ABSTRACT

AN, QI. Strategic Vertical Integration and Decentralization. (Under the direction of Dr. Shu-Cherng Fang.)

This dissertation research studies the manufacturers' incentives to integrate or decentralize in a duopoly system where competitive interaction or customer-search-based interaction occurs between two supply chains. In particular, we examine how channel structure decisions are related to upstream and downstream efforts and different market characteristics.

The first work considers two three-tier supply chains where upstream firms have the opportunity to undertake cost reduction initiatives. We find that integration increases the incentives to invest in cost reduction, and, in turn, competition based on cost reduction at the upstream level is intensified by vertically integrating. Forward integration, despite increasing the impact of price competition for the manufacturer, may be an equilibrium strategy. When two products are not perfect substitutes, the equilibrium integrating direction is also determined by product substitutability.

The second work focuses on the channel structure decisions within two three-tier asymmetric supply chains. The asymmetry arises from the difference in the customers' loyalty toward two products that compete on the basis of pricing and quality. It is found that customer loyalty asymmetry may lead the manufacturer observing weak customer loyalty to unilaterally implement decentralization. How the customer loyalty compares and the market desire for high quality products collectively shape the equilibrium channel structure.

The third work studies the impact of retailer valuation-enhancing efforts on the manufacturer's choice between directly retailing its products and wholesaling to an independent retailer. We consider a setting where customers can search between products. Different purchase schemes are distinguished according to customers' purchasing behaviors. The best response analysis provides insights into how distribution channel structure affects the purchase scheme. We explore the equilibria in terms of channel structure and purchase scheme game using factorial analysis.

Strategic Vertical Integration and Decentralization

by
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DEDICATION

To my parents.

BIOGRAPHY

Qi An was born in Xi'an and grew up in Foshan. Having discovered her passions for sciences at a yound age, she obtained the degree of Bachelor in the school of Mathematics at Beihang University. For the love of learning and discovery, she chose to pursue a doctorate degree in Edward P. Fitts Department of Industrial and Systems Engineering at NCSU. The PhD research process was by no means easy for her. Hair loss and dark circles under eyes serve as a proof of her dedication and devotion. But she found joy in carrying out independent research. Qi developed technical skills and professional expertise in research areas including optimization, data analysis, and supply chain management. She takes pride in her work.

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Thank my friends who shared the joy and tears with me. I would never forget the happiness in Daniels Hall Room 443. My officemates are also my mentor from whom I learn so much so vividly.

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Chapter 1

Introduction

In today's globalized economy, a supply chain consists of multiple business unit with different functions that interact inside or across firms. Raw materials are turned into the production of intermediate products, which in turn are input into the production of final products distributed to market. Successful design of supply chain channel involves the issue of vertical integration in which upstream and downstream processes are unified in terms of ownership and control. A firm may internally grow the business function that is a link ahead of or before. Vertical integration can be achieved externally by merging an ownership share of its upstream supplier or downstream customer. Aside from the polar case of exclusive merger, vertical integration can be partial, e.g., purchasing a share of upstream or downstream activities.

The basis of vertical integration is a shift away from managing individual processes to aligning objectives across the entire supply chain [Akk99]. The potential to improve supply chain performance and profitability arises from three aspects: (1) Management of information flows. Separation of information sources in a supply chain may cause order delay and forecast amplification. (2) Management of product flows. Multiple levels of inventory in a supply chain always result in high degrees of uncertainty and complexity. (3) Management of supply chain relationships. Independent firms in a supply chain usually lead to local optimization of decision making. One typical example is the bullwhip effect where the demand process becomes more variable as one moves up the supply chain and excessive inventories and ineffective planning are caused. Another example is double marginalization where firms at different vertical levels apply some degree of market power. As each firm marks up the price above the marginal cost, the final price paid by the customer may be significantly higher than the system-wide optimum. To eliminate such inefficiency and increase level of coordination, getting rid of profiting intermediaries is needed. By vertical integration, the internal cost is lowered and the savings can be finally transferred to the customer.

Examples of vertical integration abound in real world. The Spanish clothes brand ZARA owns a nearly completely integrated supply chain from design, production, logistics, distribution, to retail stores, achieving much higher margins than its rivals like H&M and Gap which prefer outsourcing ([Fer05]). Private brand product is a prevalent byproduct of integration. Retail chains like Target and Walmart, despite being dominant retailers of many products, carry their own stores brands. On these product lines, they are the manufacturer, the distributor, and the retailer. The grocery retailer Kroger has integrated with 37 manufacturing plants and used these facilities to produce its private products. The pricing power allows Kroger to acquire market share with low priced products. As competition in organic food groceries picked up, Whole Foods Market has soon followed with its 365 brand in an effort to be price-competitive while maintaining quality.

As opposed to developing a completely integrated supply chain, some integrating activities move vertically along the supply chain in a certain direction. In the 1970s, suppliers of integrated circuits and manufacturers of finished electronics made a burst of vertical integration moves into each other's function. Texas Instruments, a semiconductor manufacturing company, integrated into the manufacturing of calculators, watches and automotive lightning systems. Bowmar, one of the major manufacturers in hand-held calculator, acquired various integrated circuit production.

If one extends business in the direction of downstream supply chain, it is referred to as forward integration. A number of company-owned stores through which the manufacturers do the distribution on their own are an vivid example of forward integration. Apple, the leading smart phone manufacturer, operates a network of Apple stores in addition to using independent retailers like Bestbuy to sell its products to the market. Everlane, the San Francisco-based fashion brand, adopts integration of distribution which allows it to charge a reasonable price while maintaining its luxury image. Tesla, the luxury battery vehicle manufacturer, has its own distribution channel which minimizes inventory costs and allows making each car to order. Retaining direct distribution channel has benefits including distinguishing the product from the competition, maintaining relationships with customers, avoiding sharing profits with a third-party distributor, etc. Rapid growths in e-commerce and third-party logistics industry have been increasingly encouraging companies to engage in direct sales.

If one extends business in the direction of upstream supply chain, it is referred to as backward integration. The brewing company Coors manufactures all of the beer bottles on its own and its major competitor Anheuser-Busch purchases only half of its bottle demand from suppliers. One strategic reason for backward integration is to secure supply, which involves more control over costs. It is essential to owning more of the supply chain especially for a competitive market with a limited supply of raw materials (e.g. local, perishable products) or in a bidding situation. Less dependence on suppliers decreases such supply chain risks as supply disruptions, price changes, order delays, the loss of control over supply quality. Zara manufactures 60% of its own products and achieves flexibility in the variety, amount, and frequency of the new styles by taking a backward integrating approach. Another potential source of benefits from backward integration is the economies of scale. By producing instead of buying, the per unit cost can be lowered if the size of the business allows.

Decentralization is the reverse of integration where additional individual units are introduced to the supply chain and make decisions based on local information. The incentives for decentralization may come from many aspects. For example, control over products supplied earlier by external sources involves much more effort, which may be difficult for the firm to sustain core competencies. Or, delegating the sale of products to the third party retail institutions facilitates taking advantage of their experience, infrastructure and salesforce so informed marketing decisions can be made and the brand enhanced. Indirect distribution avoids the complexity of managing distribution logistics for the original equipment manufacturers. Flexibility to reduce the amount of production may be a benefit of decentralization as the firm does no longer need to maintain a production size in order to achieve the economies of scale. One example of decentralization is outsourcing where a firm hires another to perform operations, accounting for as much as 24% of all intermediate inputs in 2006 [Yus08].

The strategy of vertical integration and decentralization involves large scale engagement of resources and represents the vertical scope of a firm. Once implemented, it would be difficult to reverse and make a huge impact on the future of the firm. This thesis is motivated by the need to explore the incentives for vertical integration and decentralization in a more generalized setting. With interactions among multiple supply chains, firms' channel structure decisions (e.g., vertical integration and decentralization) can have strategic effects. A vertically integrated supply chain may raise barriers for a potential rival to enter because of increased capital costs and minimum economies sale of operations. In a duopoly system, an independent retailer may act as a shield from the direct price competition for the manufacturer [MS83]. And such buffering effect may emerge from vertical integration, when it comes to multi-tier supply chain systems [Lin14].

The focus is on the vertical integrating and decentralizing activities of manufacturers in a duopoly system. We explore different operational decisions and market characteristics and examine their interactions with the manufacturer's channel structure decisions. Game theoretic models are built to address the game-related issues arising from supply chain interactions. Throughout this dissertation, we characterize static noncooperative games and seek subgame perfect equilibria for the games investigated. Only pure-strategy equilibrium is of our interest due to its structural simplicity that links it to an actual strategic strategy to pursue.

This thesis consists of three pieces of work, each presented in one chapter. The first work examines manufacturers' channel structure decisions in the presence of the externality of upstream cost reduction effort and product differentiation. The second work studies manufacturers' vertical integration strategies for duopolistic three-tier supply chains with asymmetric customer loyalty. The third work investigates manufacturers' distribution channel design problem in relation to retailer operations that improve customer valuation under market search. In each chapter, we develop a stylized game theoretic model where the manufacturers make the integration decision considering the post-integration outcome.

Chapter 3 considers a duopolistic supply chain system consisting of three-tier supply chains. A manufacturer has raw materials supplied from an exclusive supplier and distributes its product through an exclusive retailer. Suppliers have the opportunities to invest in upstream cost reduction via process innovation activities such as lean production initiatives, inventory optimization, and quality-improvement projects. The fundamental channel design problem for the manufacturer is whether to vertically integrate and which direction to integrate. In particular, we want to understand how the integration decisions interact with competitive dynamics in the presence of cost reduction opportunity. We model the level of investment as a fixed amount by which unit upstream cost is reduced. The manufacturers determine their integration strategies first. Based on the resultant channel structure, cost reduction and pricing decisions are made. Two types of horizontal product differentiation are considered: spatial differentiation and price differentiation. In the first model, we analyze managerial insights into the impacts of cost reduction opportunity on the integration outcome. In the second model, product substitutability between two products is a new dimension to evaluate the choice of channel structure.

Chapter 4 focuses on the channel structure decisions within two asymmetric supply chains. A system of two three-tier supply chains is studied in a setting where two products compete on pricing and quality. The asymmetry is captured in demand structure and arises from differences in the customers' loyalty toward two products. We incorporate customer loyalty into the demand function and allow it to be different. We formulate a two-stage game and derive the equilibrium integration and operational decisions. We anticipate that asymmetry in customer loyalty can lead to asymmetric equilibrium outcome of vertical integration game. But there are more detailed questions to be answered: How does customer loyalty asymmetry impact manufacturers' integration decisions and the following operational decisions of quality levels and pricing. How do customer loyalty and supply chain structure compare in affecting the operational decisions? Which dynamic (e.g., price competition or quality competition) dominates in determining the equilibrium channel structure? How is vertical integration used as a strategy for the manufacturer to manage competitive effects and customer loyalty asymmetry?

Chapter 5 explicitly incorporates retailers' marketing effort to generate better product perception into distribution channel analysis. A manufacturer can either sell the product directly to the market or disintegrate its retailing function by selling through an exclusive retailer. The independent retailers can invest in practices that improve customer valuation toward the product, such as advertising, customer education, and provision of special assortment. Through vertical decentralization, retailer-initiated increase in demand can be expected. A system is considered where customers may search between two products. We formalize the decision process and derived the equilibrium results in terms of channel structure and operational decisions. There is a tradeoff faced by the manufacturer between coordinating decision making and improving customer valuation. To solve for the outcome of retail prices, different purchase schemes that characterize customers' purchasing behaviors are distinguished. We theoretically analyze the impact of channel structure on the equilibrium purchase scheme. We numerically explore the equilibria in terms of channel structure and purchase scheme using a full factorial design experiment.

Chapter 2

Literature Review

This dissertation draws on distinct streams of literature. In this chapter, we review topics that are closely related to this dissertation including supply chain channel structure (e.g., vertical integration and decentralization) and supply chain incentives (e.g, supply chain participant efforts, customer loyalty, market search). We also provide a review of methodologies applied for studying competitive decision making (e.g., game theory).

2.1 Supply Chain Channel Structure

Vertical integration and decentralization is a central issue in the studies of supply chain channel structure. A bulk of literature took an efficiency perspective and focused on the coordination issue. The classic double marginalization problem developed by Spengler [Spe50] studied pricing inefficiency caused by successive firms in a decentralized supply chain individually applying price markups that fail to optimize the overall supply chain performance. Jeuland and Shugan [JS83] identified independent manufacturer- and retailer-controlled decisions as causing a lack of coordination in the distribution channel. Cachon [Cac99] provided a comprehensive review of analytical models designed for channel coordination. With the commonly recognized potential to mitigate the negative effects of double marginalization, vertical integration has been receiving attention in the past decades. Hart and Tirole [Har90] modeled vertical integration in a strategic setting where the motive for integration is related to market foreclosure as opposed to elimination of double marginalization. Early survey of literature on vertical contractual relationships by Katz [Kat89] described how vertical integration gives operational efficiency.

An important stream of marketing literature pioneered by McGuire and Staelin [MS83] extensively studied the strategic incentives for decentralization in a duopoly industry. Not to vertically integrate with an independent profit-maximizing retailer can be an equilibrium strategy when two products are highly substitutable. Double marginalization is deliberately introduced to dampen the intensity of price competition at the manufacturer level. Following this line, Coughlan [Cou85] indicated that lack of independent marketing middlemen due to downstream integration leads to a fiercer price competition in a product-differentiated duopolistic market. Moorthy [Moo85] found that two manufacturers may not vertically integrate even with complementary competing products. Moorthy [Moo88] used the coupling between demand dependence and strategic dependence to explain why decentralization can be an equilibrium strategy. Corbett and Karmarkar [CK01] pointed out that vertical integration of successive oligopolists makes their joint profits suffer. But they did not take a game theoretical perspective to weigh the benefits of vertical integration versus those of inserting tiers into the channel. Pun and Heese [PH10] showed that the choice of distribution channel for competing manufacturers selling complementary products depends on their competitive positioning and entry sequence. Wu et al. [Wu07] addressed the problem of distribution channel design under demand uncertainty by modeling the retailer as a price-setting newsvendor. Anderson and Bao [AB10] found the coefficient of variation in market share critical in determining the benefits of using independent retailers. Recently, Huang et al. [Hua18] studied two firms' sequential decisions on channel structure and uncovered a new setting where decentralization has strategic benefits: The follower can sell through a decentralized sales channel to influence the leader's choice of quality. In these studies, each of the two retailers carries the product of only one exclusive manufacturer. Trivedi [Tri98] extended the channel structure study to the market segments in which retailers compete to sell multiple brands at the same location. Glock and Kim [GK15] focused on the manufacturer who vertically integrates with one of its retailers and found the type of competition determines the effect of vertical integration. Most recently, Li and Chen [LC18] addressed the backward integration decision of a single retailer selling products for two quality-differentiated brands.

Some papers separated the strategic effects between forward integration (decentralization) and backward integration (decentralization). Fronmueller and Reed [FR96] demonstrated the potential of forward integration in providing differentiation advantage but refuted the possibility of backward integration giving low cost. A line of papers focuses on whether the manufacturer should outsource (part of) its function to a third party, which is essentially a discussion on backward decentralization. Xiao et al. [Xia14] examined strategic outsourcing decisions for manufacturers who have quality improvement opportunities. The range over which symmetric outsourcing is an equilibrium depends on factors such as fixed setup cost, unit production cost, quality improvement efficiency, and horizontal and vertical differentiation. Wang et al. [Wan07] studied the capacity decisions and supply price games under the tradeoff between backward integration and outsourcing. Kaya and Özer [KÖ09] studied joint quality and pricing decisions in a single decentralized supply chain with outsourcing opportunity. Gilbert et al. [Gil06] found that outsourcing plays a strategic role when original equipment manufacturers compete to reduce their production costs. The line of literature on dual-channel supply chains is closely related to forward integration. A dual-channel supply chain is one where the manufacturer opens a direct distribution channel to compete with its retailers. Chiang et al. [Chi03] argued that direct marketing used for strategic channel control reduces the degree of double marginalization and indirectly increases profits through the tradition retailer channel. Cattani et al. [Cat06] analyzed a scenario where a manufacturer commits to setting a direct channel retail price that matches the retailer's price in order to mitigate channel conflict. Wang et al. [Wan09] studied how the competition between the retailer and the company store co-existing in the same location affects outcomes in the retail market.

The above papers exclusively considered two-tier (manufacturer-retailer) supply chains.

There is not much literature that dealt with integrating activities within three-tier supply chains where the manufacturer may face a choice between forward and backward integration (decentralization). Corbett and Karmarkar [CK01] focused on the structure design of multi-tier supply chains in a competitive environment, which particularly involved entry decisions and post-entry competition. Lin et al. [Lin14] studied a framework of two competitive three-tier supply chains where a manufacturer can either backward, forward integrate or stay disintegrated. [Lin14] focused on the supplier having control over quality for perishable products and perishability has a major effect impact on the equilibrium integration strategies.

2.2 Supply Chain Incentives

In literature on supply chain incentive management, we focus on two types of upstream and downstream opportunities: cost reduction effort and demand enhancement effort.

2.2.1 Cost Reduction Effort

A large body of literature considers investing money and resources to reduce production costs. Jeuland and Shugan [JS83] examined the channel coordination problem for a supply chain with a manufacturer and a retailer having a chance to reduce their respective costs. Heese and Swaminathan [HS06] investigated a product line design problem for two quality-differentiated products where cost reduction opportunity based on component commonality exists. Kim and Netessine [KN13] addressed the situation where a manufacturer and a supplier engage in a collaborative effort to reduce the uncertainty about component cost and lower the expected cost. Bernstein and Kök [BK09] studied dynamic cost reduction through process improvement in an assembly network. Loertscher et al. [Loe14] considered a stylized procurement model where a set of suppliers invest in cost reduction and a buyer makes decision about sourcing internally or externally through a first-price reverse auction.

There are papers that focused on analyzing the impact of cost reduction effort on the channel structure decisions. Gupta and Loulou [GL98] studied a distribution channel design problem for two manufacturers producing differentiated products with opportunity to reduce their individual unit cost. As cost reduction becomes less costly, selling through independent retailers is more profitable. Gupta [Gup08] extended this model by incorporating the effect of knowledge spillovers where one manufacturer's investment in process innovation may enable its competitor to reduce cost. Our first work complements these studies because the interaction and the manufacturers' decisions about channel structure are examined in multi-tier supply chains. Gilbert et al. [Gil06] studied strategic outsourcing decisions for competing original equipment manufacturers (OEMs) with cost reduction opportunity. They found that cost reducing investment can harm the profits of competing OEMs since firms tend to overinvest in cost management, and outsourcing production to an external supplier can mitigate the competitive effect because it represents a commitment of not aggressively reducing cost. The level of investment is determined prior to when the OEMs decide whether to outsource, but in our first work upstream firms postpone the decisions about cost reducing investment until the manufacturers announces their integration decisions.

2.2.2 Demand Enhancement Effort

A class of literature on channel structure has been developed that considers the distribution system where downstream industry can enhance demand by exerting marketing effort. Ghosh [Gho98] found elimination of intermediary whose role is to invest in demand-enhancing activities may not be desirable in terms of profitability and market share when the manufacturers fails to attend to retailing functions efficiently. Some literature focused on dual channel management. Tsay and Agrawal [TA04] examined the channel conflict issue that arises as a company-owned channel competes with an existing retail channel where the direct channel is at a cost disadvantage for exerting sales effort. In this case, introducing a direct channel is not necessarily detrimental to the retailer since the manufacturer can retain the retailer selling effort by reducing direct channel price, which counteracts double marginalization. Cattani [Cat06] extended this work by considering a pricing strategy in which the manufacturer commits to match the direct channel retail price with the retailer retail price. Wang et al.[Wan09] found that retailers are more willing to engage in marketing efforts when competing against company-owned stores. Chen et al. [Che08] studied a manufacturer's problem of managing dual channels where the demand in each channel depends on the service levels of both channels as well as the consumer's valuation of the product.

Free-riding is a commonly studied issue for this topic since it can be consumed by the customers who do not necessarily make purchase by nature. Bernstein [BF04] suggested that a manufacturer may purposely induce free riding by setting up a high-cost direct store to allow consumers to experience the product which in turn stimulates the sales at a retailer. Shin [Shi07] showed that free riding benefits both the free-rider and the retailer providing the service when customers are heterogeneous in their opportunity costs for shopping. Perdikaki and Swaminathan [PS13] studied retailer effort that can increase customer valuation for the product offering in a duopolistic model and found that free-riding may be the equilibrium outcome.

2.3 Customer Loyalty

In the marketing literature considering customer loyalty, some papers explored the impact of loyalty on customer behavior [Kop12; Goo14; Wan16]. But we focus on the stream where supply chain competition between two vertically differentiated supply chains was studied and the asymmetry arises from customer loyalty. Banker et al. [Ban98] which investigated a duopoly setting where the demand is modeled as linear in the price and quality levels and the cost of quality level as quadratic in the quality level. The structural asymmetry between their demand is reflected in "intrinsic demand potential".

Shaffer and Zhang [SZ02] explored the competitive effects of one-to-one promotions for two products toward which consumers have heterogeneous brand loyalty. Two supply chains compete in price and quality levels to maximize their profits. Brand loyalty is quantified as how much customers are willing to irrationally pay for their preferred band. Matsubayashi and Yamada [Mat07] analyzed the influence of customer loyalty asymmetry on the price and quality-based competition. They focused on how the asymmetry impacts the intensity of competition under varying price-sensitivity and quality-sensitivity. In traditional markets, strong customer loyalty generates a profit advantage. Chen and Xie [Che17] examined the network effect of asymmetric customer loyalty in cross-markets where a seller sells both a primary and a secondary product. In the presence of cross-market network effect, intermediate loyalty advantage in the primary product market leads to a profit disadvantage.

Wang et al. [Wan17] was the first to examine the issue of customer loyalty asymmetry from the perspective of channel structure design. In competition based on price and quality, two manufacturers either sell through an independent retailer or directly to the market. The equilibrium distribution structure depends on whether the market is price-sensitive or quality-sensitive market. Our second work is different from this work primarily because we focus on the interaction of customer loyalty and manufacturer's incentives to integrate in multi-tier supply chains.

2.4 Customer Search

A stream of literature explores consumer search behavior. Anupindi and Bassok [AB99] first considered "market search" where a fraction of customers who experience a stock-out at their local store search the other store. Two stores are both distributors for a single manufacturer. They focused on whether or not centralization of stocks increases profits for the manufacturer.

Ahn et al. [Ahn00] studied a scenario where a manufacturer-owned store and an independent retailer exist in different physical locations and customers make initial attempt to purchase at the store that is closer. All customers who visit the independent retailer and do not obtain positive customer surplus search the company store. Competition between a retailer and a manufacturers-owned store is a special case considered in our third study but we do not assume a one-way search from the retailer to the manufacturers-owned store. Instead, it is possible in our setting that customers who visit company store first search the retailer.

Perdikaki and Swaminathan [PS13] considered a duopoly setting where consumers could search among two retailers. Retailers can make investment to improve the customer valuation toward their product offering. They provided managerial insights on the impacts of customer search behavior on retailers' incentives to invest in enhancing customer valuation. Our third work is differentiated since we consider two manufacturers located in different locations individually having the option to sell through an independent retailer who can provide service to improve customer valuations.

2.5 Game Theory in Supply Chain Management

Game theory is a powerful tool to deduce rational behaviors of agents in interactive decision situation. Supply chain management (SCM) involves multiple agents with conflicting objectives. Thus, it is meaningful to understand the interaction across firms and the state of the industry that persistly exists. Questions like whether equilibria exist, what properties they have, how decisions of agents affect each other must be addressed. Pioneered by Von Neumann and Morgenstern [VNM07], game theory is pronounced for the concept of equilibrium formally introduced by Nash [Nas51]. Soon after game theory found its ideal applications in supply chain management, the recent decades have witnessed an explosion of equilibrium analysis in the SCM literature.

Among various types of games, we focus on the type of game that is most commonly seen in the SCM literature – noncooperative static games. A noncooperative game frames the competition between individual agents as opposed to cooperation among groups of agents. A static game is one where agents choose strategies simultaneously and each agent has no knowledge of the decision made by other agents before the decision making. There are other forms of games including cooperative games, dynamic games, signaling, screening, Bayesian games, etc. For a comprehensive review of these games on supply chain analysis, we refer readers to Cachon and Netessine [CN06].

Solution concepts used by noncooperative static games can be categorized into Nash and Stackelberg equilibria [LP05]. Nash equilibrium forms when agents choose their strategies simultaneously and have no incentive to deviate from the assigned strategy given that the other agents are committed to their strategies. Competition between firms at the same echelon of one or multiple supply chains can be modeled as a Nash game. The existence of uniqueness of Nash equilibrium is a central issue. Topkis [Top79] provided a special class of games termed supermodular games which encompass many applied models and have remarkable existence and uniqueness properties. Stackelberg solution [VNM07] applies when the leader agent moves first and the follower agent moves sequentially. The follower plays the best response strategy to the leader's choice and the leader makes decision anticipating the follower's response. A Stackelberg game is often used to model the vertical interaction between firms in different layers (e.g., a supplier and a retailer) or sequential supply chain decision making (e.g., strategic decisions and operational decisions).

A class of game theoretical applications in SCM is devoted to the retail competition based on different attributes. Bertrand [Ber83] captured the competitive behaviors in pricing as what could be called a game even before the formalization of game theory. Dixit [Dix79] studied the competition in a duopoly system where the demand functions are linear in two products' prices and quality levels. Banker et al. [Ban98] examined the price-quality competition where the quality decision incurs a quadratic cost. To capture the product features which the customers differ in considering attractive, Salop [Sal79] developed a duopoly model where the product markets were viewed as having a spatial representation that accounts for product differentiation. Game theoretical models have been widely adopted in the studies on channel structure to address the competition issues. McGuire and Staelin [MS83] considered the role price competition plays in determining the channel structure of a duopolistic supply chain system. The strategic interaction among price competition gives rise to the preference for a decentralized distribution channel. Moorthy [Moo85] studied the effect of interdependence (e.g., complements or substitutability) between two products on equilibrium integration decisions. Choi [Cho91] added to the channel structure literature by analyzing the impact of supply chain intermediaries on the intensity of horizontal price competition between manufacturers.

Chapter 3

Vertical Integration, Cost Reduction, and Product Differentiation

In retail competition, production cost is an important dimension of competition as price becomes a differentiator in the market. Cost is subject to change when firms make investment in the product development process. Research and development (R&D) investment is a powerful weapon on the battlefield of economic enterprise where new technologies are developed to improve the efficiency and reliability of processes and equipment. Suppliers are in a crucial position to identify cost reduction opportunities. For instance, Chrysler developed a highly regarded Supplier Cost Reduction Effort (SCORE) program where suppliers are encouraged to reduce their own costs and keep a portion of realized savings. In 1996 alone, Chrysler and its suppliers achieved $1 billion in cost savings through SCORE initiative (https://www.allpar.com/corporate/score.html).

In this chapter, we study the manufacturers' incentives for vertical integration from two competing three-tier supply chains in the presence of cost reduction opportunity at the supplier level. Specifically, we restrict our attention to a manufacturer having an exclusive supplier and retailer and do not consider them carrying products from more than one manufacturer. The manufacturer can either forward integrate by expanding its scope to the distribution of the final good, or backward integrate by taking control of the upstream supply and cost reduction decision.

Various factors are potentially at play. Both supply chains can be negatively impacted by price competition as one interferes with the other attempting to obtain more demand. Cost reduction opportunity is found detrimental to the profitability of competing firms by providing incentives to overinvest in cost reduction [GL98]. In addition, the benefits and detriments of forward or backward integration versus disintegration need to be weighed by the manufacturer. Stretching control to supply or retailing is profitable for a manufacturer in a monopolist supply chain, but is not necessarily a preferred choice when two products compete in the same market [MS83]. Despite relieving double marginalization, fewer supply chain levels may lead to fiercer price competition. As for two competing three-tier supply chains, backward integration is always the equilibrium strategy in a single period [Lin14].

We focus our attention on linear demand models and consider two types of horizontal product differentiation. One is spatial differentiation where difference between two products is modeled as spatial locations. The other is price differentiation where the demand is a function of product substitutability perceived by the customers. The two models differ in how degree of product differentiation is captured. The form of demand function affects the nature of strategic integration between two supply chains.

This work follows the standard modeling approach pioneered by McGuire and Staelin [MS83] and developed by [Lin14]. Two supply chains are symmetric in terms of demand structure and cost structure. A two-stage game is considered. In the first stage, the manufacturers decides whether to integrate, and if so, the direction of integration. In the second stage, given the channel structure determined in the first stage, two supply chains engage in competition based on cost reduction investment and pricing. Our interest complements the previous studies by adding the level of investment in cost reduction as a dimension of competition. We derive equilibrium results of cost-reduction levels and prices under different channel structures. With these results, we determine whether the equilibrium channel structure is vertically integrated or decentralized.

This chapter is organized as follows. Section 3.1 describes the framework of analysis and conducts equilibrium analysis in a spatial competition model. Section 3.2 explores the implication of product substitutability on the equilibrium channel structure. Section 3.3 summarizes the chapter.

3.1 Spatial Differentiation

The industry analyzed is comprised of two competing supply chains with a supplier (S_i), a manufacturer (M_i), and a retailer (R_i), $i = 1, 2$. In this section, we investigate Hotelling customer choice model where difference between two products is modeled as spatial locations along a linear product space or a spectrum of characteristics. Without loss of generality, the market size is normalized to one. Assume two products are located at the two ends of a line and customers are dispersed on the line with uniform density. A customer's preference is modeled by a point on the circle representative of his ideal product. Each customer incurs a transportation cost which is quadratic in the distance traveled for making the purchase. The customer utility for purchasing product i is defined as

$$U_i(p_i) = m - p_i - sx_i^2,$$

where m is customer reservation value, p_i is the retail price, x_i is the distance between product i and the customer, and s captures customer sensitivity to the distance. A risk-neutral customer purchases the product with the higher utility. After solving for location of the customer who is indifferent between two products, all customers to the left would buy one product while all customers to the right would buy the other product. Thereby, supply chain i faces a demand of the form

$$d_i = \frac{s - p_i + p_{3-i}}{2s}.$$

To ensure that the demands for two products are always nonnegative, actually, we require that

$$d_1 = \max\left\{\frac{s - p_1 + p_2}{2s}, 0\right\},$$

$$d_2 = 1 - d_1.$$

We focus on the linear transfer pricing contract. In a decentralized supply chain, each channel member has one pricing decision. Supplier i provides intermediate products at a per unit upstream price of r_i. Manufacturer i produces each product with one unit of inputs and sells it to retailer i at a wholesale price w_i. Retailer i determines the retail price p_i of the product. One firm has no direct control over the decision making of the other, but upstream firm does have the channel power to influence the final retail price by charging a per unit price to the downstream firm. It is assumed that manufacturer i and retailer i do not incur variable costs for production and retailing, but supplier i incurs c for per unit of supply if no cost reduction effort is carried out.

The level of cost reduction effort is quantified as the amount e_i by which upstream cost is reduced and incurs a fixed expenditure of ke_i^2. The positive constant k measures the easiness of cost reduction. The quadratic form indicates that the marginal cost for additional unit of cost reduction is increasing. We also assume process innovation results are protected by intellectual property rights so that one supply chain cannot free-ride on the other's investment.

Three integration choices are available for a manufacturer: disintegration (D), forward integration (F), and backward integration (B). There is a typical three-tier supply chain when the manufacturer does not integrate. A forward integrated manufacturer distributes the products himself and controls the retail price p_i himself. A backward integrated manufacturer obtains inputs of production himself and controls the cost reduction level e_i in addition to the wholesale price w_i. Let $I_i \in \{D, F, B\}$ denote manufacturer i's integration decision and $I_1 I_2$ denote the industry structure.

The game unravels as follows. First, two manufacturers simultaneously decide whether to integrate and, if so, the direction of integration. The strategic decision is observable to the competitors and cannot be modified once it is announced. Then the firms who control the supply side (a supplier or a backward-integrated manufacturer) noncooperatively set their individual cost reduction levels and upstream prices. Thereafter, a manufacturer sets its wholesale price if it decides not to integrate. Finally, the firms that take control of retailing (a retailer or a forward-integrated manufacturer) competitively determine the retail price. Two underlying assumptions are made here. First, upstream firms move before downstream firms. This is one of the most common gaming assumptions in SCM literature. Second, cost reduction decisions are made before pricing decisions as it takes advanced planning.

A two-stage game is considered. In the first stage, two manufacturers individually choose strategic integration decision. Thereby, the industry channel structure is determined. Given the resulting supply chain structure, the second stages begins. The suppliers (or the backward integrated manufacturers) noncooperatively determine their cost reduction levels, and then the upstream prices. The decentralized manufacturers set the wholesale prices. The retailers (or the forward integrated manufacturers) set their retail prices.

The profit functions for retailer i, manufacturer i, and supplier i in a typical three-tier supply chain are given by

$$\Pi_{R_i}^{D} = (p_i - w_i)d_i,$$

$$\Pi_{M_i}^{D} = (w_i - r_i)d_i,$$

$$\Pi_{S_i}^{D} = (r_i - c + e_i)d_i - ke_i^2.$$

When manufacturer i forward integrates and owns his own retail outlet, the profit functions for manufacturer i and supplier i are given by

$$\Pi_{M_i}^{F} = (p_i - r_i)d_i,$$

$$\Pi_{S_i}^{F} = (r_i - c + e_i)d_i - ke_i^2.$$

When manufacturer i backward integrates, the profit functions for retailer i and manufacturer i are given by

$$\Pi_{R_i}^B = (p_i - w_i)d_i,$$

$$\Pi_{M_i}^B = (w_i - c + e_i)d_i - ke_i^2.$$

Let $\pi_{R_i}^{I_1 I_2}$, $\pi_{M_i}^{I_1 I_2}$, $\pi_{S_i}^{I_1 I_2}$ represent the profit function for retailer i, manufacturer i, and supplier i, respectively, under channel structure $I_1 I_2$. We describe phases of supply chain participants' problems under channel structures DD, DF, DB, FF, BB, FB as follows. Those under channel structures FD, BD, BF are omitted due to symmetry. In each phase, two firms behave noncooperatively by choosing their individual decision at which neither can increase its profit by unilaterally deviating. We solve the games backwards. The conditional equilibrium retail prices are first calculated as a function of the wholesale prices. The equilibrium wholesale prices, upstream prices, and cost reduction levels are calculated subsequently.

Channel Structure DD	
Phase 1:	$\max_{e_1} \pi_{S_1}^{DD} = (r_1 - c + e_1)d_1 - ke_1^2$ $\max_{e_2} \pi_{S_2}^{DD} = (r_2 - c + e_2)d_2 - ke_2^2$
Phase 2:	$\max_{r_1} \pi_{S_1}^{DD} = (r_1 - c + e_1)d_1 - ke_1^2$ $\max_{r_2} \pi_{S_2}^{DD} = (r_2 - c + e_2)d_2 - ke_2^2$
Phase 3:	$\max_{w_1} \pi_{M_1}^{DD} = (w_1 - r_1)d_1$ $\max_{w_2} \pi_{M_2}^{DD} = (w_2 - r_2)d_2$
Phase 4:	$\max_{p_1} \pi_{R_1}^{DD} = (p_1 - w_1)d_1$ $\max_{p_2} \pi_{R_2}^{DD} = (p_2 - w_2)d_2$

Channel Structure FB	
Phase 1:	$\max_{e_1} \pi_{S_1}^{FB} = (r_1 - c + e_1)d_1 - ke_1^2$ $\max_{e_2} \pi_{M_2}^{FB} = (w_2 - c + e_2)d_2 - ke_2^2$
Phase 2:	$\max_{r_1} \pi_{S_1}^{FB} = (r_1 - c + e_1)d_1 - ke_1^2$ $\max_{w_2} \pi_{M_2}^{FB} = (w_2 - c + e_2)d_2 - ke_2^2$
Phase 3:	$\max_{p_1} \pi_{M_1}^{FB} = (p_1 - r_1)d_1$ $\max_{p_2} \pi_{R_2}^{FB} = (p_2 - w_2)d_2$

Channel Structure FF	
Phase 1:	$\max_{e_1} \pi_{S_1}^{FF} = (r_1 - c + e_1)d_1 - ke_1^2$ $\max_{e_2} \pi_{S_2}^{FF} = (r_2 - c + e_2)d_2 - ke_2^2$
Phase 2:	$\max_{r_1} \pi_{S_1}^{FF} = (r_1 - c + e_1)d_1 - ke_1^2$ $\max_{r_2} \pi_{S_2}^{FF} = (r_2 - c + e_2)d_2 - ke_2^2$
Phase 3:	$\max_{p_1} \pi_{M_1}^{FF} = (p_1 - r_1)d_1$ $\max_{p_2} \pi_{M_2}^{FF} = (p_2 - r_2)d_2$

Channel Structure BB	
Phase 1:	$\max_{e_1} \pi_{M_1}^{BB} = (w_1 - c + e_1)d_1 - ke_1^2$ $\max_{e_2} \pi_{M_2}^{BB} = (w_2 - c + e_2)d_2 - ke_2^2$
Phase 2:	$\max_{w_1} \pi_{M_1}^{BB} = (w_1 - c + e_1)d_1 - ke_1^2$ $\max_{w_2} \pi_{M_2}^{BB} = (w_2 - c + e_2)d_2 - ke_2^2$
Phase 3:	$\max_{p_1} \pi_{R_1}^{BB} = (p_1 - w_1)d_1$ $\max_{p_2} \pi_{R_2}^{BB} = (p_2 - w_2)d_2$

Channel Structure FD	
Phase 1:	$\max_{e_1} \pi_{S_1}^{FD} = (r_1 - c + e_1)d_1 - ke_1^2$ $\max_{e_2} \pi_{S_2}^{FD} = (r_2 - c + e_2)d_2 - ke_2^2$
Phase 2:	$\max_{r_1} \pi_{S_1}^{FD} = (r_1 - c + e_1)d_1 - ke_1^2$ $\max_{r_2} \pi_{S_2}^{FD} = (r_2 - c + e_2)d_2 - ke_2^2$
Phase 3:	$\max_{w_2} \pi_{M_2}^{FD} = (w_2 - r_2)d_2$
Phase 4:	$\max_{p_1} \pi_{M_1}^{FD} = (p_1 - r_1)d_1$ $\max_{p_2} \pi_{R_2}^{FD} = (p_2 - w_2)d_2$

Channel Structure BD	
Phase 1:	$\max_{e_1} \pi_{M_1}^{BD} = (w_1 - c + e_1)d_1 - ke_1^2$ $\max_{e_2} \pi_{S_2}^{BD} = (r_2 - c + e_2)d_2 - ke_2^2$
Phase 2:	$\max_{w_1} \pi_{M_1}^{BD} = (w_1 - c + e_1)d_1 - ke_1^2$ $\max_{r_2} \pi_{S_2}^{BD} = (r_2 - c + e_2)d_2 - ke_2^2$
Phase 3:	$\max_{w_2} \pi_{M_2}^{BD} = (w_2 - r_2)d_2$
Phase 4:	$\max_{p_1} \pi_{R_1}^{BD} = (p_1 - w_1)d_1$ $\max_{p_2} \pi_{R_2}^{BD} = (p_2 - w_2)d_2$

We derive the equilibrium results of cost reduction levels and prices for all possible supply chain structures $I_1I_2,\ I_1, I_2 \in \{D, F, B\}$. After quantifying the values of different integration decisions, we characterize the equilibrium decisions of vertical integration.

As a benchmark, we first provide the equilibrium results for a model where the suppliers do not make decisions about cost reduction effort and each firm only has a pricing decision to make. There exists a unique subgame equilibrium under each supply chain structure. For supply chain 1, the equilibrium pricing decisions ($r_1'^*$, $w_1'^*$, $p_1'^*$) and sales quantities ($d_1'^*$) are summarized in Table 3.1.

Table 3.1 Equilibrium quantities for supply chain 1 (no cost reduction opportunity)

I_1I_2	DD	DF/DB	FD	BD	FF/FB	BF/BB
$r_1'^*$	$c+9s$	$c+5s$	$c+7s$	–	$c+3s$	–
$w_1'^*$	$c+12s$	$c+\frac{15}{2}s$	–	$c+7s$	–	$c+3s$
$p_1'^*$	$c+13s$	$c+\frac{25}{3}s$	$c+\frac{49}{6}s$	$c+\frac{49}{6}s$	$c+4s$	$c+4s$
$d_1'^*$	$\frac{1}{2}$	$\frac{5}{12}$	$\frac{7}{12}$	$\frac{7}{12}$	$\frac{1}{2}$	$\frac{1}{2}$

When manufacturer 1 forward or backward integrates while manufacturer 2 stays disintegrated, channel structures FD and BD share the same price structure due to the same sequence of events. But manufacturer 1 is in the position of a supplier in scenario BD, while plays in the role of a retailer in scenario FD. When both manufacturers vertically integrate, channel structures FF, BB, FB, BF share the same price structure but manufacturer 1 achieves different profit. This also applies to the equilibrium results for the main model presented later.

Whether the manufacturer integrates forward or backward, the downstream division of the integrated entity accesses the intermediate products at a lower marginal cost. For this reason, the retail prices decline as the industry becomes more integrated. A cost-efficient integrated supply chain can use a relatively low retail price to attract more demand than its decentralized rival, which is the most prominent effect of vertical integration.

In duopolistic supply chain competition, manufacturers need to consider its competitor's strategy when making decisions about channel structure. The next lemma examines the manufacturer's prefer choices.

Lemma 3.1. *[Lin14] Whether the competing manufacturer vertically integrates or stays disintegrated, a manufacturer prefers backward integration (B) to disintegration (D), and next forward integration (F).*

When comparing forward integration versus disintegration, the downsides of integration outweigh the benefits. The reason is that forward integration exposes the manufacturer to the direct price competition as it moves downstream through the supply chain. When comparing backward integration versus disintegration, the benefits of integration outweigh the downsides. Backward integration is always more attractive to the manufacturer relative to forward integration because the manufacturer at the upstream supply chain feels the competitive effects less strongly. It is always in the manufacturer's best interest to integrate with the supply side, whether the competing manufacturer is vertically integrated or not.

The next lemma discusses the equilibrium integration outcome in duopolistic supply chain competition.

Lemma 3.2. *[Lin14] There is a unique and symmetric vertical integration equilibrium.*

(i) When manufacturers can choose among no disintegration (D) and forward integration (F), the equilibrium channel structure is always DD.

(ii) When manufacturers can choose among disintegration (D), forward integration (F), and backward integration (B), the equilibrium channel structure is always BB.

If choosing between forward integration and disintegration, a manufacturer would rather cooperate with an independent retailer to sell its product. Taking hold of retailing is not desired because it means direct price competition. Provided that backward integration option is an available option, a manufacturer always chooses it to stay away from price competition while gaining competitive advantage.

Lemma 3.3. *[Lin14] Both manufacturers earn less profits under channel structure BB than under channel structure DD.*

Equilibrium channel structure is always Pareto dominated by channel structure DD which results in higher profits for both manufacturers. Even though both manufacturers have incentive to backward integrate, their profitability suffers due to intensified competition. That is to say, the induced equilibrium channel structure leads to the prisoner's dilemma.

We now return our attention to the main model where the suppliers have an opportunity to invest in cost reduction. Still, we characterize the equilibrium results for the cost reduction and pricing game under different supply chain structures as well as the vertical integration game. By comparing the main model against the benchmark, we are able to capture the impact of supplier cost reduction opportunity on the manufacturers' vertical integration decisions in duopolist three-tier supply chains.

The following parametric assumption is made

$$sk \geqslant 0.022.$$

sk is an inverse measure of the market pressure to invest in cost reduction. The smaller sk is, the more market pressure for an upstream firm to invest in efforts to reduce cost. A small sk may be due to either low expenditure of cost reduction effort (k) meaning that it is cheap to reduce the per unit cost, or low level of spatial differentiation (s) implying high demand sensitivity to price. The assumption states that either k or s must be significant. Otherwise, demand might become unstable. Without this assumption, unrealistic result may occur that a disadvantaged supply chain experiences negative demand. In fact, a supply chain at worst only experiences zero sales quantity and gets driven out of the market. Similar assumption can be seen in prior research [Gil06]. In our following derivation, we define

$$\gamma = 54sk - 1 \geqslant 0.2.$$

For two identical competing three-tier supply chains, there exists a unique subgame equilibrium under each supply chain structure I_1I_2, $I_1, I_2 \in \{D, F, B\}$. For supply chain 1, the equilibrium cost reduction level (e_1^*), pricing decisions (r_1^*, w_1^*, p_1^*) and sales quantity (q_1^*) are summarized in Table 3.2.

Table 3.2 Equilibrium quantities for supply chain 1 (with cost reduction opportunity)

I_1I_2	DD	DF/DB	FD
e_1^*	$\frac{1}{6k}$	$\frac{sk-1}{6k(54sk-1)}$	$\frac{63sk-1}{6k(54sk-1)}$
r_1^*	$c+\frac{54sk-1}{6k}$	$c+\frac{1620s^2k^2-81sk+1}{6k(54sk-1)}$	$c+\frac{2268s^2k^2-108sk+1}{6k(54sk-1)}$
w_1^*	$c+\frac{72sk-1}{6k}$	$c+\frac{sk-1}{6k}$	$-$
p_1^*	$c+\frac{78sk-1}{6k}$	$c+\frac{2700s^2k^2-117sk+1}{6k(54sk-1)}$	$c+\frac{2646s^2k^2-117sk+1}{6k(54sk-1)}$
d_1^*	$\frac{1}{2}$	$\frac{sk-1}{2(54sk-1)}$	$\frac{63sk-1}{2(54sk-1)}$
I_1I_2	BD	FF/FB	BF/BB
e_1^*	$\frac{63sk-1}{6k(54sk-1)}$	$\frac{1}{6k}$	$\frac{1}{6k}$
r_1^*	$-$	$c+\frac{18sk-1}{6k}$	$-$
w_1^*	$c+\frac{2268s^2k^2-108sk+1}{6k(54sk-1)}$	$-$	$c+\frac{18sk-1}{6k}$
p_1^*	$c+\frac{2646s^2k^2-117sk+1}{6k(54sk-1)}$	$c+\frac{24sk-1}{6k}$	$c+\frac{24sk-1}{6k}$
d_1^*	$\frac{63sk-1}{2(54sk-1)}$	$\frac{1}{2}$	$\frac{1}{2}$

As compared with Table 3.1, all firms generally set a lower per unit price with cost reduction opportunity. Thereby, retail prices can be lowered and market share might be altered.

Proposition 3.1. *Given any channel structure, the supplier (or backward integrated manufacturer) receives lower profit than when there is no cost reduction opportunity.*

Suppliers (or backward integrated manufacturers) suffers from the opportunity to invest in cost reduction. There exists strategic interaction between two suppliers where they are forced to overinvest in cost reduction. Although both suppliers would be better off accepting the original upstream cost, both have an incentive to invest in cost reduction resulting in their mutual detriment. Unlike the monopolist supply chain, the addition of cost reduction opportunity does not allow firms to earn more profits in duopolistic supply chain competition.

The following proposition examines the impact of channel structure on outcomes in the operational decisions, in particular, level of cost reduction effort invested.

Proposition 3.2. *For* $I_1, I_2 \in \{F, B\}$,

(i) $e_1^{DI_2} < e_1^{DD} = e_1^{I_1 I_2}$;

(ii) $e_2^{DI_2} > e_2^{DD} = e_2^{I_1 I_2}$;

(iii) $e_2^{DI_2} - e_1^{DI_2}$ *is decreasing in* γ.

Proposition 3.2 (i) and (ii) indicate that unilaterally integrating from pure decentralization structure (i.e., DD) provides the supply chain more incentive to invest in cost reduction while dampens the rival's. In mixed channel structures (i.e. DF, DB, FD, BD), due to the reduced number of profiting intermediaries, the integrated supply chain makes bigger investment in cost reduction and has lower cost than its decentralized competitor. Such cost disparity in mixed channel structure is eliminated as both supply chains move into pure integration structures (i.e., FF, FB, BF, BB). Due to fewer supply chain tiers applying price markups combined with cost advantage, the integrated supply chain raises the competitive pressure on its rival by driving down prices for the upstream merchant and the final product. Cost reduction effort indeed increases the attractiveness of unilaterally integrating when competing against a decentralized supply chain. Furthermore, the smaller γ is, the larger marginal cost penalty for decentralization, as in Proposition 3.2 (iii).

Having characterized equilibrium results in the cost reduction and p game, we now focus on the manufacturers' profitability perspective. Let $\Pi_{M_1}^{I_1 I_2}$ denote the equilibrium profit for manufacturer 1 under supply chain structure $I_1 I_2$, $I_1, I_2 \in \{D, F, B\}$. The next theorem examines manufacturer 1's preference for different vertical integration options.

Theorem 3.1.

(i) $\Pi_{M_1}^{BD} > \Pi_{M_1}^{I_1 D}$, $I_1 \in \{D, F\}$.

(ii) $\Pi_{M_1}^{DD} > \Pi_{M_1}^{FD}$ *if and only if* $\gamma > \frac{1}{6\sqrt{3}-7}$.

(iii) $\Pi_{M_1}^{BI_2} > \Pi_{M_1}^{FI_2}$ *if and only if* $\gamma > \frac{1}{2}$, $I_2 \in \{F, B\}$.

(iv) $\Pi_{M_1}^{DI_2} > \Pi_{M_1}^{FI_2}$ *if and only if* $\gamma > \frac{1}{5-2\sqrt{3}}$, $I_2 \in \{F, B\}$.

(v) $\Pi_{M_1}^{BI_2} > \Pi_{M_1}^{DI_2}$ *if and only if* $\gamma > \bar{\gamma}$,*, where* $\bar{\gamma}$ *is the unique root of* $11\gamma^3 - 15\gamma^2 + 9\gamma - 1 = 0$, $I_2 \in \{F, B\}$

In addition to the competing supply chain structure, a manufacturer needs to take the market pressure to invest in cost reduction (γ) into account when evaluating different integration options. When facing a disintegrated competitor, a manufacturer always favors backward integration, as in Theorem 3.1 (i). Even though the supply side is burdened with the cost reduction effort, the manufacturer's choice is dominated by the fact that backward integration keeps him away from price competition while forward integration exposes him to it. The choice between disintegration and forward integration is dichotomized by a threshold of γ, as in Theorem 3.1 (ii). A small γ implies that an integrated supply chain has more ability to undercut its decentralized competitor. In that case, despite getting closer to price competition, a manufacturer would prefer forward integration to disintegration.

This rationale also applies to When a manufacturer competes against a supply chain that is vertically integrated. Forward integration dominates disintegration if γ falls below another threshold, as in Theorem 3.1 (iii). If there is sufficient pressure to make cost reduction investment, having direct control over the supply side becomes less attractive to the manufacturer, as in Theorem 3.1 (iv). In that case, there is a fairly destructive cost reduction competition at the upstream level and the manufacturer is not willing to backward integrate with the supply side since the massive cost reduction investment may hurt its profitability. Backward integration may not even dominate disintegration when γ is below a threshold value $\bar{\gamma} \in (0.14, 0.15)$, as in Theorem 3.1 (v). Facing excessive pressure to invest in cost reduction, the manufacturer would rather stay decentralized at a disadvantage in terms of competitive position than backward integrate into an aggressive cost reduction competition. Since we assume that $\gamma > 0.2$, in our setting, backward integration is always favored over decentralization.

Having characterize the manufacturer's preference for different integration options, we are able to derive their equilibrium strategies in the vertical integration game.

Theorem 3.2.

(i) When manufacturers can choose among no integration (D) and forward integration (F), either pure integration structure or pure decentralization structure is an equilibrium outcome. In particular,

$$I_1^* I_2^* = \begin{cases} FF, & \frac{1}{6\sqrt{3}-7} \geqslant \gamma, \\ FF \text{ or } DD, & \frac{1}{5-2\sqrt{3}} \geqslant \gamma > \frac{1}{6\sqrt{3}-7}, \\ DD, & \gamma > \frac{1}{5-2\sqrt{3}}. \end{cases}$$

(ii) When manufacturers can choose among no integration (D), forward integration (F) and backward integration (B), pure integration structure is always an equilibrium outcome. In particular,

$$I_1^* I_2^* = \begin{cases} FF, & \frac{1}{2} \geqslant \gamma, \\ BB, & \gamma > \frac{1}{2}. \end{cases}$$

Theorem 3.2 (i) examines the case when the manufacturer can only stay decentralized or forward integrate, if there is restrictive pressure for cost reduction, wholesaling products to an independent retailer is the equilibrium integration strategy for the manufacturer. The manufacturer uses an independent downstream retailer as a shield from the price competition. If there is moderate pressure for cost reduction, there exist two equilibria where a manufacturer chooses the same integration strategy as its competitor. If there is sufficient pressure for cost reduction, the manufacturer has an incentive to forward integrate. The reason is that cost reduction opportunity accentuates the competitive advantage an integrating supply chain has over its competitor who is not vertically integrated. With such advantage increasing as cost reduction becomes more imperative, the manufacturer would forward integrate to maintain a competitive edge.

When manufacturers competitively choose to forward or backward integrate, staying disintegrated cannot be equilibrium and both manufacturers would integrate in the same direction, as in Theorem 3.2 (ii). Thereby, a manufacturer either engages in the upstream cost reduction competition or in the downstream price competition. The direction of integration depends on the market pressure to invest in cost reduction. If there is sufficient pressure to invest in cost reduction, manufacturers would rather integrate with the retail side to avoid being forced to overinvest in cost reduction. Otherwise, backward integration appears more attractive relative to forward integration since it reduces the effects of price competition at the manufacturer level.

The inclusion of cost reduction opportunity does not change the general integrated nature of equilibrium channel structure found in the literature [Lin14]. In particular, when backward integration is an available option, disintegration can not be an equilibrium strategy. However, an interesting finding is that pure forward integration structure may be an equilibrium outcome in the single period as opposed to backward integration guaranteed to be equilibrium. The choice of integration strategy between forward integration and backward integration is contingent on both the ease of cost reduction and the intensity of retail competition.

Proposition 3.3.

(i) Manufacturers earn less profits when both integrating than when both staying decentralized.

(ii) The difference between the profit of the manufacturer under channel structure DD and that of the manufacturer under channel structure BB decreases with γ.

The integrated supply chain structure as an equilibrium vertical integration outcome always leads to the prisoner's dilemma as in Proposition 3.3 (i). When the manufacturer can only stay decentralized or forward integrate, the manufacturer might have incentives to forward integrate even though they are better off staying decentralized. Cost reduction opportunity provides a new cause of that, although the manufacturer does not take control of cost reduction effort in any case. The manufacturers may have to enter the direct retail competition because of the competitive advantage for an integrated supply chain created by cost reduction opportunity. When manufacturers can choose to forward or backward integrate, the equilibrium channel structure would definitely lead to a prisoner's dilemma for both manufacturers. In particular, when the equilibrium is pure backward integration structure, increasing pressure for cost reduction investment (i.e. a smaller γ) leads to destructive upstream cost reduction competition and makes the prisoner's dilemma worse as in Proposition 3.3 (ii).

For now, we essentially assume two products are totally substitutable. Provided that the retail prices are the same, two supply chains experience equal sales quantities with no respect to the actual pricing level. And the market is always fully covered regardless of the retail prices (i.e., $d_1 + d_2$ is a fixed value). However, in some homogeneous product markets, the industry demand is supposed to be responsive to the retail pricing level. In the next section, we explore a model where two products are partially substitutable.

3.2 Price Differentiation

In this section, we turn our attention to a demand model where product differentiation is investigated from a different aspect: substitutability between two products. We consider a system consisting of two supply chains that produce competing but imperfectly substitutable products. The objective is to understand the implications of cost reduction opportunity on channel structure management in the dimension of product substitutability.

The decision framework remains unchanged. In the first stage, two manufacturers simultaneously decide whether to integrate and, if so, the direction of integration. In the second stage, the firms who control the supply side (a supplier or a backward-integrated manufacturer) non-cooperatively set their individual cost reduction levels and upstream prices. Thereafter, a manufacturer sets its wholesale price if it decides not to integrate. Finally, the firms that take control of retailing (a retailer or a forward-integrated manufacturer) competitively determine the retail price. Also, the cost structure and profit structure for each supply chain under different channel structures remains the same as in the previous section.

We use the following demand function facing supply chain i, $i \in \{1, 2\}$, as in a standard Bertrand competition

$$d_i = 1 - bp_i + \theta bp_{3-i},$$

where $\theta \in (0, 1)$ is the substitutability parameter and b is the industry level price sensitivity. More specifically, θ is the ratio of the rate of change of quantity with respect to the competitor's price to that with respect to own price. When $\theta = 0$, the demands for two products are independent of one another. As θ approaches unity, the products are maximally substitutable. Even when two retail prices are equal, the demands experienced by two supply chains decrease with the pricing level. For the sake of parsimony, the maximum market size for product i (i.e., d_i, when $p_1 = p_2 = 0$) is scaled to one. It is guaranteed that industry demand (i.e., $d_1 + d_2$) must not increase with either product price and expand with θ. We focus on the simplest case: When prices are equal, the demands facing two supply chains are equal.

For this demand model, the market pressure to invest in cost reduction is captured by b/k. A high b/k due to either high market sensitivity to price (b) or low expenditure of cost reduction (k) indicates greater effectiveness of cost reduction effort in raising sales.

For all possible supply chain structures, we solve for the equilibrium of the second stage game using backward induction. Closed-form expressions for the equilibrium results under representative channel structures are displayed in Table 3.3. Those provided are for the channel structure where none, one, or two of the supply chains vertically integrate (e.g., DD, FD, FF, respectively). We omit the equilibrium results for a backward integrated supply chain because they share the same structure as those for a forward integrated supply chain except that the wholesale price is replaced by the upstream price. It can be seen that the equilibrium decisions depend on the degree of product substitutability (θ), market sensitivity to price (b), and the ease of cost reduction investment (k).

We illustrate the equilibrium decisions of the cost reduction levels as a function of product substitutability with respect to different channel structures in Fig 3.1. It can be seen that an integrated supply chain always invests more in cost reduction than a decentralized one. This shows the cost advantage for an integrated supply is robust in product substitutability. When two products are interdependent (i.e., $\theta > 0$), suppliers engage in cost reduction competition where they are forced to overinvest in cost reduction resulting in their mutual detriment. Across all supply chain channels, as two products become more substitutable (i.e., θ gets large), a supply chain makes more cost reduction investment and the cost difference between an integrated supply chain and its decentralized competitor increases. This indicates the impact of cost reduction opportunity increases with product substitutability in the sense that the intensity of upstream cost reduction competition and the resultant cost of decentralization increases. When two products are not perfect substitutes, two supply chains carry out more cost reduction effort when both integrating than when both staying decentralized. Provided that $\theta < 1$, the total industry demand is responsive to the retail pricing level, and thus the integrated supply chains have the incentive and the ability to further reduce their costs so the retail prices for the final product can be lowered.

We then investigate the equilibrium for the vertical integration game through a numerical study and summarize the following results.

Result 3.1.

(i) Manufacturers always choose to integrate in equilibrium and integrate in the same direction.

Table 3.3 Equilibrium quantities for two supply chains

I_1I_2	DD	FF
i	$1,2$	
e_i^*	$\frac{CGIK(BE-Lbc)}{ABEFH^2I^2k-CGKILb}$	$\frac{CG(BE-Lbc)}{E^2F^2ABk-CGLb}$
r_i^*	$\frac{2Gbc_i^*+BE}{Hb}$	$\frac{2Cbc_i^*+B}{Fb}$
w_i^*	$\frac{2Cbr_i^*+B}{Fb}$	–
p_i^*	$\frac{2bw_i^*+1}{Ab}$	$\frac{2bw_i^*+1}{Ab}$
d_i^*	$\frac{CGBE-CGLbc_i^*}{ABEFH}$	$\frac{BCE-CLbc_i^*}{ABEF}$
I_1I_2	FD	
i	1	2
e_i^*	$\frac{A_2B_1-A_1CGJ\theta}{B_1B_2-(CGJ\theta)^2}$	$\frac{A_1B_2-A_2CGJ\theta}{B_1B_2-(CGJ\theta)^2}$
r_i^*	$\frac{C\theta bc_1^*+2Gbc_2^*+(\theta+2E)B}{(4G-\theta^2)b}$	$\frac{2CGbc_2^*+G\theta bc_1^*+(E\theta+2G)B}{(4G-\theta^2)Cb}$
w_i^*	–	$\frac{Cbr_2^*+\theta br_1^*+B}{2Cb}$
p_i^*	$\frac{2br_1^*+\theta bw_2^*+B}{ABb}$	$\frac{2bw_2^*+\theta br_1^*+B}{ABb}$
d_i^*	$\frac{(\theta+2E)BG-GJbc_1^*+CG\theta bc_2^*}{2ABC(4G-\theta^2)}$	$\frac{(E\theta+2G)B-CJbc_2^*+G\theta bc_1^*}{2AB(4G-\theta^2)}$

where $c_i^* = c - e_i^*$, $A = 2-\theta$, $B = 2+\theta$, $C = 2-\theta^2$, $E = 4+\theta-2\theta^2$, $F = 4-\theta-2\theta^2$, $G = 8-9\theta^2+2\theta^4$, $H = 2G - C\theta$, $I = 2G + C\theta$, $J = 16 - 19\theta^2 + 4\theta^4$, $K = 2G^2 - C^2\theta^2$, $L = 8-2\theta-9\theta^2+\theta^3+2\theta^4$, $A_1 = (E\theta+2G)BCJb+(G\theta-CJ)CJbc$, $B_1 = 2k(4G-\theta^2)^2ABCb-C^2J^2b^2$, $A_2 = (\theta+2E)BGJb+(C\theta-J)GJbc$, $B_2 = 2k(4G-\theta^2)^2ABCb-GJ^2b^2$.

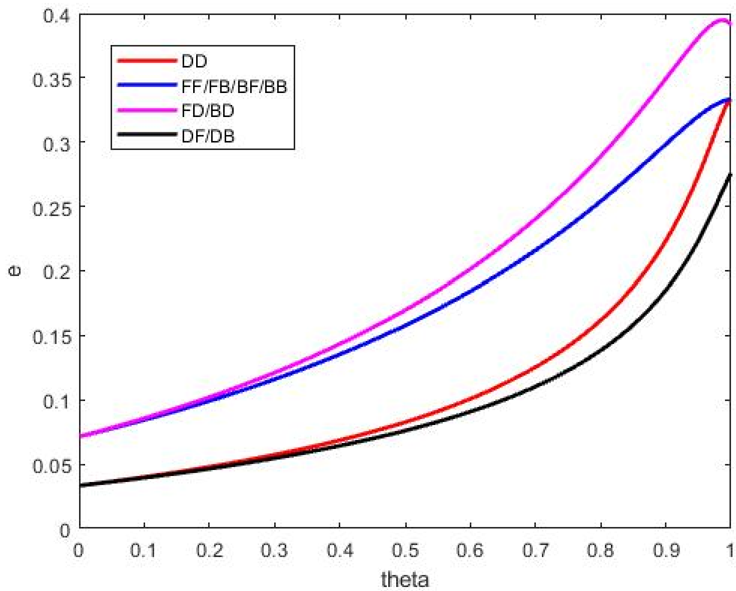

Figure 3.1 Equilibrium cost reduction level for supply chain 1 ($k = 1$, $c = 0.5$, $b = 0.5$)

(ii) There exists a threshold of b/k above which FF is the equilibrium outcome and below which BB is the equilibrium outcome.

(iii) There exists a threshold of θ below which FF is the equilibrium outcome and above which BB is the equilibrium outcome.

This result generalizes the appearance of integrated industry structure as equilibrium outcome in the dimension of product substitutability. In sharp contrast to [GL98] where disintegration is favored at high product substitutability in a duopolistic two-tier supply chains, provided that backward integration is an available option, manufacturers in duopolistic three-tier supply chains would always choose to integrate in equilibrium and integrate in the same direction. For a less interdependent market (i.e., a small θ), a supply chain operates more like a monopolist industry where integration is always favored in pursuit of coordinated decision making. For a rather interdependent market (i.e., a large θ), an integrated supply chain is more competitive in terms of cost which provides the incentive for integration.

The direction of integration depends on both the product substitutability and the market

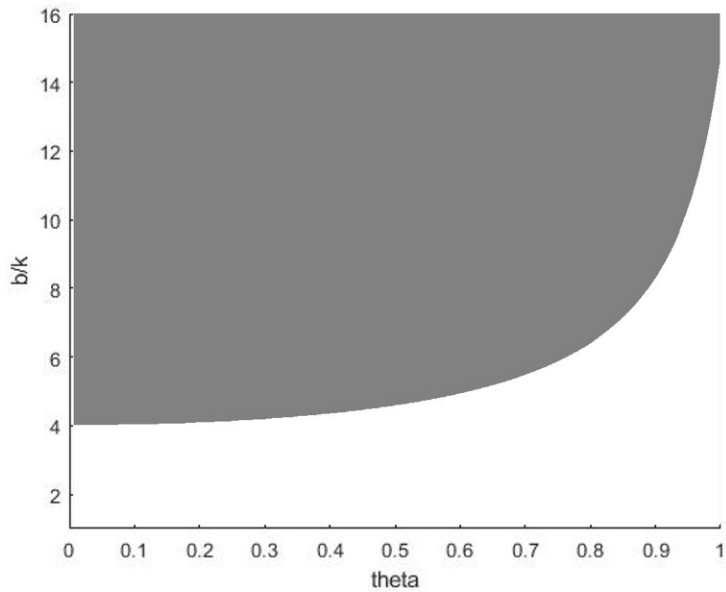

Figure 3.2 Shaded area over which FF is an equilibrium outcome

pressure for cost reduction. The feasible range of θ and b/k for forward integration to be the equilibrium strategy is depicted in Figure 3.2.

In a monopolist system, whether to forward or backward integrate is determined by comparing the benefits of having direct control over the supply side and the retail side. However, in a duopoly system, there are two effects that pull in opposite directions and jointly determine the direction of integration in equilibrium: (a) Backward integration lessens the effect of price competition for the manufacturer while forward integration strengthens it. (b) An integrated supply chain has more incentive to make cost reduction investment. The first effect is in favor of backward integration and the second effect is in favor of forward integration. In general, forward integration is preferred at low substitutability (θ) and high market pressure for cost reduction investment (b/k), where the second effect dominates due to dampened cost reduction competition and increasingly independent demands.

Result 3.2. *As θ becomes larger, the range of b/k over which FF is the equilibrium outcome decreases.*

As the demands for two products become more dependent, the first effect increases in greater magnitude than the second effect. Thus, for less values of b/k, manufacturers would choose forward integration in equilibrium instead of backward integration.

Result 3.3. *As k becomes larger, the range of θ over which FF is the equilibrium outcome decreases.*

The major role of backward integration to alleviate the impact of price competition on the manufacturer is in great need when price competition is fierce at high product substitutability. For this reason, as it becomes more costly to reduce cost, the negative effect of backward integration for engaging in destructive upstream cost reduction competition decreases. Thus, for more values of θ, backward integration turns out to be the equilibrium strategy.

3.3 Summary

The appearance of pure integration structure as equilibrium outcome is robust even in the presence of the vertical externality of supplier's cost reduction effort. By contrasting with the benchmark where no cost reduction opportunity is involved, we find that cost reduction opportunity reinforces the competitive edge an integrated supply chain has over its disintegrated competitor. In addition to the reduced level of double marginalization, vertically integrated supply chain can further undercut its disintegrated competitor as its supplier has more power to make cost reduction investment. Thereby, cost reduction opportunity increases manufacturers incentives for vertical integration. Even the choice of forward integration may dominate disintegration. To avoid an overly disadvantaged position due to unilaterally staying decentralized, manufacturers integrate even though they are better off staying disintegrated. The integrated nature of equilibrium channel structure remains across different degrees of product differentiation. We identify a threshold value of γ which must be exceeded for forward integration to be the equilibrium strategy. When there is too much pressure for cost reduction investment, backward integration leads the manufacturers into mutually destructive cost reduction competition. As it becomes costly to invest in cost reduction or the retail price competition turns less intense, forward integration leads the manufacturers into direct price competition. We find that the exact equilibrium integration outcome also depends on the levels of substitutability between two competing products.

There exist several directions to explore in future research. Currently, the original cost before cost reduction investment is modeled as a fixed value. To generalize the cost structure, one may model the original cost as stochastic following a distribution and cost reduction effort can shift the support of the distribution from which cost is drawn. The assumption of strategic integration decisions and transfer pricing contract visible to competitors is less often found in such industries as technology or pharmaceutical. It would be meaningful to ponder the issue of credible delegation decision making. Furthermore, in view of the prisoner's dilemma as a result of integrated equilibrium outcome due to cost reduction and price competition, it would be interesting to think about a mechanism that would allow the manufacturers to coordinate their channel decision toward a mutually more profitable equilibrium. Another important direction is the outsourcing problem where the manufacturer makes decision about whether or not to outsource its production to a contract manufacturer (supplier). A common setting is that both the original manufacturer and the contract manufacturer are endowed with cost reduction opportunities and the original manufacturer makes the outsourcing decision after the contract manufacturer determines the cost reduction level. With the decision making sequence of channel structure and cost reduction investment being reversed, we expect that the contract manufacturer would take more advantage of cost reduction opportunity in order to offer a wholesale price that induces the manufacturer to outsource.

Chapter 4

Channel Structure of Two Competing Supply chains with Asymmetric Customer Loyalty

Customer loyalty has been recognized as a key factor affecting a customer's decision to purchase. As a result of emotional connections and perceived unique value in the brand, customers have the dedication to purchase repeatedly. The role of brand loyalty in leading to market advantages such as favorable word of mouth, increased new customers, and resistance to competitive services, has been identified in the marketing literature [CH01]. In the 2016 Breakout Brands survey by rbb Communications, 93% of customers would pay more for a product they have an emotional connection with. 24% of them were willing to pay 50% or more for their favorite products. 43% of participants claimed no amount of money would bribe them away from their favorite brand and for the rest an average of $220,000$ was estimated to break the emotional connections (https://rbbcommunications.com/insights/breakout-brands-purchase-decision-insights). Since 2007, Apple has been using the Net Promotor Score (NPS), an index that measures the willingness of customers to recommend Apple products to other people, to manage nearly all 500 retail locations and guide decisions ranging from employee evaluation to retail strategy.

Quality, a product attribute that increases customer satisfaction and willingness to buy, is the key determinant of customer loyalty. In the rbb Communications study, 45% of respondents cited poor product quality as the primary reason they stopped buying from a brand. The recall of Galaxy Note 7 smartphones due to the batteries prone to ignite cost Samsung Electronics nearly $5 billion in 2013 revenue and directly led to a drop in Chinese market share from 20% to 2%. Consequently, such Chinese smartphone makers as Huawei, Oppo, Xiaomi have been growing fast not just in their home country but around the world, closing the gap on Samsung and Apple.

Vertical integration is a commonly visited business strategy in the literature of price-quality competition [Mat07]. As opposed to assuming two symmetric supply chains, we examine the impact of horizontal differentiation between supply chains on channel structure decision for the manufacturers. The asymmetry between supply chains arises from difference in the customers' loyalty toward two products. We explore how a combination of asymmetric demand structure and quality-price competition shapes a manufacturer's integration decision. Our model depends on and extends the classical study by Shaffer and Zhang [SZ02] that defined a customer's loyalty as the minimum value differential that induce the customer to buy the less preferred product.

We consider a system of two competitive three-tier supply chains. The quality level of product is determined by the supplier who sells immediate product to its exclusive manufacturer, who then sells the product through its exclusive retailer to the market. The manufacturer can choose to forward integrate, backward integrate, or stay decentralized. A consumer makes purchasing decision based on the product price, quality level, and his loyalty toward the product. Factors including market sensitivity to price, market sensitivity to quality, and cost of quality investment may play a role in determining the manufacturer's equilibrium integration strategy.

Our work differs from the literature in many aspects. First, we explore the setting where two supply chains are asymmetric, while the majority of vertical integration literature assumes two symmetric supply chains. The asymmetry arises from the customer loyalty toward two products. Second, two supply chains compete on prices and quality levels to maximize their profits, which differs from those studies considering exclusive price competition. Furthermore, few papers have addressed how customer loyalty affects channel structure decisions and this work is the first to study this subject in a multi-tier supply chain setting.

This chapter is organized as follows. Section 4.1 describes the modeling framework of analysis. Section 4.2 provides equilibrium results of quality levels and prices under varying levels of customer loyalty and demand sensitivity as well as equilibrium channel structure. Section 4.3 summarizes the chapter.

4.1 Modeling

We consider a price and quality-based competition between two supply chains. Let p_i be the retail price and q_i be the quality level of product i, $i = 1, 2$. A customer perceives that a product has a worth of $v_i = \beta q_i - \alpha p_i$, where α and β captures customers' average sensitivity to price and quality, $\alpha, \beta \geqslant 0$. That is, a large value of α or β conveys a high level of demand responsiveness to changes in the product's price or quality, respectively

Customer loyalty is quantified as the minimum value differential to induce the customer to purchase the less preferred product [SZ02]. A customer who has loyalty l toward product 1 would purchase product 2 only when $v_2 > v_1 + l$. In other words, customer loyalty l is the amount that the customer is willing to irrationally pay for product 1 at most. Automatically, the customer's loyalty toward product 2 is $-l$. The loyalty information $l \in [-l_2, l_1]$ is private to the customer, $l_1, l_2 > 0$. The other supply chain participants learn that l follows a uniform distribution over $[-l_2, l_1]$. Without loss of generality, we assume that l is distributed over a unit interval (i.e., $l_1 + l_2 = 1$) and that product 1 generally receives higher customer loyalty than product 2 (i.e., $l_1 > l_2$). Customers with loyalty $l \in (v_2 - v_1, l_1]$ purchase product 1 and those with $l \in [-l_2, v_2 - v_1)$ purchase product 2. Those with loyalty $v_2 - v_1$ are indifferent between two products. The asymmetry between two supply chains arises from difference in customer loyalty toward two products, represented by

$$\Delta = \frac{l_2}{l_1},$$

where $0 < \Delta < 1$. A lower Δ implies a higher level of asymmetry between two supply chains. The expected demands faced by two supply chains are

$$d_1 = l_1 - (v_2 - v_1) = l_1 - \alpha p_1 + \alpha p_2 + \beta q_1 - \beta q_2,$$

$$d_2 = l_2 - (v_1 - v_2) = l_2 - \alpha p_2 + \alpha p_1 + \beta q_2 - \beta q_1.$$

The sequence of events naturally develops a two-stage game. In the first stage, each manufacturer makes its own integration decision $I_1, I_2 \in \{N, F, B\}$, leading to the channel structure $I_1 I_2$. In the second stage, there is a Stackelberg subgame. Firms in charge of the raw materials (a supplier or a backward integrated manufacturer) competitively determine the quality level q_i. Then, they decide the unit upstream price r_i. The manufacturer, if not integrated, announces its wholesale price w_i. Finally, the firms who have control in retailing (a retailer or a forward integrated manufacturer) competitively set their retail prices p_i.

Our model goes underlying the assumption that quality levels are set before pricing decisions because they need more advanced planning. All supply chain participants (the supplier, manufacturer, and retailer) do not incur variable costs for production and retailing. Quality q_i is chosen at a quadratic fixed cost kq_i^2, as commonly seen in literature [Moo85; Ban98]. That means increasing investment in quality incurs higher costs upon suppliers, because much more efforts are required to redesign process in order for product quality to achieve a higher level.

In a disintegrated supply chain, the supplier sets the quality level and upstream price, the manufacturer sets the wholesale price, and the retailer sets the retail price to maximize their respective profits:

$$q_i^* = \arg\max_{q_i} \; r_i d_i - kq_i^2.$$

$$r_i^* = \arg\max_{r_i} \; r_i d_i - k q_i^2.$$

$$w_i^* = \arg\max_{w_i} (w_i - r_i) d_i.$$

$$p_i^* = \arg\max_{p_i} (p_i - w_i) d_i.$$

In a forward integrated channel, the manufacturer instead solves

$$p_i^* = \arg\max_{p_i} (p_i - r_i) d_i.$$

In a backward integrated channel, the manufacturer instead solves

$$q_i^* = \arg\max_{q_i} \; w_i d_i - k q_i^2.$$

$$w_i^* = \arg\max_{w_i} \; w_i d_i - k q_i^2.$$

The Stackelberg subgame under each channel structure $I_1 I_2$ is similar to that in the previous chapter. For the sake of space saving, we omit specifying all supply chain participants' problems here.

4.2 Equilibrium Results

In this section, we solve the two-stage game backward. To ensure the existence of equilibrium for the second-stage Stackelberg subgame, we make the following parametric assumption:

$$\Lambda = \frac{\beta^2}{\alpha k} < 15 l_1 + 12 l_2.$$

Increasing with market sensitivity to quality (β) and decreasing with cost of quality investment (k) and market sensitivity to price (α), Λ reflects the relative return from quality investment or the market desire for high quality products. The assumption is to ensure that relative return from quality improvement is not too high, which can be attributed to relatively high cost of quality investment, relatively high sensitivity to price, or relatively low sensitivity to quality. Without such assumption, when both supply chains are integrated, the demands may become unstable. Note that as a result of customer loyalty asymmetry, the parametric requirement imposed is more restrictive than that in [Lin14].

Conditional on the channel structure determined by the manufacturer in the first stage game, we characterize the equilibria for the second stage Stackelberg subgame. The closed-form equilibrium outcome of quality levels, prices, and sales quantities under three representative channel structures (DD, FF, FD) are displayed in Table 4.1. We omit those equilibrium decisions for a backward integrated supply chain because they share the same structure as those for a forward integrated supply chain except with the wholesale price replaced by the upstream price. It can be seen from Table 4.1 that the supply chain with strong customer loyalty (supply chain 1) always has higher product quality than the supply chain with low customer loyalty (supply chain 2) in pure decentralization structure and pure integration structure. The advantages in quality and customer loyalty constitute the competitive advantage supply chain 1 has over supply chain 2.

In the following proposition, we compare the equilibrium decisions of quality levels and sales quantities in pure decentralization structure against in pure integration structure.

Proposition 4.1. *For* $I_1, I_2 \in \{F, B\}$,

(i) $q_1^{I_1 I_2} > q_1^{DD}$; $q_2^{DD} > q_2^{I_1 I_2}$;

(ii) $d_1^{I_1 I_2} > d_1^{DD}$; $d_2^{DD} > d_2^{I_1 I_2}$;

(iii) $p_1^{I_1 I_2} < p_1^{DD}$; $p_2^{I_1 I_2} < p_2^{DD}$.

Proposition 4.1 (i) indicates that as both manufacturers integrate, supply chain 1 tends to invest more in quality improvement while supplier 2 tends to invest less. It means the quality advantage supply chain 1 has over supply chain 2 increases, as integration is more involved. Thus, when compared to the pure decentralization structure, supplier chain 1 has more sales quantities while supplier chain 2 has less in the pure integration structure, as in Proposition 4.1 (ii). From Proposition 4.1 (iii), both retail prices are lower in pure integration structure than in pure decentralization structure, implying an intensified price-quality competition.

In the next proposition, we compare the equilibrium sales quantities and quality levels within a given channel structure.

Proposition 4.2. *For* $I_1, I_2 \in \{F, B\}$,

(i) $q_1^{DD} > q_2^{DD}$; $d_1^{DD} > d_2^{DD}$;

(ii) $q_1^{I_1I_2} > q_2^{I_1I_2}$; $d_1^{I_1I_2} > d_2^{I_1I_2}$;

(iii) $q_1^{I_1D} > q_2^{I_1D}$; $d_1^{I_1D} > d_2^{I_1D}$.

(iv) $q_1^{DI_2} > q_2^{DI_2}$; $d_1^{DI_2} < d_2^{DI_2}$;

In pure channel structures, supply chain 1 always invests more in quality and experiences more demand than supply chain 2, as in Proposition 4.2 (i) and (ii). When supply chain 1 is integrated while supply chain 2 stays decentralized, supply chain 1 invests more to improve quality and attracts more demand than supply chain 2, as in Proposition 4.2 (iii). In contrast, when supply chain 1 stays decentralized while supply chain 2 is integrated, the former invests more in quality while the latter receives more demand, as in Proposition 4.2 (iv). Thus, vertical integration is a useful business strategy for the suppler chain with customer loyalty disadvantage to attract demand from its rival. An integrated supply chain always experiences more demand than its disintegrated competitor. The supply chain with strong customer loyalty always invests more in quality than its competitor with low customer loyalty. To conclude, in mixed channel structures, demand is more related to the integration strategy, while quality investing power is more related to the relative customer loyalty.

In the following proposition, we explore how the equilibrium quality levels and sales quantities change when the industry moves from/to pure channel structure to/from mixed channel structure.

Proposition 4.3. *For* $I_1, I_2 \in \{F, B\}$,

(i) $q_1^{DD} > q_1^{I_1D}$; $q_2^{DD} > q_2^{I_1D}$; $d_1^{DD} < d_1^{I_1D}$; $d_2^{DD} > d_1^{I_1D}$;

(ii) $q_1^{DD} > q_1^{DI_2}$; $q_2^{DD} > q_2^{DI_2}$; $d_1^{DD} > d_1^{DI_2}$; $d_2^{DD} < d_2^{DI_2}$;

(iii) $q_1^{I_1D} < q_1^{I_1I_2}$; $q_2^{I_1D} < q_2^{I_1I_2}$; $d_1^{I_1D} < d_1^{I_1I_2}$; $d_2^{I_1D} > d_2^{I_1I_2}$;

(iv) $q_1^{DI_2} < q_1^{I_1I_2}$; $q_2^{DI_2} > q_2^{I_1I_2}$; $d_1^{DI_2} < d_1^{I_1I_2}$; $d_2^{DI_2} > d_2^{I_1I_2}$.

When either manufacturer within pure decentralization structure unilaterally integrates, both supply chains tend to invest less in product quality, as in Proposition 4.3 (i) and (ii). The supply chain which remains disintegrated has to cut the quality investment to offset losses from the low-priced sale and reduced demand. In response, the integrated supply chain can release on its quality investment and gains from reduced double marginalization and increased demand. With manufacturer 2 within mixed channel structure integrating, supply chain 2 closes the gap between itself and supply chain 1. The competition intensifies to the extent that both supply chains are forced to invest more in product quality, as in Proposition 4.3 (iii). With manufacturer 1 within mixed channel structure integrating, supply chain 1 gains more traction on the market in terms of the increased demand and thus further improves quality to undercut its competitor, so supply chain 2 has to lower its quality investment, as in Proposition 4.3 (iv).

Let $\pi_{M_i}^{I_1I_2}$, $i = 1, 2$, be the equilibrium profit of manufacturer i under channel structure I_1I_2. Closed-form expressions for manufacturer profitability under different channel structures are provided in Table 4.2.

The next theorem compares the manufacturer's profitability for different choices of vertical integration strategies when competing with a decentralized supply chain.

Theorem 4.1.

(i) $\pi_{M_1}^{FD} < \pi_{M_1}^{DD} < \pi_{M_1}^{BD}$.

(ii) $\pi_{M_2}^{DF} < \pi_{M_2}^{DD} < \pi_{M_2}^{DB}$.

Table 4.1 Equilibrium quantities under representative channel structures

DD	$i=1$	$i=2$
q_i^*	$\frac{\beta((42\alpha k-\beta^2)l_1+(39\alpha k-\beta^2)l_2)}{3\alpha k(81\alpha k-2\beta^2)}$	$\frac{\beta((42\alpha k-\beta^2)l_2+(39\alpha k-\beta^2)l_1)}{3\alpha k(81\alpha k-2\beta^2)}$
p_i^*	$\frac{13((42\alpha k-\beta^2)l_1+(39\alpha k-\beta^2)l_2)}{\alpha(81\alpha k-2\beta^2)}$	$\frac{13((42\alpha k-\beta^2)l_2+(39\alpha k-\beta^2)l_1)}{\alpha(81\alpha k-2\beta^2)}$
w_i^*	$\frac{12((42\alpha k-\beta^2)l_1+(39\alpha k-\beta^2)l_2)}{\alpha(81\alpha k-2\beta^2)}$	$\frac{12((42\alpha k-\beta^2)l_2+(39\alpha k-\beta^2)l_1)}{\alpha(81\alpha k-2\beta^2)}$
r_i^*	$\frac{9((42\alpha k-\beta^2)l_1+(39\alpha k-\beta^2)l_2)}{\alpha(81\alpha k-2\beta^2)}$	$\frac{9((42\alpha k-\beta^2)l_2+(39\alpha k-\beta^2)l_1)}{\alpha(81\alpha k-2\beta^2)}$
d_i^*	$\frac{(42\alpha k-\beta^2)l_1+(39\alpha k-\beta^2)l_2}{81\alpha k-2\beta^2}$	$\frac{(42\alpha k-\beta^2)l_2+(39\alpha k-\beta^2)l_1}{81\alpha k-2\beta^2}$
FF	$i=1$	$i=2$
q_i^*	$\frac{\beta((15\alpha k-\beta^2)l_1+(12\alpha k-\beta^2)l_2)}{3\alpha k(27\alpha k-2\beta^2)}$	$\frac{\beta((15\alpha k-\beta^2)l_2+(12\alpha k-\beta^2)l_1)}{3\alpha k(27\alpha k-2\beta^2)}$
p_i^*	$\frac{4((15\alpha k-\beta^2)l_1+(12\alpha k-\beta^2)l_2)}{\alpha(27\alpha k-2\beta^2)}$	$\frac{4((15\alpha k-\beta^2)l_2+(12\alpha k-\beta^2)l_1)}{\alpha(27\alpha k-2\beta^2)}$
w_i^*	–	–
r_i^*	$\frac{3((15\alpha k-\beta^2)l_1+(12\alpha k-\beta^2)l_2)}{\alpha(27\alpha k-2\beta^2)}$	$\frac{3((15\alpha k-\beta^2)l_2+(12\alpha k-\beta^2)l_1)}{\alpha(27\alpha k-2\beta^2)}$
d_i^*	$\frac{(15\alpha k-\beta^2)l_1+(12\alpha k-\beta^2)l_2}{27\alpha k-2\beta^2}$	$\frac{(15\alpha k-\beta^2)l_2+(12\alpha k-\beta^2)l_1}{27\alpha k-2\beta^2}$
FD	$i=1$	$i=2$
q_i^*	$\frac{\beta((28\alpha k-\beta^2)l_1+(26\alpha k-\beta^2)l_2)}{8\alpha k(27\alpha k-\beta^2)}$	$\frac{\beta((30\alpha k-\beta^2)l_2+(24\alpha k-\beta^2)l_1)}{8\alpha k(27\alpha k-\beta^2)}$
p_i^*	$\frac{3((28\alpha k-\beta^2)l_1+(26\alpha k-\beta^2)l_2)}{\alpha(27\alpha k-\beta^2)}$	$\frac{13((30\alpha k-\beta^2)l_2+(24\alpha k-\beta^2)l_1)}{4\alpha(27\alpha k-\beta^2)}$
w_i^*	–	$\frac{3((30\alpha k-\beta^2)l_2+(24\alpha k-\beta^2)l_1)}{\alpha(27\alpha k-\beta^2)}$
r_i^*	$\frac{9((28\alpha k-\beta^2)l_1+(26\alpha k-\beta^2)l_2)}{4\alpha(27\alpha k-\beta^2)}$	$\frac{9((30\alpha k-\beta^2)l_2+(24\alpha k-\beta^2)l_1)}{4\alpha(27\alpha k-\beta^2)}$
d_i^*	$\frac{3((28\alpha k-\beta^2)l_1+(26\alpha k-\beta^2)l_2)}{4(27\alpha k-\beta^2)}$	$\frac{(30\alpha k-\beta^2)l_2+(24\alpha k-\beta^2)l_1}{4(27\alpha k-\beta^2)}$

Table 4.2 Equilibrium manufacturer profitability under different channel structures

I_1I_2	$\pi_{M_1}^{I_1I_2}$	$\pi_{M_2}^{I_1I_2}$
DD	$\frac{3((42\alpha k-\beta^2)l_1+(39\alpha k-\beta^2)l_2)^2}{\alpha(81\alpha k-2\beta^2)^2}$	$\frac{3((42\alpha k-\beta^2)l_2+(39\alpha k-\beta^2)l_1)^2}{\alpha(81\alpha k-2\beta^2)^2}$
DF	$\frac{3((30\alpha k-\beta^2)l_1+(24\alpha k-\beta^2)l_2)^2}{16\alpha(27\alpha k-\beta^2)^2}$	$\frac{9((28\alpha k-\beta^2)l_2+(26\alpha k-\beta^2)l_1)^2}{16\alpha(27\alpha k-\beta^2)^2}$
DB	$\frac{3((30\alpha k-\beta^2)l_1+(24\alpha k-\beta^2)l_2)^2}{16\alpha(27\alpha k-\beta^2)^2}$	$\frac{(108\alpha k-\beta^2)((28\alpha k-\beta^2)l_2+(26\alpha k-\beta^2)l_1)^2}{64\alpha^2k(27\alpha k-\beta^2)^2}$
FD	$\frac{9((28\alpha k-\beta^2)l_1+(26\alpha k-\beta^2)l_2)^2}{16\alpha(27\alpha k-\beta^2)^2}$	$\frac{3((30\alpha k-\beta^2)l_2+(24\alpha k-\beta^2)l_1)^2}{16\alpha(27\alpha k-\beta^2)^2}$
BD	$\frac{(108\alpha k-\beta^2)((28\alpha k-\beta^2)l_1+(26\alpha k-\beta^2)l_2)^2}{64\alpha^2k(27\alpha k-\beta^2)^2}$	$\frac{3((30\alpha k-\beta^2)l_2+(24\alpha k-\beta^2)l_1)^2}{16\alpha(27\alpha k-\beta^2)^2}$
FF	$\frac{((15\alpha k-\beta^2)l_1+(12\alpha k-\beta^2)l_2)^2}{\alpha(27\alpha k-2\beta^2)^2}$	$\frac{((15\alpha k-\beta^2)l_2+(12\alpha k-\beta^2)l_1)^2}{\alpha(27\alpha k-2\beta^2)^2}$
FB	$\frac{((15\alpha k-\beta^2)l_1+(12\alpha k-\beta^2)l_2)^2}{\alpha(27\alpha k-2\beta^2)^2}$	$\frac{(27\alpha k-\beta^2)((15\alpha k-\beta^2)l_2+(12\alpha k-\beta^2)l_1)^2}{9\alpha^2k(27\alpha k-2\beta^2)^2}$
BF	$\frac{(27\alpha k-\beta^2)((15\alpha k-\beta^2)l_1+(12\alpha k-\beta^2)l_2)^2}{9\alpha^2k(27\alpha k-2\beta^2)^2}$	$\frac{((15\alpha k-\beta^2)l_2+(12\alpha k-\beta^2)l_1)^2}{\alpha(27\alpha k-2\beta^2)^2}$
BB	$\frac{(27\alpha k-\beta^2)((15\alpha k-\beta^2)l_1+(12\alpha k-\beta^2)l_2)^2}{9\alpha^2k(27\alpha k-2\beta^2)^2}$	$\frac{(27\alpha k-\beta^2)((15\alpha k-\beta^2)l_2+(12\alpha k-\beta^2)l_1)^2}{9\alpha^2k(27\alpha k-2\beta^2)^2}$

When facing a decentralized competition, backward integration is the most preferred option and forward integration is the least preferred for both manufacturers. An integrated supply chain does not necessarily outcompete its decentralized competitor. In a competitive market, backward integration not just eliminates an intermediate level of supply chain that applies an extra price margin, but also helps the manufacturer avoid engaging in direct price competition. On the other side, forward integration intensifies the competitive effect for the manufacturer which negates the benefits of vertical integration. Such preference is regardless of sensitivity to price (α), sensitivity to quality (β), or cost of quality (k).

The next theorem compares the manufacturer's profitability for different choices of vertical integration strategy when competing with an integrated supply chain.

Theorem 4.2. *For* $I \in \{B, F\}$,

(i) $\pi_{M_1}^{DI} < \pi_{M_1}^{FI} < \pi_{M_1}^{BI}$;

(ii) $\pi_{M_2}^{ID} < \pi_{M_2}^{IB}$ *if and only if* $\Lambda < \Lambda_1(\Delta)$ *for the threshold* $\Lambda_1(\Delta)$, *as depicted in Figure 4.1;*

(iii) $\pi_{M_2}^{ID} < \pi_{M_2}^{IF}$ *if and only if* $\Lambda < \Lambda_2(\Delta)$ *for the threshold* $\Lambda_2(\Delta)$, *as depicted in Figure 4.2;*

(iv) $\pi_{M_2}^{IF} < \pi_{M_2}^{IB}$.

While forward integration is always detrimental for either manufacturer against a disintegrated competitor, this may not be not the case for a manufacturer facing an integrated competitor. Theorem 4.2 (i) indicates that manufacturer 1 would always choose integration over disintegration. By integrating supply chain 1 can gain competitive advantage brought by improved product quality and reduced level of double marginalization.

The choice of integration strategy for manufacturer 2 depends on the customer loyalty difference (Δ) and the relative return for quality investment (Λ). Theorem 4.2 (ii) shows that a combination of relatively low customer loyalty and high market desire to improve quality induces manufacturer 2 to stay decentralized instead of backward integrating. When supply chain 1 is in a fairly advantaged position in terms of customer loyalty and the market has a critical need for high quality product, supply chain 1 has an distinct competitive advantage over supply chain 2 which could force the backward integrated manufacturer 2 to overinvest in quality and thereby hurt its profitability. Otherwise, manufacturer 2 would choose backward integration over disintegration in order to exploit the benefit of vertical integration.

It can be seen from Theorem 4.2 (iii) that manufacturer 2 prefers forward integration to disintegration for most values of Λ and Δ, in sharp contrast with the notion in Theorem 4.1 that forward integration can always harm manufacturer profitability. To gain more competitive advantage, manufacturer 2 takes control of retail pricing decision to enable higher quality and lower retail price. Only when supply chain 1 is in a highly favored position empowered by the customer loyalty and the market has a rather high desire to invest in quality, manufacturer 2 needs disintegration to buffer the competition in order to achieve a high profit margin.

Although the difference in customer loyalty is critical in comparing choices of vertical integration against disintegration, backward integration always dominates forward integration regardless of customer loyalty for both manufacturers, as indicated in Theorem 4.2 (i) and (iv). The reason is sill that forward integration escalates the impact of price competition on the manufacturer while backward integration dampens it.

We conduct numerical analysis to compare two thresholds $\Lambda_1(\Delta)$ and $\Lambda_2(\Delta)$. It turns out that the region over which $\Lambda > \Lambda_1(\Delta)$ is the subset of the region over which $\Lambda > \Lambda_2(\Delta)$. In Figure 4.3, we depict manufacturer 2's preference for different integration choices when manufacturer 1 is vertically integrated.

Having characterized a manufacturer's integration preference conditional on the structure of the competing supply chain, we derive the equilibrium integration outcome in the following theorem.

Theorem 4.3.

(i) When a manufacturer can choose among disintegration (D) and forward integration (F), then

$$I_1^* I_2^* = \begin{cases} DD, & \Lambda > \Lambda_2(\Delta), \\ DD, FF, & \Lambda \leq \Lambda_2(\Delta). \end{cases}$$

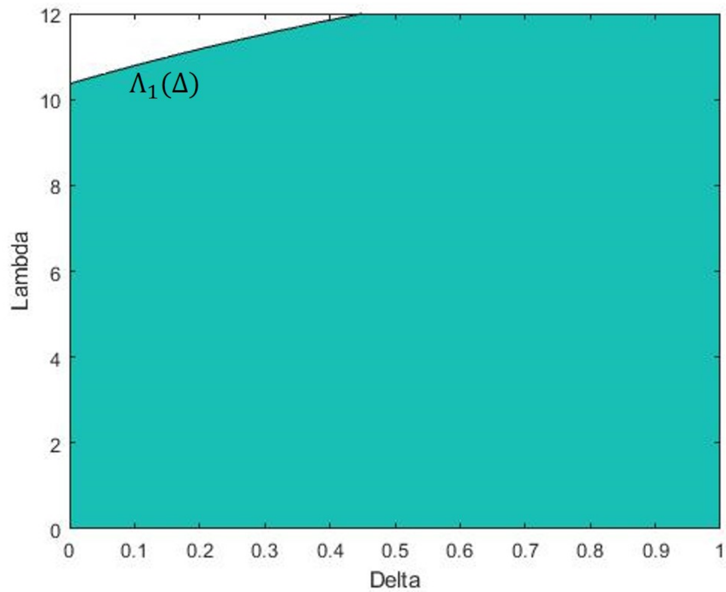

Figure 4.1 Shaded area for $\pi_{M_2}^{ID} < \pi_{M_2}^{IB}$

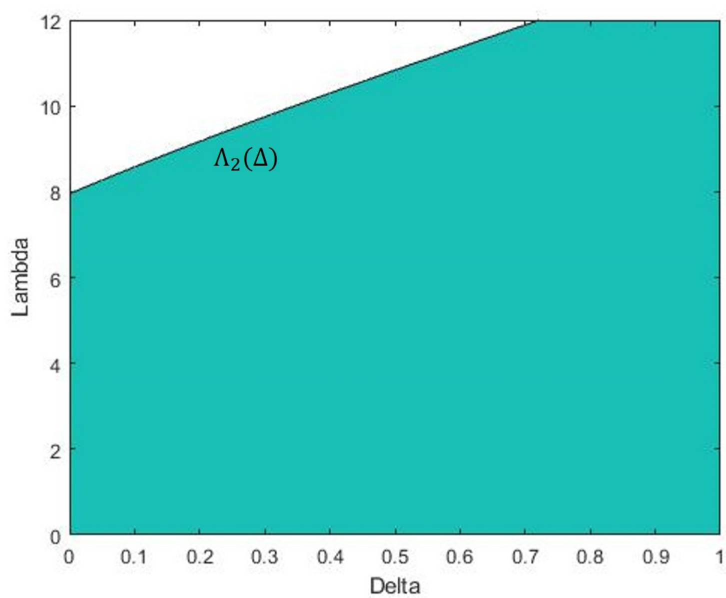

Figure 4.2 Shaded area for $\pi_{M_2}^{ID} < \pi_{M_2}^{IF}$

(ii) When a manufacturer can choose among disintegration (D), forward integration (F) and

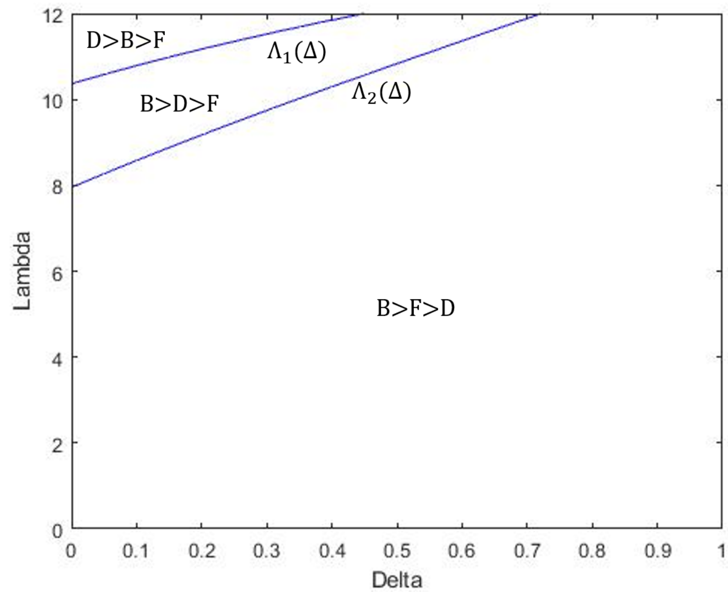

Figure 4.3 Preferred integration strategy for manufacturer 2

backward integration (B), then

$$I_1^* I_2^* = \begin{cases} BD, & \Lambda > \Lambda_1(\Delta), \\ BB, & \Lambda \leq \Lambda_1(\Delta). \end{cases}$$

When the manufacturer can choose between disintegration and forward integration, even though two supply chains are not symmetric, they adopt the same integration strategy in equilibrium. Pure decentralization structure is always in the equilibrium, and pure forward integration structure is a conditional equilibrium. If there is minor difference in two supply chains' customer loyalty, both pure decentralization structure and pure forward integration structure are equilibrium outcomes for all values of Λ. When the customer loyalty toward two products is sufficiently different and the market has a critical need for high quality, manufacturer 2 first chooses to decentralize to relax the competitive impact of competition, which induces manufacturer 1 to decentralize as well. As Δ gets smaller, the range of Λ over which pure decentralization structure is a unique equilibrium outcome increases.

When backward integration is available, there exists a unique equilibrium and the exact equilibrium outcome is collectively determined by customer loyalty asymmetry and the market desire to invest in quality. The equilibrium may be asymmetric due to customer loyalty difference. When two supply chains' customer loyalty is slightly different, both manufacturers backward integrate in order to avoid the impact of retail competition. When supply chain 1 has fairly strong customer loyalty and the market has a critical need to improve quality, the backward integrated supply chain 1 has so immense competitive advantage that manufacturer 2 would rather stay decentralized because the large upstream quality investment nullifies the benefits of backward integration. As Δ gets smaller, the range of Λ over which BD is the equilibrium increases.

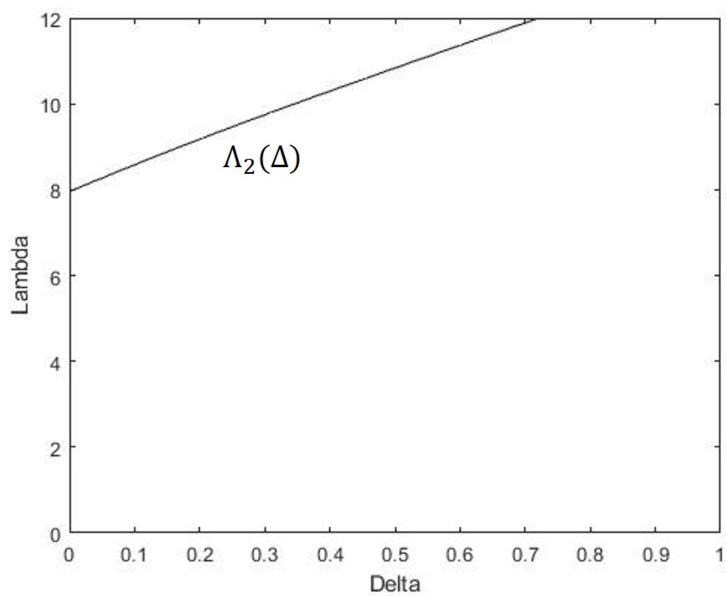

Figure 4.4 Shaded area over which $\pi_{M_1}^{FF} > \pi_{M_1}^{DD}$

Proposition 4.4.

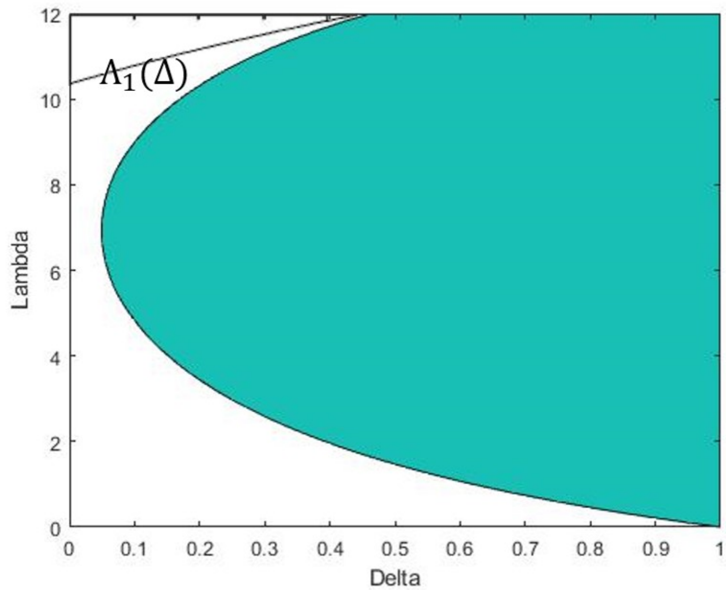

Figure 4.5 Shaded area over which $\pi_{M_1}^{DD} > \pi_{M_1}^{BB}$

(i) $\pi_{M_2}^{DD} > \pi_{M_2}^{FF}$;

(ii) $\pi_{M_2}^{DD} > \pi_{M_2}^{BB}$.

The regions over which $\pi_{M_1}^{FF} > \pi_{M_1}^{DD}$ and $\pi_{M_1}^{DD} > \pi_{M_1}^{BB}$ are illustrated in the shaded area of Figure 4.4 and Figure 4.5, respectively. When the manufacturer can only stay decentralized or forward integrate, pure decentralization structure is always the Pareto dominating equilibrium. However, when manufacturers can either forward or backward integrate, integrated equilibrium outcome does not always lead to the prisoner's dilemma. The shaded area of Figure 4.5 also depicts the region where the integrated equilibrium outcome leads to the prisoner's dilemma. Unlike manufacturer 2, manufacturer 1 does not necessarily suffer for being in an integrated industry.

4.3 Summary

When competing manufacturers have the option to forward or backward integrate, it is established in the previous studies that manufacturers would never stay decentralized but instead backward integrate into the prisoner's dilemma. However, this result does not continue to hold when two supply chains have asymmetric customer loyalty. If two supply chains compete primarily on the basis of pricing and quality control, the factors determining the integration equilibrium outcomes include the price sensitivity, quality sensitivity, and customer loyalty. We find that the decisions of vertical integration manufacturers choose in the equilibrium are collectively determined by the dynamics of customer loyalty asymmetry and the relative return in quality investment. In the mixed structure, the supply chain with strong customer loyalty always invests more in quality regardless of its integration strategy. This complements the previous chapter where the integrated supply chain always has more investing power. Asymmetry in customer loyalty can lead to asymmetric integration equilibrium outcome. When there is a sharp difference in two supply chains' customer loyalty and the market has an excessive desire for high quality product, the manufacturer with low customer loyalty may stay decentralized against a backward integrated supply chain in the equilibrium. Even if two manufacturers vertically integrate, it is not necessarily a prisoner's dilemma. When the backward integration option is not available, it is always optimal for a manufacturer to choose the same channel type as its rival. By looking at how the relative return for quality investment is used to frame the integration equilibrium results, we provide the managerial insights into recognizing the importance of market sensitivity to quality. As the market desire for quality investment plays an important role in characterizing the equilibrium channel structure, quality differentiation becomes relatively less important than price differentiation.

There are two extensions to explore. First, we may consider a general quality cost structure. In the base model, investing the quality level incurs a fixed quadratic cost for the upstream supply chain firm. It would be interesting to allow the nonlinear cost of quality investment to take the form of a linear variable cost plus a quadratic fixed cost as frequently seen in the marketing literature ([MY08; SZ02]). Second, we may allow the cost of quality parameter k to differ between suppliers to reflect the efficiency difference of quality investment between two supply chains. Furthermore, in our model, product quality is determined by the upstream supply chain firm alone. However, in practice, even the retailers can affect the perceived product quality. To account for this, the consumer utility can be appended with an additional term which represents the quality contribution by the other supply chain firms.

Chapter 5

Decentralize to Enhance Customer Valuation under Market Search

There has been a rapid trend toward repositioning customer experience in retail management. The 2015 Gartner survey found that 89% of the companies expect to compete on the basis of customer experience. Moreover, marketing budgets account for 10.2% of revenue among the companies surveyed (https://blogs.gartner.com/jake-sorofman/gartner-surveys-confirm-customer-experience-new-battlefield). Creating customer value encompasses a range of retailer practices. Traditional ones include launching sales event and limited-time offers on an annual or periodic basis, sending coupons individualized to customers through a loyalty program, offering the mobile payment checkout option in conjunction with credit card offer, etc. To create additional appeal for the products, showrooms that allow customers to experience the merchandise in an inviting environment are widely used, mostly in the automotive, furniture and fashion retailing. There are innovative ways for retailers to fulfill customer needs. The retail giant Target debuted the Target Open House in San Francisco where connected devices like light bulbs, coffee kettles, thermostats are showcased in a model home setting. Foot locker launched the Power store that provides an immersive digital platform where in-store certified athletes can answer customers' individual sports needs. Nordstrom Local delivers a luxury shopping experience where customers can get manicures, cocktails from the bar, and clothing alteration.

One phenomenon closely associated with the marketing practices is free-riding where customers take advantage of the free access to product information and try-on experience provided by one retailer while purchase with another retailer. In a survey [HS13], 67% of the respondents admitted adopting free-riding in their past purchases. With increased use of the Internet, free-riding behavior is increasingly salient as a customer usually visits a store first and then finds a more appealing online deal at a different store. Free-riding may ruthlessly undermine the benefits of valuation-enhancing efforts. The threat is that retailers may be discouraged from implementing new marketing ideas if they also result in demand increase for its competitor.

Tradition roles for manufacturers and retailers have been less distinct and their activities more intertwined. It is common for a manufacturer to be a direct seller and retail the goods to customers. As today's customers crave a more personalized shopping journey, professional retailers rise up to fill the gap and retailers' marketing role has been recognized. To adapt to the shifting needs for customer valuation, there emerges a prominent trend where a manufacturer decentralizes the retailing function to a third-party retailer in order to manage customer value.

In this chapter, we develop a stylized model to address the manufacturers' distribution channel design problem. We consider that two manufacturers are located in different markets serving separate customer bases. The central question is whether manufacturers should decentralize its retailing function via an exclusive retailer that independently sells its product to the market. Depending on the supply chain configuration, a manufacturer may either wholesale its products to the downstream retailer or do the direct sales. Retailers can deploy marketing efforts that provide a positive shopping experience and enhance customer valuation toward the product. To incorporate the impact of improving customer valuation on general populations, we consider a setting where customers can search between products. That is, improvement in valuation in one store, if any, can be transferred to the shopping experience in the other store.

This work follows Perdikaki and Swaminathan's modeling framework of retailer-initiated increases in customer valuation [PS13]. Their work specifically considers retailers' decisions to invest in valuation-enhancing practices, but our work focuses on the tradeoff faced by the manufacturer between coordinating decision making and improving customer valuation. The manufacturers decide whether to decentralize its retailing function. Given the supply chain channel structure, two stores noncooperatively determine prices. To derive the equilibrium prices, we distinguish between different purchase schemes depending on customers' purchasing behaviors. We also investigate the impact of distribution channel design on the equilibrium purchase scheme outcome.

This chapter is organized as follows. Section 5.1 describes the modeling framework and formulates the multi-stage game. Section 5.2 provides the analytical results for the equilibrium pricing decisions. Section 5.3 analyzes the equilibrium channel structure through numerical analysis. Section 5.4 summarizes the chapter.

5.1 Modeling

We consider a duopoly model where a manufacturer originally sells the products to the market through the company store which can be a brick and mortar or an online store. A manufacturer has the option to distribute the products through its exclusive retailer who can improve customer valuation. For convenience, we refer to retailer i or the company store owned by manufacturer i, whichever applies to the distribution channel, as store i, $i = 1, 2$.

Product i incurs a per unit production cost c_i to manufacturer i and is offered by store i at retail price p_i. Two stores are located at some distance from each other. Customers visit store i at transportation cost t_i, which can be interpreted as the real cost of travelling, the opportunity cost of time or the implicit cost of inconvenience [Bal98]. We assume that γ proportion of the total population visit the store 1 first and the remaining $1 - \gamma$ proportion visit store 2 first. If they do not make purchase at the first store, they may search the other store. Assuming each customer makes the first attempt to purchase at a closer store, we refer to the store a customer visits first as his local store.

Customers are heterogeneous in their valuation of a product. We denote a customer's individual valuation by v and assume it to be uniformly distributed over $[0, 1]$. A customer would buy the product from his local store provided that his individual valuation v exceeds or is equal to the sum of retail price p_i and transportation cost t_i. In other words, a customer would buy a product when he encounters a non-negative net customer surplus $v - p_i - t_i$, $i = 1, 2$. Customers who visit the local store but do not purchase have their valuation toward the product enhanced, which is assumed to correspond to a fixed linear shift α so his valuation is updated as $v + \alpha$. Thereby, despite having visited their local stores without buying anything, these customers have more understanding of the product and are more willing to purchase. A fraction δ of them visits the other store with the updated customer valuation. The search process incurs transportation cost $\triangle t$ for taking an additional trip from one store to the other store. If the customer has a non-negative net utility $v - p_i - t_j - \triangle t$ at the second store, he purchases the product, $i = 1, 2$, $j = 3 - i$. Otherwise, he just leaves the system. We require $1 > t_i + c_i$ to make certain a customer would purchase at the local store at a reasonable price.

The sequence of events unravels as follows: Two manufacturers simultaneously decide whether to delegate their retailing functions to an independent retailer. To facilitate our discussion, we define $y_i \in \{0, 1\}$, $i = 1, 2$, as an indicator of manufacturer i's decision, where $y_i = 0$ denotes manufacturer i does the distribution itself (I), and $y_i = 1$ denotes manufacturer i sells its products through an independent retailer (D). Let $I_1I_2 \in \{DD, DI, ID, II\}$ denote the industry channel structure. Then, the decentralized manufacturer (if any) determines the optimal wholesale price charged to its downstream retailer. Finally, the retailers (or the direct selling manufacturers) competitively announce their retail prices. Customers then visit their local stores and possibly conduct product search.

We study the multi-stage game backward. To solve for the equilibrium prices given the channel structure, the following types of demand need to be distinguished.

(a) Store i experiences demand exclusively from local customers (L).

(b) Store i experiences demand exclusively from searching customers (S).

(c) Store i experiences demand from both local customers and searching customers (M).

Denote the proportion of the market that initially visit store i as

$$\gamma_i = \begin{cases} \gamma & \text{if } i = 1, \\ 1-\gamma & \text{if } i = 2. \end{cases}$$

In case L, the expected demand faced by store i is given by

$$d_i^L = \gamma_i(1 + y_i\alpha - p_i - t_i). \tag{5.1}$$

A proportion γ_i of the market initially visits store i. If manufacturer i does the distribution on its own (i.e., $y_i = 0$), customer valuation v remains unchanged while shopping with store i. Otherwise (i.e., $y_i = 1$), visiting retailer i improves the customer valuation v by α. The customer with updated valuation $v_i = v + y_i\alpha$ makes purchase if he encounters a non-negative net utility, i.e., $v_i \geqslant p_i + t_i$. Hence, store i expects a demand of $\gamma_i\mathbb{P}(v_i \geqslant p_i + t_i)$ when it only has business from local customers.

In case S, the expected demand faced by store i is given by

$$d_i^S = \begin{cases} (1-\gamma_i)\delta(p_j + y_i(1-y_j)\alpha - p_i - \triangle t), & 1 + y_j\alpha - p_j - t_j > 0, \\ (1-\gamma_i)\delta(1 + (y_i + y_j - y_iy_j)\alpha - p_i - t_j - \triangle t), & 1 + y_j\alpha - p_j - t_j \leqslant 0. \end{cases}$$

A proportion $1 - \gamma_i$ of the market initially visits store j and a customer has updated valuation $v_j = v + y_j\alpha$. A proportion δ of those who visit store j first but obtain negative customer surplus (i.e., $v_j < p_j + t_j$) search store i. Improvement in valuation, if any, is transferred to the shopping experience in the second store. For a customer who did not have valuation improved in store j and then searches store i, if manufacturer i sells through retailer i (i.e., $y_i = 1$), his valuation v is also updated as $v + \alpha$. Essentially, the customer searches store i with valuation $\hat{v} = v_j + y_i(1-y_j)\alpha$. A searching customer purchases in store i provided that $\hat{v} \geqslant p_i + t_j + \triangle t$.

The above inequalities imply that for a customer who searches store i and makes purchase, his original valuation $v \in [0,1]$ satisfies

$$p_i + t_j + \triangle t - y_i(1-y_j)\alpha \leqslant v + y_j\alpha < p_j + t_j,$$

$$p_i + t_j + \triangle t - y_i(1-y_j)\alpha \leqslant v + y_j\alpha \leqslant 1 + y_j\alpha.$$

Essentially, which of the above two inequalities takes effect depends on the demand source of store j: (i) If store j ever experiences demand from local customers (local demand), i.e., $p_j + t_j \leqslant 1 + y_j\alpha$, the first inequality leads to $p_j + y_i(1-y_j)\alpha - p_i - \triangle t > 0$. (ii) If store j does not experience any local demand, i.e., $p_j + t_j \geqslant 1 + y_j\alpha$, the second inequality implies $1 + (y_i + y_j - y_iy_j)\alpha - p_i - t_j - \triangle t \geqslant 0$.

In case M, the expected demand faced by store i is given by

$$d_i^M = \begin{cases} \gamma_i(1 + y_i\alpha - p_i - t_i) + (1-\gamma_i)\delta(p_j + y_i(1-y_j)\alpha - p_i - \triangle t) \\ \qquad\qquad\qquad\qquad\qquad\qquad 1 + y_j\alpha - p_j - t_j > 0, \\ \gamma_i(1 + y_i\alpha - p_i - t_i) + (1-\gamma_i)\delta(1 + (y_i + y_j - y_iy_j)\alpha - p_i - t_j - \triangle t) \\ \qquad\qquad\qquad\qquad\qquad\qquad 1 + y_j\alpha - p_j - t_j \leqslant 0. \end{cases}$$

The first term corresponds to the local demand and the second term corresponds to the demand from the customers who search (searching demand). Again, the demand expression is contingent on the same discussion of store j's demand source as in case S.

Note that the demand expression for one store may involve the discussion of the other store's demand source. To allow for an amenable analysis, we categorize the purchasing behaviors of customers into the following purchase schemes.

LL: All customers only purchase in their local store.

LS: Store 1's local customers may purchase in both stores. Store 2's local customers do not purchase.

LM: Store 1's local customers may purchase in both stores. Store 2's local customers only purchase in store 2.

SL: Store 1's local customers do not purchase. Store 2's local customers may purchase in both stores.

SS: All customers only purchase when they search.

SM: Store 1's local customers only purchase when they search. Store 2's local customers may purchase in both stores.

ML: Store 1's local customers only purchase in store 1. Store 2's local customers may purchase in both stores.

MS: Store 1's local customers may purchase in both stores. Store 2's local customers only purchase when they search.

MM: All customers may purchase in both stores.

With different purchase schemes outlined, we regard (L), (S), (M) as pure strategies that a store can choose, which indicate the demand source that the store intends to achieve via its pricing decision. A three-stage game can be outlined. In the first stage, manufacturers determine whether or not to open up an independent distribution channel. In the second stage, considering the channel structure determined in the first stage game, two stores competitively choose their pricing strategies among (L), (S), (M) that lead to a purchase scheme. We refer to this as the purchasing game.

Within a purchase scheme P_1P_2, $P_1, P_2 \in \{\text{L, S, M}\}$, if manufacturer i decentralizes the retailing function by selling through retailer i, their profit functions are, respectively,

$$\pi_{M_i}^{P_1P_2} = (w_i - c_i)d_i^{P_1P_2},$$
$$\pi_{R_i}^{P_1P_2} = (p_i - w_i)d_i^{P_1P_2}.$$

If manufacturer i sells directly to the market, its profit function is

$$\pi_{M_i}^{P_1P_2} = (p_i - c_i)d_i^{P_1P_2}.$$

In the third stage, given the combination of channel structure and purchase scheme, manufacturer i (if ever decentralizing the distribution channel) determines w_i that maximizes its profit, and then, the retailers (or the direct selling manufacturer) competitively announce their retail prices (p_i, p_j). We refer to this as the pricing game.

Characterization of two stores' demands $(d_1^{P_1P_2}, d_2^{P_1P_2})$ within each purchase scheme P_1P_2 and constraints imposed on the retail prices are presented below. The constraints are to distinguish different purchase schemes and ensure positive demand for two stores.

Purchase scheme	Characterization of demand
LL	$d_1^{LL} = \gamma(1 + y_1\alpha - p_1 - t_1)$ $d_2^{LL} = (1-\gamma)(1 + y_2\alpha - p_2 - t_2)$
LM	$d_1^{LM} = \gamma(1 + y_1\alpha - p_1 - t_1)$ $d_2^{LM} = (1-\gamma)(1 + y_2\alpha - p_2 - t_2) + \gamma\delta(p_1 + (1-y_1)y_2\alpha - p_2 - \triangle t)$
LS	$d_1^{LS} = \gamma(1 + y_1\alpha - p_1 - t_1)$ $d_2^{LS} = \gamma\delta(p_1 + (1-y_1)y_2\alpha - p_2 - \triangle t)$
SL	$d_1^{SL} = (1-\gamma)\delta(p_2 + y_1(1-y_2)\alpha - p_1 - \triangle t)$ $d_2^{SL} = (1-\gamma)(1 + y_2\alpha - p_2 - t_2)$
SS	$d_1^{SS} = (1-\gamma)\delta(1 + (y_1 + y_2 - y_1y_2)\alpha - p_1 - t_2 - \triangle t)$ $d_2^{SS} = \gamma\delta(1 + (y_1 + y_2 - y_1y_2)\alpha - p_2 - t_1 - \triangle t)$
SM	$d_1^{SM} = (1-\gamma)\delta(p_2 + y_1(1-y_2)\alpha - p_1 - \triangle t)$ $d_2^{SM} = (1-\gamma)(1 + y_2\alpha - p_2 - t_2) + \gamma\delta(1 + (y_1 + y_2 - y_1y_2)\alpha - p_2 - t_1 - \triangle t)$
ML	$d_1^{ML} = \gamma(1 + y_1\alpha - p_1 - t_1) + (1-\gamma)\delta(p_2 + y_1(1-y_2)\alpha - p_1 - \triangle t)$ $d_2^{ML} = (1-\gamma)(1 + y_2\alpha - p_2 - t_2)$
MS	$d_1^{MS} = \gamma(1 + y_1\alpha - p_1 - t_1) + (1-\gamma)\delta(1 + (y_1 + y_2 - y_1y_2)\alpha - p_1 - t_2 - \triangle t)$ $d_2^{MS} = \gamma\delta(p_1 + (1-y_1)y_2\alpha - p_2 - \triangle t)$
MM	$d_1^{MM} = \gamma(1 + y_1\alpha - p_1 - t_1) + (1-\gamma)\delta(p_2 + y_1(1-y_2)\alpha - p_1 - \triangle t)$ $d_2^{MM} = (1-\gamma)(1 + y_2\alpha - p_2 - t_2) + \gamma\delta(p_1 + (1-y_1)y_2\alpha - p_2 - \triangle t)$

Purchase scheme	Conditions for (p_1, p_2)
LL	$1 + y_1\alpha - p_1 - t_1 > 0$ $p_2 + y_1(1 - y_2)\alpha - p_1 - \triangle t \leqslant 0$ $1 + y_2\alpha - p_2 - t_2 > 0$ $p_1 + (1 - y_1)y_2\alpha - p_2 - \triangle t \leqslant 0$
LM	$1 + y_1\alpha - p_1 - t_1 > 0$ $p_2 + y_1(1 - y_2)\alpha - p_1 - \triangle t \leqslant 0$ $1 + y_2\alpha - p_2 - t_2 > 0$ $p_1 + (1 - y_1)y_2\alpha - p_2 - \triangle t > 0$
LS	$1 + y_1\alpha - p_1 - t_1 > 0$ $1 + (y_1 + y_2 - y_1 y_2)\alpha - p_1 - t_2 - \triangle t \leqslant 0$ $1 + y_2\alpha - p_2 - t_2 \leqslant 0$ $p_1 + (1 - y_1)y_2\alpha - p_2 - \triangle t > 0$
SL	$1 + y_1\alpha - p_1 - t_1 \leqslant 0$ $p_2 + y_1(1 - y_2)\alpha - p_1 - \triangle t > 0$ $1 + y_2\alpha - p_2 - t_2 > 0$ $1 + (y_1 + y_2 - y_1 y_2)\alpha - p_2 - t_1 - \triangle t \leqslant 0$
SS	$1 + y_1\alpha - p_1 - t_1 \leqslant 0$ $1 + (y_1 + y_2 - y_1 y_2)\alpha - p_1 - t_2 - \triangle t > 0$ $1 + y_2\alpha - p_2 - t_2 \leqslant 0$ $1 + (y_1 + y_2 - y_1 y_2)\alpha - p_2 - t_1 - \triangle t > 0$
SM	$1 + y_1\alpha - p_1 - t_1 \leqslant 0$ $p_2 + y_1(1 - y_2)\alpha - p_1 - \triangle t > 0$ $1 + y_2\alpha - p_2 - t_2 > 0$ $1 + (y_1 + y_2 - y_1 y_2)\alpha - p_2 - t_1 - \triangle t > 0$
ML	$1 + y_1\alpha - p_1 - t_1 > 0$ $p_2 + y_1(1 - y_2)\alpha - p_1 - \triangle t > 0$ $1 + y_2\alpha - p_2 - t_2 > 0$ $p_1 + (1 - y_1)y_2\alpha - p_2 - \triangle t \leqslant 0$
MS	$1 + y_1\alpha - p_1 - t_1 > 0$ $1 + (y_1 + y_2 - y_1 y_2)\alpha - p_1 - t_2 - \triangle t > 0$ $1 + y_2\alpha - p_2 - t_2 \leqslant 0$ $p_1 + (1 - y_1)y_2\alpha - p_2 - \triangle t > 0$
MM	$1 + y_1\alpha - p_1 - t_1 > 0$ $p_2 + y_1(1 - y_2)\alpha - p_1 - \triangle t > 0$ $1 + y_2\alpha - p_2 - t_2 > 0$ $p_1 + (1 - y_1)y_2\alpha - p_2 - \triangle t > 0$

5.2 Equilibrium Analysis

The analysis framework is as follows. We solve the pricing game first by assuming the combination of channel structure and purchase scheme as given. Knowing the equilibrium prices and profits within each purchase scheme, we explore the equilibrium purchase scheme for the purchasing game and then the equilibrium channel structure for the first stage game.

5.2.1 Pricing Game

Denote every combination of channel structure and purchase scheme by a duopoly scenario $I_1I_2P_1P_2$, where I_1I_2 refers to the channel structure and P_1P_2 refers to the purchase scheme. Taking the duopoly scenario as given, we characterize the equilibrium results for the pricing game.

The demand expressions specified by the purchase scheme are somewhat complex as compared to those in the previous chapters. In the following theorem, we show that there exists a unique price equilibrium for every combination of channel structure and purchase scheme.

Theorem 5.1. *For each instance of duopoly scenario, there exists a unique Nash equilibrium in the pricing game.*

If both manufacturers sell through retailers (i.e. channel structure DD), for a given purchase scheme P_1P_2, we solve the pricing game by backward induction and first derive the equilibrium results of retail prices conditional on the wholesale prices. The closed-form expressions for equilibrium retail prices are presented in Table 5.1. The equilibrium retail price for a manufacturer who does direct sales can be also found in Table 5.1 by setting $w_i = c_i$. For channel structures DI, ID, DD, we substitute the equilibrium retail prices as functions of wholesale prices back and derive the closed-form expression of the equilibrium wholesale price for manufacturer who decentralizes its retailing function (i.e., $I_i = D$) displayed in Table 5.2.

Table 5.1 Closed form expressions for equilibrium retail prices

P_1P_2 \ I_1I_2		DD
LL	p_1	$\frac{1+y_1\alpha-t_1+w_1}{2}$
	p_2	$\frac{1+y_2\alpha-t_2+w_2}{2}$
LS	p_1	$\frac{1+y_1\alpha-t_1+w_1}{2}$
	p_2	$\frac{1+(y_1+y_2-y_1y_2)\alpha-t_1-\triangle t+w_1+w_2}{2}$
LM	p_1	$\frac{1+y_1\alpha-t_1+w_1}{2}$
	p_2	$\frac{2(1-\gamma)(1+y_2\alpha-t_2+w_2)+\gamma\delta(1+(y_1+2y_2-2y_1y_2)\alpha-t_1-2\triangle t+w_1+2w_2)}{2(1-\gamma+\gamma\delta)}$
SL	p_1	$\frac{1+(2y_1+y_2-2y_1y_2)\alpha-t_2-2\triangle t+2w_1+w_2}{2}$
	p_2	$\frac{1+y_2\alpha-t_2+w_2}{2}$
SS	p_1	$\frac{1+(y_1+y_2-y_1y_2)\alpha-t_2-\triangle t+w_1}{2}$
	p_2	$\frac{1+(y_1+y_2-y_1y_2)\alpha-\triangle t-t_1+w_2}{2}$
SM	p_1	$\frac{1+(2y_1+y_2-2y_1y_2)\alpha-2\triangle t+2w_1+w_2}{4}+\frac{-(1-\gamma)t_2+\gamma\delta((y_1(1-y_2)\alpha-t_1-\triangle t)}{4(1-\gamma+\gamma\delta)}$
	p_2	$\frac{(1-\gamma)(1+y_2\alpha-t_2+w_2)+\gamma\delta(1+(y_1+y_2-y_1y_2)\alpha-t_1-\triangle t+w_2)}{2(1-\gamma+\gamma\delta)}$
ML	p_1	$\frac{2\gamma(1+y_1\alpha-t_1+w_1)+(1-\gamma)\delta(1+(2y_1+y_2-2y_1y_2)\alpha-t_2-2\triangle t+2w_1+w_2)}{2(\gamma+(1-\gamma)\delta)}$
	p_2	$\frac{1+y_2\alpha-t_2+w_2}{2}$
MS	p_1	$\frac{\gamma(1+y_1\alpha-t_1+w_1)+(1-\gamma)\delta(1+(y_1+y_2-y_1y_2)\alpha-t_2-\triangle t+w_1)}{2(\gamma+(1-\gamma)\delta)}$
	p_2	$\frac{1+(y_1+2y_2-2y_1y_2)\alpha-2\triangle t+w_1+2w_2}{4}+\frac{-\gamma t_1+(1-\gamma)\delta(y_2(1-y_1)\alpha-t_2-\triangle t)}{4(\gamma+(1-\gamma)\delta)}$
MM	p_1	$\frac{a_1((1-\gamma)(1+y_2\alpha-t_2+w_2)+\gamma\delta((1-y_1)y_2\alpha-\triangle t+w_2))}{2(1-a_1a_2)(1-\gamma+\gamma\delta)}+\frac{(\gamma(1+y_1\alpha-t_1+w_1)+(1-\gamma)\delta(y_1(1-y_2)\alpha-\triangle t+w_1))}{2(1-a_1a_2)(\gamma+(1-\gamma)\delta)}$
	p_2	$\frac{a_2(\gamma(1+y_1\alpha-t_1+w_1)+(1-\gamma)\delta(y_1(1-y_2)\alpha-\triangle t+w_1))}{2(1-a_1a_2)(\gamma+(1-\gamma)\delta)}+\frac{((1-\gamma)(1+y_2\alpha-t_2+w_2)+\gamma\delta((1-y_1)y_2\alpha-\triangle t+w_2))}{2(1-a_1a_2)(1-\gamma+\gamma\delta)}$

where $a_1=\frac{(1-\gamma)\delta}{2(\gamma+(1-\gamma)\delta)}$, $a_2=\frac{\gamma\delta}{2(1-\gamma+\gamma\delta)}$.

Table 5.2 Closed form expressions for equilibrium wholesale prices

P_1P_2 \ I_1I_2		DI/DD ID/DD
LL	w_1	$\frac{1+y_1\alpha-t_1+c_1}{2}$
	w_2	$\frac{1+y_2\alpha-t_2+c_2}{2}$
LS	w_1	$\frac{1+y_1\alpha-t_1+c_1}{2}$
	w_2	$\frac{p_1^{LS}+(1-y_1)y_2\alpha-\triangle t+c_2}{2}$
LM	w_1	$\frac{1+y_1\alpha-t_1+c_1}{2}$
	w_2	$\frac{(1-\gamma)(1+y_2\alpha-t_2+c_2)+\gamma\delta(p_1^{LM}+(1-y_1)y_2\alpha-\triangle t+c_2)}{2(1-\gamma+\gamma\delta)}$
SL	w_1	$\frac{p_2^{SL}+y_1(1-y_2)\alpha-\triangle t+c_1}{2}$
	w_2	$\frac{1+y_2\alpha-t_2+c_2}{2}$
SS	w_1	$\frac{1+(y_1+y_2-y_1y_2)\alpha-t_2-\triangle t+c_1}{2}$
	w_2	$\frac{1+(y_1+y_2-y_1y_2)\alpha-\triangle t-t_1+c_2}{2}$
SM	w_1	$\frac{p_2^{SM}+y_1(1-y_2)\alpha-\triangle t+c_1}{2}$
	w_2	$\frac{(1-\gamma)(1+y_2\alpha-t_2+c_2)+\gamma\delta(1+(y_1+y_2-y_1y_2)\alpha-\triangle t-t_1+c_2)}{2(1-\gamma+\gamma\delta)}$
ML	w_1	$\frac{\gamma(1+y_1\alpha-t_1+c_1)+(1-\gamma)\delta(p_2^{ML}+y_1(1-y_2)\alpha-\triangle t+c_1)}{2(\gamma+(1-\gamma)\delta)}$
	w_2	$\frac{1+y_2\alpha-t_2+c_2}{2}$
MS	w_1	$\frac{\gamma(1+y_1\alpha-t_1+c_1)+(1-\gamma)\delta(1+(y_1+y_2-y_1y_2)\alpha-t_2-\triangle t+c_1)}{2(\gamma+(1-\gamma)\delta)}$
	w_2	$\frac{p_1^{MS}+(1-y_1)y_2\alpha-\triangle t+c_2}{2}$
P_1P_2 \ I_1I_2		DI ID
MM	w_1	$\frac{a_1((1-\gamma)(1+y_2\alpha-t_2+c_2)+\gamma\delta(1+(y_1+y_2-y_1y_2)\alpha-\triangle t-t_1+c_2))}{2(1-2a_1a_2)(1-\gamma+\gamma\delta)} + \frac{(1-2a_1-2a_1a_2)(1+y_1\alpha-t_1+c_1)+2a_1(y_1(1-y_2)\alpha-\triangle t+c_1)}{2(1-2a_1a_2)}$
	w_2	$\frac{a_2(\gamma(1+y_1\alpha-t_1+c_1)+(1-\gamma)\delta(1+(y_1+y_2-y_1y_2)\alpha-\triangle t-t_2+c_1))}{2(1-2a_1a_2)(\gamma+(1-\gamma)\delta)} + \frac{(1-2a_2-2a_1a_2)(1+y_2\alpha-t_2+c_2)+2a_2(y_2(1-y_1)\alpha-\triangle t+c_2)}{2(1-2a_1a_2)}$
P_1P_2 \ I_1I_2		DD
MM	w_1	$\frac{b_1f_2+f_1}{1-b_1b_2}$
	w_2	$\frac{b_2f_1+f_2}{1-b_1b_2}$

where $a_1 = \frac{(1-\gamma)\delta}{2(\gamma+(1-\gamma)\delta)}$, $a_2 = \frac{\gamma\delta}{2(1-\gamma+\gamma\delta)}$, $b_1 = \frac{a_1}{2(1-2a_1a_2)}$, $b_2 = \frac{a_2}{2(1-2a_1a_2)}$, $f_1 = \frac{c_1}{2} + \frac{((1-2a_1-2a_1a_2)(1+\alpha-t_1)+a_1(1-2a_2)(1+\alpha-t_2)+2a_1a_2(1+\alpha-t_1-\triangle t)-2a_1\triangle t)}{2(1-2a_1a_2)}$, $f_2 = \frac{c_2}{2} + \frac{((1-2a_2-2a_1a_2)(1+\alpha-t_2)+a_2(1-2a_1)(1+\alpha-t_1)+2a_1a_2(1+\alpha-t_2-\triangle t)-2a_2\triangle t)}{2(1-2a_1a_2)}$.

After the equilibrium prices are calculated, the constraints for the corresponding purchase scheme need to be checked. If not satisfied, it means customers have incentives to deviate to another purchase scheme. Thereby, this purchase scheme cannot be the equilibrium for the purchasing game. Note that if a store does not experience searching demand, it is not affected by the pricing decision of the other store and operates as if in a monopoly market.

5.2.2 Purchasing Game

In the purchasing game, store i adopts strategy $P_i \in \{\text{L, S, M}\}$ while anticipating the equilibrium prices within different purchase schemes, $i = 1, 2$. Essentially, two stores competitively choose the retail prices that induce customers' purchasing behaviors toward a certain purchase scheme. For any given channel structure, we identify a customer purchase scheme that is the equilibrium for the purchasing game referred to as the purchase equilibrium. If there are multiple Nash equilibria, we select the Pareto dominating one.

For further equilibrium analysis for the purchasing game, we create an index to determine the potential return on sales from searching customers relative to local customers. The MPMR index (maximum profit margin ratio) for store i is defined as

$$\text{MPMR}_i = \frac{\text{Maximum profit margin store } i \text{ can obtain from pure searching sales}}{\text{Maximum profit margin store } i \text{ can obtain from pure local sales}}.$$

The MPMR index measures how much profit store i can obtain from a customer when it exclusively experience sales from local customers as compared to when it exclusively experience sales from searching customers.

In the following theorems, we characterize the best response strategy for a manufacturer-owned store.

Theorem 5.2. *In a channel structure where manufacturer i directly sells to the market (i.e., $y_i = 0$), suppose store j only experiences local or searching demand (i.e., $P_j = L$ or S), $i = 1, 2$,*

$j = 3-i$. *There exist two thresholds* $\theta_1 = \frac{\sqrt{\gamma_i^2+\gamma_i(1-\gamma_i)\delta}-\gamma_i}{(1-\gamma_i)\delta}$ *and* $\theta_2 = \frac{\sqrt{(1-\gamma_i)^2\delta^2+\gamma_i(1-\gamma_i)\delta}+(1-\gamma_i)\delta}{(1-\gamma_i)\delta}$ *such that*

(i) if $MPMR_i \leqslant \theta_1$, *store i's best response is to only experience local demand (L);*

(ii) if $\theta_1 < MPMR_i < \theta_2$, *store i's best response is to experience demand from both local and searching customers (M);*

(iii) if $\theta_2 \leqslant MPMR_i$, *store i's best response is to only experience searching demand (S).*

The maximum profit margin manufacturer-owned store i can obtain from pure local sales is $1-t_i-c_i$. The maximum profit margin manufacturer-owned store i can obtain from pure searching sales is $p_j^{SL} - \triangle t - c_i$ if store j only experiences local demand (i.e., P_j = L), and $1+(1-y_j)\alpha - t_j - \triangle t - c_i$ if store j only experience searching demand (i.e., P_j = S).

Theorem 5.3. *In a channel structure where manufacturer i directly sells to the market (i.e.,* $y_i = 0$*), suppose store j experiences both local and searching demand (i.e.,* P_j = *M),* $i = 1,2$, $j = 3-i$. *Let* $a_1 = \frac{(1-\gamma_i)\delta}{2(\gamma_i+(1-\gamma_i)\delta)}$ *and* $a_2 = \frac{\gamma_i\delta}{2(1-\gamma_i+\gamma_i\delta)}$. *There exist two thresholds* $\tilde{\theta_1} = \frac{\sqrt{1-2a_1}(1-a_1a_2)-(1-2a_1-2a_1a_2)}{2a_1}$ *and* $\tilde{\theta_2} = \frac{1-2a_1-2a_1a_2}{\sqrt{2a_1}(1-a_1a_2)-2a_1}$ *such that*

(i) if $MPMR_i \leqslant \tilde{\theta_1}$, *store i's best response is to only experience local demand (L);*

(ii) if $\tilde{\theta_1} < MPMR_i < \tilde{\theta_2}$, *store i's best response is to experience demand from both local and searching customers (M);*

(iii) if $\tilde{\theta_2} \leqslant MPMR_i$, *store i's best response is to only experience searching demand (S).*

The maximum profit margin manufacturer-owned store i can obtain from pure local sales is $1-t_i-c_i$, and the maximum profit margin manufacturer-owned store i can obtain from pure searching sales is $p_j^{SM} - \triangle t - c_i$ if store j experiences demand from both local and searching customers (i.e., P_j = M).

In the following theorem, we characterize the best response strategy for a retail store.

Theorem 5.4. *In a channel structure where manufacturer i sells its product through an independent retailer (i.e., $y_i = 1$), suppose store j only experiences local or searching demand (i.e., P_j = L or S), $i = 1, 2$, $j = 3 - i$. There exist two thresholds $\bar{\theta}_1 = \max(\frac{3\gamma_i}{(4\gamma_i+(1-\gamma_i)\delta}, \frac{\sqrt{\gamma_i^2+\gamma_i(1-\gamma_i)\delta}-\gamma_i}{(1-\gamma_i)\delta})$ and $\bar{\theta}_2 = \min(\frac{4(1-\gamma_i)\delta+\gamma_i}{3(1-\gamma_i)\delta}, \frac{\sqrt{(1-\gamma_i)^2\delta^2+\gamma_i(1-\gamma_i)\delta}+(1-\gamma_i)\delta}{(1-\gamma_i)\delta})$ such that*

(i) if $MPMR_i \leqslant \bar{\theta}_1$, store i's best response is to only experience local demand (L);

(ii) if $\bar{\theta}_1 < MPMR_i < \bar{\theta}_2$, store i's best response is to experience demand from both local and searching customers (M);

(iii) if $\bar{\theta}_2 \leqslant MPMR_i$, store i's best response is to only experience searching demand (S).

The maximum profit margin manufacturer-owned store i can obtain from pure local sales is $1 + \alpha - t_i - c_i$. The maximum profit margin manufacturer-owned store i can obtain from pure searching sales is $p_j + (1-y_j)\alpha - \triangle t - c_i$ if store j only experiences local sales (i.e., P_j = L), and $1+\alpha-t_j-\triangle t-c_i$ if store j only experience searching sales (i.e., P_j = S). Note that $\theta_1 \leqslant \bar{\theta}_1$ and $\bar{\theta}_2 \leqslant \theta_2$, which means when manufacturer i sells its product through an independent retailer, for less values of MPMR$_i$, manufacturer i would choose to experience demand of mixed sources.

In Theorems 5.2-5.4, two thresholds for the MPMR index are discussed. Store i does not want to experience searching demand if MPMR$_i$ falls below the first threshold, and does not want to experience local demand if MPMR$_i$ goes above the second threshold. The thresholds are characterized in terms of the proportion of customers that visit store i first (γ_i) and the proportion of customers that search among those who do not purchase in the first visited store (δ).

Proposition 5.1. *Whether a store is manufacturer-owned (i.e., $y_i = 0$) or a retailer (i.e., $y_i = 1$), $i = 1, 2$,*

(i) if the best response to competing store's strategy (S) is (L), then the best response to competing store's strategy (L) is (L);

(ii) if the best response to competing store's strategy (L) is (S), then the best response to competing store's strategy (S) is (S).

When store j's local customers do not purchase at their local store and only purchase while searching and store i's best response is to only serve its local customers, that implies a high potential in store i's local market. Thereby, if store j only serves its local customers and thus less customers would search store i, store i has more reason to focus on its local market.

When store j's only serves its local customers and store i's best response is to only serve the searching customers, that implies a high potential in store j's local market. Thereby, if store j's local customers do not purchase at their local store and thus more customers would search store i, store i has more reason to focus on its searching customers.

Proposition 5.2. *For $i = 1, 2$, $j = 3 - i$,*

(i) facing a manufacturer-owned store (i.e., $y_j = 0$) which chooses strategy (L) or (S), if the best response of being a retail store (i.e., $y_i = 1$) is (L), then the best response of being a manufacturer-owned store (i.e., $y_i = 0$) is (L);

(ii) facing a manufacturer-owned store (i.e., $y_j = 0$) which chooses strategy (L) or (S), if the best response of being a manufacturer-owned store i (i.e., $y_i = 0$) is (S), then the best response of being a retail store (i.e., $y_i = 1$) is (S);

(iii) facing a retail store (i.e., $y_j = 1$) which chooses strategy (L) or (S), if the best response of being a manufacturer-owned store (i.e., $y_i = 0$) is (L), then the best response of being a retail store (i.e., $y_i = 1$) is (L).

When competing with manufacturer-owned store j that does not improve customer valuation and experiences demand exclusively from local or searching customers, the customers searching store i are more likely to purchase in the retail store where their valuation is improved than in the manufacturer-owned store where their valuation remains unchanged. If retail store i's best response is to focus on its local customers, so is manufacturer-owned store i's best response. If manufacturer-owned store i's best response is to focus on its searching customers, so is retail store i's best response.

When competing with retail store j that improves customer valuation and experiences demand exclusively from local or searching customers, the customers searching store i are equally likely to purchase in the retail store and in the manufacturer-owned store. The provision of valuation-enhancing practices by store i only has an impact its local customers. If manufacturer-owned store i's best response is to focus on its local customers, so is retail store i's best response.

The following theorem shows which of the purchase schemes cannot be purchase Nash equilibrium under certain channel structures.

Theorem 5.5. *When two manufacturers both do the direct sales or both sell through an independent retailer, i.e., in channel structures DD and II, at most one store obtains searching sales in equilibrium.*

Purchase schemes MM, MS, SM, SS cannot be the equilibrium when two manufacturers choose the same distribution structure. Making no difference in improving customer valuation, two stores are only differentiated in terms of the retail price and the transportation cost, and there is only one-way searching. Two products can be directly compared in a sense that customers only flow from the less attractive product to the more attractive one.

Deriving the equilibrium purchase scheme for any arbitrary combination of parameters is analytically intractable. In the next section, we conduct a numerical study to investigate the equilibrium purchase scheme for a given channel structure.

5.3 Computational Insights

In this section, we numerically study the equilibrium result in terms of channel structure and purchase scheme. We use a full factorial design experiment, which is designed to explore the effects of multiple independent factors upon a single dependent variable. The experiment design is summarized in Table 5.3.

Table 5.3 Full factorial design

Parameters	Values
γ	0.1 0.3, 0.5, 0.7, 0.9
δ	0.2, 0.5, 0.8
c_1	0.2, 0.3, 0.4
c_2	0.2, 0.3, 0.4
t_1	0.2, 0.4, 0.6
t_2	0.2, 0.4, 0.6
$\triangle t$	0.02, 0.1, 0.2
α	0.05, 0.1, 0.2, 0.3

The combination of parameters needs to satisfy three inequality conditions. For $i = 1, 2$, $j = 3 - i$,

$$1 > t_i + c_i,$$

$$1 > t_j + \triangle t + c_i,$$

$$\alpha \leqslant t_i + c_i.$$

The first condition means there exists positive profit margin for selling product i to local customers. The second condition means there exists positive profit margin for selling product i to searching customers. The third condition means the magnitude of customer valuation improvement cannot be excessively large. We do not implement those combinations of parameters that fail these conditions.

There are 27540 instances in total that satisfy all three conditions. For each of the instances, we identify a purchase scheme that is an equilibrium for each channel structure scenario. Those instances that lead to multiple equilibria that cannot be ranked are not considered. In our factorial design, there are 4683 instances that lead to two equilibrium purchase schemes that cannot be ranked. Then, we identify the equilibrium channel structure for the remaining instances. There are 471 instances that lead to two equilibrium channel structures that cannot be ranked. There remain 22326 instances to be investigated.

Table 5.4 Frequency of equilibrium purchase scheme

P_1P_2	LL	LM	LS	ML	MM	MS	SL	SM	SS
%	32.42%	28.04%	1.69%	28.04%	7.93%	0.09%	1.69%	0.09%	0%

Table 5.4 summarizes the frequency of each type of equilibrium purchase scheme. The induced purchase scheme that occurs most frequently is LL where all customers only purchase in their local stores. A significant proportion of instances lead to purchase schemes LM and ML where both stores experience local demand and only one store experiences searching demand. A small proportion of instances lead to purchase scheme MM where both stores experience local and searching demand, and the equilibrium channel structure for these instances must be DI or ID. The candidacy of purchase schemes LS, MS, SL, SM to be an equilibrium cannot be ruled out.

Table 5.5 Frequency of equilibrium channel structure

I_1I_2	DD	DI	ID	II
%	11.84%	24.70%	24.70%	38.75%

Table 5.5 provides the frequency of each type of equilibrium channel structure. The induced channel structure that occurs most frequently is II where both manufacturers do direct sales.

However, almost half of the instances lead to mixed channel structure DI or ID where there is only one store offering valuation-enhancing services. A small proportion of instances lead to channel structure DD where both manufacturers find decentralizing its retailing function to an independent retailer more profitable.

Table 5.6 Frequency of combination of channel structure and purchase scheme

P_1P_2 \ I_1I_2	LL	LM	LS	ML	MM	MS	SL	SM	SS
DD	5.39%	3.22%	0%	3.22%	0%	0%	0%	0%	0%
DI	2.32%	12.20%	1.55%	4.49%	3.96%	0.07%	0.08%	0.03%	0%
ID	2.32%	4.49%	0.08%	12.20%	3.96%	0.03%	1.55%	0.07%	0%
II	22.39%	8.13%	0.05%	8.13%	0%	0%	0.05%	0%	0%

Table 5.6 provides the frequency of each combination of channel structure and purchase scheme in equilibrium. When both manufacturers choose to do direct sales, they most likely price in a way so as to discourage their local customer to buy from the rival store. Essentially, 57.78% $(= \frac{22.39}{38.75} * 100\%)$ of the cases where the equilibrium channel structure is II lead to purchase scheme LL where no searching exists between two stores. 41.96% $(= \frac{8.13}{38.75} * 2 * 100\%)$ of the cases lead to purchase scheme LM or ML where one store experiences searching demand. When there is no marketing activity, both manufacturer-owned stores place great emphasis on their local customers.

When only manufacturer opens an independent distribution channel, the percentage of the cases that lead to purchase scheme LL drops to 9.39% $(= \frac{2.32}{24.70} * 100\%)$. 49.39% $(= \frac{12.20}{24.70} * 2 * 100\%)$ of the cases where the equilibrium channel structure is ID or DI lead to purchase scheme ML or LM, respectively. Most likely, two stores price such that the manufacturer-owned store experiences searching customers who have their product valuation enhanced in the retail store. In that case, the manufacturer-owned store free rides the marketing efforts provided in the retail store.

When both manufacturers decentralize their retailing functions to respective independent retailers, although decentralized decision making introduces inefficiency, marketing opportunities may provide a profiting opportunity. 45.52% (= $\frac{5.39}{11.84} * 100\%$) of the cases where the equilibrium channel structure is DD lead to purchase scheme LL. With marketing initiatives on both sides, retail stores put emphasis on their local customers. 54.39% (= $\frac{3.22}{11.84} * 2 * 100\%$) of the cases lead to purchase scheme LM or ML where one store experiences searching demand. By comparing to channel structure II, it can be seen that decentralization leads to increased level of customer search.

5.4 Summary

We study the impact of retailer valuation-enhancing efforts on the manufacturer decision about whether to directly retail its products or wholesale to an independent retailers. A stylized model is developed in which customers can search among products. After the manufacturers competitively decide whether or not to decentralize its retailing function to a downstream retailer, two supply chains make their pricing decisions. Different purchase schemes are distinguished according to customers' purchasing behaviors. We analytically characterize the equilibrium pricing decisions for a given combination of channel structure and purchase scheme. The best response analysis provides insights how the integration decisions impact the equilibrium purchase scheme. We explore the equilibrium in terms of channel structure and purchase scheme using factorial analysis. The existence of free-riding has been recognized.

Although we mathematically define the problem, since some of the equilibrium decisions are analytically intractable, we carry out factorial analysis with use of computer which allows us to examine several factors simultaneously. But the insights obtained from numerical study cannot be guaranteed to be universally true. The bottom line is that this analysis serves as a preliminary study allowing us to obtain some basic insights into the distribution channel design in the presence of retailers' valuation-enhancing effort. Currently, we assume all customer valuation is equally enhanced after visiting the local store and the amount by which customer valuation is improved is fixed. However, retailers in real life usually differ in their abilities of enhancing customer valuation and might be able to decide their own level of investment. Attempts to introduce retailers' endogenous decisions as to how much to improve customer valuation may be an interesting direction.

Chapter 6

Conclusion and Future Research

6.1 Conclusion

In this thesis, we characterize different scenarios where manufacturers seek to vertically integrate with another operation or decentralize its function to an independent entity in its supply chain for more benefits. We concentrate on a duopoly system where two supply chains have direction competition or market-search-based interaction. Manufacturers' incentives to integrate and decentralize are investigated in relation to upstream and downstream efforts as well as market characteristics. Game theoretical models are developed to address the strategic interaction between two supply chains. We explore the equilibrium channel structure and its supply chain implications. Some managerial insights contrary to the literature are uncovered.

Chapter 3 examines whether it is worthwhile for a manufacturer to carry out supplying or retailing functions where there exists cost reduction opportunity on the supply side. In two competing three-tier supply chains, the manufacturer can choose to disintegrate, forward integrate and backward integrate. We explicitly model the level of investments in cost reduction as a decision made by upstream firms and explore their impacts on manufacturers' channel structure decision. The supplier opportunity creates a competition based in cost reduction at the upstream level. Also, it reinforces the competitive edge an integrated supply chain has over its disintegrated competitor. The market desire for cost reduction effort is critical in evaluating values of vertical integration. In the presence of cost reduction opportunity, forward integration could be an equilibrium. For high degrees of substitutability, each manufacturer is more likely to backward integrate. This work argues that manufacturers may integrate in the opposite direction as opposed to the literature [Lin14] when backward integration is an available option.

Chapter 4 extends the analysis of manufacturer incentives to vertically integrate to a competitive setting of two asymmetric three-tier supply chains. The asymmetry arises from the customer loyalty toward two products. Two supply chains compete on the basis of price and quality. We formulate a two-stage game and derive the equilibrium integration and operational decisions. When backward integration option is not available, it is always optimal for a manufacturer to choose the same channel type as its rival. But when backward integration option is not available, asymmetric channel structure may arise due to asymmetry in customer loyalty. The decision of whether or not to integrate and which direction to integrate depends on both the difference in customer loyalty and the relative return to invest in quality. Specifically, the interaction between a sharp difference in two supply chains' customer loyalty and excessive market desire for quality investment may make disintegration attractive for the manufacturer with relatively low customer loyalty. In this setting, two manufacturers do not necessarily get into a prisoner's dilemma by both vertically integrating.

Chapter 5 considers two manufacturers located in different markets individually having the option to sell through an independent retail store which deploy practices that improve customer valuation toward the products. The impact of retailer valuation-enhancing efforts on manufacturers incentives to decentralize has been explored in a context where customers search between two locations. The best response analysis is conducted to provide insights into the equilibrium purchase scheme for a given channel structure. We explore the equilibria in terms of purchase scheme and channel structure game using factorial analysis. Our equilibrium results characterize the tradeoff faced by the manufacturer between coordinating decision making and improving customer valuation. The existence of free-riding phenomenon where one manufacturer-owned store takes advantage of the marketing efforts provided in the other retail store has been recognized. Also, we internalize the cost of valuation-enhancing practices as the cost of decentralized decision-making.

6.2 Future research

There are a few possible directions for future research from demand structure and decision structure.

We adopt linear deterministic demand throughout this thesis and focus on a linear pricing contract. One future direction is to test if the original observations continue to hold for more complicated demand model. For example, stochastic demand in which case we may consider contracts with a per unit price and some conditional payments dependent on a resolution of demand uncertainty, such as buy back contract, quantity flexibility contract, revenue sharing.

We consider that both firms in the same supply chain level simultaneously make their decisions. In fact, there are other decision structures in the real life. For example, within the same level of supply chain, one firm can make a decision earlier than the other. A Stackelberg subgame is needed to study this type of decision structure: One firm is the Stackelberg leader and makes decision, and then the other firm observes the decision and makes his own response.

Our equilibrium analysis for operational decisions is established under the supplier-Stackelberg scenario. The upstream firms move before the downstream firms. It would be interesting to investigate how the manufacturer's incentives to vertically integrate and decentralize change when the retailer has the Stackelberg channel leadership. A possible area of future research in the study of channel choices would be to use a bargaining framework to examine how channel decisions depend on the relative bargaining power of the manufacturers.

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APPENDICES

Derivation of Table 3.2

We first derive the equilibrium results when both manufacturers stay decentralized (i.e., channel structure DD) by backward induction. Consider the retailers' pricing game. For $i = 1, 2$, supply chain i's demand is $d_i = \frac{s-p_i+p_{3-i}}{2s}$. Retailer i's profit is $\Pi_{R_i} = (p_i - w_i)d_i$. Retailers competitively determine their retail price to maximize their profits. It is straightforward that the retailer's profit function is concave in its retail price, with the wholesale prices and its competitor's retail price fixed. We obtain each retailer's reaction function by differentiating its profit function partially with respect to its own retail price and equating the first-order condition to zero. Thus,

$$p_i^* = \frac{2}{3}w_i + \frac{1}{3}w_{3-i} + s,$$

$$d_i^* = \frac{3s - w_i + w_{3-i}}{6s}.$$

Next, we solve the manufacturers' pricing game. Manufacturer i's profit is $\Pi_{M_i} = (w_i - r_i)d_i$. It is straightforward that the manufacturer's profit function is concave in its wholesale price. We solve for the equilibrium wholesale price using the first order condition $\frac{\partial \Pi_{M_i}}{\partial w_i} = 0$ and obtain

$$w_i^* = \frac{2}{3}r_i + \frac{1}{3}r_{3-i} + 3s,$$

$$d_i^* = \frac{9s - r_i + r_{3-i}}{18s}.$$

Then, we solve the suppliers' pricing game. Supplier i's profit is $\Pi_{S_i} = (r_i - c + e_i)d_i - ke_i^2$. The supplier's profit function is concave in its upstream prices. We solve for the equilibrium upstream price using the first order condition $\frac{\partial \Pi_{S_i}}{\partial r_i} = 0$ and obtain

$$r_i^* = c - \frac{2}{3}e_i - \frac{1}{3}e_{3-i} + 9s,$$

$$d_i^* = \frac{27s + e_i - e_{3-i}}{54s}.$$

Lastly, we solve the suppliers' cost reduction game. After verifying that the Hessian matrix for supplier i's profit function is negative definite. We solve for the equilibrium cost reduction level using the first order condition. Thereby, the equilibrium quantities displayed in Table 3.1 are obtained. The uniqueness of equilibrium is derived from the concavity of each firm's profit function.

We then demonstrate how we obtain the equilibrium results when only manufacturer (e.g., manufacturer 1) integrates (e.g. backward integrates). The retailers' pricing game remains unchanged. For manufacturer 2's pricing problem, the first order condition of manufacturer 2's profit function gives

$$w_2^* = \frac{1}{2}w_1 + \frac{1}{2}r_2 + \frac{3}{2}s.$$

And two supply chains' demands become

$$d_1^* = \frac{9s - w_1 + r_2}{12s},$$

$$d_2^* = \frac{3s - r_2 + w_1}{12s}.$$

Manufacturer 1's and supplier 2's profit functions are $\Pi_{M_1} = (w_1 - c + e_1)d_1 - ke_1^2$ and $\Pi_{S_2} = (r_2 - c + e_2)d_2 - ke_2^2$, respectively, which are jointly concave. The set of simultaneous equations that results from their first-order conditions gives the equilibrium results displayed in Table 3.1.

The equilibrium results under the other channel structures can be calculated in a similar manner. □

Proof of Proposition 3.1.

We list the profits for supplier 1, manufacturer 1, and retailer 1 under different channel structures when there is no cost reduction opportunity in the following table.

Table: Equilibrium profits for supply chain 1 (no cost reduction opportunity)

I_1I_2	DD	DF/DB	FD	BD	FF/FB	BF/BB
$\pi_{S_1}^{\prime I_1I_2}$	$\frac{9s}{2}$	$\frac{25s}{12}$	$\frac{49s}{12}$	–	$\frac{3s}{2}$	–
$\pi_{M_1}^{\prime I_1I_2}$	$\frac{3s}{2}$	$\frac{25s}{24}$	$\frac{49s}{72}$	$\frac{49s}{12}$	$\frac{s}{2}$	$\frac{3s}{2}$
$\pi_{R_1}^{\prime I_1I_2}$	$\frac{s}{2}$	$\frac{25s}{72}$	–	$\frac{49s}{72}$	–	$\frac{s}{2}$

We list the profits for supplier 1, manufacturer 1, and retailer 1 under different channel structures when there is cost reduction opportunity in the following table.

Table: Equilibrium profits for supply chain 1 (with cost reduction opportunity)

I_1I_2	DD	DF/DB	FD
$\pi_{S_1}^{I_1I_2}$	$\frac{162sk-1}{36k}$	$\frac{(108sk-1)(45sk-1)^2}{36k(54sk-1)^2}$	$\frac{(108sk-1)(63sk-1)^2}{36k(54sk-1)^2}$
$\pi_{M_1}^{I_1I_2}$	$\frac{3s}{2}$	$\frac{3(45sk-1)^2}{2(54sk-1)^2}$	$\frac{s(63sk-1)^2}{2(54sk-1)^2}$
$\pi_{R_1}^{I_1I_2}$	$\frac{s}{2}$	$\frac{s(45sk-1)^2}{2(54sk-1)^2}$	–
I_1I_2	BD	FF/FB	BF/BB
$\pi_{S_1}^{I_1I_2}$	–	$\frac{54sk-1}{36k}$	–
$\pi_{M_1}^{I_1I_2}$	$\frac{(108sk-1)(63sk-1)^2}{36k(54sk-1)^2}$	$\frac{s}{2}$	$\frac{54sk-1}{36k}$
$\pi_{R_1}^{I_1I_2}$	$\frac{s(63sk-1^2)}{2(54sk-1)^2}$	–	$\frac{s}{2}$

By comparing two tables, it is easy to verify that $\Pi_{S_1}^{\prime I_1I_2} < \Pi_{S_1}^{I_1I_2}$ for all $I_1I_2 \in \{D, F, B\}$. $\square$

Proof of Proposition 3.2.

The proof of (i) and (ii) is straightforward from Table 3.2. For (iii), $e_2^{DI_2} - e_1^{DI_2} = \frac{1}{6} + \frac{1}{6\gamma}$, which is obviously decreasing in γ. $\square$

Proof of Theorem 3.1.

(i) $\Pi_{M_1}^{BD} > \Pi_{M_1}^{FD}$ can be obtained from the parametric assumption. $\Pi_{M_1}^{BD} > \Pi_{M_1}^{DD}$ if and only if $62\gamma^2 + 41\gamma^2 + 16\gamma + 1 > 0$ which always holds provided that γ is nonnegative.

(ii) $\Pi_{M_1}^{DD} > \Pi_{M_1}^{FD}$ if and only if $59\gamma^2 - 14\gamma - 1 > 0$. The larger root of the above quadratic is $\frac{1}{6\sqrt{3}-7}$ and the smaller root is negative.

(iii) $\Pi_{M_1}^{BI_2} > \Pi_{M_1}^{FI_2}$ if and only if $\gamma > \frac{1}{2}$.

(iv) $\Pi_{M_1}^{DI_2} > \Pi_{M_1}^{FI_2}$ if and only if $13\gamma^2 - 10\gamma + 1 > 0$. The larger root of the above quadratic is $\frac{1}{5-2\sqrt{3}}$ and the smaller root is negative.

(v) $\Pi_{M_1}^{BI_2} > \Pi_{M_1}^{DI_2}$ if and only if $11\gamma^3 - 15\gamma^2 + 9\gamma - 1 > 0$. Due to being strictly increasing, the above quadratic at most has one root. It is easy to check that it has a unique root and the root is positive. $\square$

Proof of Theorem 3.2.

From Theorem 3.1, when competing with a decentralized supply chain, the manufacturer's best response integration strategy is (B). When competing with an integrated supply chain, the manufacturer's best response integration strategy is (B) if $\gamma > \frac{1}{2}$, and (F) otherwise. The equilibrium channel structure can be derived accordingly. $\square$

Proof of Proposition 3.3.

$\Pi_{M_1}^{DD} > \Pi_{M_1}^{BB}$ and $\Pi_{M_1}^{DD} > \Pi_{M_1}^{FF}$ can be easily verified by checking the two tables provided in the proof of Proposition 3.1. $\square$

Proof of Proposition 4.1.

(i) $q_1^{I_1I_2} - q_1^{DD} = q_2^{DD} - q_2^{I_1I_2} = \frac{27\alpha k\beta(l_1-l_2)}{(27\alpha k-2\beta^2)(81\alpha k-2\beta^2)} > 0$.

(ii) $d_1^{I_1I_2} - d_1^{DD} = d_2^{DD} - d_2^{I_1I_2} = \frac{81\alpha^2k^2(l_1-l_2)}{(27\alpha k-2\beta^2)(81\alpha k-2\beta^2)} > 0$

(iii) $p_1^{I_1I_2} - p_1^{DD} = p_2^{I_1I_2} - p_2^{DD} = \frac{-9(1098\alpha^2k^2-111\alpha k\beta^2+2\beta^4)l_1-9(1009\alpha^2k^2-105\alpha k\beta^2+2\beta^4)l_2}{\alpha(27\alpha k-2\beta^2)(81\alpha k-2\beta^2)} = \frac{-9(2107\alpha^2k^2-216\alpha k\beta^2+4\beta^4)l_2}{\alpha(27\alpha k-2\beta^2)(81\alpha k-2\beta^2)} < 0.$ □

Proof of Proposition 4.2.

(i) and (ii) can be derived from Table 4.1 by considering $l_1 > l_2$.

(iii) $q_1^{DI_2} > q_2^{DI_2} = \frac{\beta(l_1-l_2)}{2(27\alpha k-\beta^2)} > 0$, $d_1^{DI_2} - d_2^{DI_2} = \frac{-(12l_1+15l_2)}{27\alpha k-\beta^2} > 0.$

(iv) $q_1^{I_1D} > q_2^{I_1D} = \frac{\beta(l_1-l_2)}{2(27\alpha k-\beta^2)} > 0$. $d_1^{I_1D} = d_2^{I_1D} = \frac{15l_1+12l_2}{27\alpha k-\beta^2} > 0.$ □

Proof of Proposition 4.3.

(i) $q_1^{DD} - q_1^{I_1D} = \frac{\beta((2268\alpha^2k^2-141\alpha k\beta^2+2\beta^4)l_1+(2106\alpha^2k^2-129\alpha k\beta^2+2\beta^4)l_2)}{24\alpha k(27\alpha k-\beta^2)(81\alpha k-2\beta^2)} = \frac{\beta(4374\alpha^2k^2-270\alpha k\beta^2+4\beta^4)l_2}{24\alpha k(27\alpha k-\beta^2)(81\alpha k-2\beta^2)} > 0$. The last inequality holds from the parametric assumption. $q_2^{DD} - q_2^{I_1D} = \frac{\beta((1782\alpha^2k^2-129\alpha k\beta^2+2\beta^4)l_2+(2592\alpha^2k^2-141\alpha k\beta^2+2\beta^4)l_1)}{24\alpha k(27\alpha k-\beta^2)(81\alpha k-2\beta^2)} > \frac{\beta(4374\alpha^2k^2-270\alpha k\beta^2+4\beta^4)l_2}{24\alpha k(27\alpha k-\beta^2)(81\alpha k-2\beta^2)} > 0$. $d_1^{I_1D} - d_1^{DD} = d_2^{DD} - d_2^{I_1D} = \frac{(2268\alpha^2k^2-135\alpha k\beta^2+2\beta^4)l_1+(2106\alpha^2k^2-135\alpha k\beta^2+2\beta^4)l_2}{4(27\alpha k-\beta^2)(81\alpha k-2\beta^2)} > \frac{(4374\alpha^2k^2-270\alpha k\beta^2+4\beta^4)l_2}{4(27\alpha k-\beta^2)(81\alpha k-2\beta^2)} > 0$. (ii) can be proved similarly.

(iii) $q_1^{I_1I_2} - q_1^{I_1D} = \frac{\beta((972\alpha^2k^2-87\alpha k\beta^2+2\beta^4)l_1+(486\alpha^2k^2-75\alpha k\beta^2+2\beta^4)l_2)}{24\alpha k(27\alpha k-\beta^2)(81\alpha k-2\beta^2)} = \frac{\beta(1458\alpha^2k^2-162\alpha k\beta^2+4\beta^4)l_2}{24\alpha k(27\alpha k-\beta^2)(81\alpha k-2\beta^2)} > 0$. The last inequality holds from the parametric assumption. $q_2^{I_1I_2} - q_2^{I_1D} = \frac{\beta((810\alpha^2k^2-75\alpha k\beta^2+2\beta^4)l_2+(648\alpha^2k^2-87\alpha k\beta^2+2\beta^4)l_1)}{24\alpha k(27\alpha k-\beta^2)(81\alpha k-2\beta^2)} > \frac{\beta(1458\alpha^2k^2-162\alpha k\beta^2+4\beta^4)l_2}{24\alpha k(27\alpha k-\beta^2)(81\alpha k-2\beta^2)} > 0$. $d_1^{I_1D} - d_1^{I_1I_2} = d_2^{I_1I_2} - d_2^{I_1D} = \frac{(648\alpha^2k^2-81\alpha k\beta^2+2\beta^4)l_1+(810\alpha^2k^2-81\alpha k\beta^2+2\beta^4)l_2}{4(27\alpha k-\beta^2)(81\alpha k-2\beta^2)} > \frac{(1458\alpha^2k^2-162\alpha k\beta^2+4\beta^4)l_2}{4(27\alpha k-\beta^2)(81\alpha k-2\beta^2)} > 0$. (iv) can be proved similarly. □

Proof of Theorem 4.1.

(i) $\pi_{M_1}^{BD} > \pi_{M_1}^{DD}$ is equivalent to $(108-\Lambda)(81-2\Lambda)^2((28-\Lambda)+(26-\Lambda)\Delta)^2 > 192(27-\Lambda)^2((42-\Lambda)+(39-\Lambda)\Delta)^2 > 0$. An implicit plot of the condition shows that the above condition is satisfied in the specified range of parameters ($0 < \Delta < 1$, $0 < \Lambda < 15+12\Delta$). $\pi_{M_1}^{DD} > \pi_{M_1}^{FD}$ and (ii) can be proved similarly. □

Proof of Theorem 4.2.

(i) $\pi_{M_1}^{BI} > \pi_{M_1}^{FI}$ is equivalent to $\Lambda < 18$, which is satisfied from the parametric assumption. $\pi_{M_1}^{FI} > \pi_{M_1}^{DI}$ is equivalent to $16(27-\Lambda)^2((15-\Lambda)+(12-\Lambda)\Delta)^2 > 3(27-2\Lambda)^2((30-\Lambda)+(24-\Lambda)\Delta)^2$. An implicit plot of the condition shows that the above condition is satisfied in the specified range of parameters.

(ii) $\pi_{M_2}^{IB} > \pi_{M_2}^{ID}$ if and only if $16(27-\Lambda)^3((15-\Lambda)\Delta+(12-\Lambda))^2 > 27(27-2\Lambda)^2((30-\Lambda)\Delta+(24-\Lambda))^2$. By plotting the above condition in Fig 4.1 we show that this is true if and only if $\Lambda < \Lambda_1(\Delta)$ for the threshold $\Lambda_1(\Delta)$.

(iii) $\pi_{M_2}^{IF} > \pi_{M_2}^{ID}$ if and only if $16(27-\Lambda)^2((15-\Lambda)\Delta+(12-\Lambda))^2 > 3((30-\Lambda)\Delta+(24-\Lambda))^2$. By plotting the above condition in Fig 4.2 we show that this is true if and only if $\Lambda < \Lambda_2(\Delta)$ for the threshold $\Lambda_2(\Delta)$.

(iii) $\pi_{M_2}^{IB} > \pi_{M_2}^{IF}$ is equivalent to $\Lambda < 18$, which is satisfied from the parametric assumption. □

Proof of Theorem 4.3. The equilibrium channel structure can be obtained by examining the best response results shown in Theorems 4.1-4.2. □

Proof of Proposition 4.4.

$\pi_{M_2}^{DD} > \pi_{M_2}^{FF}$ is equivalent to $3(27-2\Lambda)^2((42-\Lambda)\Delta+(39-\Lambda))^2 > (81-2\Lambda)^2((15-\Lambda)\Delta+(12-\Lambda))^2$. An implicit plot of the above condition shows that the condition is satisfied in the specified range of parameters. $\pi_{M_2}^{DD} > \pi_{M_2}^{BB}$ can be proved similarly. □

Proof of Theorem 5.1.

Existence of equilibrium: We illustrate the proof for the duopoly scenario IIMM where both manufacturers sell directly to the market and two manufacturer-owned stores experience both local and searching demand. Store i's expected profit is expressed as $\pi_i^{MM} = (p_i - c_i)(\gamma_i(1 + y_i\alpha - p_i - t_i) + (1-\gamma_i)\delta(p_j + y_i(1-y_j)\alpha - p_i - \triangle t))$, where $i = 1, 2$, $j = 3 - i$. We have $\frac{\partial^2 \pi_i^{MM}}{\partial p_i \partial p_j} = (1-\gamma_i)\delta$. Since $\frac{\partial^2 \pi_i^{MM}}{\partial p_i \partial p_j} \geqslant 0$, π_i^{MM} is supermodular in (p_1, p_2), there exists at least one equilibrium [Top79]. Existence of equilibrium for other duopoly scenarios can be proved in the same manner.

Uniqueness of equilibrium: We use "diagonal dominance" condition to prove uniqueness. Take duopoly scenario IIMM as example. Since $\frac{\partial^2 \pi_i^{MM}}{\partial^2 p_i} = -\gamma_i - (1-\gamma_i)\delta < \left|\frac{\partial^2 \pi_i^{MM}}{\partial p_i \partial p_j}\right|$, the "diagonal dominance" condition holds, implying the uniqueness of equilibrium [CN06]. Uniqueness of equilibrium for other duopoly scenarios can be proved in the same manner. □

Proof of Theorem 5.2.

Without loss of generality, let $i = 1$ and $j = 2$. We already know that $y_1 = 0$. Consider the case where store 2 only experiences local demand (i.e., P_j = L). Since $1 - c_1 - t_1 > 0$, we have $1 + y_1\alpha - p_1^{LL} - t_1 > 0$. That means if in purchase scheme LL, store 1's optimal pricing decision guarantees positive local demand. No searching demand for store 1 in purchase scheme LL, i.e., $p_2^{LL} + y_1(1-y_2)\alpha - p_1^{LL} - \triangle t \leqslant 0$, requires $\frac{1}{2}(1 - t_1 - c_1) \geqslant p_2^{LL} - \triangle t - c_1$. Positive local and searching demand in purchase scheme ML, i.e., $1 + y_1\alpha - p_1^{ML} - t_1 > 0$ and $p_2^{ML} + y_1(1-y_2)\alpha - p_1^{ML} - \triangle t > 0$, requires $(\gamma + 2(1-\gamma)\delta)(1 - t_1 - c_1) > (1-\gamma)\delta(p_2^{ML} - \triangle t - c_1)$ and $(2\gamma + (1-\gamma)\delta)(p_2^{ML} - \triangle t - c_1) > \gamma(1 - t_1 - c_1)$, respectively. No local demand for store 1 in purchase scheme SL, i.e., $1 + y_1\alpha - p_1^{SL} - t_1 \leqslant 0$, requires $p_2^{SL} - \triangle t - c_1 \geqslant 2(1 - t_1 - c_1)$. Positive searching demand in purchase scheme SL, i.e., $p_2^{SL} + y_1(1-y_2)\alpha - p_1^{SL} - \triangle t > 0$, requires $p_2^{SL} - \triangle t - c_1 > \frac{1}{2}(1 - t_1 - c_1)$. Store 1's optimal profits in purchase schemes LL, ML, SL are $\pi_1^{LL} = \frac{\gamma(1-t_1-c_1)^2}{4}$, $\pi_1^{ML} = \frac{(\gamma(1-t_1-c_1)+(1-\gamma)\delta(p_2^{ML}-\triangle t-c_1))^2}{4(\gamma+(1-\gamma)\delta)}$, $\pi_1^{SL} = \frac{(1-\gamma)\delta(p_2^{SL}-\triangle t-c_1)^2}{4}$, respectively. Since $p_2^{LL} = p_2^{ML} = p_2^{SL}$, we use p_2^{*L} to refer them in the following discussion.

(i) $p_2^{*L} - \triangle t - c_1 \leqslant \frac{\gamma}{2\gamma+(1-\gamma)\delta}(1 - t_1 - c_1)$:

It follows that $p_2^{LL} + y_1(1-y_2)\alpha - p_1^{LL} - \triangle t \leqslant 0$, $1 + y_1\alpha - p_1^{ML} - t_1 > 0$, $p_2^{ML} + y_1(1-y_2)\alpha -$

$p_1^{ML} - \triangle t \leqslant 0$, and $1 + y_1\alpha - p_1^{SL} - t_1 > 0$. This means store 1 has incentive to price so as to obtain all the sales from local customers. Customers are induced to deviate away from purchase scheme SL or ML to LL.

(ii) $\frac{\gamma}{2\gamma+(1-\gamma)\delta}(1 - t_1 - c_1) < p_2^{*L} - \triangle t - c_1 \leqslant \theta_1(1 - t_1 - c_1)$:

It follows that $p_2^{LL} + y_1(1-y_2)\alpha - p_1^{LL} - \triangle t \leqslant 0$, $1 + y_1\alpha - p_1^{ML} - t_1 > 0$ $p_2^{ML} + y_1(1-y_2)\alpha - p_1^{ML} - \triangle t > 0$, and $1 + y_1\alpha - p_1^{SL} - t_1 > 0$. Store 1 has the incentive to price so as to obtain positive sales from local customers. Customers are induced to deviate away from purchase scheme SL. Since $\pi_1^{LL} \geqslant \pi_1^{ML}$, purchase scheme LL is optimal for store 1 .

(iii) $\theta_1(1 - t_1 - c_1) < p_2^{*L} - \triangle t - c_1 \leqslant \frac{1}{2}(1 - t_1 - c_1)$:

It follows that $p_2^{LL} + y_1(1-y_2)\alpha - p_1^{LL} - \triangle t \leqslant 0$, $1 + y_1\alpha - p_1^{ML} - t_1 > 0$, $p_2^{ML} + y_1(1-y_2)\alpha - p_1^{ML} - \triangle t > 0$, and $1 + y_1\alpha - p_1^{SL} - t_1 > 0$. Store 1 has the incentive to price so as to obtain positive sales from local customers. Customers are induced to deviate away from purchase scheme SL. Since $\pi_1^{LL} < \pi_1^{ML}$, purchase scheme ML is optimal for store 1.

(iv) $\frac{1}{2}(1 - t_1 - c_1) < p_2^{*L} - \triangle t - c_1 < 2(1 - t_1 - c_1)$:

It follows that $p_2^{LL} + y_1(1-y_2)\alpha - p_1^{LL} - \triangle t > 0$, $1 + y_1\alpha - p_1^{ML} - t_1 > 0$, $p_2^{ML} + y_1(1-y_2)\alpha - p_1^{ML} - \triangle t > 0$, and $1 + y_1\alpha - p_1^{SL} - t_1 > 0$. Store 1 has the incentive to price so as to induce local and searching customers to purchase. Customers are induced to deviate away from purchase scheme LL or SL to ML.

(v) $2(1 - t_1 - c_1) \leqslant p_2^{*L} - \triangle t - c_1 < \theta_2(1 - t_1 - c_1)$:

It follows that $p_2^{LL} + y_1(1-y_2)\alpha - p_1^{LL} - \triangle t > 0$, $1 + y_1\alpha - p_1^{ML} - t_1 > 0$, $p_2^{ML} + y_1(1-y_2)\alpha - p_1^{ML} - \triangle t > 0$, and $1 + y_1\alpha - p_1^{SL} - t_1 \leqslant 0$, $p_2^{SL} + y_1(1-y_2)\alpha - p_1^{SL} - \triangle t > 0$. Store 1 has the incentive to price so as to obtain positive sales from searching customers. Customers are induced to deviate away from purchase scheme LL. Since $\pi_1^{SL} < \pi_1^{ML}$, purchase scheme ML is optimal for store 1.

(vi) $\theta_2(1 - t_1 - c_1) \leqslant p_2^{*L} - \triangle t - c_1 < (2 + \frac{\gamma}{(1-\gamma)\delta})(1 - t_1 - c_1)$:

It follows that $p_2^{LL} + y_1(1-y_2)\alpha - p_1^{LL} - \triangle t > 0$, $1 + y_1\alpha - p_1^{ML} - t_1 > 0$, $p_2^{ML} + y_1(1-y_2)\alpha -$

$p_1^{ML} - \triangle t > 0$, $1 + y_1\alpha - p_1^{SL} - t_1 \leqslant 0$, and $p_2^{SL} + y_1(1-y_2)\alpha - p_1^{SL} - \triangle t > 0$. Store 1 has the incentive to price so as to obtain positive sales from searching customers. Customers are induced to deviate away from purchase scheme LL. Since $\pi_1^{SL} \geqslant \pi_1^{ML}$, purchase scheme SL is optimal for store 1.

(vii) $(2 + \frac{\gamma}{(1-\gamma)\delta})(1 - t_1 - c_1) \leqslant p_2^{*L} - \triangle t - c_1$:
It follows that $p_2^{LL} + y_1(1-y_2)\alpha - p_1^{LL} - \triangle t > 0$, $1 + y_1\alpha - p_1^{ML} - t_1 \leqslant 0$, $p_2^{ML} + y_1(1-y_2)\alpha - p_1^{ML} - \triangle t > 0$, $1 + y_1\alpha - p_1^{SL} - t_1 \leqslant 0$, and $p_2^{SL} + y_1(1-y_2)\alpha - p_1^{SL} - \triangle t > 0$. This means store 1 has incentive to price so as to obtain all the sales from searching customers. Customers are induced to deviate from purchase scheme LL or ML to SL.

The proof for the case where store 2 only experiences searching demand (i.e., P_j = S) follows the same logic. □

Proof of Theorem 5.3.

Without loss of generality, let $i = 1$ and $j = 2$. We already know that $y_1 = 0$. Since $1 - c_1 - t_1 > 0$, we have $1 + y_1\alpha - p_1^{LM} - t_1 > 0$. That means if in purchase scheme LM, store 1's optimal pricing decision guarantees positive local demand.

No searching demand for store 1 in purchase scheme LM, i.e., $p_2^{LM} + y_1(1-y_2)\alpha - p_1^{LM} - \triangle t \leqslant 0$, is equivalent to

$$\begin{aligned}
& \frac{(1-\gamma)p_2^{LL} + \gamma\delta p_2^{LS}}{1-\gamma+\gamma\delta} - p_1^{LM} - \triangle t \leqslant 0 \\
\Longleftrightarrow\quad & \frac{(1-\gamma)p_2^{LL} + \gamma\delta p_2^{LS}}{1-\gamma+\gamma\delta} - \triangle t - c_1 \leqslant \frac{1}{2}(1 - t_1 - c_1) \\
\Longleftrightarrow\quad & \frac{(1-\gamma)p_2^{LL} + \gamma\delta p_2^{SS}}{1-\gamma+\gamma\delta} - \triangle t - c_1 \leqslant \frac{1+a_2}{2}(1 - t_1 - c_1) \\
\Longleftrightarrow\quad & p_2^{SM} - \triangle t - c_1 \leqslant \frac{1+a_2}{2}(1 - t_1 - c_1).
\end{aligned}$$

The optimal pair of retail prices in purchase scheme MM can be expressed as

$$\begin{aligned} p_1^{MM} &= \frac{1}{1-a_1a_2}(a_1(p_2^{LM} - a_2p_1^{LM}) + p_1^{ML} - a_1p_2^{ML}), \\ {}_2^{MM} &= \frac{1}{1-a_1a_2}(a_2(p_1^{ML} - a_1p_2^{ML}) + p_2^{LM} - a_2p_1^{LM}). \end{aligned}$$

Positive local demand for store 1 in purchase scheme MM, i.e., $1 + y_1\alpha - p_1^{MM} - t_1 > 0$, is equivalent to

$$\begin{aligned} & (1 - p_1^{ML} - t_1) - a_1a_2(1 - p_1^{LM} - t_1) - a_1p_2^{LM} + a_1p_2^{ML} > 0 \\ \Longleftrightarrow\quad & (1 - \frac{\gamma p_1^{LL} + (1-\gamma)\delta p_1^{SL}}{\gamma + (1-\gamma)\delta} - t_1) - a_1a_2(1 - p_1^{LM} - t_1) - a_1p_2^{LM} + a_1p_2^{ML} > 0 \\ \Longleftrightarrow\quad & (1 - 2a_1 - a_1a_2)(1 - p_1^{LL} - t_1) + 2a_1(1 - p_1^{SL} - t_1) - a_1p_2^{LM} + a_1p_2^{ML} > 0 \\ \Longleftrightarrow\quad & (1 - 2a_1 - a_1a_2)\frac{1 - t_1 - c_1}{2} + 2a_1(1 - \frac{p_2^{ML} - \triangle t + c_1}{2} - t_1) + a_1p_2^{ML} \\ & > a_1\frac{(1-\gamma)p_2^{LL} + \gamma\delta p_2^{LS}}{1 - \gamma + \gamma\delta} \\ \Longleftrightarrow\quad & (1 - 2a_1 - a_1a_2)\frac{1 - t_1 - c_1}{2} + 2a_1(1 - t_1 - \frac{-\triangle t + c_1}{2}) > a_1\frac{(1-\gamma)p_2^{LL} + \gamma\delta p_2^{LS}}{1 - \gamma + \gamma\delta} \\ \Longleftrightarrow\quad & (1 + 2a_1 - a_1a_2)\frac{1 - t_1 - c_1}{2} > a_1(\frac{(1-\gamma)p_2^{LL} + \gamma\delta p_2^{LS}}{1 - \gamma + \gamma\delta} - \triangle t - c_1) \\ \Longleftrightarrow\quad & \frac{1 + 2a_1 - a_1a_2}{2a_1}(1 - t_1 - c_1) > \frac{(1-\gamma)p_2^{LL} + \gamma\delta p_2^{LS}}{1 - \gamma + \gamma\delta} - \triangle t - c_1 \\ \Longleftrightarrow\quad & \frac{1 + 2a_1}{2a_1}(1 - t_1 - c_1) > \frac{(1-\gamma)p_2^{LL} + \gamma\delta p_2^{SS}}{1 - \gamma + \gamma\delta} - \triangle t - c_1. \\ \Longleftrightarrow\quad & \frac{1 + 2a_1}{2a_1}(1 - t_1 - c_1) > p_2^{SM} - \triangle t - c_1. \end{aligned}$$

Positive searching demand for store 1 in purchase scheme MM, i.e., $p_2^{MM} + y_1(1 - y_2)\alpha -$

$p_1^{MM} - \triangle t > 0$, is equivalent to

$$\begin{aligned}
& (1 + a_1 a_2 - 2a_2)(p_2^{LL} - \triangle t - c_1) + (2a_2 - 2a_1 a_2)(p_2^{LS} - \triangle t - c_1) \\
& > (1 - 2a_1 + a_1 a_2)p_1^{LL} + (2a_1 - 2a_1 a_2)p_1^{SL} + (a_1 a_2 - 1)c_1 \\
\iff & (1 + a_1 a_2 - 2a_2)(p_2^{LL} - \triangle t - c_1) + (2a_2 - 2a_1 a_2)(p_2^{LS} - \triangle t - c_1) \\
& > (1 - 2a_1 + a_1 a_2)(p_1^{LL} - c_1) + (2a_1 - 2a_1 a_2)(p_1^{SL} - c_1) \\
\iff & (1 + a_1 a_2 - 2a_2)(p_2^{LL} - \triangle t - c_1) + (2a_2 - 2a_1 a_2)(p_2^{LS} - \triangle t - c_1) \\
& > (1 - 2a_1 + a_1 a_2)\frac{1 - t_1 - c_1}{2} + (a_1 - a_1 a_2)(p_2^{SL} - \triangle t - c_1) \\
\iff & (1 + 2a_1 a_2 - a_1 - 2a_2)(p_2^{LL} - \triangle t - c_1) + (2a_2 - 2a_1 a_2)(p_2^{LS} - \triangle t - c_1) \\
& > (1 - 2a_1 + a_1 a_2)\frac{1 - t_1 - c_1}{2} \\
\iff & (1 - a_1)(1 - 2a_2)(p_2^{LL} - \triangle t - c_1) + 2a_2(1 - a_1)(p_2^{LS} - \triangle t - c_1) \\
& > (1 - 2a_1 + a_1 a_2)\frac{1 - t_1 - c_1}{2} \\
\iff & \frac{(1-\gamma)p_2^{LL} + \gamma\delta p_2^{LS}}{1 - \gamma + \gamma\delta} - \triangle t - c_1 > \frac{1 - 2a_1 + a_1 a_2}{2(1 - a_1)}(1 - t_1 - c_1) \\
\iff & \frac{(1-\gamma)p_2^{LL} + \gamma\delta p_2^{SS}}{1 - \gamma + \gamma\delta} - \triangle t - c_1 > \frac{1 - 2a_1 + a_2}{2(1 - a_1)}(1 - t_1 - c_1) \\
\iff & p_2^{SM} - \triangle t - c_1 > \frac{1 - 2a_1 + a_2}{2(1 - a_1)}(1 - t_1 - c_1)
\end{aligned}$$

No local demand for store 1 in purchase scheme SM, i.e., $1 + y_1\alpha - p_1^{SM} - t_1 \leqslant 0$, is equivalent to

$$\begin{aligned}
& 2(1 - t_1) - (p_2^{SM} - \triangle t + c_1) \\
\iff & 2(1 - t_1 - c_1) - \frac{(1-\gamma)p_2^{SL} + \gamma\delta p_2^{SS}}{1 - \gamma + \gamma\delta} - (-\triangle t - c_1) \leqslant 0 \\
\iff & 2(1 - t_1 - c_1) \leqslant p_2^{SM} - \triangle t - c_1
\end{aligned}$$

Positive searching demand for store 1 in purchase scheme SM, i.e., $p_2^{SM} + y_1(1 - y_2)\alpha - p_1^{SM} - \triangle t > 0$, is equivalent to $p_2^{SM} - \triangle t - c_1 > 0$.

Store 1's optimal profit in purchase scheme LM is $\pi_1^{LM} = \frac{\gamma(1-t_1-c_1)^2}{4}$.

With the relations that

$$\begin{aligned} p_1^{MM} - c_1 &= \frac{(1-2a_1-2a_1a_2)(1-t_1-c_1) + 2a_1(p_2^{SM} - \triangle t - c_1)}{2(1-a_1a_2)}, \\ 1 - p_1^{MM} - t_1 &= \frac{(1+2a_1)(1-t_1-c_1) - 2a_1(p_2^{SM} - \triangle t - c_1)}{2(1-a_1a_2)}, \\ p_2^{MM} - p_1^{MM} - \triangle t &= \frac{2(1-a_1)(p_2^{SM} - \triangle t - c_1) - (1-2a_1+a_2)(1-t_1-c_1)}{2(1-a_1a_2)}, \end{aligned}$$

store 1's optimal profit in purchase scheme MM is

$$\begin{aligned} \pi_1^{MM} &= (p_1^{MM} - c_1)(\gamma(1 - p_1^{MM} - t_1) + (1-\gamma)\delta(p_2^{MM} - p_1^{MM} - \triangle t) \\ &= \frac{(\gamma + (1-\gamma)\delta)((1-2a_1-2a_1a_2)(1-t_1-c_1) + 2a_1(p_2^{SM} - \triangle t - c_1))^2}{4(1-a_1a_2)^2}. \end{aligned}$$

With the relations that

$$\begin{aligned} p_1^{SM} - c_1 &= \frac{1}{2}(p_2^{SM} - \triangle t - c_1), \\ p_2^{SM} - p_1^{SM} - \triangle t &= \frac{1}{2}(p_2^{SM} - \triangle t - c_1), \end{aligned}$$

store 1's optimal profit in purchase scheme SM is

$$\pi_1^{SM} = \frac{(1-\gamma)\delta}{4}(p_2^{SM} - \triangle t - c_1)^2.$$

(i) $p_2^{SM} - \triangle t - c_1 \leqslant \frac{1-2a_1+a_2}{2(1-a_1)}(1-t_1-c_1)$:

It follows that $p_2^{LM} + y_1(1-y_2)\alpha - p_1^{LM} - \triangle t \leqslant 0$, $1 + y_1\alpha - p_1^{MM} - t_1 > 0$, $p_2^{MM} + y_1(1-y_2)\alpha - p_1^{MM} - \triangle t \leqslant 0$, and $1 + y_1\alpha - p_1^{SM} - t_1 > 0$. This means store 1 has incentive to price so as to obtain all the sales from local customers. Customers are induced to deviate away from purchase scheme SM or MM to LM.

(ii) $\frac{1-2a_1+a_2}{2(1-a_1)}(1-t_1-c_1) < p_2^{SM} - \triangle t - c_1 \leqslant \tilde{\theta}_1(1-t_1-c_1)$:

It follows that $p_2^{LM} + y_1(1-y_2)\alpha - p_1^{LM} - \triangle t \leqslant 0$, $1 + y_1\alpha - p_1^{MM} - t_1 > 0$ and $p_2^{MM} + y_1(1-y_2)\alpha - p_1^{MM} - \triangle t > 0$, and $1 + y_1\alpha - p_1^{SM} - t_1 > 0$. Store 1 has the incentive to price so as to obtain positive sales from local customers. Customers are induced to deviate away from purchase scheme SM. Since $\pi_1^{LM} \geqslant \pi_1^{MM}$, purchase scheme LM is optimal for store 1.

(iii) $\tilde{\theta}_1(1-t_1-c_1) < p_2^{SM} - \triangle t - c_1 \leqslant \frac{1+a_2}{2}(1-t_1-c_1)$:

It follows that $p_2^{LM} + y_1(1-y_2)\alpha - p_1^{LM} - \triangle t \leqslant 0$, $1 + y_1\alpha - p_1^{MM} - t_1 > 0$ and $p_2^{MM} + y_1(1-y_2)\alpha - p_1^{MM} - \triangle t > 0$, and $1 + y_1\alpha - p_1^{SM} - t_1 > 0$. Store 1 has the incentive to price so as to obtain positive sales from local customers. Customers are induced to deviate away from purchase scheme SM. Since $\pi_1^{LM} < \pi_1^{MM}$, purchase scheme MM is optimal for store 1.

(iv) $\frac{1+a_2}{2}(1-t_1-c_1) < p_2^{SM} - \triangle t - c_1 < 2(1-t_1-c_1)$:

It follows that $p_2^{LM} + y_1(1-y_2)\alpha - p_1^{LM} - \triangle t > 0$, $1 + y_1\alpha - p_1^{MM} - t_1 > 0$, $p_2^{MM} + y_1(1-y_2)\alpha - p_1^{MM} - \triangle t > 0$, and $1 + y_1\alpha - p_1^{SM} - t_1 > 0$. Store 1 has the incentive to price so as to induce local and searching customers to purchase. Customers are induced to deviate from purchase scheme LM or SM to MM.

(v) $2(1-t_1-c_1) \leqslant p_2^{SM} - \triangle t - c_1 < \tilde{\theta}_2(1-t_1-c_1)$:

It follows that $p_2^{LM} + y_1(1-y_2)\alpha - p_1^{LM} - \triangle t > 0$, $1 + y_1\alpha - p_1^{MM} - t_1 > 0$, $p_2^{MM} + y_1(1-y_2)\alpha - p_1^{MM} - \triangle t > 0$, $1 + y_1\alpha - p_1^{SM} - t_1 \leqslant 0$, and $p_2^{SM} + y_1(1-y_2)\alpha - p_1^{SM} - \triangle t > 0$. Store 1 has the incentive to price so as to obtain positive sales from searching customers. Customers are induced to deviate away from purchase scheme LM. Since $\pi_1^{SM} < \pi_1^{MM}$, purchase scheme MM is optimal for store 1.

(vi) $\tilde{\theta}_2(1-t_1-c_1) \leqslant p_2^{SM} - \triangle t - c_1 < \frac{1+2a_1}{2a_1}(1-t_1-c_1)$:

It follows that $p_2^{LM} + y_1(1-y_2)\alpha - p_1^{LM} - \triangle t > 0$, $1 + y_1\alpha - p_1^{MM} - t_1 > 0$, $p_2^{MM} + y_1(1-y_2)\alpha - p_1^{MM} - \triangle t > 0$, $1 + y_1\alpha - p_1^{SM} - t_1 \leqslant 0$, and $p_2^{SM} + y_1(1-y_2)\alpha - p_1^{SM} - \triangle t > 0$. Store 1 has the incentive to price so as to obtain positive sales from searching customers. Customers are induced to deviate away from purchase scheme LM. Since $\pi_1^{SM} \geqslant \pi_1^{MM}$, purchase scheme SM is optimal for store 1.

(vii) $\frac{1+2a_1}{2a_1}(1-t_1-c_1) \leqslant (1-\gamma)(p_2^{LL}-\triangle t-c_1)+\gamma\delta(p_2^{LS}-\triangle t-c_1)$:

It follows that $p_2^{LM}+y_1(1-y_2)\alpha-p_1^{LM}-\triangle t>0$, $1+y_1\alpha-p_1^{MM}-t_1\leqslant 0$, $p_2^{MM}+y_1(1-y_2)\alpha-p_1^{MM}-\triangle t>0$, $1+y_1\alpha-p_1^{SM}-t_1\leqslant 0$, and $p_2^{SM}+y_1(1-y_2)\alpha-p_1^{SM}-\triangle t>0$. This means store 1 has incentive to price so as to obtain all the sales from searching customers. Customers are induced to deviate from purchase scheme LM or MM to SM. □

Proof of Theorem 5.4.

Without loss of generality, let $i=1$ and $j=2$. Consider store 2 only experiences local demand (i.e., $P_j=$ L). Since $1-c_1-t_1>0$, we have $1+y_1\alpha-p_1^{LL}-t_1>0$. That means store 1's optimal pricing decision in purchase scheme LL guarantees positive local demand. No searching demand in purchase scheme LL, i.e., $p_j^{LL}+y_1(1-y_2)\alpha-p_1^{LL}-\triangle t\leqslant 0$, requires $\frac{3}{4}(1+\alpha-t_1-c_1)\geqslant p_j^{LL}+(1-y_2)\alpha-\triangle t-c_1$. Positive local and searching demand in purchase scheme ML, i.e., $1+y_1\alpha-p_1^{ML}-t_1>0$ and $p_j^{ML}+y_1(1-y_2)\alpha-p_1^{ML}-\triangle t>0$, requires $(\gamma+4(1-\gamma)\delta)(1+\alpha-t_1-c_1)>3(1-\gamma)\delta(p_j+(1-y_2)\alpha-\triangle t-c_1)$ and $(4\gamma+(1-\gamma)\delta)(p_j+(1-y_2)\alpha-\triangle t-c_1)>3\gamma(1+\alpha-t_1-c_1)$, respectively. No local demand in purchase scheme SL, i.e., $1+y_1\alpha-p_1^{SL}-t_1\leqslant 0$ holds requires $p_j^{SL}+(1-y_2)\alpha-\triangle t-c_1\geqslant\frac{4}{3}(1+\alpha-t_1-c_1)$. Positive searching demand in purchase scheme SL, i.e., $p_2^{SL}+y_1(1-y_2)\alpha-p_1^{SL}-\triangle t>0$, requires $p_2^{SL}-\triangle t-c_1>\frac{3}{4}(1+\alpha-t_1-c_1)\geqslant p_j+(1-y_2)\alpha-\triangle t-c_1$. Store 1's optimal profits in purchase schemes LL, ML, SL are $\pi_1^{LL}=\frac{3\gamma(1+y_1\alpha-t_1+c_1)^2}{16}$, $\pi_1^{ML}=\frac{3(\gamma(1+y_1\alpha-t_1+c_1)+(1-\gamma)\delta(p_j+y_1(1-y_2)\alpha-\triangle t+c_1))^2}{16(\gamma+(1-\gamma)\delta)}$, $\pi_1^{SL}=\frac{3(1-\gamma)\delta(p_j+y_1(1-y_2)\alpha-\triangle t+c_1)^2}{16}$, respectively. Since $p_2^{LL}=p_2^{ML}=p_2^{SL}$, we use p_2^{*L} to refer them in the following discussion.

(i) $p_2^{*L}+(1-y_2)\alpha-\triangle t-c_1\leqslant\frac{3\gamma}{4\gamma+(1-\gamma)\delta}(1+\alpha-t_1-c_1)$:

$p_2^{LL}+y_1(1-y_2)\alpha-p_1^{LL}-\triangle t\leqslant 0$, $1+\alpha-p_1^{ML}-t_1>0$, $p_2^{ML}+y_1(1-y_2)\alpha-p_1^{ML}-\triangle t\leqslant 0$, and $1+\alpha-p_1^{SL}-t_1>0$. This means store 1 has incentive to price so as to obtain all the sales from local customers. Customers are induced to deviate away from purchase scheme SL or ML to LL.

(ii) $\frac{3\gamma}{4\gamma+(1-\gamma)\delta}(1+\alpha-t_1-c_1) < p_2^{*L} + (1-y_2)\alpha - \triangle t - c_1 \leqslant \bar{\theta}_1(1+\alpha-t_1-c_1)$:
$p_2^{LL} + y_1(1-y_2)\alpha - p_1^{LL} - \triangle t \leqslant 0$, $1+\alpha-p_1^{ML}-t_1>0$, $p_2^{ML}+y_1(1-y_2)\alpha-p_1^{ML}-\triangle t>0$, and $1+\alpha-p_1^{SL}-t_1>0$. Store 1 has the incentive to price so as to obtain positive sales from local customers. Customers are induced to deviate away from purchase scheme SL. Since $\pi_1^{LL} \geqslant \pi_1^{ML}$, purchase scheme LL is optimal for store 1.

(iii) $\bar{\theta}_1(1+\alpha-t_1-c_1) < p_2^{*L} + (1-y_2)\alpha - \triangle t - c_1 \leqslant \frac{3}{4}(1+\alpha-t_1-c_1)$:
$p_2^{LL} + y_1(1-y_2)\alpha - p_1^{LL} - \triangle t \leqslant 0$, $1+\alpha-p_1^{ML}-t_1>0$, $p_2^{ML}+y_1(1-y_2)\alpha-p_1^{ML}-\triangle t>0$, and $1+\alpha-p_1^{SL}-t_1>0$. Store 1 has the incentive to price so as to obtain positive sales from local customers. Customers are induced to deviate away from purchase scheme SL. Since $\pi_1^{LL} < \pi_1^{ML}$, purchase scheme ML is optimal for store 1.

(iv) $\frac{3}{4}(1+\alpha-t_1-c_1) < p_2^{*L} + (1-y_2)\alpha - \triangle t - c_1 < \frac{4}{3}(1+\alpha-t_1-c_1)$:
$p_2^{LL} + y_1(1-y_2)\alpha - p_1^{LL} - \triangle t > 0$, $1+\alpha-p_1^{ML}-t_1>0$, $p_2^{ML}+y_1(1-y_2)\alpha-p_1^{ML}-\triangle t>0$, and $1+\alpha-p_1^{SL}-t_1>0$. Store 1 has the incentive to price so as to induce local and searching customers to purchase. Customers are induced to deviate from purchase scheme LL or SL to ML.

(v) $\frac{4}{3}(1+\alpha-t_1-c_1) \leqslant p_2^{*L} + (1-y_2)\alpha - \triangle t - c_1 < \bar{\theta}_2(1+\alpha-t_1-c_1)$:
$p_2^{LL} + y_1(1-y_2)\alpha - p_1^{LL} - \triangle t > 0$, $1+\alpha-p_1^{ML}-t_1>0$, $p_2^{ML}+y_1(1-y_2)\alpha-p_1^{ML}-\triangle t>0$, $1+\alpha-p_1^{SL}-t_1 \leqslant 0$, and $p_2^{SL}+y_1(1-y_2)\alpha-p_1^{SL}-\triangle t>0$. Store 1 has the incentive to price so as to obtain positive sales from searching customers. Customers are induced to deviate away from purchase scheme LL. Since $\pi_1^{SL} < \pi_1^{ML}$, purchase scheme ML is optimal for store 1.

(vi) $\bar{\theta}_2(1+\alpha-t_1-c_1) \leqslant p_2^{*L} + (1-y_2)\alpha - \triangle t - c_1 < (\frac{4}{3}+\frac{\gamma}{3(1-\gamma)\delta})(1+\alpha-t_1-c_1)$:
$p_2^{LL} + y_1(1-y_2)\alpha - p_1^{LL} - \triangle t > 0$, $1+\alpha-p_1^{ML}-t_1>0$, $p_2^{ML}+y_1(1-y_2)\alpha-p_1^{ML}-\triangle t>0$, $1+\alpha-p_1^{SL}-t_1 \leqslant 0$, and $p_2^{SL}+y_1(1-y_2)\alpha-p_1^{SL}-\triangle t>0$.. Store 1 has the incentive to price so as to obtain positive sales from searching customers. Customers are induced to deviate away from purchase scheme LL. Since $\pi_1^{SL} \geqslant \pi_1^{ML}$, it is optimal for store 1 purchase scheme SL.

(vii) $(\frac{4}{3}+\frac{\gamma}{3(1-\gamma)\delta})(1+\alpha-t_1-c_1) \leqslant p_2^{*L} + (1-y_2)\alpha - \triangle t - c_1$:

$p_2^{LL} + y_1(1-y_2)\alpha - p_1^{LL} - \triangle t > 0$,$1+\alpha - p_1^{ML} - t_1 \leqslant 0$, $p_2^{ML} + y_1(1-y_2)\alpha - p_1^{ML} - \triangle t > 0$, $1+\alpha-p_1^{SL}-t_1 \leqslant 0$, and $p_2^{SL}+y_1(1-y_2)\alpha - p_1^{SL} - \triangle t > 0$. This means store 1 has incentive to price so as to obtain all the sales from searching customers. Customers are induced to deviate from purchase scheme LL or ML to SL.

The proof for the case where store 2 only experiences searching demand (i.e., $P_2 = \mathrm{S}$) follows the same logic. □

Proof of Proposition 5.1.

Without loss of generality, let $i=1$ and $j=2$.

(i) when $y_1 = 0$, that the best response to the competing store's strategy (S) is (L) implies $1 + y_2\alpha - t_2 - \triangle t - c_1 \leqslant \theta_1(1-t_1-c_1)$ from Theorem 5.2. Since $p_2^{*L} < 1+\alpha-t_2$ by the assumption $1-t_2-c_2 > 0$, $p_2^{*L} - \triangle t - c_1 \leqslant \theta_1(1-t_1-c_1)$ holds. Thus the best response to the competing store's strategy (L) is (L). When $y_1 = 1$, that the best response to the competing store's strategy (S) is (L) implies $1+\alpha-t_2-\triangle t - c_1 \leqslant \bar{\theta}_1(1+\alpha-t_1-c_1)$ from Theorem 5.4. Since $p_2^{*L} < 1+\alpha-t_2$ by the assumption $1-t_2-c_2 > 0$, $p_2^{*L}+(1-y_2)\alpha-\triangle t-c_1 \leqslant \bar{\theta}_1(1+\alpha-t_1-c_1)$ holds. Thus the best response to the competing store's strategy (L) is (L).

(ii) When $y_1 = 0$, that the best response to the competing store's strategy (L) is (S) implies $\theta_2(1-t_1-c_1) \leqslant p_2^{*L} - \triangle t - c_1$ from Theorem 5.2. Since $p_2^{*L} < 1+\alpha-t_2$ by the assumption $1-t_2-c_2 > 0$, $\theta_2(1-t_1-c_1) \leqslant 1+y_2\alpha-t_2-\triangle t - c_1$ holds. Thus the best response to the competing store's strategy (S) is (S). When $y_1 = 1$, that the best response to the competing store's strategy (L) is (S) implies $\bar{\theta}_2(1+\alpha-t_1-c_1) \leqslant p_2^{*L}+(1-y_2)\alpha-\triangle t-c_1$ from Theorem 5.4. Since $p_2^{*L} < 1+\alpha-t_2$ by the assumption $1-t_2-c_2 > 0$, $\bar{\theta}_2(1+\alpha-t_1-c_1) \leqslant 1+\alpha-t_2-\triangle t-c_1$ holds. Thus the best response to the competing store's strategy (S) is (S). □

Proof of Proposition 5.2.

Without loss of generality, let $i=1$ and $j=2$.

(i) Given $y_2 = 0$. That the best response to the competing store's strategy (L) is (L) when $y_1 = 1$ means that $p_2^{*L} + \alpha - \triangle t - c_1 \leqslant \bar{\theta}_1(1 + \alpha - t_1 - c_1)$ from Theorem 5.4. Since $\theta_1 \leqslant \bar{\theta}_1$, we obtain $p_2^{*L} - \triangle t - c_1 \leqslant \theta_1(1 - t_1 - c_1)$, which indicates the best response to the competing store's strategy (L) is (L) when $y_1 = 0$ from Theorem 5.2. That the best response to the competing store's strategy (S) is (L) when $y_1 = 1$ means that $1 + \alpha - t_2 - \triangle t - c_1 \leqslant \bar{\theta}_1(1 + \alpha - t_1 - c_1)$ from Theorem 5.4. Since $\theta_1 \leqslant \bar{\theta}_1$, we obtain $1 + \alpha - t_2 - \triangle t - c_1 \leqslant \theta_1(1 - t_1 - c_1)$, which indicates the best response to the competing store's strategy (S) is (L) when $y_1 = 0$ from Theorem 5.2.

(ii) Given $y_2 = 0$. That the best response to the competing store's strategy (L) is (S) when $y_1 = 0$ means that $\theta_2(1 - t_1 - c_1) \leqslant p_2^{*L} - \triangle t - c_1$ from Theorem 5.2. Since $\bar{\theta}_2 \leqslant \theta_2$, we obtain $\bar{\theta}_2(1 + \alpha - t_1 - c_1) \leqslant p_2^{*L} + \alpha - \triangle t - c_1$, which indicates the best response to the competing store's strategy (L) is (S) when $y_1 = 1$ from Theorem 5.4. That the best response to the competing store's strategy (S) is (S) when $y_1 = 0$ means that $\theta_2(1 - t_1 - c_1) \leqslant 1 - t_2 - \triangle t - c_1$ holds from Theorem 5.2. Since $\bar{\theta}_2 \leqslant \theta_2$, we obtain $\bar{\theta}_2(1 + \alpha - t_1 - c_1) \leqslant 1 + \alpha - t_2 - \triangle t - c_1$, which indicates the best response to the competing store's strategy (S) is (S) when $y_1 = 1$ from Theorem 5.4.

(iii) Given $y_2 = 1$. That the best response to the competing store's strategy (L) is (L) when $y_1 = 0$ means that $p_2^{*L} - \triangle t - c_1 \leqslant \theta_1(1 - t_1 - c_1)$from Theorem 5.2. Since $\theta_1 \leqslant \bar{\theta}_1$, we obtain $p_2^{*L} - \triangle t - c_1 \leqslant \bar{\theta}_1(1 + \alpha - t_1 - c_1)$, which indicates the best response to the competing store's strategy (L) is (L) when $y_1 = 1$ from Theorem 5.4. That the best response to the competing store's strategy (S) is (L) when $y_1 = 0$ means that $1 + \alpha - t_2 - \triangle t - c_1 \leqslant \theta_1(1 - t_1 - c_1)$ from Theorem 5.2. Since $\theta_1 \leqslant \bar{\theta}_1$, we obtain $1 + \alpha - t_2 - \triangle t - c_1 \leqslant \bar{\theta}_1(1 + \alpha - t_1 - c_1)$, which indicates the best response to the competing store's strategy (S) is (L) when $y_1 = 1$ from Theorem 5.4. □

Proof of Theorem 5.5.

Without loss of generality, let $i = 1$ and $j = 2$. Under channel structure II, we investigate four purchase schemes where both stores obtain sales from searching customers and explain why these purchase schemes cannot be equilibrium.

(i) In purchase scheme MM, a customer searching Store 1 with valuation $\hat{v}$ searches and buys from Store 1 provided that $p_1+t_2+\triangle t < \hat{v} \leqslant p_2+t_2$. That is, Store 1 experiences positive searching demand if and only if $p_2 > p_1 + \triangle t$. However, $p_1 > p_2 + \triangle t$ and $p_2 > p_1 + \triangle t$ cannot hold simultaneously. Hence, MM does not exist and thus cannot be equilibrium.

(ii) In purchase scheme SS, to ensure that no local demand and positive searching demand requires $1-p_1-t_1 \leqslant 0$, $1-p_1-t_2-\triangle t > 0$. The last two inequalities lead to $1-p_1-t_1+1-p_2-t_2 > 2\triangle t$, which contradicts with the first two inequalities. Therefore, SS does not exist and thus cannot be equilibrium.

(iii) In purchase scheme MS, to ensure no local demand for store 2 and positive searching demand for both stores requires $1 - p_2 - t_2 \leqslant 0$, $1 - p_1 - t_2 - \triangle t > 0$, $p_1 - p_2 - \triangle t > 0$. The last two inequalities lead to $1 - p_1 - t_2 - \triangle t > 0$ and $p_1 - p_2 - \triangle t > 0$, we have $1 - p_2 - t_2 > 1-p_1-t_2+\triangle t > t_2+\triangle t-t_2+\triangle t > 0$, which contradict with the first inequality. $1-p_2-t_2 \leqslant 0$. Thus, MS does not exist and thus cannot be equilibrium.

(iv) For purchase scheme SM, the proof is similar to (iii).

The proof for the channel structure DD follows the same logic. □