Brand and Private Label Model

After considering the empirical tests supporting the Single Product model results in the last chapter, we now turn our attention to the empirical tests related to the national brand and private label competition models from Chapter 4. In this chapter, we links the theoretical results developed in the Chapter 4 to empirical tests using the Dominick’s Finer Food data set. Since we are dealing with directly-competing products, the emphasis is given to the relative prices, profits, quantity of the national brand and private label products. Prices difference is again used as the quality indicator for our empirical investigations. We begin the chapter by summarizing the findings from the simulations in Chapter 4. We discuss the overview of the data set regarding to the private label products and outline the techniques and modifications applied to the data set to generate the national brand and private label products pairs. Then, we proceed to the empirical tests for the national brand and private label model. The quality proxy variable is tested for significant relationships with market outcome variables such as profit ratio, market shares and variables of differences. We conclude the chapter by connecting the objectives of various empirical tests and discussing how they help unify the overall concept of the study.

7.1 Preparing NBPL Information From the Data Set

Same as Chapter 6, we continue to use the Dominick’s Finer Food weekly store purchasing data as the data for our empirical investigations. Before we begin our empirical tests on the data set, we first identify the portion of the data set relevant for our study. The initial data set includes the private label brand and all the national brands offered in the supermarket chain.
We identify the pairing or grouping of private label and its corresponding national brand(s) for particular products. After the grouping is done, we then can focus on the differences in the values of their market variables.

We use product descriptions for the pairing of NB and PL products. The private label products in the data set are shown to be a selection of mostly primary, basic or mainstream characteristics whereas the national brands offer more variety in the product lines. There are also many national brands, each offering various degrees of product variations. The numbers of products and the flavors offered under each national brand vary across the product categories. For the pairing purpose, we assume that the private label aims at the leading national brand for particular products. To identify the corresponding national brands, we calculate the total sale information and obtain the top leading national brands that can be the direct targets of the private label products. After we identify the relevant national brand products, we match the private label products to the national brand products of the same descriptions.

There are two brands in the product descriptions fitting with the private label specification. There are products recorded under the Dominick’s brand as well as products under a “Generic” brand. Since the descriptions of the products are mostly similar, we treat both brands as if they are of the same brand. In addition, both the store brand and the generic brand should be managed in the same way by the store, leading us to believe that they are fundamentally the same and should be treated as a single brand.

Before we match the national brand and private label products into pairs, we first consider the number of the national brand products available in each product categories from the Dominick’s data set. The number of private label products is presented in Table 7.1.
Table 7.1: The Numbers of the Private Label Products

<table>
<thead>
<tr>
<th>Category</th>
<th>Bottled Juices</th>
<th>Cereals</th>
<th>Cheese</th>
<th>Cookies</th>
<th>Crackers</th>
<th>Canned Soup</th>
<th>Front-end Candies</th>
</tr>
</thead>
<tbody>
<tr>
<td>NB-PL Pairs</td>
<td>49</td>
<td>25</td>
<td>76</td>
<td>41</td>
<td>3</td>
<td>24</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Category</th>
<th>Frozen Dinners</th>
<th>Frozen Entrees</th>
<th>Frozen Juices</th>
<th>Oatmeal</th>
<th>Soft Drinks</th>
<th>Snack Crackers</th>
<th>Tuna</th>
</tr>
</thead>
<tbody>
<tr>
<td>NB-PL Pairs</td>
<td>0</td>
<td>15</td>
<td>14</td>
<td>6</td>
<td>59</td>
<td>10</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 7.1 shows a wide variety of private label products across product categories. They range from none in Frozen Dinners to 76 store brand items in Cheese. The variation suggests the differences in market for each product, where one market may be more suitable than another for private label products. Choosing the categories to use in empirical tests for NITEM regressions and NBPL regressions prove to be challenging. In matching the national brand to the private label products, we not only consider the product description but also the product package size. We match national brand and private label products based on both the exact descriptions and the product size.\(^\text{16}\) Under these grouping criteria, not all of the private label products can be matched to top national brand products. We select four categories: Bottled Juices, Cereals, Canned Soup and Frozen Juices, for the empirical tests in this chapter.

\(^{16}\) Although it is possible to match products of different size and calculate the per-ounce price to use in place of the usual price, which allows for a more flexible matching of NB and PL products, the price information obtained this way can be misleading. The per-ounce price should vary depending on the original size of products, making it impractical to apply the per-ounce price in the matching criteria.
7.2 Data Descriptions for the National Brand and Private Label Pairs

Using the criteria discussed in Section 7.1, we identify the national brand and private label products pairs in Bottled Juices, Cereals, Canned Soup and Frozen Juices categories. We discover that not all private label products have exact corresponding national brand products for product descriptions and sizes. Some of the private label products are repetitive. Consequently, the actual numbers of pairs for the product categories we are interested in are not identical to the numbers of the private label products shown in Table 7.1. We generate the summary means statistics per brand for each product category and report the information in Table 7.2.

Table 7.2: The Summary Statistics for the National Brand and Private Label Pairs

<table>
<thead>
<tr>
<th>Summary Statistics</th>
<th>Product Category</th>
<th>Bottled Juices</th>
<th>Canned Soup</th>
<th>Cereals</th>
<th>Frozen Juices</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>NB</td>
<td>PL</td>
<td>NB</td>
<td>PL</td>
</tr>
<tr>
<td>Retail Price</td>
<td></td>
<td>2.632</td>
<td>1.808</td>
<td>0.873</td>
<td>0.65</td>
</tr>
<tr>
<td>Quantity</td>
<td></td>
<td>302,120</td>
<td>131,527</td>
<td>2,673,131</td>
<td>276,610</td>
</tr>
<tr>
<td>Number of Observation</td>
<td></td>
<td>12</td>
<td>12</td>
<td>15</td>
<td>15</td>
</tr>
</tbody>
</table>

The summary statistics shown in Table 7.2 follow our prior intuition regarding the national brand and the private label products. The table shows that the mean retail prices for the national brand products are higher than the mean retail prices for the private label products in all categories. Generally, the price differences are approximately 23% to 31% of the national brand prices, suggesting that the private label prices are not too far apart from the national brand in all groups. We also get a confirmation that the retailer gets a higher marginal profit from selling the private label products than from selling the national brand products. Table 7.2 shows that the
profit ratios are higher in the private label groups with the exception of Bottled Juices category; although the profit ratios are quite close for Canned Soup and Frozen Juices. The mean retail prices and the mean profit ratios also suggest significant differences in prices and profit ratios across product categories. The information on the mean value suggests in the degree of market penetration from the private label product. For example, in Canned Soup, the national brand sale volume is much larger than the sale of private label counterparts, suggesting a strong market power of the national brand in the market for competing products. The Bottled Juices category has significantly lower ratio between the national brand quantity and the private label quantity, leading to a conclusion that the presence of the private label products may be stronger in this category. However, the mean quantity information in Table 7.2 only includes the sale from the national brand products with pairs. The other national brand products that are not competing directly with the private label products are not presented. The information ascertained here relates to the relative competitiveness between the private label and the national brand counterparts. It is not necessarily representative of the overall private label presence in the market.

We look at the plots for prices and profit ratios for products in each category to gain more information regarding the relationships and patterns between the national brand and the private label products. Figure 7.1 is the set of plots for the retail prices in each category.
Figure 7.1: The Scatter Plots for the National Brand and Private Label Retail Prices
All the plots in Figure 7.1 support the conclusion we draw earlier from Table 7.2. Even at the UPC level, the national brand products have higher prices than the private label counterparts in all product categories. The scattered plots show the prices are particularly close for products in Canned Soup category with half of the private label products having prices at almost the same level as their national brand pairings. The plots also show that generally the differences between prices vary within categories. This may suggest that the retailer does not have particular rules designed for each category specifically for the pricing of private label products. To get a better insight into the pricing rules, we consider the scattered plots for the profit ratios in Figure 7.2.

Unlike the retail price scattered plots in Figure 7.1, the profit ratio scattered plots in Figure 7.2 show some mixed trends concerning the profit ratio of the national brand and the private label products. Although the profit ratios for the private label products are generally higher than the profit ratios for the national brand in all categories, some pairs in Bottled Juices, Canned Soup and Frozen Juices have the national brand profit ratios higher than the private label profit ratios. The plots suggest that the retailer does not always gain a higher profit margin selling the private label than selling the national brand manufacturer. The observation raises a
few questions regarding the profit margin of a product as well as the role of the private label products from the retailer’s standpoint. If the retailer gains higher profit from selling the national brand, why would he want to introduce the private label product to compete with the existing national brand and reduce its demand? This seems to suggest a possibility of the different role of private label than the one we assume in the theoretical models in Chapter 4. Some of the observations we draw in this section can be investigated further using empirical tests. We will revisit some issues, such as the price and profit gaps, in the Section 7.4.

Figure 7.2: The Scatter Plots for the National Brand and Private Label Profit Ratios
7.3 Theoretical Findings Summary

Due to the complication of the optimal condition for quality, we need to rely primarily on the simulations for the results from Chapter 4. The simulations are undertaken for the main model, which focuses on the national brand manufacturer’s decisions. We acknowledge that the competition between the national brand and private label is a continuing process; the simulations provide a snapshot of an ongoing strategic interaction between the manufacturer and the retailer.
The change in the demand specification results in the simulation parameters changing from elasticity and cost parameters in Chapter 3 to be cost and quality parameters in Chapter 4. It follows that the results of the optimization problem are functions of these cost and quality parameters. Consequently, the testable relationships we draw from the optimization results start from the quality cost parameter in Table 7.3 before moving on to the private label quality parameter in Table 7.4.

Table 7.3: Simulation Results for Increasing Quality Cost

<table>
<thead>
<tr>
<th>Variable Parameter</th>
<th>Optimal NB Quality</th>
<th>Optimal Prices</th>
<th>Price Ratio PNB/PPL</th>
<th>Optimal NB Quantity</th>
<th>Optimal PL Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality Cost</td>
<td>Increasing slight S-Shape</td>
<td>Increasing slight S-Shape</td>
<td>Increasing slightly concave</td>
<td>Decreasing slightly convex</td>
<td>Increasing Slightly Concave</td>
</tr>
<tr>
<td>Quantity Ratio</td>
<td>Manufacturer Profit</td>
<td>Retailer Profit</td>
<td>Profit Ratio</td>
<td>Difference in Profit</td>
<td></td>
</tr>
<tr>
<td>DPL/DNB Increasing Convex</td>
<td>Decreasing</td>
<td>Increasing</td>
<td>PiR/PiM Increasing</td>
<td>PiR-PiM Increasing</td>
<td></td>
</tr>
</tbody>
</table>

The simulation results provide several hypotheses relating to the national brand and private label relation. The simulation suggests larger quality differences lead to the higher retail prices set for national brand and private label. The widening quality gap also associates with the increasing price ratio (defined by the national brand price divided by the private label price), the increasing private label market share and the larger retailer profit ratio.
As shown in Table 7.4, we get similar results from the simulations for the private label quality variation. The increase in the private label quality induces the national brand manufacturer to choose higher quality. The increase in the national brand quality is at a larger magnitude when compared to the private label quality increase, leading to the widening gap between the national brand and the private label quality as the private label quality improves. The increasing quality levels result in higher costs and higher prices for both products. The relatively high price of the national brand causes the consumers to gradually switch from the national brand product to the private label product. Nonetheless, the overall profits are increasing for both firms.

We intend to use the simulation results as the starting point for the empirical questions. However, the empirical tests can be expanded further to include additional topics related to the national brand and private label competitions that are not directly stated in the simulation results.
Because of the missing quality information from the data set, we need to make several assumptions and modifications, which may affect some assumptions we previously used in our theoretical model. The discussions regarding the differences between the regressions and the theoretical models will accompany the regression results and will be further discussed in the concluding chapter.

7.4 The Empirical Tests for the National Brand and Private Label Competition Models

We are primarily interested in the product quality and its relationship to other market outcomes within the national brand and private label framework. From Chapter 4 simulations, we look at the cases where the quality cost changes and investigate how the manufacturer and the retailer react toward the changes. Since the product quality is not directly observed from the data set, we consider some other substitutes referencing the level of product quality. Focusing on the national brand and private label pairs, we consider the relative quality difference, which can be approximated, in a similar manner as that from the Single Product empirical tests, from the difference in prices between the national brand and private label products. The difference in prices should suggest the gap in the quality levels of the two products; or, similarly, how different in terms of quality and the satisfaction consumers realize from purchasing each of the two products.

Clearly, the price difference and the quality difference are not equivalent. Quality is not exactly translated to prices and a difference in quality does not necessarily fully transform into a price difference. Nonetheless, the private label product should be close in characteristics to the national brand counterpart, making the difference between the two products be in the quality-
related area. Since they are assumed to be direct competitors and are designed to be as close a substitute as possible, we should be able to assume that generally they only differ in the consumer perception of “quality”. Among many factors, the difference in prices can involve quality or perceived quality in the national brand and private label pairing.

In addition to the price difference, we also look at the other relative performance and the relative measures between the two brands. The relative strength and relative performances are suggested in the simulation results. We address these issues using the information available from the Dominick’s data set. In particular, we consider the quantity, price and profit ratio. The price ratio and quantity ratio (market shares) can explain, in part, the relationship between national brand and private label standing in the market given their relative quality. Accompanying the quality level and quality differences, the relative performance indicators can strengthen the analysis into how the product quality works in the competitive products setting.

7.4.1 Testing the Impact of Price Differences on Market Outcomes

When considering the two competing products, it is reasonable to assume that the difference in prices has something to do with the difference between the two products’ quality levels. This is even more convincing when the two products are national brand and private label products. Since the private label products are designed to compete directly with their national brand counterparts, the characteristics of products should be similar. The only difference as far as most consumers concerned is in quality, which can be in physical quality or psychological quality such as brand names. In addition, the theoretical simulations for both the quality cost and the private label quality level suggest a positive relation between the quality difference and the price difference. In both cases, the increase in quality difference follows with the increase in the price difference. Consequently, we focus on the price difference between national brand and
private label products as a reasonable proxy for perceived quality difference between the two products.

Using price differences, we investigate how the quality difference affects the market outcomes in various food product categories. We are primarily interested in retailer’s profit ratio, quantity demand and price level. Our simulations indicate that the quality difference corresponds directly to the optimal national brand quality level. They suggest that an increase in quality differences between the national brand and private label products will lead to a reduction in the national brand demand, an increase in private label demand, an increase in both prices, and a possible reduction in the national brand profit. We will test these components using a series of regressions.

Using several choices for aggregation, we can derive multiple values for differences. For these initial tests, we also use the most aggregated versions, where the data set is aggregated by NB-PL group, which are the same as those in the previous set of regressions. Similar to the regressions in the Single Products Tests in Section 6.5.1, there are two measures of deviations we can use for the differences: standard deviation and range. We ultimately use the standard deviation to avoid a linear relationship the price range may have with the price level.

Similar to the previous chapter, we begin the regressions by investigating the influence of the price difference on the profit ratio. We look at how the quality difference between national brand and private label relates to the average profit ratio within the brands pair. We investigate the relationship by regressing the price deviation on the group profit ratio. The results are presented in Table 7.5.
Table 7.5: The Impact of Price Deviation on Profit Ratio for Overall Data

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Explanatory Variables</th>
<th>Cereals</th>
<th>Canned Soup</th>
<th>Frozen Juices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profit Ratio</td>
<td>Intercept</td>
<td>33.357</td>
<td>14.176</td>
<td>39.123</td>
</tr>
<tr>
<td></td>
<td>Price Dev</td>
<td>-11.658</td>
<td>14.414</td>
<td>-16.102</td>
</tr>
<tr>
<td>$R^2$</td>
<td></td>
<td>0.354</td>
<td>0.345</td>
<td>0.417</td>
</tr>
<tr>
<td>Number of Observation</td>
<td></td>
<td>13</td>
<td>15</td>
<td>9</td>
</tr>
</tbody>
</table>

Note: Bottled Juices regression is not reported due to its negligible explanatory power.

Table 7.5 shows that the regressions of price deviation on profit ratio offer mixed results across categories. There are three groups presenting significant results. Two of the three categories – Cereals and Frozen Entrees – indicate the price deviation (i.e., the quality difference) is negatively associated with profit ratio. When the quality difference between brands increases, the average level of profit reduces for Cereals and Frozen Entrees products. Conversely, the resulting coefficient from the Canned Soup products is positive, meaning the brands pair with larger quality difference will also have a higher profit ratio, in general. Although there is evidence supporting the positive relation between the retailer profit and the increase in quality difference; with the empirical tests splitting in opposite directions, we cannot conclusively summarize whether the connection between quality difference and overall profit will follow our theoretical results.

We further investigate the profit deviation in place of the profit level to see if the results differ. The simulation results regarding the profit difference indicates an increase in profit difference in relation with the increase in quality difference. The regression results in Table 7.6 indicate that only the Canned Soup category provides significant (also positive) coefficient.
suggesting that quality difference may bring about a larger profit difference between brands. The results state that the larger quality difference between national brand and private label makes the retailer set the profit ratio gap further apart for the two brands. With the private label products generally having a higher profit ratio, the results imply that the profit ratio of the private label products increases at a relatively higher rate than that of the national brand competitor, which supports the theoretical findings for both the quality cost simulations and the private label quality simulations.

Table 7.6: The Impact of Price Deviation on Profit Ratio Deviation for Overall Data

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Explanatory Variables</th>
<th>Canned Soup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profit Ratio Dev</td>
<td>Intercept</td>
<td>7.371</td>
</tr>
<tr>
<td></td>
<td>Price Dev</td>
<td>8.006</td>
</tr>
<tr>
<td>R²</td>
<td></td>
<td>0.476</td>
</tr>
<tr>
<td>Number of Observation</td>
<td></td>
<td>15</td>
</tr>
</tbody>
</table>

Note: All regressions except Canned Soup are not reported due to their negligible explanatory power.

7.4.2 Tests on Relative Price, Quantity and Profit Measures

In considering the competition between the national brand and private label products in relation to the quality choices, it is reasonable to put emphasize on the relative values of various market outcomes. A natural first step is to see the products as paired comparisons and to measure the impacts of relative choices on the relative performances. The simulation results from Chapter 4 present several observations regarding the relative performances and relative measures.
of the two products in relation to the change in the quality difference. By considering the relative performance of firms, we may better understand the dynamics between the two products, which help us understand the quality decisions in the competitive products setting. The data on national brand and private label products offer various relative measures between the two competing brands. These relative measures allow us to further investigate the market outcomes and the role quality (and possibly price level) play in determining the relative success or failures of the products. Specifically, they suggest how well a product is performing when compared to its competitor. When considered with other explanatory variables, the relative measures can indicate what factors influences the relative performances.

First, the price ratio is defined by national brand price divided by private label price. Since we expect the national brand product to always have a higher price than the private label product due to the higher quality assumption, we also expect the price ratio to be greater than one. Similar to the price difference, the price ratio reveals the magnitude of the gap between the national brand and the private label prices. We expect the two prices to be closely related. Nonetheless, as discussed earlier, the price deviation is an indicator of how the quality levels differ across brand; whereas, the price ratio is not necessarily conveying the same message. The relative price measure offered by the price ratio may be used as a measure for relative performance and standing of brands in the market. The simulation results indicate that the quality gap is positively associated to the price ratio in both sets of the simulations. This is reasonable since the increasing quality level of national brand relative to the quality level of private label should result in a larger increase in cost, and then price, of national brand product relative to that of private label. Table 7.7 considers the regressions supporting this relationship between the quality difference and the price ratio.
Table 7.7: Regressions of Price Deviation and Price Ratio

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Explanatory Variables</th>
<th>Cereals</th>
<th>Canned Soup</th>
<th>Frozen Juices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price ratio</td>
<td>Intercept</td>
<td>2.304</td>
<td>1.015</td>
<td>0.948</td>
</tr>
<tr>
<td>PNB/PPL</td>
<td>Price Dev</td>
<td>-0.840</td>
<td>0.880</td>
<td>0.662&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>R²</td>
<td></td>
<td>0.240</td>
<td>0.427</td>
<td>0.287</td>
</tr>
<tr>
<td>Number of Observation</td>
<td></td>
<td>13</td>
<td>15</td>
<td>9</td>
</tr>
</tbody>
</table>

Note: Bottled Juices and Frozen Juices regressions are not reported due to its negligible explanatory power. “b” denotes the coefficient is significant at 10% confidence level.

Table 7.7 offer significant coefficients in three of four categories: Cereals, Canned Soup and Frozen Juices. Interestingly, the regressions coefficients result in two opposite directions for price deviation impacts. In Cereals, the price deviation is negatively impacting the price ratio, suggesting that when the national brand and private label products have close quality, the price ratio between the two becomes far apart, and is contrary to our theoretical findings. The Canned Soup and Frozen Juices categories have positive regression coefficients which supports our simulation results. For the positive coefficients, the national brand becomes relatively more expansive as the quality level is far apart from that of the private label. Reasonably, the increase in the quality difference put on the products makes the national brand product more expensive relative to the private label competitor.

We next consider the quantity ratio as a measure for relative performance between the national brand and the private label products. The quantity ratio from the simulations is defined by the private label quantity divided by the national brand quantity. The simulation results indicate positive relationship between the price (i.e. quality) difference and the quantity ratio.
The results suggest that as the quality cost increases and the quality difference expands the national brand product starts to lose its market share and the ratio defined by the private label quantity divided by the national brand quantity keeps increasing. This is a result of the private label capturing a larger share of the market, which is a loss from national brand due to the increase in price. The increase in the quantity ratio comes together with an increase in the price levels for both national brand and private label products.

Table 7.8: The Impact of Price Deviation on Quantity Ratio

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Explanatory Variables</th>
<th>Bottled Juice</th>
<th>Cereals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity ratio</td>
<td>Intercept</td>
<td>-4.112</td>
<td>-14.554</td>
</tr>
<tr>
<td>QNB/QPL</td>
<td>Price Dev</td>
<td>7.824</td>
<td>19.53</td>
</tr>
<tr>
<td>R²</td>
<td></td>
<td>0.319</td>
<td>0.218</td>
</tr>
<tr>
<td>Number of Observation</td>
<td></td>
<td>12</td>
<td>13</td>
</tr>
</tbody>
</table>

Note: Canned Soup and Frozen Juices regressions are not reported due to its negligible explanatory power. “a” denotes the coefficient is not significant at 5% confidence level.

From Table 7.8, we have the regression coefficient for Bottled Juices being significant at 5% confident level; whereas the coefficient for cereals is significant at 10% level. In addition to relatively weak results, the coefficient findings from Table 7.8 differ from our theoretical finding. The increase in the quality gap between the two does not lead national brand products losing market share to the private label product. On the contrary, the increase in quality gap leads to an increase in market share for the national brand. The reason underlying this result may indicate that the difference in quality making the national brand more appealing and, at the same time, does not bring about a significantly large price change. Consequently, the national brand products are more appealing if their quality levels are more distant from the quality level for
private label. Under this reasoning, the resulting coefficients would follow those found in Table 7.8 and will be different from the prior conclusions derived from the simulations.

There is also another explanation for this difference between our simulation results and the empirical findings. In the ideal situation of the two products market, the ratio would represent the exact market share. However, we face multiple products market where the consumers may switch to other products not within the national brand and private label products group entirely. As a result, the quantity ratio is not exactly the market share but should be a good indicator of how the products are performing in comparison to their peers – in this case, their direct competitors.

The last relative measure we consider is the relative profit ratio difference. Since the information in the data set allows us to impute only the retailer’s profit ratio, we can calculate the retailer’s profit ratio for the national brand and the private label products. Since the profit ratios are from the retailer’s position, the ratio computed indicates the relative performance of products from the retailer’s perspective, which are not presented directly in our simulations. Nonetheless, it should be a reasonable proxy for the relative performance between the national brand and private label products. The profit ratio difference between the NB profit ratio and the PL profit ratio indicates how much the retailer gains from selling each unit of product. According to the data set, the profit ratios of private label products are not necessarily higher than those of national brand counterpart one may expect. The retailer does not always get a larger share of profit from the private label product than the national brand product.

We consider how the quality difference relates to the relative profit ratio setting between national brand and private label products. The relative profit ratio is defined by the national
brand profit ratio divided by the private label profit ratio. We are interested in observing how the quality difference impacts the relative profit ratio. The simulation results suggest that the overall profit for the retailer increases when the quality gap expands due to the expansion of demand for the private label product arising from the sharp national brand price rises. The results suggest that the relative profit ratio is actually increasing as the amount of national brand sold shrinks more than the rate of profit shrinks. Also, the expanding gap in quality should allow the retailer to charge proportionally more for higher quality product, resulting in the national brand product having a relatively higher profit ratio.

Table 7.9: Impact of Price Deviation on Relative Profit Ratio

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Explanatory Variables</th>
<th>Cereals</th>
<th>Canned Soup</th>
<th>Frozen Juices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative Profit Ratio</td>
<td>Intercept</td>
<td>1.015</td>
<td>0.378</td>
<td>0.516</td>
</tr>
<tr>
<td>NBProfit/PLProfit</td>
<td>Price Dev</td>
<td>0.468a</td>
<td>1.800</td>
<td>0.908</td>
</tr>
<tr>
<td>R²</td>
<td></td>
<td>0.135</td>
<td>0.678</td>
<td>0.389</td>
</tr>
</tbody>
</table>

Note: Bottled Juices regression is not reported due to its negligible explanatory power. The superscript “a” indicates the coefficient is not significant at 5% confidence level.

From the regression results presented in Table 7.9, we find some evidence supporting the simulation results. In the Canned Soup and Frozen Juices category we find strong regression estimations with significant coefficients suggesting that the ratio between the national brand profit ratio and the private label profit ratio is increasing with the price deviation. In this category, the expansion in the quality difference between brands leads to a relatively larger increase in the profit ratio for the national brand products. The regression estimations from
Cereals may be of opposite sign but it is insignificant. The evidences from the Canned Soup and Frozen Juices categories offer support to our theoretical findings regarding the positive relationship between the quality difference and the relative profit ratio.

Lastly, we consider the combined regressions which aim at explaining the variables influencing the profit ratio. We consider the price deviation and the quantity ratio as we investigate how the quality difference and the market share influence the profit ratio setting when considered together. The regression is aimed at investigating the influences of quality and market power together on the retailer’s performance. The regression results are shown in Table 7.10.

Table 7.10: Impact of Price Difference and Market Share on Profit Ratio

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Explanatory Variables</th>
<th>Cereals</th>
<th>Canned Soup</th>
<th>Frozen Juices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Profit Ratio</td>
<td>Intercept</td>
<td>29.508</td>
<td>13.054</td>
<td>39.714</td>
</tr>
<tr>
<td></td>
<td>Price Dev</td>
<td>-6.493a</td>
<td>16.601</td>
<td>-15.695</td>
</tr>
<tr>
<td></td>
<td>Q Ratio</td>
<td>-0.264</td>
<td>0.001a</td>
<td>-0.146a</td>
</tr>
<tr>
<td>R²</td>
<td></td>
<td>0.533</td>
<td>0.361</td>
<td>0.270</td>
</tr>
<tr>
<td>Number of Observation</td>
<td></td>
<td>13</td>
<td>15</td>
<td>9</td>
</tr>
</tbody>
</table>

Note: Bottled Juices regression is not reported due to its negligible explanatory power. The superscript “a” indicates the coefficient is not significant at 5% confidence level.

According to the results in Table 7.10, the regressions for Cereals, Canned Soup and Frozen Juices show significant and strong results indicating the relationships between the explanatory variables and the profit ratio. Interestingly, in all regressions, only one explanatory variable is significant. When the price deviation produces significant coefficient, the coefficient for quantity ratio is insignificant, and vice versa. The results are consistent to what we discover earlier for each of these explanatory variables. The price deviation has mixed effects on the profit
ratio, with a positive coefficient for Canned Soup and a negative coefficient for Frozen Juices. Similar to the regressions before, the impact of quality difference on profit ratio is inconclusive.

The regression results indicate that the quantity ratio is negatively related to the average profit ratio. This suggests that the profit ratio for groups with a strong national brand is actually lower than the groups with a weak national brand. This is reasonable considering that the profit ratio information we have is for the retailer. The negative relationship between the national brand manufacturer and the profit ratio set by the retailer can imply the stronger profit ratio set by the manufacturer for its product. Since the national brand products with high quality differences generally have higher prices, the lower profit ratio set by the retailer may indicate that a larger part of the profit is taken by the national brand manufacturer, resulting in the retailer charging only a fraction of the quality improvement benefit. However, without the information on the manufacturer’s profit, we can only speculate the reasoning for the negative relationship between profit ratio and the national brand market power.

7.5 Concluding Comments

In this chapter, we test the theoretical results generated in Chapter 4 for the national brand and private label competition models. We use the private label products in the Dominick’s Finer Food data to generate pairs of the national brand and private label products for our empirical tests. Since the NB-PL matching information is not directly available, we manually match national brand to private label using the descriptions provided by the data. The numbers of private label products presented in each product category are not generally large, which suggest the nature of private label products is not as widely available like in the current climate. Using
the total number of private label product as a deciding factor, we focus on the Bottled Juices, Cereals, Canned Soup and Frozen Juices categories.

Similar to the empirical tests for the Single Product model, we consider the quality variables and their relationships with the firms’ decision variables. We propose using the price difference for the proxy of the quality difference between brands. We also employ the relative performance measures, such as price ratio, profit-ratio ratio and quantity ratio, to gauge the performance of national brand and private label products. Generally, the empirical results provide supports to the theoretical solutions from Chapter 4. Most regressions support that quality difference and quality cost are related to most firms’ decision variables. However, the empirical results for national brand and private label products do not support as strongly the theoretical findings from Chapter 4 as the tests for Chapter 3. We also find mixed, inconclusive results in some empirical tests with the coefficients vary across categories. The variations found across categories may imply the differences in the market characteristics, leading to different relationships among national brand and private label products that are not captured in our theoretical models.
Chapter 8: Concluding Remarks

This study addresses the behaviors of firms inside the distribution channel. Using the quality level as the firm’s strategic tool, we focus on the optimal decisions and market outcomes when one or more firms can choose the quality level of their products. To be specific, we focus the area of our study to the physical product quality per unit of production rather than the overall quality investment. The quality component refers to a physical change to the product with the manufacturer’s quality cost denoted for quality in each unit of production. This is different from the traditional consideration of quality where the quality cost is considered a fixed cost that firms pay in a long term investment project. The framework discussed in this study does not contradict the traditional model setup but rather adds to the existing concept of the quality choice. The per-unit physical cost for product quality is suitable for several situations such as ingredient improvement, the addition of inputs or a change in product formula. Even if the firm has to pay for fixed investment or R&D cost, the change in quality is still present and it yields an actual change in the production cost. Under these circumstances, the decision to improve the product is considered as a change in marginal unit cost dependent to quality level.

Although the general discussion for the study is the investigation into the firms’ decisions on the product quality level, we are interested primarily in the impacts of quality on the overall decisions and market outcomes throughout the distribution channel. By focusing on quality as a strategic instrument, we will be able to understand how a choice variable of a firm influences the optimal decisions and the overall outcomes in the distribution channel. Since generally the quality level is applied by the manufacturer at the production stage, we believe that the product quality is more likely the manufacturer’s strategic tool. Consequently, we focus on how the decisions of the manufacturer impact or change the decisions of the retailer, and whether the
presence of product quality as a choice variable helps improve the performance and the market power of the manufacturer (or the retailer) in the distribution channel.

We consider two important topics for our discussion on the quality choice in the distribution channel. First, we look at the quality choice for an individual product. We build a static model discussing how the manufacturer chooses the product quality and consider how the quality impacts the decisions of the retailer and ultimately the decisions of the consumers. Second, we investigate the quality choice for competing products - more specifically, for the competition between the national brand and the private label products. By considering the national brand and private label competitions instead of any two national brands, we are able to emphasize on the interplay of firms in the distribution channel. The presence of private label is generally aimed at reducing the power and the influence of the national brand product on the market. With the product quality generally acting as a choice variable that improves a firm’s performance, the study of quality in the national brand and private label setting helps us understand how the manufacturer and the retailer interact inside the distribution channel in a wider perspective.

The theoretical findings for both the single product models and the national brand-private label models are tested empirically using a consumer purchasing data set of packaged food categories from the Dominick’s Finer Food supermarket chain. The data set contains a unique coding system that allows researchers to identify various versions of the same product so we can track products with improvements. Dominick’s Finer Food also offers store brands in most product categories, when we can use the private label brand to test among the competing products models. Identifying the national brand from the sales volume, we match the national brand and the private label products using the UPC description available from the Dominick’s
data. We then use the identified pairs of national brand and private label to test the results from the competing products models.

8.1 Theoretical Section for the Single-Product Models

The theoretical study on the manufacturer’s quality choice begins with the single product model. Here, we consider how the production decisions and the retail decisions are made from the manufacturer and the retailer when, in addition to prices, the product quality is under a firm’s control. The manufacturer decides on the quality of the product, which influences the production cost and the wholesale prices. The wholesale price, in turn, affects the retailer’s choices, which are a pass-through to the consumers. The decision on the product quality level has an effect on all parties in the distribution channel. Our goal is to identify how the presence of quality and its level influence the other optimal choices; namely, the wholesale and the retail prices, and the market outcomes, such as demand and profit.

We consider the quality cost as a cost per unit of production. The production cost of quality is applied to every unit made by the manufacturer and the cost depends on the quality level chosen by the manufacturer. The cost structure is important in determining the quality level assigned to the product. Our models consider two scenarios. First, we have a constant marginal cost for quality per unit of product, meaning that, for each increment of quality level, the cost of applying additional increment remains the same. The linear quality cost schedule makes it not particularly expensive to apply high quality to the product. Alternatively, we consider a convex cost specification where it becomes increasingly more expensive to apply a higher product quality. The convex cost specification makes it more difficult for the
manufacturer to choose high quality, implying the difficulty in producing the high quality product. The two scenarios are considered separately and the outcomes for each scenario are simulated under variation in cost and elasticity parameters.

For the linear quality cost specification, we look at the solutions for the variations in quality cost and quality elasticity. The simulation results for the quality cost reflect our prior expectation on how the firms would react toward an increase in quality cost and how the interactions of firms in the distribution would change in response to the increase. The manufacturer chooses a lower quality level when the cost of quality increases. The reduction in quality due to the increased cost is so significant that it lowers the overall manufacturing cost, resulting in the retail price reduction. The lower price attracts more consumers and raises the demand. Nonetheless, the simulation result for firms profit indicates that the drop in quality and the increase in demand are good for the manufacturer only at some low cost level. The increase in quality cost leads to a reduction in the manufacturer and the retailer profits at high cost levels. In addition, the retailer always earns higher profit than the manufacturer at all cost levels and his relative profit ratio increases as the quality cost increases, indicating that the rise in quality cost hurts the manufacturer more than it does to the retailer. We also obtain some expected results from the simulations for the quality elasticity variation. When the consumers are more responsive to quality, which is the case with high elasticity, the manufacturer chooses high quality for the product. The increase quality level follows by a rise in the retail price and a drop in demand. The profit results are not straight-forward with the profits decreasing until the mid-level of quality elasticity (at around unity) before increasing for both firms. Similar to the quality cost simulation, the retailer always earn higher profit and the relative profit ratio is increasingly
better for the retailer as the quality elasticity increases. Both simulations suggest that, under a linear quality cost specification, the retailer generally performs better than the manufacturer.

We compare the simulation results for the linear quality cost with the simulation results for the convex quality cost. Interestingly, the quality cost, which plays a big part in determining the firm optimal decisions, is only a determinant for the optimal quality choice but not for the optimal wholesale price. The result indicates that the quality cost component impacts the manufacturer’s choice of quality but the manufacturer does not change price when the cost changes. When there is a change in quality cost, he will adjust the quality level without changing the wholesale price. In absence of the quality cost impacts on all choice variables, we look at the simulations for the variations in the price elasticity and the quality elasticity instead. For the quality elasticity, the overall results are similar to those from the linear quality cost simulations. The manufacturer applies a high level of quality for product with a high quality elasticity level. The high quality level is matched with high wholesale and retail prices and low quantity demand. In contrast to the linear quality model, the manufacturer performs relatively better than the retailer by earning a higher profit than the retailer. The increase in the quality elasticity reduces the profits for both firms and reduces the gap between the manufacturer’s and the retailer’s profits.

The impacts of price elasticity differ from those of the quality elasticity. Naturally, a high price elasticity level means the consumers are more price-sensitive and more averse to high price products. An increase in the price elasticity persuades the manufacturer to lower the product quality to keep the price low. As a result, the consumer demand rises with the reduction in the optimal price. The increase in demand dominates the price reduction at first, leading to an increase in profits for both the manufacturer and the retailer. However, the increase in demand
cannot catch up with a steeply decreasing price, resulting in a reduction in profit for the relatively high elasticity level.

In addition to the static models, we consider the single product model in the dynamic context. Among many variations in the multi-period model settings, we choose to focus on the quality stock investment scenario. In such case, the product quality is an aggregated value of quality investment over time. We discover that, under our specification, price is a function of non-quality cost but not of quality cost. This is similar to our findings in the convex cost specification for a single period model. The simulation results indicate that the manufacturer continues to invest in quality even though he cannot charge for it via the wholesale price.

8.2 Empirical Section for the Single Product Models

We investigate the Dominick’s Finer Food data set for empirical evidence that may support our findings in the theoretical model. In the absence of direct quality information from the data set, we investigate the price difference between the original and the improved versions for quality indicators in our empirical analysis. We propose that the price difference should signal the quality improvement between versions, which may suggest either the quality cost or the quality level. We find a negative relationship between price difference and profit ratio. The quarterly data regressions on the subject indicate that the higher price difference is associated with a lower profit ratio. The results lead us to believe that the price difference appears to be signaling quality level, with the regression results in accordance with our quality level results. In addition, the regressions for the price difference on the profit difference show a positive relationship between the two variables in all product categories. The relationship is generally
convex, indicating that a larger change in quality brings about a larger change in the marginal profit earned by the retailer. A further investigation into the proportional change in price suggests that the relationship remains positive even when the price difference is weighted by the mean price level.

The empirical tests also investigate the impact of elasticity on the profit ratio. We find that the elasticity has a positive impact on the retailer’s profit ratio although the power of the regression is not always strong across regressions. The results offer some support to the theoretical models where both the linear and the convex cost specifications having the profit moves in the same direction as the price elasticity. Our attempts to single out the quality elasticity by considering the elasticity difference between versions do not provide the elasticity value that has significant relationship to the market decision variables in many regressions although the significant coefficients generally follow the theoretical results. This suggests we may need to refine the quality elasticity measure to be able to test the relationship of quality elasticity on market variables.

8.3 Theoretical Section for the National Brand and Private Label Models

For a further understanding in the interactions of firms in the distribution channel, we consider another type of competition that is becoming more prevalent in the recent years. The competition between the national brand and the private label products change the relationships between the manufacturer and the retailer from the single product models discussed in Chapters 2 and 3. The private label product is controlled by the retailer, who offers both the national brand and the private label in the store. The private label product is a direct competition of the national
brand, with the characteristics and specifications of the product catered to be close to those of the national brand product. Conceptually, private label products should improve the standing of the retailer within the distribution channel by weakening the manufacturer control on demand and diverting more control toward the retailer.

Building on variable reservation price schedules and consumer distributions, we form optimization problems for both the retailer and the national brand manufacturer in product competition. The optimal conditions for prices and quality tell us that the decisions for the two products are closely related. Due to the complexity and the non-linearity of the optimal solutions, we rely on the simulations for insights into the firms’ optimal decisions and market outcomes. We consider the variation in quality cost and the variation in private label quality for our simulations. The variation in the quality cost produces surprising results for optimal prices and other market outcomes. As the quality cost increases, the national brand manufacturer picks a higher quality level for the product. Instead of the reduction in the quality level to save the production cost, the optimal solution suggests that the manufacturer increases the quality level when its price increases. The increase in quality, in addition to the increase in quality price, drives up the manufacturing cost and the resulting prices and drives down the demand for the product. One explanation for this decision rule may be that the increase in quality is advisable in the face of reduction in demand due to the increase in price from the rising quality cost. To look competitive to the consumers, the national brand product needs to improve in quality as its base cost increases. Although the expansion in quality leads to an even further increase in cost, the alternative of staying at the same quality level and let the cost and the price rise results in a lower profit level.
Due to the increase in national brand price, some consumers switch from the national brand to private label, increasing the market share of private label after an increase in quality cost. It is interesting to point out that the retail price of private label also moves closely with the retail price for national brand, with the private label retail price rising significantly as the quality cost increases. However, the real manufacturing cost for the private label does not increase as much as the retail price, mostly because the quality of private label product remains constant throughout. The sharp increase in the private label retail price suggests that the retailer earns significantly more selling private label product as the quality of the national brand rises from the increasing quality cost. Initially, the retailer already earns more than the manufacturer in the market. The rise in the private label price and the drop in national brand demand results in an even wider gap between the national brand manufacturer profit and the retailer profit. According to the simulation results, the retailer does considerably better than the national brand manufacturer when the quality cost increases.

It seems reasonable to find that an increase in quality cost penalize the national brand manufacturer more than the retailer. With the national brand product relying on its relatively higher quality to position itself above its competitor, the increase in quality cost will make it more difficult as well as costly to the manufacturer to maintain his distinctive position. Our model suggests that the national brand manufacturer may choose to increase quality to counteract the increase in price and to make the product more appealing to consumers. It appears that even as the private label quality remains constant, it is better for the national brand manufacturer to distinguish himself even more from his competitor compared to when the quality cost is high. This results in a higher quality gap between the national brand and private label products for products with a high price level.
In contrast, the retailer does not need to do the same for the private label product because of its reputation of lower quality from the outset. Interestingly, even with a fixed quality level, the retailer can increase private label price in accordance with the rise in national brand price without really changing any characteristics of his product. With the national brand price increases, the consumers, who cannot support the national brand product, need to find an alternative and switch to the cheaper products. Knowing that the national brand price increases significantly, the retailer can set the private label price higher, as long as it is not too high to discourage the consumers from switching. Our simulations show that a firm can increase the price significantly without a physical change in his product if his direct competitor increases his price.

The finding offers an interesting alternative to the story about firm’s reaction toward his competitor is quality increases. Normally, we may assume that the firm wants to reduce its price if its competitor comes up with a better product to persuade consumers to remain with the product. Our model suggests that, from the already lower quality firm’s perspective, the increase in quality from his competitor does not necessary result in a reduction in price. The low quality product may perform better by increasing its price than reducing its price. This is because the lower quality product is designed to supply the consumers who cannot afford the high price product. The increase in price for the high quality product then allows the low quality product to raise its price alongside and the low quality product can still act as the alternative to the high price product. When the private label product is considered as the substitute, the increase in quality of the national brand product can justify the rise in private label price without any changes in its quality level.
In addition to the quality cost, we consider the simulations for the variation in private label quality. Since the model is originally designed for a fixed private label quality parameter, it is interesting and important to see how the optimal solutions vary with the change in private label quality. The simulation results indicate that the optimal quality choice for the national brand product increases in relation to the increase in private label quality. The national brand manufacturer will improve his product quality to compete with the improved quality private label. More interestingly, the results suggest that the increase in quality of national brand product is proportionally larger than the increase in private label quality. As a result, the quality gap between the two products increases as the private label quality rises. The relatively greater increase in quality drives the manufacturing cost for the national brand product up significantly; whereas the manufacturing cost of private label increases only slightly as the quality increases. As the gap between the wholesale prices for both products widens increasingly, the simulation result suggests that the retail prices for the two products are much closer to one another than their manufacturing cost or wholesale prices.

The simulation results for the quality cost variation and the private label quality variation portray similar ideas about quality difference and retailer pricing decisions. In both cases, the national brand manufacturer tries to distinguish his product from the private label product. The distinction between the two products is more prominent for expensive, high cost and high quality level products. When the quality cost increases, leading to the quality level increases, the gap between the two product quality levels become significantly larger. Similarly, when the private label product quality rises and the national brand product reacts with even higher quality, the gap expands. The results imply the national brand manufacturer prefers to keep the quality
particularly far apart from the private label product when the product is of high quality and high price.

Another observation from the simulation results is the increase in the private label retail price in relation with the rise in the nation brand price. In these cases, the increase in private label price is significantly higher than the actual change in its quality cost. The price rise appears to be responding to the spike in the national brand price. The results lead us to believe that the retailer is better off increasing his price when the national brand manufacturer acts in any way that leads to an increase in the price of its product. The increase in price does not need to accompany any significant changes in characteristics of the private label product. The retailer can take advantage of consumer substitutions to earn substantially higher profit when the national brand price increases.

The result that the retailer increases price to follow the national brand price relies on the necessity of consumers to purchase a product. Because the consumers are assumed to buy one product, the less desirability of the national brand forces the consumers into buying the relatively more desirable private label product. In the case of our simulations, the avoidance follows from the increase in prices. Clearly, this is not necessarily the case in other market settings. If there are other possible substitutes, such as the second national brand or a similar product with different characteristic dimensions, the consumers may not switch to the private label. The increase in private label price may not be an optimal strategy and may instead hurt the retailer by pushing the customers away from buying the private label product. With other substitutes, the retailer loses the necessary substitution and cannot free-ride on the national brand price increase. However, it is possible that the retailer may still be able to increase price for a smaller margin without changing any physical characteristics of the product. Because consumers still need to
find a substitute for the higher price national brand, the increased-price private label can still be attractive depending on the tightness of the market (in term of the product characteristics space) and the closeness between national brand and private label products. If the private label product is a very close substitute and the other national brand is originally targeting different consumer group, the increase in national brand price can still be associated to a sharp increase in private label price.

8.4 Empirical Section for the National Brand and Private Label Models

Similar to the empirical tests for the single product models, we use the price difference as an indicator for the quality difference. The national brand and private label models focus on a pair of brands, making it more convincing in claiming that the difference in prices is a translation of the difference in quality. The price difference regressions on profit ratio level offer mixed signal on the direction of the relationships between quality and profit ratio. We observe both positive and negative relationships, and both the increase in profit ratio following the large change in price (which is assumed to represent the change in quality) and the decrease in profit ratio. Our simulations predict an increase in the retailer profit ratio due to the substitution from the national brand to the private label allowing for the increase in price without having to increase its production cost. Nonetheless, the simulation results may be more appropriate for the empirical evidences in the private label products rather than the national brand products; and the increase in profit ratio can be more prevalent in the private label group. We also find the relationship between the price difference and profit difference not strong or significant in most categories, resulting in our inability to confirm any relationship between the quality gap and the
profit ratio difference. The only significant regression indicates a positive relationship, which is similar to our simulation result. By considering the overall pair information, we may dilute the significant relationship, making it more difficult to detect in the regressions.

The pairing of brands makes the relative measures between the two brands an appealing topic for the empirical tests. We focus on the issues around the quality differences and test several ratios with the price difference variable. The regressions for the price ratio produce inconclusive evidence on the relationship between quality gap and the retail price ratio. We expect to see a negative relationship but the results are mix. The demand ratio is more conclusive with the regressions indicating a positive relationship between price difference and quantity ratio. Interestingly, the results imply that the larger gap in quality between the national brand and the private label product results in the national brand gaining larger market share. The results are reasonable considering that the wider quality gap induces consumers to purchase the product as well as differentiating the national brand product from the private label product. However, our model suggests the widening gap in quality results in a higher price for the national brand, which discourages consumers from buying. The empirical results are not consistent with the theoretical findings. The profit ratio regressions offer only one significant and strong result, which shows a positive relationship between the price difference and the ratio of the profit ratio. It appears that in one product group, the retailer earns more per unit from national brand than from the private label when the gap between their respective prices increases.

Our empirical results suggest that the difference between the national brand and the private label quality benefits the national brand manufacturer. The widening gap also allows the retailer to enjoy higher profit margin from the national brand than before. The positive impacts from the increasing gap of national brand are not necessarily consistent with the simulation
results. However, this is not necessarily a contradiction. Our simulations motivate the widening quality gap by the increase in quality cost and the increase in private label quality; both of which may not be the reason for the widening quality gap observed in the data set. It is possible that by considering the quality gap from various products in the same data set, we include many factors influencing the quality gap together. Many reasons motivating the quality difference are presented in the data set; and they can have different impacts on the relative performances of the two brands.

8.5 Model Extensions and Future Research Ideas

Several extensions and modifications of the current models can expand the discussions and provide greater insights into related issues concerning the product quality in the distribution channel. Multiple issues and questions arise from our study, which can be investigated further. Some proposed ideas for extensions are already discussed in details at the end of their related chapters so we only discuss some topics briefly in this concluding chapter. We also present some ideas for model modifications related to the issues from the empirical tests here.

Our single product models focus on the unit quality improvement that brings about an increase in quality as well as an increase in cost. It is also possible that the manufacturer is interested in acquiring a technology that reduces the quality cost of an existing product quality level or even a technology that produces better product quality at a lower cost. These different scenarios require different model setups with other variations in cost specifications. We discuss the model with cost saving technology prior to Chapter 3. Due to the cost saving characteristic of the technology, we may want to expand the model setup to incorporate the technology
investment generating the cost for the future cost reduction. We would like to compare the results from the multi-period fixed cost setting and the single product setting to distinguish the differences in the optimal quality and the optimal cost level. We speculate that the single product setting may result in the lower price with a slightly higher optimal quality whereas the multi-period investment model may result in higher prices for earlier periods and lower prices in the periods after the cost reducing technology is discovered. The higher prices during the pre-discovery period are the results of the fixed cost of R&D or installing the new technology.

The cost-reducing and quality-improving model can be a combination of the two models: the one presented in Chapter 3 and the model we just propose. Because of the dual-benefit nature of the setup, the model is interesting even in the single product setting. The manufacturer faces a technology that reduces its production cost and also improves consumer demand and willingness to pay. We are interested in how the benefit from the technology pans out in the distribution channel. How much will the cost saving benefit the manufacturer relative to the benefit realized by the retailer? As the owner of the technology, the manufacturer is able to reap the benefits from the cost reduction but the retailer relative performance can still be improved. Incidentally, the retailer can gain benefits without having to invest or pay for anything in the process. Even though the manufacturer is better off with the new technology, it is possible that the technology benefits the retailer more. The pricing strategy is also interesting in this setting. Since the consumers are willing to pay more for better products, how will the manufacturer manage the cost saving element in the presence of the possible increase in the retail price? The cost saving element will naturally reduce the price whereas the quality improvement element will increase the retail price. We are interested in the changes in the wholesale and the retail prices as well as their relative values resulted from the new technology. Lastly, we are interested in the
factors determining the outcomes and the relative performances in the distribution channel. For example, we want to know how the quality cost, the non-quality cost, the elasticity and the quality deviation influence the optimal prices, quality and demand.

For the competing product model, we would like to expand the models to incorporate more characteristics of the products. When two products are considered, it is not only the quality level that matters but also the differences in quality of the two products. Our theoretical model produces some results regarding the quality differences between the national brand and the private label products but it is not a theory specifically designed to address the issues of quality difference. We are interested in further investigating a theoretical model focusing on the quality difference and how it impacts the pricing decisions and other market outcomes. Instead of having one firm choosing quality level given another firm initial quality, the model can focus on the quality gap between the two products. In one way, the model can be similar to the model we currently develop since the choice of one firm’s quality given another firm quality fixed is identical to choosing the quality difference and our current derived demand has the quality difference specified. Nonetheless, we may be able to develop a model where the quality difference takes center-stage. Also, the cost specification may incorporate the difference in quality as a component for cost. From the national brand manufacturer’s standpoint, the closeness between the national brand and the private label quality may be considered a part of the cost. With our current demand and cost specifications, the cost for the closeness of quality occurs indirectly through the reduction in demand. We can build the cost related to quality difference directly onto the cost specification. The resulting model can either focus on the national brand manufacturer or the retailer choosing optimal quality difference to maximize his
profit, which is more flexible in addressing the issue of quality difference than the model setup we currently use.

Our product competition model contains one national brand manufacturer and one private label product. Although generally not focusing on the distribution channel relation, the alternative specifications involving multiple national brands are discussed in varying degrees in the literature. Nonetheless, we may be interested in the situation for multiple private label products. Because not all retailers use the same strategy for their private label products, the market contains many retailers that position themselves differently targeting various consumer segments. The national brand manufacturer is likely to have only one pricing and quality strategy per product reacting toward multiple private label quality and pricing strategies. Since the national brand manufacturer is concerned about various private label products, how can he optimally choose the strategy for a product to best counter multiple competitions from private label? Generally, a national brand manufacturer has multiple products in one line targeting various consumer segments. Is this sufficient to counteract the competition from multiple private labels? Should a national brand manufacturer react toward the private label competition in the same manner as his other national brand competitors? One way to address the issue is to look at a multiple product competition model with multiple retailers and multiple private labels. There are two dimensions for this model. First, this can be similar to the multi-product competition model with multiple national brands; but instead of another national brand, we have another private label product. However, the private label products are not sold at all retail stores. Only one private label is presented at any retail store. The model needs to accommodate the partial availability of private labels competing with the national brand product.
It is important to realize that our outcomes depend on the derived demand specifications. A future focus is to modify the demand to incorporate other scenarios that are more suitable for specific cases regarding the national brand and private label market. For example, in our original model, the consumers are aware of the difference in quality level between the national brand and the private label products. How should the model change if we have some part of consumers not being able to distinguish the differences even with the actual physical difference presented? The case would correspond to the story where some consumers claim the two products are identical whereas other consumers prefer the national brand because they can feel the difference. The usual reservation price schedule we use may not be suitable for the consumer segment with an inability to differentiate the quality of the two brands. Some kind of a combined demand model incorporating the two consumer segments can replace the derived demand model where the rest of the model setting may remain the same. We speculate that this setup would result in a decreased level of optimal quality because a smaller portion of consumers are able to enjoy the quality difference. The product quality is then a cost that can only be partially realized by some consumer groups. We may also be interested in finding a strategy for the national brand manufacturer to lessen the impact of consumers with an inability to differentiate quality differences. Some sale strategies that help the manufacturer separate one segment of consumers from another would be useful. Also, we are interested in whether the presence of the new consumer group benefits the retailer. Without the ability to distinguish quality, the consumers would pick the cheaper product, which is traditionally the private label product. Depending on the existence of non-purchasing consumers and other competing products, the retailer would change the optimal quality level for his private label product to capture a larger proportion of consumers. The non-differentiating consumers benefit the retailer but hurt the national brand.
manufacturer. We would also speculate that the overall consumers welfare is worsen off potentially by the introduction of the non-differentiating consumers in the market. When some consumers cannot differentiate product quality, consumers in the entire market may be impacted.
References


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