STUDY OF BEHAVIORAL OPERATIONS IN A DUAL-CHANNEL SUPPLY CHAIN

LIU CHENGLI

PhD

The Hong Kong Polytechnic University

2019

The Hong Kong Polytechnic University

Department of Industrial and Systems Engineering

Study of Behavioral Operations in a Dual-Channel Supply Chain

LIU Chengli

A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy

June 2018

CERTIFICATE OF ORIGINALITY

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it reproduces no material previously published or written, nor material that has been accepted for the award of any other degree or diploma, except where due acknowledgment has been made in the text.

_________________________________ (Signed)

_____Liu Chengli__________________(Name of student)

Abstract

The purpose of this study is to determine the pricing strategies in a dual-channel supply chain with people's non-hyper-rational behavioral patterns. This study proposes four objectives: 1) analyze the optimal sales effort deployment strategies in dual-channel supply chains; 2) model the overestimation in the newsvendor game; 3) determine the optimal prices and insights for the dual-channel supply chains with overconfident consumers; and 4) determine the optimal prices and insights for the dual-channel supply chains with loss-averse consumers.

To fulfill the study objectives, this study first introduces the model of a dual-channel supply chain and discuss the optimal sales efforts deployment problem. A sales effort competition game is set up in the dual-channel supply chain between a manufacturer and a retailer. Interestingly, the optimal sales effort and the profit of the manufacturer and the retailer can be limited by the other's efficiency of sales effort. Next, the newsvendor game with the occurrence of overestimation is studied, to explore the feature of overconfidence. The study shows that overestimation leads to a demand steal effect, which reduces the competitor's order quantity.

The issues of overconfidence and loss aversion are then studied in the dual-channel supply chain in sequence. Overconfident consumers are modeled in the first place. This study creates the model of overconfident consumers who are overprecise in their valuation of a product in the dual-channel supply chain by assuming that the consumers choose the channel for buying to maximize their utilities. As a result, the profit of the manufacturer and the retailer are reduced by consumers' overconfidence. Consumers can benefit from overconfidence because lower prices are offered. Then, loss aversion in the dual-channel supply chain is discussed. Products are generally classified into two categories based on their preference utility point: 1) basic product which has a lower reference utility for consumers and 2) luxury goods which have a higher reference utility for consumers. The results encourage manufacturers of basic goods to engage in the dual-channel strategy. However, manufacturers of luxury goods are not suggested to adopt the dual-channel supply chain strategy because the demand for direct channels(i.e. online channel) is negligible if consumers are loss-averse, and the demand for the retail channel remains unchanged compared with the single retail channel supply chain.

This study extends the literature on behavioral operations research regarding the dual-channel supply chain. The models of non-hyper-rational behaviors in the dual-channel supply chain are the main contributions of this research, such as the model of the loss aversion of consumers and the model of overconfident consumers. The pricing strategies of the manufacturer and the retailer facing loss-averse consumers and overconfident consumers are presented. The impacts on the profit of the manufacturer and the retailer are studied.

Publications

Journal papers

C. Liu, C.K.M. Lee, and, K.L. Choy, (2016). Sales effort deployment in decentralized dual-channel distribution. *Industrial Management & Data Systems*, *116*(4), pp.821-837.

C. Liu, C.K.M. Lee, (2016). The Competitive Newsvendor Game with Overestimated Demand. *World Academy of Science, Engineering, and Technology, International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering*, *10*(4), pp.678-68

C. Liu, C.K.M. Lee, (2018). Pricing Strategy in Dual-channel Supply Chains with Loss-averse Consumers. *Asia-Pacific Journal of Operational Research* (under review)

C. Liu, C.K.M. Lee, L. Zhang, (2018). Pricing Strategy in Dual-channel Supply Chains with Loss-averse Consumers. *International Journal of Production Economics*. (under review)

Conference papers

C. Liu, C.K.M. Lee, and, K.L. Choy, (2015). Marketing Strategy of Decentralized Dual-channel Distribution. In *The 9th International Conference on Operations and Supply Chain Management (ICOSCM).* Ningbo, China, July 12-15, 2015.

C. Liu, C.K.M. Lee, (2018). Pricing Strategy in Dual-Channel Supply Chain with Loss-Averse Consumers. In *4th Annual International Conference on Industrial, Systems and Design Engineering*. Athens, Greece, June 25-28, 2017.

C. Liu, C.K.M. Lee, (2018). Optimal Prices of Centralized Dual-Channel Supply Chain with Overconfident Consumers. In *The 12th International Conference on Operations and Supply Chain Management (ICOSCM).* Qingdao, China, July 12-15, 2018.

Acknowledgments

I would like to express my sincere gratitude to my supervisor, Dr. Carman Lee, who diligently guided my research in the last four years. Dr. Carman Lee not only provided valuable suggestions for my research but also offered me great encouragements during my study. Without Dr. Carman Lee, this research could not have been completed. It was my pleasure to conduct the research under Dr. Carman Lee's supervision.

I owe my deepest gratitude to my family. They gave me solid supports during the whole period of my study and research. Their love is the source of my strength.

Finally, I appreciate the financial support from the Research Grants Council of the Hong Kong, and Research Committee, Department of Industrial Systems Engineering of the Hong Kong Polytechnic University.

Table of Contents

List of Figures

List of Tables

1. Introduction

In a traditional, indirect manner, manufacturers in different industries sell their products to retailers who then sell these products to consumers. For example, in France, Samsung, Apple, Huawei, etc. engage retailers, including Carrefour, Fnac, Darty, and many others, to sell their mobile phone products. The rapid development of the Internet has laid a solid foundation for manufacturers to directly sell their products to consumers through their websites (Dan et al., 2012; Ding et al., 2016). The manufacturers' practices of selling products both directly and indirectly has given rise to the concept of the dual-channel supply chain which includes a direct channel and a retail channel. In the retail channel, the manufacturer sells the products to the retailer at a wholesale price and the retailer sells the product to the consumers at a retail price; whereas in the direct channel, the manufacturer sells the products to the consumers at a direct price. Manufacturers that are often cited as adopting dual-channels in product distribution practices include Sony Electronics, Apple Computers, IBM, and Dell and the retailers are Best Buy and Circuit City (Wang et al., 2016; Li et al., 2015; Xu et al., 2014). As noted in (Ding et al., 2016), one of the important issues in dual-channel supply chains is determining the prices properly so that the chain members' profits can be maximized. Recognizing the importance of such pricing decisions, many authors have proposed different models for chain members to establish the optimal pricing strategies (Ding et al., 2016; Fruchter and Tapiero; 2005; Martin-Herran and Taboubi, 2015; to name but a few).

While in the available studies, the pricing models are developed by taking into account the interactions between the different actors, including the consumers, and their impacts on the chain members' profits, they are underpinned by a common assumption: product demand is created by consumers who do not have any cognitive bias, thus valuing the products in a neutral way. In practice, humans' decisions are easily affected by non-hyper-rational behavior patterns such as loss aversion and overconfidence. Loss aversion indicates that people prefer avoiding losses to acquiring gains. Overconfidence indicates that people tend to be more confident in his or her judgments and estimations. Both loss aversion and overconfidence have been observed in a variety of fields, e.g., business investment decisions (Malmendier and Tate, 2005; Benartzi and Thaler, 1995), and trading practices (Statman et al., 2006; Haigh and List, 2005).

Therefore, loss aversion and overconfidence can occur in the dual-channel supply chain. The pricing strategy of dual-channel supply chain needs to be revisited with the consideration of non-hyper-rational behavioral patterns, such as loss aversion and overconfidence. Additionally, impacts of loss aversion and overconfidence on the dual-channel supply chain are discussed. This pioneering study explores the pricing strategy in the dual-channel supply chain with loss aversion and overconfidence. It contributes to the development of behavioral operations research in the dual-channel supply chain.

In this chapter, the background of the behavioral operations research in the dual-channel supply chain is introduced in Section 1.1. The research motivations are described in Section 1.2. Research objectives are identified in Section 1.3. Organization of the report is given in Section 1.4.

1.1. Background

An increasing number of consumers have begun to shop online in the last two decades, supported by the highly secure online payments from financial institutions and low-cost delivery services provided by third-party logistics. Recently, there is a new trend of people starting to shop online through mobile devices due to the expansion of the Internet (Cameron et al., 2012). This has led to the growth of business-to-consumer (B2C) e-commerce which has become an important part of the retailing industry. On the one hand, the B2C e-commerce sales worldwide reached 1,233 billion U.S. dollars in 2013. The global B2C e-commerce sales are forecast to be 2,356 billion U.S. dollars in the next five years (Statista.com, 2017b). On the other hand, B2C e-commerce sales as a percentage of global gross domestic product (GDP) have steadily increased since 2009 and reached 0.92% of global GDP in 2013. The figure is expected to rise continuously to 1.61% in 2018 (Statista.com, 2017b). Therefore, online retailing is an important topic that both managers and scholars cannot ignore. In this regard, many manufacturers have adopted the dual-channel supply chain strategy, such as Nike and IBM. Taking Nike as an example, although wholesales to retailers are still the largest part of the company’s revenue, its sales from the direct channel accounted for 23% of the total revenue in the fiscal year 2015, with a continuous and significant increase of online sales. This indicates that a direct channel online has the potential to be the main profit source for manufacturers.

Once the dual-channel supply chain is adopted, it can benefit both the manufacturer and the retailer. It has been pointed out that a direct channel online provides better accessibility to products than the traditional retail channel (Coelho et al., 2003), thus enabling the manufacturer to reach a larger number of potential consumers. For the manufacturer, the direct channel online allows for a higher profit margin than the retail channel (Chen et al., 2012). Additionally, more data on the consumers can be collected from the website, in order to analyze their purchase behaviors for the purpose of formulating marketing and production strategies (Chiang et al., 2003). It has also been shown that the direct channel online can protect manufacturers from revenue decrease due to demand dropping through the retail channel (Stern et al., 1996). Wallace et al. (2004) stated that the dual-channel structure contributes to the consumers' loyalty to the product, while the portfolio of services provided to the customers is enhanced. Consumers can get benefit from the dual-channel supply chains, as detailed information about the product is available online to support consumers' decision-making in the retail store. David and Adida (2015) analyzed a dual-channel supply chain model with differentiated retailers. It has been shown that the manufacturer has an incentive to have as many retailers as possible. The manufacturer can gain a profit even if the retailer channel sets a lower price for the product than the direct channel.

However, retailers argue that their profits are reduced by "channel conflict", as part of the orders in the direct channel online are stolen from the traditional retail channel (Chiang et al., 2003). Luo et al. (2016) stated that the direct channel online is taking a free ride on the pre-sales services from the retailer. Customers can have free trials of products at the retailers' stores, but they eventually purchase the products on the direct channel online. Some powerful retailers have defended themselves from this aggressively. For example, Home Depot, the largest retailer for home improvement and construction products in the United States, informed its suppliers to stop selling online; Otherwise, the partnership would be ended (Brooker, 1999). To avoid "channel conflict," some manufacturers like Levi's Strauss & Co have closed their direct channel online (Collett, 1999). At the same time, some manufacturers have tried to persuade retailers that a different market segment is targeted by the direct channel (Keenan, 1999). To avoid "channel conflict", SVSOUND provides their products under a brand "SVSOUND" to the retailer while selling products branded as "SBS-01" online(Melewar et al., 2010).

Even though the issue of channel conflicts exists, the benefits of establishing a direct channel online are modest at best (Chiang et al., 2003). Geyskens et al. (2002) indicate that the direct channel online has a positive impact on a firm's stock, so that a lower stock level can be maintained. Additionally, they found that a large firm with a few direct channels can outperform a small firm with more direct channels based on financial performance. Scholars and company managers have both realized it is a critical issue to discuss how to coordinate the direct channel and the retail channel, in order to eliminate the channel conflict and enhance the profits of both the manufacturer and the retailer. Overall, the collaboration of the dual-channel leads to challenges in term of marketing, pricing, and inventory management.

In the previous research on the dual-channel supply chain, all of the participants were assumed to be fully rational with regard to maximizing the expected utility. However, it has been shown that decision makers can be impacted by non-hyper-rational behavior patterns such as loss aversion and overconfidence. Loss aversion indicates that a person prefers to avoid losses rather than to earn a profit when making decisions under conditions of uncertainties. Kahneman and Tversky (1979) illustrated the occurrence of loss aversion by an experiment that let students choose between two options as shown in Figure 1.1. Option A gave the student 2,500 with a probability of 0.33, or 2,400 with a probability of 0.66, or 0 with a probability of 0.01. Option B gave the student 2,400 for sure. The students were informed of the outcomes of each option before making their choices. The results showed that 82% of the students prefer Option B while Option A gave a higher expected utility of 2,409.

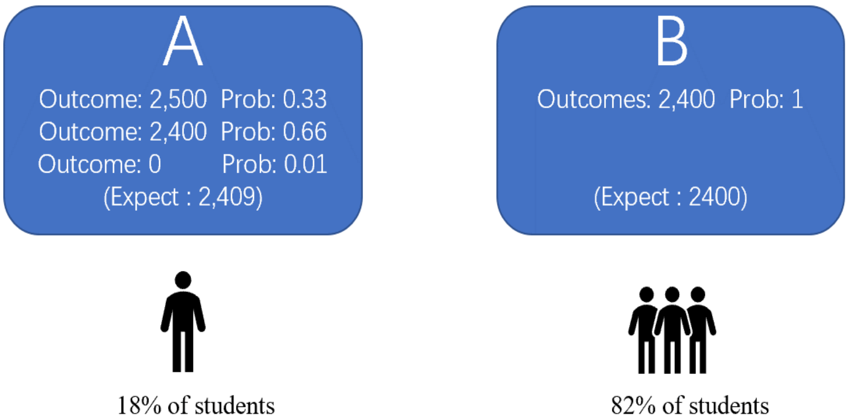

Figure 1.1 Loss aversion student experiment

Kahneman and Tversky (1979) also introduced the prospect theory which explained the decision maker's loss-averse behavior mathematically. Since loss aversion was introduced, it has been discussed in various fields, such as finance (Benartzi and Thaler, 1993; Barberis et al., 1999; Meng, 2014), and industrial organization (Kőszegi and Rabin, 2009a; Heidhues and Kőszegi, 2014). Based on the discussions on loss aversion, behavioral operations research has been developed, which is defined as "*the study of potentially non-hyper-rational actors in operational contexts*" (Croson et al., 2013).

Besides, it has been found that some people tend to be overconfident in their decision-making process. There are three kinds of overconfidence: (1) overestimation where people overrate their performance in prediction; (2) overprecision where people overrate the stability of their performance in prediction; (3) overplacement where people overrate their performance compared to the competitors in prediction. Grimes (2002) asked 253 students to estimate their performance after taking a midterm examination in Macroeconomics(as shown in Figure 1.2 (page 9)). The average expected score was 77.23, with a standard deviation of 12.45%; while the real average performance was 70.31, with a standard deviation of 15.08%.

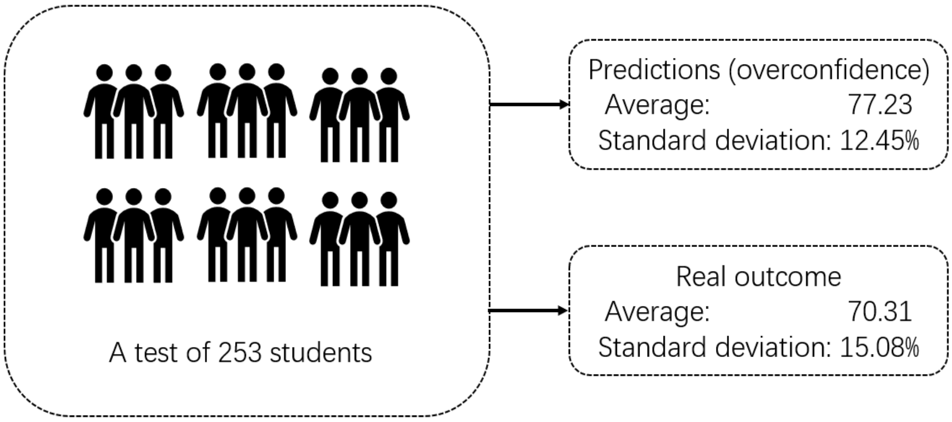

Figure 1.2 Student overconfidence experiment (adapted from Grimes (2002))

Overconfidence is found not only among students but also among the public. For example, it has been shown that people tend to be overconfident in picking the winner of a basketball game (Ronis and Yates, 1987). Overconfidence occurs in ordinary people as well as in well-trained decision makers. Braun and Yaniv (1992) found that overconfidence occurs in the economic forecasts made by experts. Entrepreneurs showed an overconfidence bias in their business decision-making processes (Busenitz and Barney, 1997). An analyst who experiences short-term earnings predictions become overconfident in future earnings forecasting (Hilary and Menzly, 2006). Compared with the results from the information acceleration method to forecast the sales of Toyota Celica with the actual sales in 1991, it turns out that the information acceleration model overestimated those sales by 10% (Urban et al., 1996). Pope and Schweitzer (2011) analyzed 2.5 million putts in a number of golf tournaments, and they found even the best players, such as Tiger Woods, in their abilities in the game.

It has been shown that the boom-and-bust effect of a new product can lead to overestimations by newsvendors, wholesalers, and manufacturers in the growth stage of the demand (Paich and Sterman, 1993). For example, in January 2016, Apple, the largest smartphone company in the world, cut iPhone's planned production by 30% in the subsequent quarter (January 2016 to March 2016). Therefore, non-hyper-rational behavior patterns, like loss aversion and overconfidence, are widespread and easily affect the decision makers. As the dual-channel supply chain is a strategy widely adopted in business, managers and scholars should study the effects of human being's non-hyper-rational behavior patterns in the dual-channel supply chain.

In this research, the idea of behavioral operations research is introduced into the dual-channel supply chain study. In the early stage of the research, This study solves one dual-channel supply chain and one overconfidence problem to lay the foundation of the research. In the first place, the sales effort deployment problem in the dual channel supply chain is solved. The basic features of the dual-channel supply channel can be explored in a discussion of the sales effort deployment problem in the dual-channel supply chain. In the second place, overconfidence in the dual-channel supply chain is discussed. A discussion of the overestimation of the competing newsvendor game provides a basic understanding of the overconfidence. In the main stage, overconfident consumers' overprecise valuation of the products is modeled in the dual-channel supply chain. The optimal pricing strategy of the manufacturer and the retailer is studied. The impacts of overconfident consumers on the dual-channel supply chain are discussed. Then, loss-averse consumers are modeled based on the prospect theory. The optimal pricing strategy facing loss aversion consumers is determined. The impacts of the loss-averse consumers on the profits of the manufacturer and the retailer are discussed.

1.2. Motivations of the research

There are two motivations behind this study of the non-hyper-rational behavioral patterns in the dual-channel supply chain.

Firstly, consumers have been observed to have non-hyper-rational behavioral patterns, like overconfidence and loss aversion, despite the wide range of empirical results. Kalyanaram and Winer (1995) indicate that consumers use reference prices in making decisions on their brand selection. For example, if the consumers have formed reference prices, the effects of sales promotions will be greatly affected. Consistent price promotions result in consumers having a lower reference price. As a result, later promotions will not be as attractive to consumers and they will feel the return to the "normal" price as a price increase. Loss-averse consumers who are more sensitive to "losses" are commonly observed as well. Consumers are especially averse to paying the price when it exceeds their expectation of the purchase price (Heidhues et al., 2008). Consumers have also been found to be overconfident. DellaVigna and Malmendier (2006) indicate that consumers are overconfident about their self-discipline with regards to attending the gym. Based on a novel dataset from 7,752 members of U.S. health clubs over three years, they found that the consumers could have saved 40% by choosing to pay-per-visit rate instead of the monthly membership fee. Grubb and Osborne (2015) found that consumers are overprecise about their cellular service demand. Using detailed data of U.S. students' cellular phone service usage from 2002 to 2004, they found that the deviation of consumers' underestimation of their future usage of their cellular phone was 62%. (Further empirical studies can be found in the literature review). In summary, it can be concluded that consumers have a variety of non-hyper-rational behavioral patterns.

Secondly, although individuals' non-hyper-rational behavioral patterns have been widely discussed in area of asset pricing(Daniel et al., 2001), inventory models (Zhao and Lv, 2011), and the newsvendor game(Ren and Croson, 2013), the study of non-hyper-rational behavioral patterns in the dual-channel supply chain is still in the early stage. For example, Easley and Yang (2015) modeled loss-averse investors in asset pricing. They found that loss aversion affects an investor's survival prospects mainly through its effects on the investor's portfolio holding. Ancarani et al. (2016) studied the overconfidence in the inventory management of the supply chain via a series of experiments. They found that overconfident inventory managers are less careful in the management of their inventories, and this leads to more costs. Therefore, they suggested that benchmarks should be provided to managers that allow them to assess their performance correctly in relative terms. In the dual-channel supply chain, Ma et al. (2016) analyzed the pricing and advertising competition in a dual-channel supply chain with overconfident manufacturers. Since the dual-channel supply chain strategy has been adopted in various industries, it leads to the question of what is the pricing strategy when consumers are overconfident or loss-averse? This is a great concern for the managers of manufacturers and retailers. While widely discussed in other fields, such as inventory management, non-hyper-rational behavioral patterns in the dual-channel supply chain urgently need to be studied.

In summary, the motivations for this study of the non-hyper-rational behavioral patterns in the dual-channel supply chain are driven by two reasons: (1) non-hyper-rational behavioral patterns are widely observed, (2) studies of non-hyper-rational behavioral patterns is in the early stage. In this study, we study the behavior of overconfident and loss-averse consumers to analyze the effects on the demands and pricing in the dual-channel supply chain. Useful managerial insights are drawn based on these research findings.

1.3. Objectives of the research

This study aims at studying the pricing strategy for the dual-channel when there are participants with non-hyper-rational behavioral patterns such as overconfidence and loss aversion. Furthermore, the impacts of customers' behavior of overconfidence and loss aversion on the dual-channel supply chain are discussed. To complete the research objective, two research stages have been defined. In the first stage, this study explores the features of the dual-channel supply chain and a typical non-hyper-rational behavioral pattern: overconfidence. The second stage is the main stage of the research which discusses the dual-channel supply chain with overconfident consumers and loss-averse consumers. The relationship between the two stages is shown in Figure 1.3

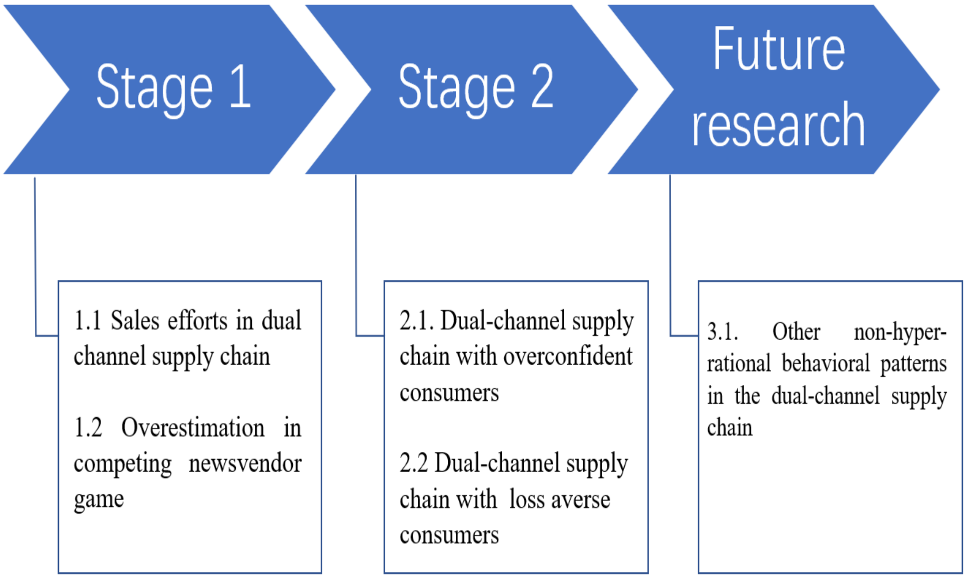

Figure 1.3 Two stages of the research

In the first stage of the research, the foundation is laid for understanding the dual-channel supply chain and the issue of overconfidence. A sales efforts deployment problem is discussed in the dual-channel supply chain. The first objective is to determine the optimal sales effort deployment for both the manufacturer and the retailer in a dual-channel supply chain. Besides, this study tries to figure out the impacts of the sales efforts on the profits of the retail channel and the direct channel (this study refer to sales effort as the activities of both the manufacturer and the retailer to increase demand such as through advertisements). The second objective is to discuss overconfidence in a competing newsvendor game which is a classical operation research problem and is less complex than the dual-channel supply chain. Additionally, the impact of the overestimated demand in the newsvendor competitive game is analyzed.

The second stage comprises the main part of this research. In this stage, overconfidence and loss aversion are studied in the dual-channel supply chain based on the foundation laid out in the first stage of this research. The third objective is to examine the pricing strategy for the dual-channel supply chain with overconfident consumers who have overprecise valuations of the product. The impacts of the overconfident consumers on the profits of the manufacturers and retailers are discussed. Then, the fourth objective is to determine the optimal prices in the dual-channel supply chain with loss-averse consumers who are more sensitive to “losses” than “gains”. The loss-averse consumers are modeled based on the prospect theory (Kahneman and Tversky, 1979). While loss aversion is reference point-dependent, the products are generally classified into two categories: 1) basic goods, which have a lower reference utility for consumers and 2) luxury goods, which have a higher reference utility for the consumers. Therefore, the optimal pricing strategy in dual-channel supply chains with regard to basic goods and luxury goods should be determined. In addition, the impacts of loss aversion on the dual-channel supply chain are analyzed.

1.4. Research Scope

This research focuses on the dual-channel supply chain in the retail industry. Under the body of knowledge for behavior operations research, it is generally classified as cognitive psychology, social psychology, group dynamics and system dynamics. This study focuses on cognitive psychology. Within cognitive psychology, there are overconfidence, loss aversion, anchoring effect. This study concentrates on overconfidence and loss aversion as those two aspects have been widely observed in human behavior.

1.5. Organization of the report

In Chapter 1, an introduction of behavioral operations research on the dual-channel supply chain is introduced, as well as describing the background of the research. Then, the research motivations for this study are described. The research objectives were identified. Finally, the organization of the report is presented.

In Chapter 2, the literature related to dual-channel supply chains and to behavioral operations research is reviewed. In the first place, the literature on dual-channel supply chains is examined with respect to pricing, inventories, and the channel coordination mechanism is reviewed. Secondly, the literature on behavioral operations research is reviewed. This study first reviews the bodies of knowledge of behavioral operations research. Then, loss aversion and overconfidence as the most widespread cognitive biases are then examined. The major empirical studies and mathematical models applied in loss aversion and overconfidence are discussed. Finally, the research gaps of behavioral operations research on the dual-channel supply chain are identified

In Chapter 3, the deployment of sales efforts in the dual-channel supply chain is discussed. A sales effort competition game is set up in a dual channel distribution between a manufacturer and a retailer. The demand under sales efforts is determined based on the consumer's valuation, the consumers' channel preference, and the sales efforts. Then, the optimal sales effort deployment is studied based on a game theory approach which allows the retailer and the manufacturer to maximize their profits. Then, this study analyzes the sales effort overlap and its impacts on the dual-channel supply chain. Finally, a summary is provided.

In Chapter 4, overestimation in a competing newsvendor game is studied. We introduce overestimation, which is one type of overconfidence, where people think they have a better performance than they have. A model of an overestimating newsvendor in the competing newsvendor game is created. In the first case, one overestimating newsvendor in the competing newsvendor game is analyzed. In the second, the competing newsvendor game with two overestimating newsvendors is discussed. Finally, a summary is provided.

In Chapter 5, overconfident consumers, who are overprecise in their valuation of a product, are modeled in the dual-channel supply chain. The demand in the dual-channel supply chain with overconfident consumers is analyzed. The optimal pricing strategy in a centralized dual-channel supply chain is first discussed. Then, a decentralized dual-channel supply chain with loss-averse consumers using the Stackelberg game theory is modeled. The optimal pricing strategy of the manufacturer and the retailer is provided. Then, a numerical example is presented to illustrate the findings. Finally, a summary of the dual-channel supply chain with the overconfident consumers is provided.

In Chapter 6, this study discusses the dual-channel supply chain with loss-averse consumers. loss-averse consumers are modeled based on the prospect theory. The demand in the dual-channel supply chain with loss-averse consumers is analyzed. Then, the optimal pricing strategy of the decentralized dual-channel supply chain with loss-averse consumers is determined. A numerical example is presented to illustrate the findings. Finally, A summary of the dual-channel supply chain with the loss-averse consumers is provided.

In Chapter 7, the conclusions of the study are revealed. The main findings of the study of the behavioral dual-channel supply chain are addressed. The contributions of the study are pointed out. The limitations of the study are explained. Additionally, future studies in the area of behavioral operations research are suggested.

2. Literature Review

2.1. Introduction

In this section, the literature related to behavioral operations research in the dual-channel supply channel is reviewed. There are two fields of literature that need to be reviewed, the first of which is the dual-channel supply chain. With the development of e-commerce, an increasing number of researchers and managers are concerned about the impact of direct channels online. One the one hand, the direct channel online from the manufacturer gives consumers more conveniences to access products. On the other hand, the direct channel online affects the profits of the traditional independent retailer. Pricing problems, inventory management, and channel collaboration are typical topics in studies of the dual-channel supply chain. The second field is behavioral operations research. In general operations research, it is assumed that the participants in the analyzed systems, such as the suppliers and retailers, are fully-rational decision makers whose decisions are not affected by their cognition and surroundings. However, increasing numbers of non-hyper-rational behavioral patterns have been found in empirical studies. Therefore, the number of behavioral operations research studies that consider non-hyper-rational behavioral patterns is rising. This leads to the necessity to revisit typical operations research and to seek improvements.

In Section 2.2, the methodology of the literature is introduced. In Section 2.3, the literature related to dual-channel supply chains is reviewed. It is focused on the pricing problem, inventory management, and on the collaboration mechanism of the dual-channel supply chain. In Section 2.4, The development of behavioral operations research is reviewed. The major works on overconfidence and loss aversion are examined. In Section 2.5, the research gap is addressed.

2.2. Review methodology

This literature review aims at providing an overview of the dual-channel supply chain and of behavioral operations research. The major works are summarized and classified. Finally, the research gaps and research opportunities are identified based on the review.

To fulfill the literature review objective, this review has followed the framework of Jenner et al. (2004) for qualitative content research. There are four major steps: 1) material collection; 2) descriptive analysis; 3) category selection; 4) material evaluation.

The literature review process was designed as shown is in Figure 2.1 (page 24). In the first step, databases are searched to obtain the possible papers related to our topic. The databases this review used for this search was Science Direct by Elsevier, Scopus, and SpringLink. As a compliment to the database, Google Scholar was used to searching for related publications. In this case, almost all the related papers were covered by these databases. To collect papers about dual-channel supply chain and behavioral operations research, a conditional search based on combinations of related keywords is conducted. The keywords were “dual-channel”, “pricing”, “behavioral operations research”, “loss aversion”, “overconfidence”, etc. In this stage, the materials were collected. Then, a quickly checked the abstract of each paper is conducted to classify them according to their topic. Next, a detailed reading of the valuable papers was conducted. While reading the main content of the papers, we adjusted the categories of the papers.

After all the related papers were classified, a well-structured literature review was completed. Through this process, a total of 181 papers were reviewed.

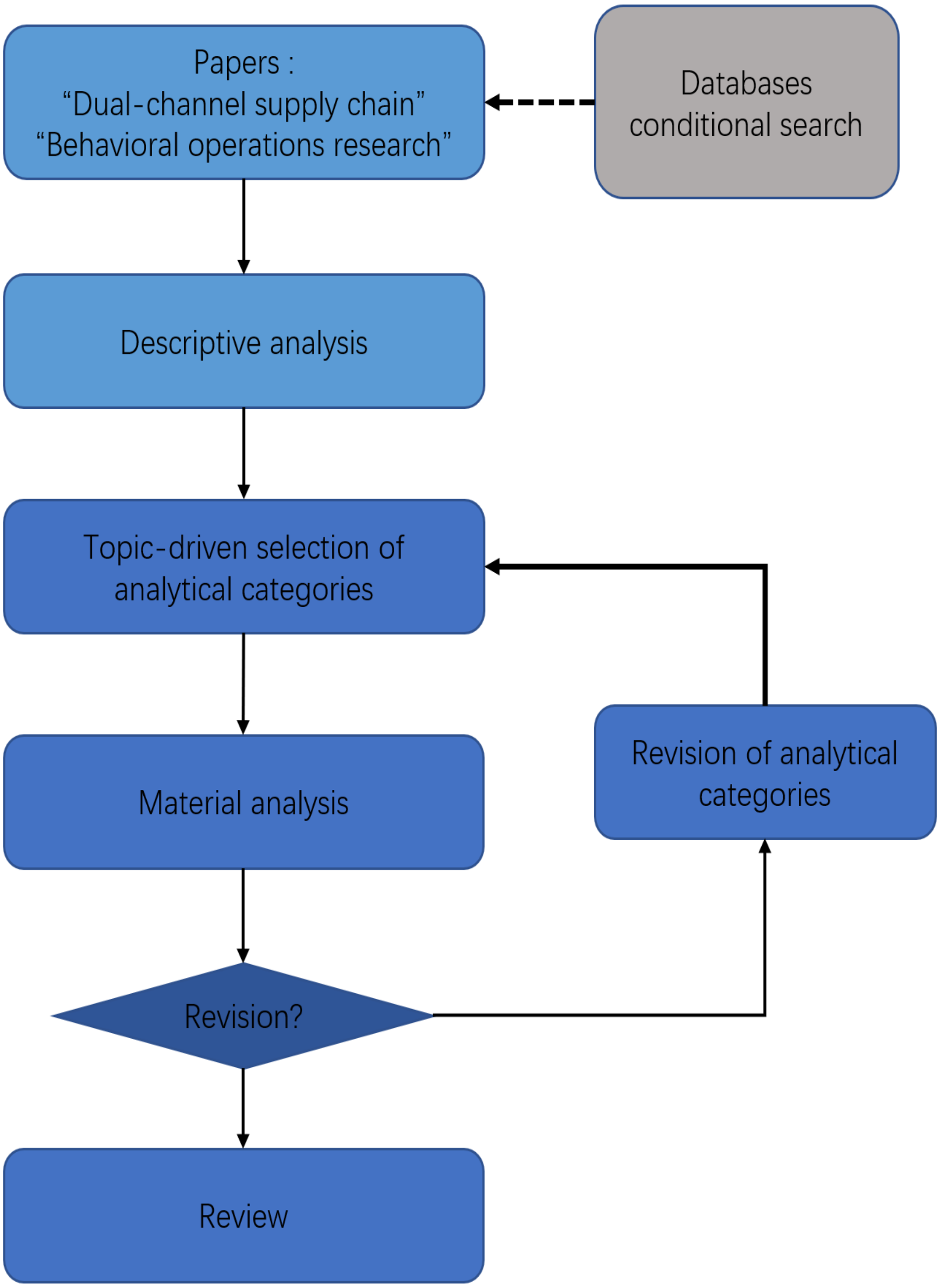

Figure 2.1 Flow chart of the literature review

2.3. Dual-channel supply chain

With highly secure online payments supported by financial institutions and low-cost delivery services provided by third-party logistics, an increasing number of consumers are beginning to shop online. This has led to the fact that B2C e-commerce has grown into an important part of the retail industry.

Retailers argue that their profits are being reduced by “channel conflict” and that orders on the direct channel should be placed through the traditional retail channel. Therefore, scholars have examined the pricing and inventory strategy under the dual-channel supply chain to identify any conflicts of interest between the retailer and the manufacturer. The direct channel and retail channel involve a competition of pricing and inventory.

At the same time, researchers have suggested many forms of mechanism to achieve coordination between the retailer and the manufacturer, and the benefits of the direct channel online are discussed.

In this section, the scope of the research involving dual-channel supply chains is presented. the literature is classified into two categories: competition and coordination. Figure 2.2 (page 26) illustrates the review structure of the dual-channel supply chains. In terms of the channel competitions, we have reviewed the work discussing the pricing-only model in the dual-channel supply chain and the pricing model with other variables, such as the retailer services and delivery time (a detailed discussion is provided in the sections below). Besides, the inventory policies in the dual-channel supply chains are reviewed. In terms of the channel coordination, we have reviewed the major works on coordination mechanism designs such as pricing schemes and profit-sharing contracts. Finally, the additional benefits of the direct channel online are reviewed.

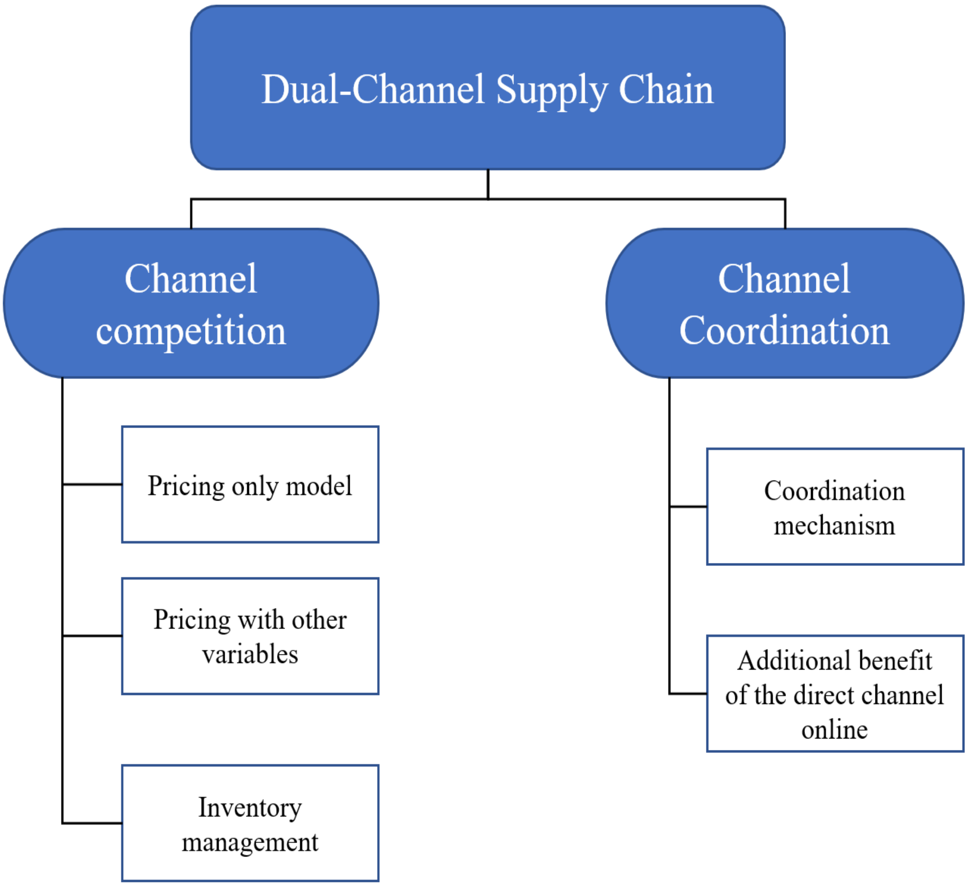

Figure 2.2 Review structure of the dual-channel supply chain

2.3.1. Channel competing in dual-channel supply chains

The pricing and inventory management of a product under a dual-channel supply chain are a critical issue for both the manufacturer and retailer. It should be pointed out that the retail channel has a low level of efficiency in pricing which leads to a higher price and a lower demand due to double marginalization (Spengler, 1950) where the existence of the retailer and the higher marginal cost of the product leads to a higher product price and a lower total profit. Jeuland and Shugan (1983) indicate that the vertically-integrated channel is the optimal option for achieving the maximum profits. Nevertheless, the direct channel can be more efficient in regard to pricing without double marginalization. Based on the nature of dual-channel supply chains, a Stackelberg game is commonly modeled with the manufacturer and the retailer. The manufacturer is the Stackelberg leader, who sets the direct price and the wholesale price in the first place. Then the retailer determines the retail price based on the direct price and wholesale price. With respect to the principle of no arbitrage, it is common for that the wholesale price to be lower than the direct channel price. Otherwise, the retailer would prefer to purchase the products through the direct channel instead of buying them wholesale. Interestingly, the actions of Stackelberg followers should be modeled in the first place when solving the Stackelberg game.

2.3.1.1. Pricing only model of the dual-channel supply chain

Much research supports the notion that applying the same price across all channels is the optimal pricing strategy. Chiang et al. (2003) modeled the demand of each channel by assuming that the consumers are rational with regard to their channel preference when choosing the channel to maximize the expected utility. They indicated that the optimal prices of the product in the retail channel and the direct channel online should be the same, while the retail channel loses consumers to the direct channel online. Fruchter and Tapiero (2005) assumed the heterogeneous consumers who have a lower valuation of the product online than the retail channel in store due to the impossibility of a physical inspection of the product. Studying the pricing problem at the infinite time horizon without a discount, they found that the optimal pricing strategy should set the same price in the retail channel and the direct channel. Cattani et al. (2006) analyzed a special case in which the retailer had strong bargaining power so that the manufacturer could only set the wholesale price, but the price of the direct channel followed the retail price set by the retailer. Martín-Herrán and Taboubi (2015) investigated the pricing strategy of dual-channel supply chains under a dynamic approach. They considered the carry-over effect which is based on Adaption Level theory (Helson, 1964) which implies that a previous price will affect the consumers' judgment. They found that there is a time interval where a dual-channel supply chain with an independent retailer performs better than a dual-channel supply chain with the retail channel controlled by a manufacturer. Moon et al. (2010) provided a computational answer for the dynamic pricing and inventory in dual-channel supply chains. Yao and Liu (2005) studied the pricing strategy under a Stackelberg game setting, with the pricing under a Bertrand game setting. They modeled the demand with respect to the consumer utility and channel preference. It was shown that in both the Stackelberg game and the Bertrand game, the dual-channel leads to cost-effective retail services. Apart from the Stackelberg game, Huang and Swaminathan (2009) compared four different pricing strategies in the dual-channel: 1) the direct channel price follows the retail price; 2) set the direct channel price to maximize the manufacturer profit; 3) set the same price across channels; and 4) maximize total profit as the retailer and the manufacturer are integrated. They concluded that the optimal direct channel price should be less than the retail channel price. Yan (2008a) extended the dual-channel study to a multi-channel study with online direct channels in the Bertrand competition and Stackelberg competition. It has been proved that a low-high pricing policy is the optimal strategy when online channels have an equal or lower marginal cost for the product. Ding et al. (2016) considered a hierarchical pricing process in the order of the wholesale price, the retail price and the direct channel price. This shows that the equal price and the price-matching strategy may be the optimal approach.

Since in the above research it is assumed that the manufacturer and the retailer shared the demand information, Yue and Liu (2006) examined the value of such information sharing in dual-channel supply chains. They concluded that the manufacturer can always be better off from sharing while the retailer only benefits from the sharing if the manufacturer's demand information is sufficient. Yan and Ghose (2010) further studied the impact of forecast information sharing of consumers' willingness to pay. This study showed that the retailer can gain more than the manufacturer by sharing information within a market with a high level of volatility. Zhou et al. (2011) have shown that the discriminate prices strategy is an effective tool in the information-sharing mechanism. Cao et al. (2013) modeled asymmetric cost information in dual-channel supply chains. They designed a wholesale contract to reach an equilibrium, where a higher retailer's cost leads to a higher wholesale price. By comparing asymmetric and symmetric costs, they also determined the value of the cost information.

Li et al. (2014b) studied the pricing strategies of the dual-channel supply chain of small and medium-sized enterprises. He et al. (2014) modeled the wholesale price to the retailer under exogenous and endogenous order transshipments since consumers searching is commonly assumed when stock out happens. As the concern for the environment is rising, the pricing and green policy in dual-channel supply chains has been discussed. Li et al. (2016) showed that the manufacturer would adopt a dual-channel supply chain when the green costs are at a critical level. Surprisingly, they found the retail channel price in a centralized green dual-channel to be higher than the retail channel price in a decentralized green dual-channel supply chain. Saha (2016) first modeled a three-echelon dual-channel supply chain, which showed that the optimal retail price is always larger than when there is a retail channel only. The inconsistent prices between the direct channel and the retail channel can generate more profit than a consistent price across channels. Soleimani (2016) determined the optimal pricing strategy when some of the variables are fuzzy.

2.3.1.2. Pricing model with other decision variables

To further analyze the issue of pricing in dual-channel supply chains, scholars have considered additional factors such as sales efforts, retail services, and demand disruptions. Tsay and Agrawal (2004) further analyzed a dual-channel supply chain with the assumption that the demand of each channel is in proportion to the total demand that was affected by the sales effort in each channel. They indicated that the manufacturer and the retailer could increase their profits by reducing the wholesale price. Dumrongsiri et al. (2008) drew the same conclusion by studying utility of consumers who are sensitive to the service quality. Yan and Pei (2009) studied retail service in the dual-channel pricing model. They found that competition in the services leads to better retail services which benefit the retailer with a lower wholesale price and a larger sales volume. Dan et al. (2012) further analyzed the retail services in decentralized and centralized dual-channel supply chains. They showed that a centralized dual-channel supply chain should have better retail services and higher prices. Li and Li (2016) further analyzed the pricing with retail services with respect to the retailer's fairness concerns. It has been found that the efficiency of dual-channel supply chains decreases with the fairness concerns of the retailer and the increasing consumer loyalty to the retailer. With respect to the retail services in the dual-channel supply chain, Hu and Li (2012) applied a model with an unknown demand distribution, which showed that the retailer services and profits should increase with the demand means. Yan and Ghose (2010) suggested a computational approach for the pricing strategy in a dual-channel supply chain where remanufactured products can be sold in both direct and retail channels. Hua et al. (2010) introduced the lead time of delivery as a decision variable in the dual-channel supply chain. In the decentralized dual-channel supply chain, the shorter the lead time of delivery, the higher the price in the direct channel and lower the price in the retail channel. Later on, Xu et al. (2012) reached a similar conclusion by taking lead time as a decision variable that delivery time should slow down due to competition between the direct channel online and the retail channel. Tsao and Su (2012) established a dual-channel pricing model with different warranty lengths. Huang et al. (2012) brought demand disruption into the dual-channel supply chain, which leads to penalties due to a deviation. Prices should be raised when a demand disruption occurs. Additionally, it shows that the central decision maker can benefit from the demand disruption. Panda et al. (2015) studied the pricing of a dual-channel supply chain regarding replenishment policies. It is assumed that the unit cost of the product is decreased continuously.

Since risk-neutral agents were always assumed in the prior research, Li et al. (2014a) introduced a risk-averse retailer in a dual-channel supply chain where the manufacturer remained risk neutral. It turned out that the retail price and the order quantity decrease as the retailer raise its aversion to risk. All the studies above discussed a single product sold in a dual-channel supply chain. However, it shows that the manufacturer always has a product line combined with various products. Rodríguez and Aydın (2015) analyzed the case where the retailer has to determine a subset of products to sell while all products of the manufacturer are available online. They found the retail price and the direct price should follow the "equal effective margin". Ma et al. (2013) analyzed a closed-loop dual-channel supply chain with a government consumption-subsidy to consumers. It was shown that government subsidies contribute to the expansion of the closed-loop dual-channel supply chain. Due to the limited storage of the manufacturer, Xiao and Shi (2016) argued that the supply priority within the retailer channel and the direct channel is an important issue. They found that the supply in the retailer should take precedence if there is a low surplus in the retail channel. The additional variables considered in the pricing of a dual-channel supply chain are summarized in Table 2.1 below.

Table 2.1 Additional variables modeled in pricing of a dual-channel supply chain

Additional variables	Paper
Service	Dumrongsiri et al. (2008) Yan and Pei (2009) Dan et al. (2012) Li and Li (2016)
Unknown demand distribution	Hu and Li (2012)
Remanufactured products	Yan and Ghose (2010)
Lead time of delivery	Hua et al. (2010) Xu et al. (2012)
Warranty lengths	Tsao and Su (2012)
Demand disruption	Huang et al. (2012)
Replenishment policies	Panda et al. (2015)
A risk-averse retailer	Li et al. (2014a)
Subset of products	Rodríguez and Aydın (2015)
Government consumption-subsidy	Ma et al. (2013)
Supply priority	Xiao and Shi (2016)

2.3.1.3. Inventory management in dual-channel supply chains

The other challenge to be addressed in dual-channel supply chains is inventory management. When a direct channel online is introduced, the product demand structure is changed. Therefore, the inventory allocation strategy should be redesigned to connect with the inventory and to balance the inventory levels in the retailer's warehouse and the manufacturer's warehouse. Additionally, inventory management is a key element of the order fulfillment capacity of the manufacturer and the retailer. A well-maintained stock level leads to satisfying demand and lower operation cost. When the manufacturer establishes a direct channel online, a two-echelon dual-channel supply chain is generally modeled while the upper echelon is the warehouse of the manufacturer and the lower echelon is the storage of the retailer.

Previously, the multi-echelon inventory problem was studied under the assumption that no relationship exists among echelons (Clark and Scarf, 1960). Based on this assumption, scholars tried to minimize the backorder (Sherbrooke, 1968), determined the optimal lots size and safety stock (Grahovac and Chakravarty, 2001), and considered a repairable system (Diaz and Fu, 1997). Two-echelon dual-channel supply chains contribute to the study of which two-echelon inventory systems are interacted with by consumers' searching when stockout occurs. Chiang and Monahan (2005) first modeled the two-echelon dual-channel supply chain and found that it is a dominant strategy when compared to the retail-only and direct channel-only strategies, where the total demand is split between each channel linearly due to the channel preference. This research only provided a primary result because it applied assumptions of a one-for-one inventory replenishment policy and allowed for backorders. Lee and Wu (2006) discussed the inventory replenishment policies in a two-echelon supply chain with respect to the bullwhip effect in the supply chain. They introduced a statistical process control replenishment policy by setting an upper control limit and lower control limit. Their simulations showed that the statistical process control replenishment policy outperforms the traditional event-triggered policy and time-triggered policy. Mitra (2009) developed a two-echelon inventory management model with returns in a deterministic model and a stochastic model. To formulate a general inventory policy, different holding costs at the different echelons and setup costs were considered. Yao et al. (2009) studied three different inventory policies: decentralized inventory management, Stackelberg inventory management and outsourcing of inventory management to a third party. It should be pointed out that outsourced orders of direct channels are better even if the saved cost per unit is less than the unit fee. Chiang (2010) modeled stock out-based inventory management in the context of a dual-channel supply chain. He showed that the channel efficiency is reduced with a low level of double marginalization due to channel competition. Then, the setup of production and delivery was considered in the two-echelon dual-channel supply chain (Takahashi et al., 2011), in which the production begins when the inventory drops to a minimum level. Takahashi et al. (2011) showed that the higher the consumer preference for the direct channel, the lower the total cost. Later on, Parvini et al. (2014) further extended the two-echelon dual-channel supply chain with the return rate which is dependent on the demand. The dynamic programming approach was applied to solve the problem. It showed that managing a depot for returns to the retailer is more important for cost reduction. Carrillo et al. (2014) studied the stocking decisions under dual-channel supply chains regarding environmental issues. Yu et al. (2015) proposed the optimal warehouse management procedures in dual-channel supply chains when an incentive policy for deteriorating items is applied.

2.3.2.Channel conflict and coordination

While most managers and scholars acknowledge channel conflict, some scholars argue that “channel conflict” does not always occur. Rhee and Park (2000) stated that the dual-channel supply chain is an optimal strategy for both manufacturers and retailers when consumers share a similar valuation of the products through different channels. In Rhee’s model, products in the retail channels give higher value to consumers due to the retailer services with no channel preference in the model. Chiang and Monahan (2005) state that the dual-channel structure is preferred by the manufacturer and the retailer if consumers’ channel preference is in a certain range. However, Tsay and Agrawal (2004) analyzed the sales efforts in dual-channel supply chains and argued that dual-channel supply chains are always not preferred by the manufacturer. Cai (2010) further compared the dual-channel structure with different channel structures, finding that a dual-channel can benefit the manufacturer more than the direct channel online-only strategy. According to the literature above, it can be concluded that a dual-channel supply chain is always optimal for the manufacturer. However, the retailer would prefer a dual-channel supply chain in limited situations. Therefore, this leads to the question of how to coordinate the retail channel and the direct channel online to provide profits for both the manufacturer and the retailer.

2.3.2.1. Coordination with the mechanism design

Since the dual-channel supply chains can only provide benefits for manufacturers and retailers in limited situations, scholars have tried to design a mechanism to coordinate the dual-channels with a common sense approach. Boyaci (2005) established a model with an independent manufacturer and a retail channel with respect to inventory management under a stochastic demand system. Frustratingly, he found that the simplest mechanisms such as buy-back contracts and the price-only contracts cannot coordinate the profits of the manufacturer and the retailer. Although a penalty contract, where a unit penalty is applied for every unsatisfied demand can achieve coordination, since unsatisfied demand is difficult to be observed, the penalty contract is almost impossible to be practiced in business. In order to eliminate the channel conflict and achieve coordination in the decentralized dual-channel supply chain, some mechanisms have been developed. The profit-sharing contract between the retailer and the manufacturer has been discussed most. Yan (2008b) proposed a profit-sharing contract which makes manufacturers and retailers split the profit increase by the dual-channel structure. Chen et al. (2012) stated that a contract for the arrangement of the wholesale price between the manufacturer and the retail and the direct channel price can only benefit the retailer but not the manufacturer. However, implementing a two-part tariff or a profit-sharing agreement leads to a win-win situation. A two-part tariff contract sets the wholesale price to be equal to the unit production cost. Meanwhile, lump sum fees will be charged to the retailer. The profit sharing arrangement allows the retailer and the manufacturer to set channel-wide linear sharing to achieve the coordination. Cai (2010) proposed a pricing strategy with a revenue sharing contract for the profit increase to reach both the manufacturer and the retailer. It should be pointed out that Cai's pricing strategy set the price of the retail channel higher than the price in the direct channel. Chiang (2010) coordinated the inventory competition in the dual-channel supply chain with stock-out substitution using a linear contract. At the same time, the revenue will be shared in the same proportions. Ryan et al. (2013) discussed a minimum retail price constrained revenue sharing contract where the revenue of the retail channel will be shared due to the minimum retail price the manufacturer offers to the retailer and a gain/loss sharing contract, which would allow the manufacturer to have a share in the gains and losses of the retailer. of the retailer. They found that when the retailer own a large share of the market, the manufacturer could apply these contracts to formulate a pricing strategy. Cao (2014) first modeled the demand disruption of both channels in the coordination of the dual-channel supply chain. He introduced a revenue-sharing contract with a wholesale price arrangement for coordination. It has been shown that the higher the disruption, the higher the wholesale price will be. He also calculated the value of the demand disruption information. Shang and Yang (2015) further analyzed the factors of risk preference and negotiation power in the coordination of the dual-channel supply chains. They designed a profit-sharing contract to redistribute the extra profit in the dual-channel supply chain. Panda et al. (2015) considered replenishment policies, and the proposed a profit-sharing contract and adjusted the wholesale price to achieve the coordination.

Other than profit-sharing contract, there are other mechanisms such as pricing discount contracts and tariff contracts will be reviewed in the following part. Cai et al. (2009) introduced price discount contracts and pricing schemes to reduce channel conflict, which would benefit the retailer and manufacturer through the retail channel. It assumes two types of consumer in the market: retailer loyal and brand loyal. Additionally, they discussed the situation where the retailer is powerful enough to be the Stackelberg leader. They concluded that the retailer may not have the advantages of the manufacturer. Xu et al. (2014) proposed a two-way sharing contract to eliminate the channel conflict in the dual-channel supply chains with risk-averse players. This two-way sharing contract allows the manufacturer to obtain a fraction of profit from the retailer channel and the retailer to receive a partial profit from the direct channel to achieve the channel coordination. Huang et al. (2013) modeled the production cost disruptions in dual-channel supply chains. It has been shown that production plans of the dual-channel will be impacted by a product disruption only when a certain threshold is exceeded. Zhang et al. (2015) figured out a method to handle both the demand disruption and a production cost disruption, which is a modified two-part tariff contract where a moderate lump sum fee is charged to achieve the coordination of the dual-channel supply chain. In most cases, only the lump sum fee charged to the retailer needs adjustment to coordinate the dual-channel supply chain. Besides, they found a contract adjustment benefit zone where the manufacturer and the retailer can gain by an adjustment of the contract when the demand increases or production cost drops. Li et al. (2014b) designed a retailer transshipment dual-channel model and stated that transshipment with a designed price can achieve channel coordination.. Li et al. (2016a) modeled a green dual-channel supply chain which also applied a two-part tariff contract. In this case, the lump sum fee should fall into a range between the upper limit and lower limit to coordinate the manufacturer and the retailer. Luo et al. (2016) further analyzed the free-riding effect within the dual-channel supply chains, which is not necessarily harmful to the retailer. An interesting finding suggests that an increased free riding leads to a lower price disparity in the dual-channel supply chain. Then Luo designed a three-part tariff contract based on the orders and the service level, to achieve a win-win situation. This contract encourages the retailer to enhance its service level and eases the price competition in the dual-channel. Since a three-echelon dual-channel supply chain was proposed, a combined downward direct channel discount contract is designed for coordination (Saha, 2016). The mechanism above has the contract involved, but Pei and Yan (2015) suggested using a supportive retail services strategy which would let the manufacturer offer financial support to the retail services. They found that the manufacturer would like to invest more in the supportive retail services if the product is more compatible with the online channel. Liao et al. (2015) considered a dual-channel hotel distribution system with hotel rooms available both online and offline. It found that the commission override model is effective for improving a hotel's profit. The commission override model is the combination of a wholesale contract and a consignment contract. In a summary, the mechanisms for channel coordination are grouped in Table 2.2

Table 2.2 Mechanism for channel coordination

Mechanism	Paper
Profit sharing contract	Yan (2008b) Chen et al. (2012) Cai (2010) Ryan et al. (2013) Cao (2014) Shang and Yang (2015) Panda et al. (2015)
Price discount contracts	Cai et al. (2009)
Linear contract	Chiang (2010)
Two-way sharing contract	Xu et al. (2014) Zhang et al. (2015)
Transshipment with a designed price	Li et al. (2014b) Zhang et al. (2015) Li et al. (2016a)
Two-part tariff	Chen et al. (2012)
Three-part tariff contract	Luo et al. (2016)
Supportive retail services strategy	Pei and Yan (2015)
Combination of a wholesale contract and a consignment contract.	Liao et al. (2015)

2.4. Behavioral operations research

In the literature reviewed above, there is an embedded assumption of rational behavior as (1) selecting the preference with higher value; (2) making conscious, cognitive, and deliberate decisions; (3) making decisions with full information, and can discriminate useful information; and (4) optimizing the benefits when compared with the payoff (Simon, 1986). However, an increasing number of observations of non-hyper-rational behaviors are reported, such as overconfidence and loss aversion. In the last few decades, scholars engaged in behavioral operations research have taken human being's non-hyper-rational behaviors into consideration. Croson et al. (2013) define behavioral operations as "*the study of potentially non-hyper-rational actors in operational contexts*". There are two major tasks in behavioral operations research: 1) identifying the non-hyper-rational behavioral patterns that exist in human judgment and decision-making in operational contexts through surveys or empirical studies; 2) modeling non-hyper-rational behavioral patterns in the operations to improve work outcomes, such as profit and productivity. In this chapter, we provide a brief introduction of the contributing domains of in behavioral operations research.

In recent years, both the number and diversity of papers in the field of behavioral operations have been increased Loch and Wu (2007) surveyed the research methodologies and summarized operation problems in behavioral operations research. The research methods involved in behavioral operations research are field case studies, controlled experiments, survey methods, math modeling, and simulation. Loch and Wu (2007) classified behavioral operations problems into two groups: (1) individual decision-making biases, such as prospect theory and regret theory; and (2) social preferences, such as decisions influenced by emotions and group identity. Then they proposed the cultural studies in behavioral operations research as a potential future research area.

Bendoly et al. (2010) further provided a theoretical foundation of behavioral operations research. They summarized the four bodies of knowledge that are related to behavioral operations: cognitive psychology, social psychology, group dynamics, and system dynamics as shown in Figure 2.3 (page 46).

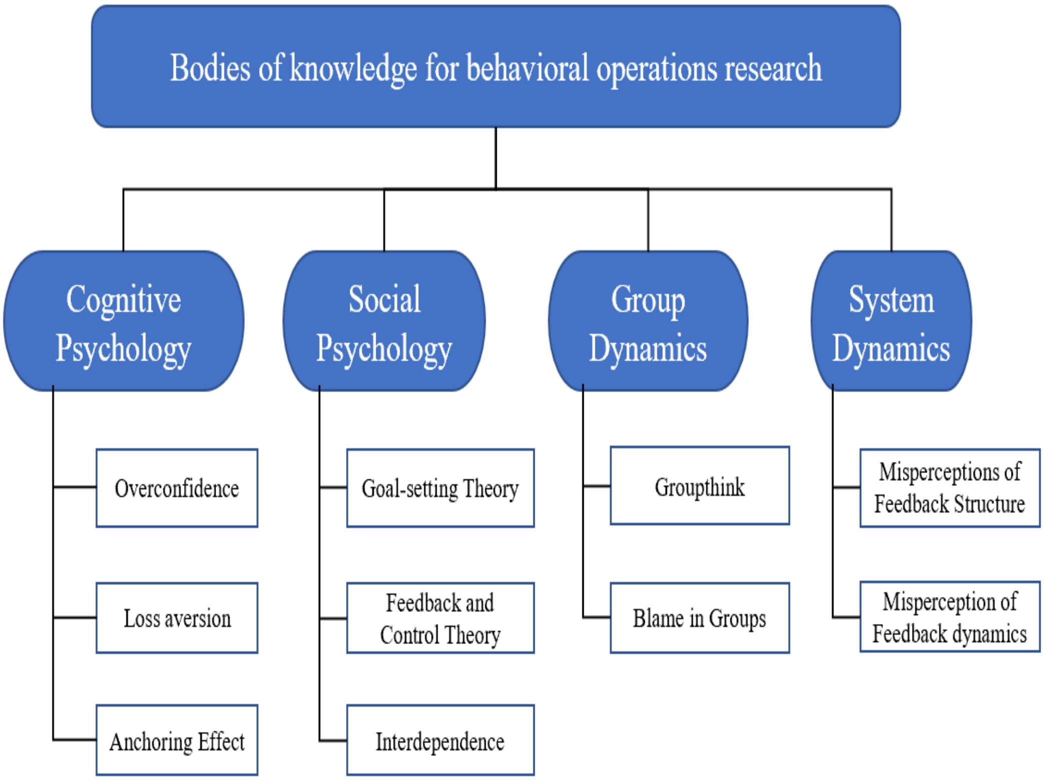

Figure 2.3 Bodies of knowledge for behavioral operations research

Cognitive psychology focuses on the individual decision-making processes that deviate systematically. Bendoly et al. (2010) further classified these systematic deviations into two groups: heuristics and biases. Heuristics involve the rule of thumb that people use to make decisions, which occurs during the process of decision-making. Overconfidence is a typical heuristic trait. Biases are the observed deviations in decision-making which describe the outcomes of the decisions. Loss aversion is one of the typical biases. Most heuristics and biases are identified through experiments and empirical studies.

Social psychology is related to the organizational psychology research that studies how individuals' motivation is affected by the settings of the organization.

The individual's efforts, persistence, and planning are impacted by motivations consciously or unconsciously. In turn, the motivation is affected by the person's mindset, the feedback they receive and interaction with the people around. The following part gives a brief introduction of the theories developed based on goals, feedback, and interdependence. Latham and Locke (1991) introduced goal setting theory that the goal of the individual in a task has a profound effect on the performance of the individual. Sevier (1992) found that the lack of a clear goal leads to failure in a JIT (Just-in-Time) project implementation. The feedback and control theory suggests the people use the feedback they have received to regulate their behavior (Campion and Lord, 1982). The interdependence theory focuses on how an individual's motivation is impacted by the performance and efforts of his/her co-workers.

While cognitive psychology and social psychology focus on the individual's decision-making, group dynamics investigates how individuals jointly make decisions as a group. "Groupthink" and "blame" are typical group dynamics issues that have been discussed in operations research. Groupthink is defined as "a mode of thinking that people engage in when they are deeply involved in a cohesive in-group when the members" (Janis, 1982). Therefore, groupthink requires the members to share a strong "we feeling". The blame in groups indicates that individuals tend to blame others for poor outcomes (Bendoly and Swink, 2007). Weber et al. (2001) indicate that the subjects in larger groups blame the leader more frequently, as has been revealed in experiments.

System dynamics involve studies of the system-level decisions that deviate from the normal and the designs of mechanisms to improve them (Bendoly et al., 2010). Therefore, system dynamics often focus on a higher level than individual and group behaviors. The feedback process is one of the main topics in system dynamics. Misperceptions of feedback in a structure is an error in the system dynamics, in that people will apply deficient mental models, which change the structure and behavior of the system, to guide their decisions. For example, Dana Jr and Petruzzi (2001) show that when newsvendors provide feedback to consumers of product availability, the newsvendors should maintain a higher inventory level. Misperceptions of feedback dynamics are another error in system dynamics in that people can realize the feedback structure in the system but are not capable of recognizing its impact. For example, it is difficult for people to estimate exponential growth when the growth rate and the forecast horizons are large (Wagenaar and Sagaria, 1975).

The main objective of this study is to determine and analyze the pricing strategy of the dual-channel supply chain with loss-averse or overconfident consumers. Therefore, the literature related to overconfidence, loss aversion, and the anchoring effect shall be reviewed in detail in the following parts of this study.

2.4.1.Overconfidence

The phenomenon of “overconfidence” was first discovered in1969 (Alpert and Raiffa, 1982). However, Russo and Schoemaker (1992) contributed to drawing scholars’ attention after he proved that managers tend to be overconfident. Russo and Schoemaker (1992) asked managers to provide a confidence range for its estimations for ten general-knowledge questions. Most managers have a confidence level of above 90%. However, on average, managers make correct estimations only five out of 10 times. In other words, they are overconfident about the correctness of their estimations.

Then, some studies investigated the relationship between overconfidence and individuals’ characteristics, such as gender and age. Kovalchik et al. (2005) compared the overconfidence level of elderly individuals (average age 82) and younger individuals (average age 20). It demonstrated that the elderly are less overconfident than the youth. Van Loon et al. (2017) monitored the learning of children ranging from age 7 to 12. Interesting, the trend of overconfidence is declining with age when the child is studying difficult concepts. Barber and Odean (2001) analyzed transactions over 35,000 securities household accounts. It showed that men are more overconfident than women. Huang and Kisgen (2013) supported that men are more overconfident than women and that women execute fewer acquisitions and issue fewer debts than men. Lundeberg et al. (2000) investigated 551 postsecondary students from 25 universities in five countries. The results showed that individuals' overconfidence level is related to their country and culture.

It has been found that overconfidence can affect decision-making in a variety of fields. It has been shown that individuals tend to be overconfident in the success rate of entry into a new business (Camerer and Lovallo, 1999). Zacharakis and Shepherd (2001) indicated that 49 out of 51 participating venture capitalists were overconfident in the investment decision-making process, overrating the likelihood of success of the project. Croson et al. (2008) indicated that the newsvendor tends to be overprecise in its demand forecast. They experimentally showed that overpreciseness could explain one-third of the order mistakes in Schweitzer and Cachon's (2000) research. Schweitzer and Cachon (2000) drew attention to the decision bias in the newsvendor game by experiments which showed that students, as participants, tend to order more low-profit margin products and less high-profit margin products. The phenomenon found by Schweitzer and Cachon (2000) is called the "pull to center" effect. Bolton et al. (2012) came to the same conclusion by setting the managers as experiment participants. Malmendier and Tate (2005) analyzed 477 large publicly traded U.S. firms in the years of 1980 to 1994. They found CEOs likely to be overconfident and result in corporate investment distortion. Malmendier et al. (2007) indicated that managers of firms, who tend to be confident, believe that their firms are undervalued and external financings are overpriced. Goel and Thakor (2008) indicated that the board prefers to promote overconfident executives to CEO.

Gervais and Odean (2001) found that traders are learning to be overconfident in the process of knowing its ability to earn. Based on this, Chuang and Susmel (2011) compared individual and institutional investors. It turns out that individual investors are more overconfident because they are more aggressive and tend to invest in risky securities. Hirshleifer et al. (2012) showed the positive side of overconfidence. They analyzed the preference of CEOs in public listed firms from 1993 to 2003. The CEOs of innovative industries, who have more confidence, would invest more in research and development projects, leading to highly innovative successful cases.

Since overconfidence can affect decision-making in a variety of industries, many studies have modeled overconfidence and analyzed the impacts. Burnside et al. (2011) modeled the overconfident investor and found that overconfidence can be an explanation for the premium puzzle. Ren and Croson (2013) used an overconfident bias model to explain the “pull-to-center effect” observed by Schweitzer and Cachon (2000). Li et al. (2016b) introduced overconfident participants into the competing newsvendor game. They introduced the model of the overconfident newsvendor who has an overconfident demand distribution D defined as:

$$D: \ \alpha\mu + (1-\alpha)X \tag{2.1}$$

where X is the random distribution of the newsvendor, μ is the mean of the random distribution, $E(X)=\mu$, and α is the parameter that measures overconfidence, $\alpha \in [0,1]$. If $\alpha = 0$, the newsvendor is not overconfident. Demand though by the newsvendor is not affected by overconfidence, $D = X$. If $\alpha = 1$, the newsvendor is extremely overconfident, and the newsvendor thinks the demand is constant, $D = \mu = E(X)$.

Based on this model, Li et al. (2016b) showed that overconfidence can positively increase competing newsvendor profit. Ma et al. (2016) studied overconfident manufacturers in a dual-channel supply chain structure with two manufacturers. It is a simplified dual-channel supply chain that has two independent manufacturers. Wang et al. (2015) investigated the ordering strategy and disposing of the policies of overconfident retailers. It shows that a retailer's profit is not always reduced by overconfidence. Herweg and Müller (2016) modeled overconfident buyers in the used goods market where buyers have limited information about the quality of the product. The outcomes showed that overconfident buyers can prevent adverse selection.

2.4.2.Loss aversion

Samuelson (1963) first illustrated “loss aversion” by reporting that his colleague refused a bet that would have a half chance to win \$200 and a half chance to lose \$100. Kahneman and Tversky (1979) explained “loss aversion” by introducing the “prospect theory”. According to the prospect theory, a concave weighting function should be multiplied by unbiased utility regarding the reference point, and a convex weighting function should be multiplied by the unbiased utility. Kőszegi and Rabin (2006) explored the setting of the reference point in the prospect theory. They assumed the reference point is determined by the environment which is an individual’s rational expectations according to observations of past outcomes.

Therefore, the expected utility based on prospect theory should be:

$$U=\sum_{i=1}^{n}\pi(p_i)v(x_i) \tag{2.2}$$

where U is the expected utility of the decision maker, x_i are the outcomes that could happen in the future, and p_i are the possibilities of the outcomes x_i. Therefore, $\pi(p_i)$ is the weighting function of the utility of the outcomes $v(x_i)$. A typical utility function based on prospect theory is shown in Figure 2.4 (page 54). It passes through the reference point. The outcomes above the reference point are recognized as gains, and the outcomes below the reference point are recognized as losses. Additionally, the curve for losses is steeper than gains suggesting that losses outweigh gains.

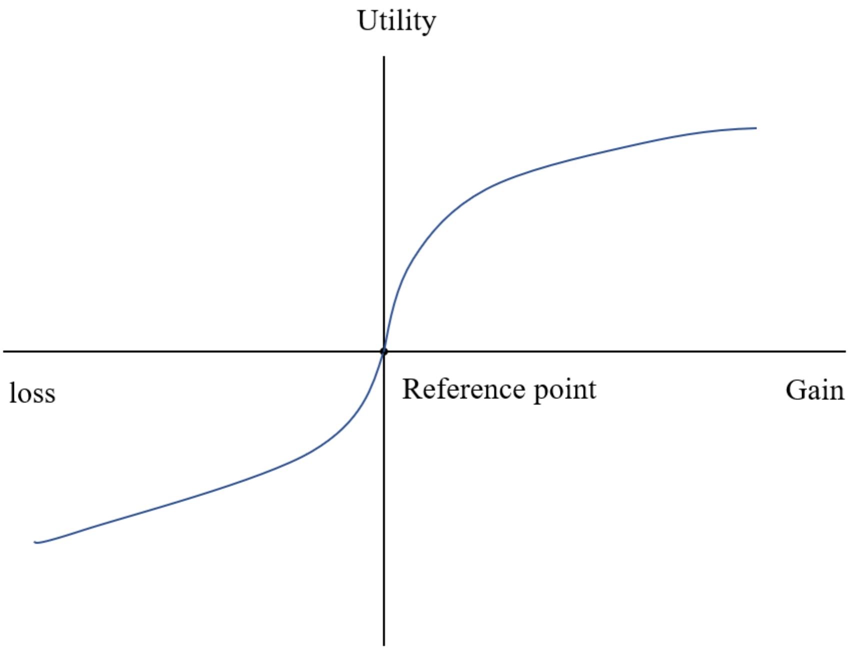

Figure 2.4 A typical utility function based on the prospect theory

There are numbers of experiments exploring loss aversion in a variety of fields. Thaler et al. (1997) experimentally investigated the effect of loss aversion on risk taking. They indicated that loss-averse investors prefer to take risks while their investments are reviewed less often. Odean (1998) monitored the records for 10,000 accounts. It was found that investors strongly prefer realized gains to realized losses. Genesove and Mayer (2001) analyzed housing market data from Boston. They found that sellers had shown evidence of loss aversion which can explain the positive correlation between price and volume in real estate markets. Schmidt and Traub (2002) tested the preference conditions for loss aversion and found female subjects to have a higher chance of being loss-averse than males. Based on 50,000 customers' insurance data, Sydnor (2010) found that customers are loss-averse in that customers are willing to buy a plan with low deductibles where the cost is significantly higher than its value. Dimmock and Kouwenberg (2010) collected survey data for household portfolios. They found that higher loss aversion leads to the lower direct holding of securities. Loss aversion promotes indirect holding such as mutual funds.

Loss aversion has been modeled and discussed in many industries. Barberis and Huang (2008) studied a one-period asset pricing problem considered by loss-averse investors. They indicated that positively skewed securities would be overpriced while negatively skewed securities would be underpriced. Kőszegi and Rabin (2009b) developed a dynamics model for consumption planning with loss-averse individuals. It showed that loss-averse individuals overconsume early if the news resonates more with current consumption. Shi and Xiao (2008) modeled two loss-averse retailers in a supply chain. Buyback contracts and markdown-price contracts are designed to coordinate retailers. Heidhues and Kőszegi (2014) discussed the pricing strategy of a rational retailer facing loss-averse consumers. They indicated that loss aversion could have positive effects on the retailer.

The newsvendor game, as a classical problem for supply chain management, has been widely discussed with the consideration of loss aversion. Wang and Webster (2009) indicated that there is a larger optimal order in the loss-averse newsvendor problem. Then, Wang (2010) extended loss aversion to the newsvendor game and found the “loss-averse effect” can decrease the total order quantity. Long and Nasiry (2014) modeled loss aversion with a positive reference point and explained the inconsistent derivation from the optimal order found by Schweitzer and Cachon (2000). Liu et al. (2013a) further analyzed the loss-averse newsvendor game with product substitution. However, in the dual-channel supply chain, we only found that Nicolau (2013) discussed reference point-dependent loss aversion in the dual-channel in respect of tourism packages in a multinomial logit model. It has been found that consumers tend to be loss-averse in the direct channel online.

2.4.3.Anchoring effect

The anchoring effect is one of the most common cognitive heuristics. Tversky and Kahneman (1974) described the anchoring effect as the disproportionate influence on decision-makers to make judgments that are biased toward an initially presented value (the "anchor"). It suggests that people tend to rely on the first acquired information to process the subsequent decisions. Blankenship et al. (2008) illustrated the anchoring effect through an experiment. They invited 53 students and divided them into two groups. For the first group, they gave students a material which mentions the age of 48(the anchor). For the second group, age 23 (the anchor) was mentioned in the material. Then, they asked the students the age of Neil Armstrong when he walked on the moon. In the results, the first group gave answers around the age of 45. The second group of students gave answers near the age of 25 as shown in Figure 2.5.

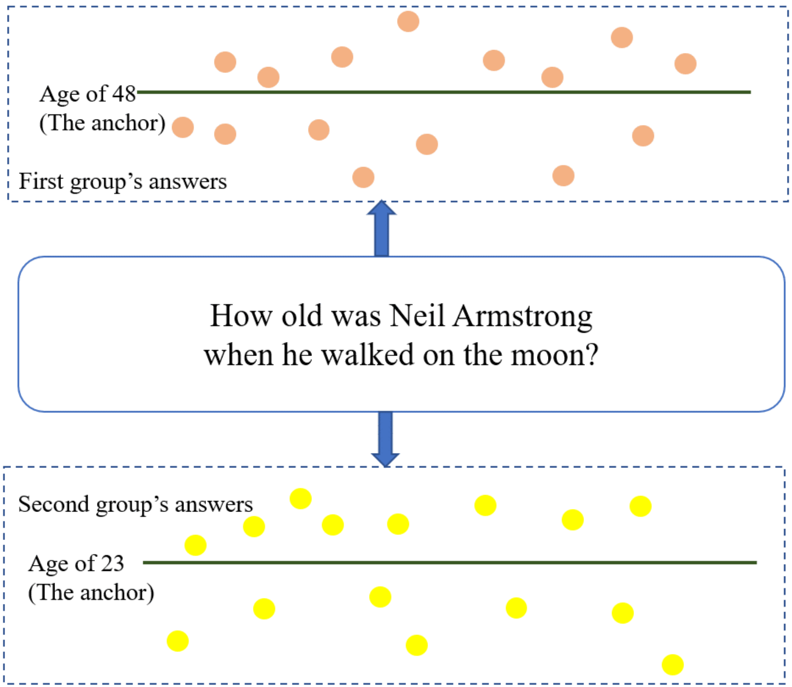

Figure 2.5 The anchoring effect experiment by Blankenship et al. (2008)

The anchoring effect has been observed in many fields. Mussweiler (2001) illustrated the juridical decision makings can be affected by the anchoring effect. He found that sentience which is demanded by the attorney or prosecutor or recommended by a probation officer is likely to be an anchor and the results can be influenced by these anchors. Ariely et al. (2003) found that consumers' valuations of products are anchored even if full information is provided. However, the anchor for consumers seems to be arbitrary. Sometimes, the social security number can be the anchor. Northcraft and Neale (1987) found that the anchor effect exists in the appraised value of real estate. Their experiments indicated that the appraised value deviates from the actual value by around 10% when an anchor is provided to real estate agents. Critcher and Gilovich (2008) experimentally showed that: (1) people's estimation of the performance of an athlete can be anchored by the number on his jersey; (2) the sales forecast of the domestic market can be anchored by the product's model number; (3) the estimation of spending in a restaurant can be anchored by the number in the name of the restaurant. Besides, the anchoring effect has been observed in many domains, such as general knowledge (McElroy and Dowd, 2007; Mussweiler and Englich, 2005) and negotiation (Mussweiler and Englich, 2005)

While observations of the anchoring effect are increasing, explanations of the anchor effect are needed. Tversky and Kahneman (1974) hold the view that people make their final estimation based on the adjustment of the provided initial value. The initial value serves as the reference point for the adjustment. The anchoring effect occurs when insufficient adjustment is made. However, the existence of the adjustment process is doubted in the anchoring effect. It has been demonstrated that the anchoring effect influences the decision maker in a subliminal manner (Mussweiler and Englich, 2005). The other explanation of the anchoring effect is "*confirmatory hypothesis testing*" (Chapman and Johnson, 1999; Mussweiler and Strack, 1999; Wegener et al., 2010). It suggests that the provided initial information is activated information in the decision-making process. The decision maker subconsciously thinks that the anchor value is a plausible answer. Then, the hypothesis that the anchor value and similar values of the anchor value are the correct answer is tested in the mind. Therefore, the anchoring effect is an information activation process.

From the explanations of the anchoring effect, it can be seen that the anchoring effect is very difficult to be mathematically modeled. Therefore, most anchoring effect research used experiments or data analysis. Wansink et al. (1998) studied the impacts of consumers' purchase quantity decisions with the anchoring effect. They modeled consumers whose default anchor is low (quantity of one or two) with insufficient upward adjustment. Then, field experiments on supermarket consumers were conducted. They found that consumers' quantity decisions can be influenced by the "suggestion", such as justified stockpiling and anchor-based promotions. Campbell and Sharpe (2009) analyzed the anchoring effect in monthly-released financial data. They found that professional forecasts are impacted by the anchoring effect based on the previous values released. Bokhari and Geltner (2011) analyzed the anchoring effect and loss aversion in U.S. commercial real estate using sales data in the year from 2001 to 2009. They found that the anchoring effect has larger effects on the transaction price of real estate than loss aversion does. Park et al. (2011) studied the anchoring effect in the pricing strategy of new products. Consumers are anchored by the price of the existing product. The result suggests that new product prices will be higher than the profit-maximizing price of the fully-rational model.

2.5. Research gap

From the review of the dual-channel supply chain, it can be shown that most papers on the dual-channel supply chain focus on the pricing and coordination of channels. There are few studies focused on the marketing and sales efforts in the dual-channel supply chain. However, marketing is a critical issue in business. Both manufacturers and retailers invest a lot in their sales efforts. Liu et al. (2013b) determined the co-op advertising model in dual-channel supply chains where the manufacturer and the retailer share the total advertising fee linearly. This strategy is not easy to be put into practice due to the independence of the retail channel and the direct channel online. Therefore, the sales effort deployment problem in the decentralized dual-channel supply chain is urged to be solved. To fulfill this research gap, sales efforts deployment in the dual-channel supply chains is studied in the first stage of research. This study aims at identifying optimal sales effort deployment in dual-channel supply chains.

In the research of sales efforts in the dual-channel supply chain, we realized that the “economic man” who maximizes the expected profit is a foundation assumption of the research. However, according to the literature review, it has been found an increasing number of papers reporting the non-hyper-rational behaviors of decision makers, such as loss aversion and overconfidence. At the same time, there are also increasing numbers of studies that discuss the impact of the non-hyper-rational behaviors of decision makers in economics, finance, corporate management, and supply chains. However, behavioral operations research about the dual-channel supply chain is still in the early stage. There is a limited number of studies investigating the impacts of the non-hyper-rational behaviors on the dual-channel supply chain. We only found that Ma et al. (2016) studied overconfident manufacturers in a dual-channel supply chain structure with two manufacturers. Because dual-channel supply chains are widely adopted in business, it is important to study the non-hyper-rational behaviors in dual-channel supply and provide useful insights to managers. To fulfill this research gap, overconfident consumers and loss-averse consumers in the dual channel supply chain is modeled and discussed in the second stage. Additionally, current studies on the anchoring effect in mainly focus on empirical analysis, while the anchoring effect is difficult to be mathematically modeled in the supply chain. This research gap will be fulfilled in future research.

3. Sales Efforts Deployment in a Decentralized Dual-Channel Supply Chain

As discussed in the literature review, there are arguments for “channel conflict” between the retail channel and direct channel. It has been stated that the direct channel online can increase the cooperative profit in the price setting game among manufacturers and individual retailers (Chiang et al., 2003). At the same time, the dual-channel distribution strategy has been widely accepted by firms of various industries. However, the sales operation of the manufacturer and the retailer is facing challenges posed by the dual-channel supply chain. This study aims at determining the optimal sales effort deployment for both the manufacturer and the retailer in a dual-channel distribution. Besides we try to figure out the impact of sales efforts on the profit of the retail channel and direct channel. We refer to sales effort as the activities of both the manufacturer and the retailer to increase demand such as via advertisements. We formulate this problem in two stages. In the first stage, we determine the demand of each channel by assuming rational consumers who try to maximize their utility in the purchasing process. Then, the retailer and the manufacturer deploy their optimal sales efforts according to the demand and the response of each other. Additionally, we assume that the price of a product is fixed and consistent in both the retail channel and the direct channel online.

This chapter is organized as follows. In Section 3.1, the consumers’ valuation under the sales efforts of the manufacturer and retailer is modeled. In Section 3.2, we introduce "consumers' channel preference". In Section 3.3, we analyze the demand of the dual-channel supply chain under sales efforts and consumers' channel preference. In Section 3.4, we determine the optimal sales efforts deployment dual-channel supply chain. Additionally, a discussion of the optimal sales efforts is provided. In Section 3.5, a numerical example is presented. Finally, in Section 3.6, a summary is provided.

3.1. Sales effort on consumers' valuation

In this part, we introduce the consumers' valuation of the product and how sales effort impact on it. We assume that each consumer has a heterogeneous valuation (v) of the product. The distribution function of valuation ($n(v)$) indicates the number of consumers who share the specific valuation v. We define the distribution with the following properties: $n(v)$ is a continuous function such that:

$$v = 0, n(v) = 0 \tag{3.1}$$

$$v = \infty, n(\infty) = 0 \tag{3.2}$$

$$Any \;\; v \epsilon R_+ \, n(v) \geq 0 \tag{3.3}$$

Let $N(v) = \int_0^v n(u)du$, indicates the number of consumers who have a valuation between [0, v]. Additionally, we normalized the market size to one. Therefore, $N(v)$ is a monotonically increasing function such that:

$$v = 0, N(v) = 0 \tag{3.4}$$

$$v = \infty, N(\infty) = 1 \tag{3.5}$$

In this research, we measure sales effort in proportion to the increasing demand. For instance, if the original demand is D, the demand will increase to $(1 + s)D$ while a sales effort s is put on the market. We define the distribution of the consumer's valuation under sales effort (s) as ($n'(v)$), such that:

$$n'(v) = n(v)(1 + s_d + s_r - s_r * s_d) \tag{3.6}$$

where： s_r is the sales effort from the retail channel

s_d is the sales effort from the direct channel

$s_t = s_d + s_r - s_r s_d$, is the overall sales effort on the market, where $s_r * s_d$ is the overlap between the sales efforts from the retail channel and the direct channel ($s_r \cap s_d$). Figure 3.1 shows the overall sales effort on the market in a dual-channel supply chain. It illustrates the overall sales effort distribution under sales efforts from both the direct channel and retail channel. For example, when sales effort from the retail channel is 0.18 and the sales efforts from the direct channel is 0.15, the total sales efforts of the dual-channel supply chain to consumers is 0.3.

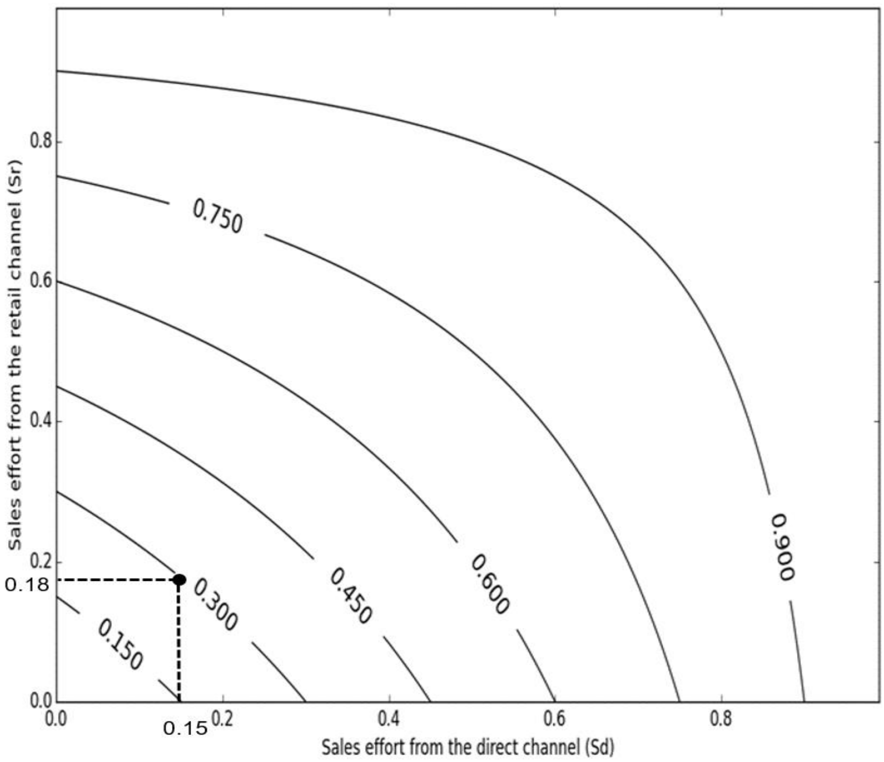

Figure 3.1 Overall sales efforts on the market

3.2. Customer's channel preference

In this part, we define the customer's channel preference between the direct channel online and the traditional retail channel as θ. Let 1 to be the neutral value of the customer's channel preference. In this case, $\theta = 1$ means that consumers can buy the product either in the retail channel or online direct channel. $\theta > 1$, means that consumers prefer the direct channel over the retail channel. $\theta < 1$ indicates that consumers prefer the retail channel over the direct channel.

Although shopping online has been widely accepted by consumers for its convenience, consumers may still prefer the retail channel over the direct channel $(\theta < 1)$. Kacen et al. (2013) conducted a survey and showed that the mean channel preference range from 0.8 to 0.92 for durable and nondurable goods. Consumers prefer to buy the products through the traditional retail channel due to the low service quality in the direct channel online (Devaraj et al., 2002).

Based on consumers' channel preference, the consumer's expected value of the product is θv in the direct channel online while the expected value of the product is v in the retail channel. Due to consumers' preference of channels, there is a valuation deviation between the retail and direct channels, $v\,(1 - \theta)$.

3.3. The demand for the direct channel and the retail channel

In the dual-channel supply chain, we assume that a consistent price of the product is fixed as p in both the direct and retail channel. AnthemMarketingSolutions (2015) released a semi-annual report of online and offline pricing of consumer goods, which included a number of regularly, purchased categories. It showed that 71 % of reviewed items have the same price across the retail channel and the online direct channel. Moreover, 88% of Hardware/Home Improvement items had the same price both offline and online.

When a customer purchases a product in a retail channel, consumers not only consider product price p but also the channel access cost. For instance, when a customer decides to buy a product from a retail store, it involves traveling and time costs. If a customer intends to buy a product via the direct channel, it involves the delivery fee and the time spent waiting for delivery. We define the access cost of the direct channel as c_d, and access cost of the retail channel as c_r. As the direct channel on the Internet is much more convenient to access, we assume that the access cost of the retail channel is larger than for the direct channel, $c_r > c_d$.

According to the assumptions above, the utility of customers π_c is set when they purchase through a direct channel or retail channel as:

$$\pi_c = \begin{cases} v - p - c_r\,, & if\ purchased\ from\ retail\ channel \\ \theta v - p - c_d, & if\ purchased\ from\ direct\ channel \end{cases} \tag{3.7}$$

We assume that all the consumers try to maximize their utility in the purchase process. If the product cannot provide positive utility to the consumer, the consumer will walk away. Otherwise, the customer will choose the channel which gives larger utility to the consumer in the transaction. For consumers whose product valuation meets the condition, $v - p - c_r \geq 0$ ($v \geq p + c_r$), they will consider buying the product from the retail channel. We define the minimum valuation required for purchase via the retail channel, v^r, as the sum of the price and access cost of the retail channel, $v^r = p + c_r$. Similarly, the minimum valuation for purchasing via the direct channel is v^d, which should be the sum of the price of the product and the access cost of the direct channel over the channel preference, $v^d = (p + c_d)/\theta$. When both channels have positive utility for a consumer, he or she will choose the channel with the larger utility. Then, the breakeven valuation (v^{rd}) for channel selection is the valuation with the same utility by both channels, $v - p - c_r = \theta v - p - c_d$. Therefore, we have a breakeven valuation value $v^{rd} = \frac{c_r - c_d}{1-\theta}$. When $\theta > 1$, consumers who have a valuation larger than v^{rd} will select the direct channel (online sales). Correspondingly, for $\theta < 1$, consumers who have a valuation larger than v^{rd}, will select the retail channel.

When $\theta > 1$, it can be shown that the value of v^{rd} is smaller than zero, and $v^d = \frac{p+c_d}{\theta} < v^r = p + c_r$. There will always be $v^{rd} < 0 < v^d < v^r$. In this case, consumers, whose valuation is larger than v^d will buy the product via the direct channel online. Other consumers whose valuation is smaller than v^d will walk away without any transaction. Intuitively, sales effort from the retail channel is zero while demand of the retail channel (D_r) is zero.

When $\theta < 1$, there is a relationship between the minimum purchase valuations $v^d < v^r < v^{rd}$[1]. In this case, consumers whose valuation is larger than v^{rd} will buy the product via the retail channel. Then, we consider the case $v^r < v^d$ under $\theta < 1$. Following the same proof as above, it can be shown that: $v^{rd} < v^r < v^d$. Consumers, whose valuation is larger than v^r, will buy the product via the retail channel.

In summary, demand in the direct and retail channels under different consumers' channel preferences is:

$$D_d = \begin{cases} (1 - N(\frac{p+c_d}{\theta}))(1 + s_d) & if\ \theta > 1 \\ (N\left(\frac{c_r - c_d}{1-\theta}\right) - N\left(\frac{p+c_d}{\theta}\right))(1 + s_r + s_d - s_d s_r) & if\ \frac{p+c_d}{p+c_r} < \theta < 1 \\ 0 & if\ \theta < \frac{p+c_d}{p+c_r} \end{cases} \tag{3.8}$$

$$D_r = \begin{cases} 0 & if\ \theta > 1 \\ (1 - N(\frac{c_r - c_d}{1-\theta}))(1 + s_r + s_d - s_d s_r) & if\ \frac{p+c_d}{p+c_r} < \theta < 1 \\ (1 - N(p + c_r))(1 + s_r + s_d - s_d s_r\ ) & if\ \theta < \frac{p+c_d}{p+c_d} \end{cases} \tag{3.9}$$

where $c_r > c_d$*is assumed.*

[1] When $\theta < 1$, there is $v^d < v^r$. If $v^d < v^r$, then $v^d - v^r < 0$, which implies $\theta > \frac{p+c_d}{p+c_r}$. The product of $v^{rd} - v^r$ is $\frac{c_r+c_d}{1-\theta} - (p + c_r) > \frac{c_r+c_d}{1-\frac{p+c_d}{p+c_r}} - (p + c_r)= p + c_r - (p + c_r) = 0$. Therefore, $v^d < v^r < v^{rd}$

3.4. Sales effort deployment in the dual-channel supply chain

In this part, a decentralized dual-channel supply chain is modeled. The price of a product is p in both the retail channel and the direct channel (online). The average cost of the product is c for the manufacturer. The manufacturer offers a wholesale price ω to the retailer for every product. Since the retailer is independent of the manufacturer, a sale effort setting game between the manufacturer and the retailer is formed. The objective of the manufacturer and the retailer is to maximize their profits by deploying sales effort independently. We assume that the manufacturer and the retailer share common knowledge about the demand of both the direct channel online and the retail channel. The structure of the model is shown in Figure 3.2 (page 72).

Corresponding to the sales effort either from the retail channel and the direct channel online, there are the costs of sales effort. We assume that the cost of the sales effort is linear to the quadratic of the sales effort. There have been many previous research studies related to retailing with a similar cost structure (Lau et al., 2010); (Iyer, 1998). We define sales effort cost as C_s such that: $C_s = \eta s^2/2$ where s is the sales effort, and η is the cost of the sales effort. Let η_r and η_d be the costs of the squared sales effort in the retail and direct channels.

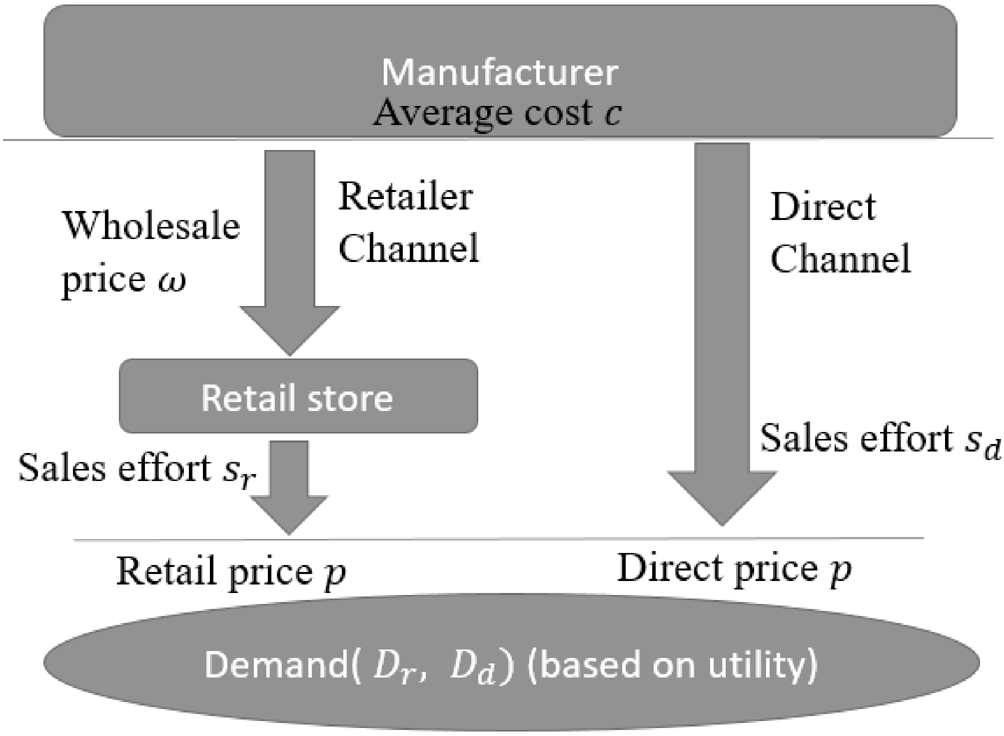

Figure 3.2 Structure of a decentralized dual-channel supply chain

Then, the profit of the retailer can be modeled as the revenue through the retail channel minus the sales effort cost of the retail channel:

$$\pi_r = (p - \omega)D_r - \frac{\eta_r s_r^2}{2} \tag{3.10}$$

The profit of the manufacturer is the overall revenue from the direct channel and wholesale from the retail channel minus the sales effort cost of the direct channel:

$$\pi_m = (\omega - c)D_r + (p - c)D_d - \frac{\eta_d s_d^2}{2} \tag{3.11}$$

According to the demand function above and the utility of the manufacturer and the retailer, the optimal sales effort can be determined by game theory in the following scenarios. The optimal sales efforts under three different types of channel preference are tabulated in Table 3.1 (The proof of uniqueness and existence is provided in Appendix 1). From Table 3.1, it can be found that (a) When consumers only choose the direct channel, $\theta > 1$, the optimal sales effort by the manufacturer increases with the revenue of the direct channel, $(p-c)\left(1-N\left(\frac{p+c_d}{\theta}\right)\right)$, decreasing with the cost of the sales effort of the direct channel, η_d. (b)When consumers choose both the direct channel and the retail channel for purchasing, $1 > \theta > \frac{p+c_d}{p+c_r}$, the optimal sales efforts by the manufacturer and the retailer decrease with the cost of the sales efforts of both direct channel and retailers, η_d and η_r. (c) When consumers only choose the retailer channel for purchasing, $\frac{p+c_d}{p+c_r} > \theta > 0$, then the optimal sales effort of the retailer increases with the cost of the sales effort of manufacturers. At the same time, the optimal sales effort of the manufacturers decreases with the cost of the sales effort of the retailers.

Furthermore, several propositions are presented below:

Proposition 3.1 *When consumers prefer a direct channel (online store) rather than a retail channel, the optimal sales effort increase with the preference of the direct channel, with an upper boundary of* $(p-c)/\eta_d$.

Proof:

As consumers only purchase via the direct channel, the optimal sales effort of the manufacturers is

$$s_d^* = \frac{(p-c)(1-N(\frac{p+c_d}{\theta}))}{\eta_d} \tag{3.12}$$

Table 3.1 The optimal sales effort strategy to maximize profit under different channel preference θ

Channel Preference θ	$\theta > 1$	$1 > \theta > \frac{p+c_d}{p+c_r}$	$\frac{p+c_d}{p+c_r} > \theta > 0$
Marginal value relationship	$1 > v^r > v^d$	$1 > v^{rd} > v^r > v^d$	$v^d > v^r > v^{rd}$
Sales effort of retail channel s_r^*	0	$\frac{(l+m)l-\eta_d l}{(l+m)l+\eta_d\eta_r}$	$\frac{ab-\eta_d a}{ab-\eta_d\eta_r}$
Sales effort of direct channel s_d^*	k/η_d	$\frac{(l+m)(l-\eta_r)}{(l+m)l+\eta_d\eta_r}$	$\frac{ab-\eta_r b}{ab-\eta_d\eta_r}$
Sales effort overlap $s_d^* * s_r^*$	0	$\frac{(l+m)(l-\eta_r)(l+m-\eta_d)l}{((l+m)l+\eta_d\eta_r)^2}$	$\frac{(ab-\eta_d a)(ab-\eta_r b)}{(n-\eta_d\eta_r)^2}$

$k = (p-c)\left(1-N\left(\frac{p+c_d}{\theta}\right)\right)$ **: Profit of the manufacturer in direct channel without sales effort if** $\theta > 1$

$l = (\omega-c)(1-N(\frac{c_r-c_d}{1-\theta}))$ **: Profit of the manufacturer in retail channel without sales effort if** $1 > \theta > \frac{p+c_d}{p+c_r}$

$m = (p-c)(N\left(\frac{c_r-c_d}{1-\theta}\right) - N\left(\frac{p+c_d}{\theta}\right))$ **Profit of the manufacturer in direct channel without sales effort if** $1 > \theta > \frac{p+c_d}{p+c_r}$

$a = (p-\omega)(1-N(p+c_r))$ **: Profit of the manufacturer in retail channel without sales effort if** $\frac{p+c_d}{p+c_r} > \theta > 0$

$b = (\omega-c)(1-N(p+c_r))$ **: Profit of the manufacturer in retail channel without sales effort if** $\frac{p+c_d}{p+c_r} > \theta > 0$

where $c_r > c_d$, $v^r = p + c_r$, $v^d = \frac{p+c_d}{\theta}$, $v^{rd} = \frac{c_r-c_d}{1-\theta}$

Consider $\frac{\partial s_d^*}{\partial N(\frac{p+c_d}{\theta})} = -1 < 0$ and the fact that $N(v)$ is a monotonically increasing function, $\frac{\partial s_d^*}{\partial \frac{p+c_d}{\theta}}$ is always less than zero. Therefore, the optimal sales effort increases with the preference of the direct channel ($\frac{\partial s_d^*}{\partial \theta} > 0$). In the other words, even if all consumers choose the direct channel, the sales department of the manufacturer should have more sales activity while the consumers' preference for the direct channel is increasing. There is an upper boundary of sales effort of the manufacturer given as:

$$\lim_{\theta \to \infty} s_d^* = \lim_{\theta \to \infty} \frac{(p-c)(1-N(\frac{p+c_d}{\theta}))}{\eta_d} = (p-c)/\eta_d \tag{3.13}$$

Assume that manufacturers make the optimal sales effort on the market, and the contributed profit (CP) should be the revenue increased by the sales activities minus the cost of the sales effort. Therefore, manufacturers' contributed profit (CP) by the sales effort is shown below, when all consumers choose the direct channel:

$$CP = \pi_m(with\ sales\ efforts) - \pi_m(without\ \ sales\ efforts)$$

$$= \frac{(p-c)^2(1-N\left(\frac{p+c_d}{\theta}\right))^2}{2\eta_d} = 0.5(p-c)(1-N\left(\frac{p+c_d}{\theta}\right)s_d^* \tag{3.14}$$

This shows that the contributed profit of the manufacturer is half of the increased revenue from the sales effort when the optimal sales effort is made.

Proposition 3.2 *In the dual-channel supply chain, the retailer's profit could be limited by the sales effort cost of the manufacturer. The manufacturer's profit is limited by the cost of the sales effort of the retailer.*

Proof:

The optimal sales efforts of the manufacturer and the retailer can be presented in the following form:

$$\mathrm{s}_{\mathrm{r}}^{*} = \frac{(l+m-\eta_d)l}{(l+m)l+\eta_d\eta_r} \tag{3.15}$$

$$\mathrm{s}_{\mathrm{d}}^{*} = \frac{(l+m)(l-\eta_r)}{(l+m)l+\eta_d\eta_r} \tag{3.16}$$

From the equations above, the optimal sales effort of the retail channel, $\mathrm{s}_{\mathrm{r}}^{*}$ will be less than zero while the cost of the sales effort by direct channel η_d is larger than the total profit that manufacturer gained from the retail channel and the direct channel without sales effort, $l+m$. At the same time, the optimal sales effort from the direct channel $\mathrm{s}_{\mathrm{d}}^{*}$ will be a negative value when the cost of the sales effort by retail channel η_r is larger than the manufacturer's profit from the retail channel without sales effort l. However, the sales effort can only be larger or equal to zero. In this case, no sales effort will be expected from the retail channel or the direct channel. Therefore, the retailer's profit and the manufacturer's profit cannot be maximized to its potential maximum due to the low efficiency of the sales effort of the other channel. We define the threshold sales effort of the direct channel and retail channel as:

$$\widehat{\eta_d} = l + m \tag{3.17}$$

$$\widehat{\eta_r} = l \tag{3.18}$$

Where: $l = (\omega - c)(1 - N(\frac{c_r - c_d}{1-\theta}))$

$$m = (p - c)(N\left(\frac{c_r - c_d}{1-\theta}\right) - N\left(\frac{p + c_d}{\theta}\right)),$$

In order to avoid a negative optimal sales effort, it is suggested that the manufacturer and the retailer collaborate with each other to keep the cost of the sales effort at a low level.

Proposition 3.3 *When customers only buy a product via the retail channel, the optimal sales efforts by the manufacturer and the retailer are the same in reaching the potential maximum profits.*

Proof:

When only the retail channel has the demand, the optimal sales efforts from the manufacturer and the retailer are:

$$s_d^* = \frac{ab - \eta_r b}{ab - \eta_d \eta_r} \tag{3.19}$$

$$s_r^* = \frac{ab - \eta_d a}{ab - \eta_d \eta_r} \tag{3.20}$$

Where $a = (p - \omega)(1 - N(p + c_r))$

$$b = (\omega - c)(1 - N(p + c_r))$$

Since the profit of the manufacturer and the retailer increase with the optimal sales effort, we try to maximize the optimal sales effort with respect to the cost of the sales effort of the manufacturer and the retailer that managed by operation of the manufacturer and the retailer. The following equations show the optimal condition of the costs of sales effort.

$$\frac{\partial s_d^*}{\partial \eta_d} = \eta_r(ab - \eta_r b)(ab - \eta_d \eta_r)^{-2} = 0 \tag{3.21}$$

$$\frac{\partial s_r^*}{\partial \eta_r} = \eta_d(ab - \eta_d a)(ab - \eta_d \eta_r)^{-2} = 0 \tag{3.22}$$

It should be noted that the following equation must hold in order to meet the optimal condition above.

$$\eta_r(\omega - c) = \eta_d(p - \omega) \tag{3.23}$$

It is important for the retailer and the manufacturer to maintain the cost based on the retail price, wholesale price and average cost. If we consider the Equation (3.21) and (3.22) according to Equation (3.23), it is indicated that the optimal sales effort from the retailer is equal to the optimal effort from the manufacturer:

$$s_d^* = s_r^* \tag{3.24}$$

3.5. Numerical example

In this section, a numerical example of sales effort deployment is demonstrated. We assume that consumers' valuation distribution is a standard lognormal distribution with a total of 10,000 consumers. The lognormal distribution is the distribution Y=ln(X), where X is a standard normal distribution. The probability distribution function and cumulative distribution fit our assumption about the consumer valuation distribution (Equations (3.1), (3.2), (3.3), (3.4) and (3.5)). The price of a product is set as US$5 in both the direct channel online and the retail channel. The manufacturer offers a wholesale price of US$4.5 to the partner retailer. The manufacturer's average cost of the product is US$4. For the consumers, the accessing cost of the retail channel is US$0.6 while the access cost of the direct channel (online store) is US$0.1. At the same time, the retailer's sales effort rate is 0.1 while the rate of sales effort' cost of the manufacturer is 0.2.

According to the model introduced above, we can have a breakeven channel preference between the retail channel the direct channel of $\frac{p+c_d}{p+c_r} = 0.91$. We present the optimal sales efforts and corresponding demand and profits under different channel preferences in Table 3.2, as follows:

Table 3.2 Example of sales effort deployment in different channels preferences

channel-preference	**1.1 (Direct channel only)**		**0.95 (Both channels)**		**0.8 (Retail channel only)**	
s_r^*	0		0.29		0.19	
s_d^*	2.65		0.1		0.92	
$s_r * s_d$	0		0.029		0.17	
	without sales effort	with sales effort	without sales effort	with sales effort	without sales effort	with sales effort
D_r	0	0	2337	3181(36%)*	4527	8745(93%)*
D_d	5315	19442(265%)*	2366	3220(36%)*	0	0
π_r	0	0	1168.5	1548(32%)*	2264	4354(92%)*
π_m of R	0	0	1168.5	1590(36%)*	2264	4362(93%)*
π_m of D	5315	12378(133%)*	2366	3211(36%)*	0	-838
π_m total	5315	12378(133%)*	3535.5	4801(36%)*	2264	3534(56%)*

"π_m of R " is the manufacturer's profit from the retail channel

"π_m of D" is the manufacturer's profit from the direct channel online

***shows the difference between the value before the sales effort and after the sales effort in percentage**

While the direct channel dominates the market due to high consumer preference ($\theta = 1.1$), it shows that a large sales effort from the manufacturer (2.65) is needed to reach the optimal profit, which also shows that the potential market size is huge. The product sold through the direct channel has increased by 265% to 19,442 units compared to sales of 5,312 units without sales effort. This leads to a profit of US$12,378 which is more than twice the profit without sales effort. When all consumers choose the direct channel, Figure 3.3 (page 81) shows the optimal sales effort from the manufacturer in relation to the consumers' preference. At the same time, the increasing rate slows down with consumers' channel preference. According to Proposition 1, the upper boundary of sales effort is$(p - c)/\eta_d$ which tends towards a value of 5. It can be found that when a consumer's channel preference is relatively low, taking the value of 2, the optimal sales effort increases with channel preference at a high ratio. In this scenario, the manufacturer can increase its profit by enhancing the consumer's channel preference. If consumers have a channel preference of 0.95, there would be a win-win situation for the manufacturer and retailer. For the retailer, the demand of the retail channel increases by 36% with sales effort of 0.29. At the same time, the retailer's overall profit reaches US$1,548, an increase of 32%. Surprisingly, the demand for the direct channel and the manufacturer's profit increase by 36% with only a sales effort of 0.1. The manufacturer benefits from the sales activities of the retailer. However, based on Proposition 2, the threshold cost of the sales effort of the direct channel is 0.353 which is larger than the current direct channel's cost of the sales effort. At the same time, the threshold cost of the sales effort of the retail channel is 0.117 which is larger than the current cost of the retail channel. This guarantees that both channels can make sales efforts on the market in the optimal situation.

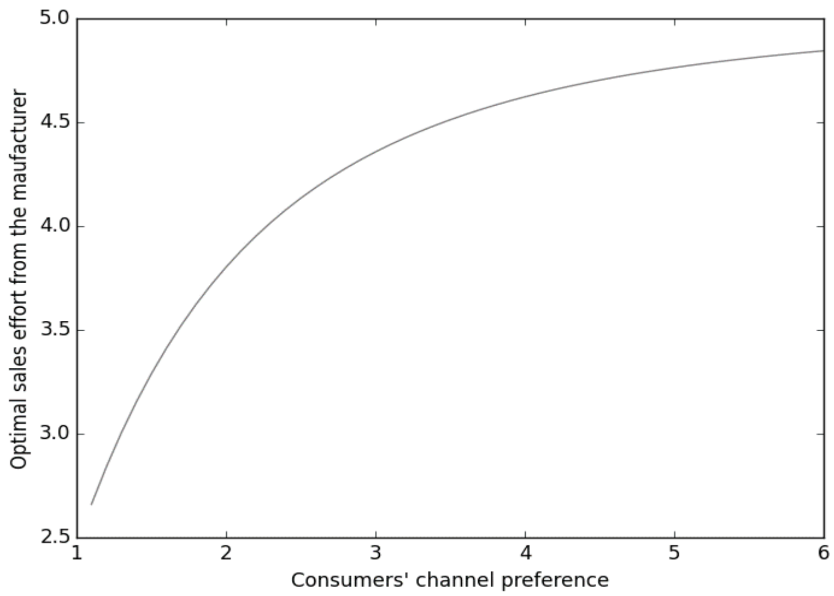

Figure 3.3 The optimal sales effort respects to consumers' channel preference

Furthermore, we analyze the optimal sales efforts and profits of the retailer and the manufacturer while the retailer's cost of sales effort is rising as shown in Figure 3.4. It indicates that once the retailer's cost of sales effort exceeds the threshold rate $\widehat{\eta_r}$, the optimal sales effort of the direct channel will reduce to zero. Meanwhile, the corresponding sales effort of the retailer and overall sales effort will drop to a low level. This also illustrates that the profits of the manufacturer and the retailer decrease with the retailer's cost of sales effort. Once the retailer's cost of sales effort reaches the threshold value $\widehat{\eta_r}$, both the retailer and the manufacturer suffer profit losses where the manufacturer loses more. Therefore, it is important for the manufacturer and the retailer to ensure that each other has a cost of sales effort which is lower than the threshold. Otherwise, both the manufacturer and the retailer will suffer profit loss.

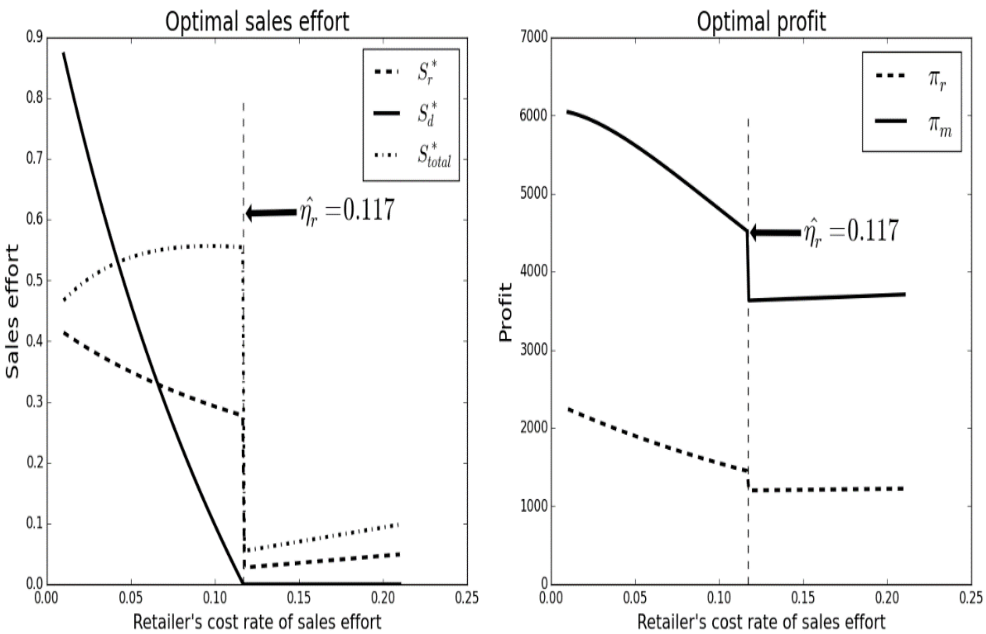

Figure 3.4 Optimal sales effort and profits respect to retailer's cost of sales effort

Under the condition of consumers having a low preference for the direct channel such as 0.8 (i.e. customers prefer the direct channel), compared with the profit of both channels without sales efforts, the profit of the retailer increases by US$2,090. In the view of the manufacturer, although the sales activities in the direct channel only lead to costs of US$838 in the direct channel, it finally increases the profit of the manufacturer by US$3543 due to sales rise in the retailer channel. This indicates that the direct channel can be a useful marketing channel while all consumers purchase via the retailer channel. According to Proposition 3, if we adjust the costs of the sales effort based on Equation (3.19) and Equation (3.20), then $\eta_r = \eta_d = 0.226$. Correspondingly, the optimal sales efforts by the manufacturer and the retailer are the same with a value of 0.5. In this case, the optimal profit of the manufacturer and the retailer will increase to US$5,003. In this case, the increased cost of sales efforts of the manufacturer and the retailer leads to a profit rise for both parties. This demonstrates the fact that it is important for the manufacturer and retailer to maintain their efficiencies of sales effort.

3.6. Summary

The purpose of this study is to determine the optimal sale effort deployment under the dual-channel supply chain, which combines a traditional brick and mortar retail channel from the partner retailer and a direct channel from the manufacturer. A sales effort competition game is set up in the dual-channel supply chain between the manufacturer and the retailer. Demand under sales efforts is determined based on the consumer valuation, consumer's channel preference, and sales efforts. Then, the optimal sales effort deployment is studied with a game theory approach, which allows the retailer and the manufacturer to maximize their profit. Consumers' channel preference is a key parameter of the demand assignment in the dual-channel supply chain. Interestingly, the optimal sales effort and the profit of the manufacturer and the retailer can be limited by the other's sales effort efficiency. The finding suggests that the manufacturer and the retailer should collaborate to enhance the efficiency of their sales efforts. It also shows that the manufacturer can utilize the direct channel as an important marketing channel even though no profit is acquired through the direct channel. This research contributes to a better understanding of the demand in the dual-channel supply chain under sales efforts. Additionally, the research results provide a useful framework for sales efforts deployment under different consumers' channel preferences in the dual-channel supply chain.

4. Overestimation in a Competing Newsvendors Game

In this chapter, we try to analyze the second type of confidence, overestimation in the newsvendor game. Since Arrow et al. (1951) first introduced the newsvendor problem in 1951, it has become an important and fundamental problem in operations research. The study on the overconfidence in a competing newsvendor game can lay foundation on the study of overconfidence in a dual-channel supply chain. In its original setting, a single newsvendor has to decide the optimal order under a known demand probability distribution with the cost of the order and the penalty of stock-out. The newsvendor is assumed to maximize his expected profit by trading off the losses of stock-out and leftover. The newsvendor model contributes to the inventory management in the fashion and sport goods industries, as well as the retailing of the manufactured products (Gallego and Moon, 1993). With the development of game theory, it is possible to analyze the equilibrium decision-making between multiple players. In 1988, Polar first introduced the competition between two players in the newsvendor game with the independent demand of each newsvendor (Parlar, 1988). In Polar’s setting, each player’s product is a substitute for the other’s with a known substitute rate when stocking out. Polar proved the existence and uniqueness of the Nash equilibrium in the competitive newsvendor game. Lippman and McCardle (1997) extended the newsvendor game to the competition between two newsvendors while demand is split from the total demand.

In this chapter, we define the “overestimating newsvendor” as the person who solely overestimating his/her demand information. The demand for the newsvendors, who overestimate the demand, follows the Poisson process. The overestimating newsvendor has a demand forecast with a higher mean value. In the first case, we discuss the competing newsvendor game with only one newsvendor overestimating the demand. Then, the second case of two newsvendors making overestimates is further analyzed. The results show that overestimation leads to a lower price and it can steal demand from the other newsvendor.

This chapter is organized as follows. In Section 4.1, overestimated demand is analyzed. In Section 4.2, we analyze the inventory strategy for competing newsvendors with only one overestimating newsvendor. In Section 4.3, we discuss inventory strategy while both newsvendors make overestimates. In Section 4.4, we summarize the findings and draw conclusions from the study.

4.1. Demand Overestimation

The traditional newsvendor problem has been well studied. It describes the inventory competition between two independent newsvendors. In the competitive newsvendor game setting, there are two independent newsvendors selling a homogeneous product to consumers. Newsvendor i sets the product price as r_i with an average cost c_i. In a single period, the random demand for the product for newsvendor i, D_i, follows a known distribution with a cumulative distribution function (CDF) $F_i(\cdot)$ and a probability density function (PDF) $f_i(\cdot)$. The CDF of demand $F_i(\cdot)$ is assumed to be continuously differentiable, invertible, and increasing. The product has no salvage value left at the end of the period. At the same time, there is no penalty cost for the unsatisfied demand due to limited inventory. However, the unsatisfied demand of newsvendor i will be transferred to the other newsvendor. The newsvendors have to determine an order quantity to maximize their expected profit at the beginning of the period. Based on the first-order condition, the best response of the newsvendor i to maximize profits in respect to the newsvendor j's action is $B_i(Q_j) = F^{-1}_{D_i+(D_j-Q_j)^+}\left(\frac{r_i-c_i}{r_i}\right)$ where $\frac{r_i-c_i}{r_i}$ is the critical fractile. Therefore, the equilibrium orders (Q_j^*, Q_i^*) are the orders meeting the best response function.

Compared with the traditional competitive newsvendor game, newsvendors are assumed to overestimate their demand. Given that the demand forecast by a third-party institution D_i is available for all newsvendors, newsvendor i holds the belief that it should have a higher demand D_i' which follows a CDF $F_i'(\cdot)$ and PDF $f_i'(\cdot)$. Let D_i' be the overestimated demand, which follows the same distribution as unbiased demand with a higher mean value. Suppose the overestimated demand information is private. In this study, we let the forecast demand for each newsvendor from the third-party institution follow an exponential distribution with a mean of $1/\lambda_i$. The overestimated demand of newsvendor i follows an exponential distribution with a mean of $1/\lambda_i'$, where $\lambda_i > \lambda_i'$. Let $\Delta\lambda_i = \lambda_i - \lambda_i'$. The overestimation level of newsvendor i is defined as $OL_i = \Delta\lambda_i/\lambda_i$.

4.2. One overestimating newsvendor

In the first place, we discuss the case where only one newsvendor overestimates its demand, while the other newsvendor remains unbiased. Figure 4.1 shows the model structure when only one newsvendor overestimates his own demand. Therefore, the overestimating newsvendor will determine its equilibrium order by its own overestimated demand information and unbiased demand information provided by a third party, while the other newsvendor only responds to the third party's provided objective demand information.

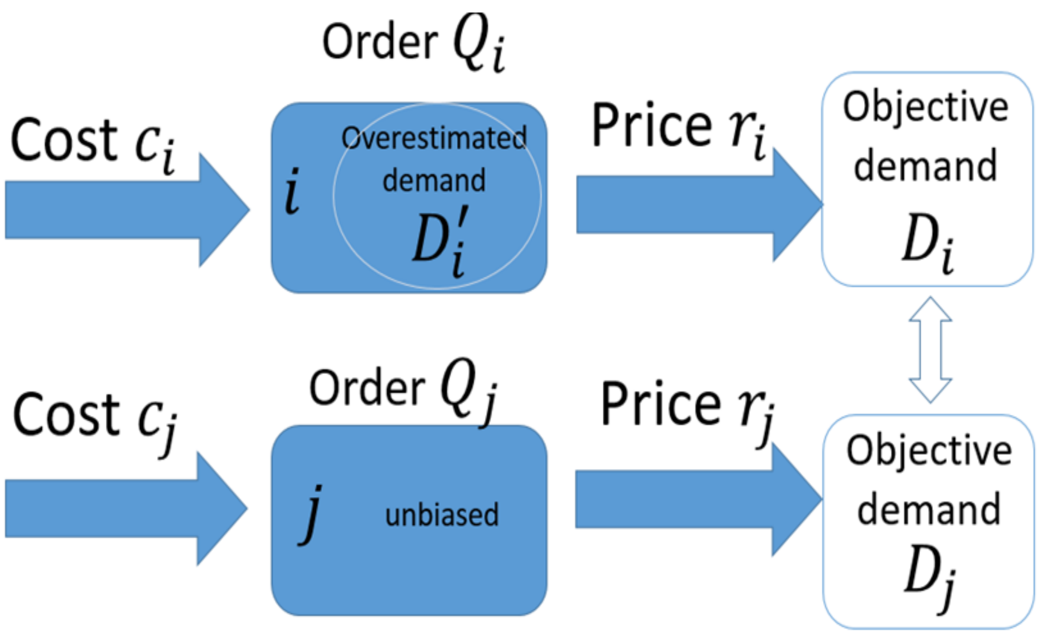

Figure 4.1 Model structure with only one overestimating newsvendor

Let newsvendor i's order quantity be biased by overestimation of Q_{i0}. The payoff functions of overestimating newsvendor i and unbiased newsvendor j are shown in Equations (4.1) and (4.2):

$$\pi_i\left(Q_{i0}, Q_{j0}\right) = E_D\left(r_i \min\left(D_i' + \left(D_j - Q_{j0}\right)^+, Q_{i0}\right) - c_i Q_{i0}\right) \tag{4.1}$$

$$\pi_j\left(Q_{i0}, Q_{j0}\right) = E_D\left(r_j \min\left(D_j + (D_i - Q_{i0})^+, Q_{j0}\right) - c_j Q_{j0}\right) \tag{4.2}$$

According to the first-order condition, the Nash equilibrium of competitive newsvendor's order (Q_{io}^*, Q_{jo}^*) satisfies Equations (4.3) and (4.4):

$$\int_0^{Q_{jo}^*} f_i'(x) F_j'(Q_{io}^* + Q_{jo}^* - x) dx = \frac{r_i - c_i}{r_i} \tag{4.3}$$

$$\int_0^{Q_{io}^*} f_j(x) F_j(Q_{jo}^* + Q_{io}^* - x) dx = \frac{r_j - c_j}{r_j} \tag{4.4}$$

There still exists a unique Nash equilibrium of the overestimated competitive newsvendor game with only one overestimating newsvendor. The proof follows the typical newsvendor game.

Proposition 4.1 *Overestimation effect: the overestimating newsvendor can steal demand from the unbiased newsvendor, but the overall supply of the product increases.*

$$Q_{io}^* > Q_i^*, \quad Q_{jo}^* < Q_j^* \tag{4.5}$$

$Q_{io}'(\lambda_i) < 0$ is proved in Appendix 2. Therefore, the change of newsvendor i 's equilibrium order should be positive ($Q_{io}^* - Q_i^*$) $=$ $Q_i'(\lambda_i)|_{Q_i(Q_j)}(-\Delta\lambda_i) > 0$. Meanwhile, the difference of newsvendor j 's equilibrium order is negative, ($Q_{jo}^* - Q_j^*$) $=$ $Q_j'(Q_i)|_{Q_j(Q_i)}(Q_{io}^* - Q_i^*) < 0$.

Considering that newsvendor j's best response order is negatively correlated with the order of newsvendor i, $-1 \leq Q_j'(Q_i)|_{Q_j(Q_i)} \leq 0$, the total supply of the product by newsvendors increases, $Q_{io}^* + Q_{jo}^* - (Q_i^* - Q_j^*) = (Q_j'(Q_i)|_{Q_j(Q_i)} + 1) * (Q_{io}^* - Q_i^*) > 0$. Figure 4.2 indicates the outcomes of one overestimating newsvendor in the competing newsvendor game. The original Nash equilibrium point A,(Q_i^*, Q_j^*), shifts to the new Nash equilibrium point B, $(Q_{jo}^*$,$Q_{io}^*)$. The figure indicates that $Q_i^* < Q_{io}^*$and $Q_j^* > Q_{jo}^*$

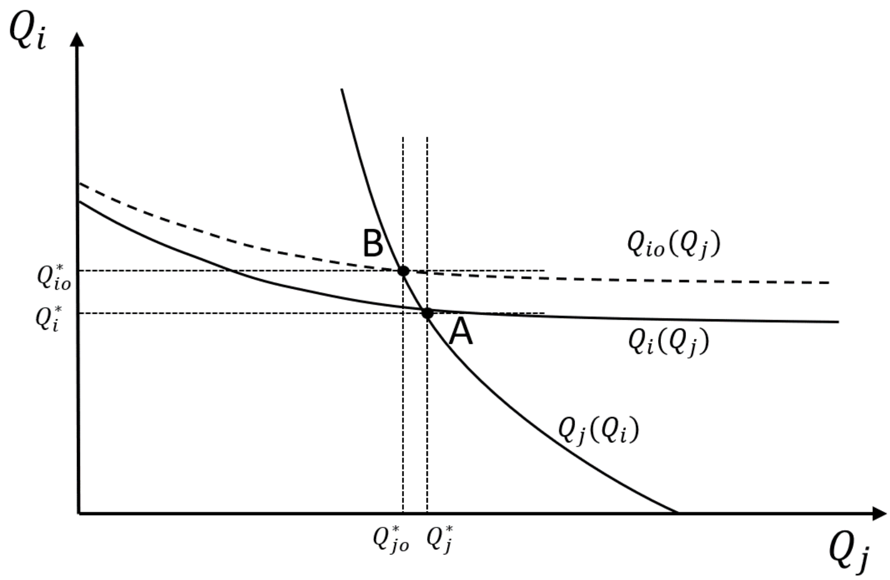

Figure 4.2 Nash equilibrium with one overestimating newsvendor

.

4.3. Two overestimating Newsvendors

Having studied one overestimating newsvendor, this section discusses the situation with two newsvendors who overestimate their demand. Figure 4.3 shows the model structure when both newsvendors overestimate their demand. Newsvendor i has a cost of c_i and sells products to consumers at a price r_i. Newsvendor i has an overestimated demand $D_i^{'}$. At the same time, newsvendor j has a cost c_j and sells products to consumers at a price r_j. Newsvendor j has an overestimated demand $D_i^{'}$. The objective demand of newsvendor i and newsvendor j are D_i and D_j. Newsvendor i and newsvendor j have to determine their order quantity Q_i and Q_j to maximize their profits.

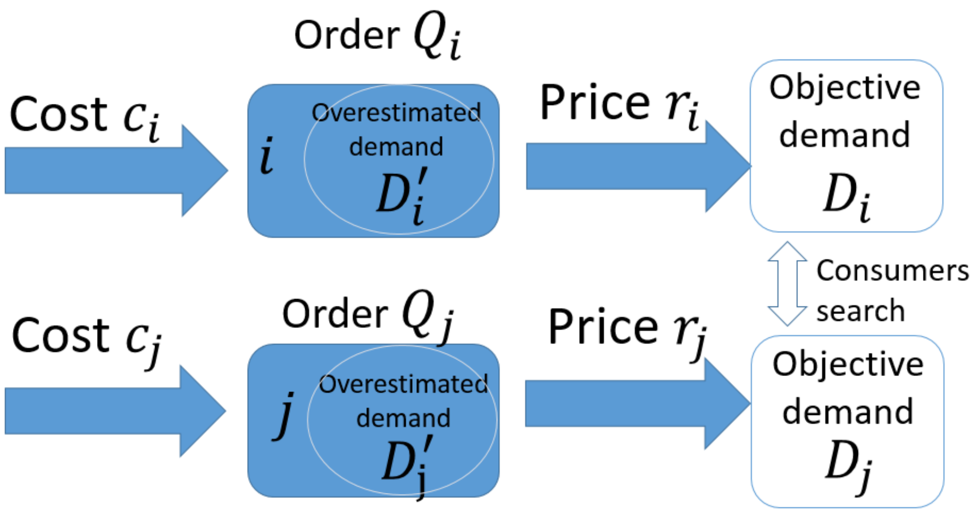

Figure 4.3 Model structure with two overestimating newsvendors

Under this setting, the payoff function of two overestimating newsvendors can be modeled as follows:

$$\pi_i(Q_{i0}, Q_{j0}) = E_D\left(r_i \min\left(D_i' + (D_j - Q_{j0})^+, Q_{i0}\right) - c_i Q_{i0}\right) \tag{4.6}$$

Therefore, the Nash equilibrium of competitive overestimating newsvendors (Q_{io}^*, Q_{jo}^*) should satisfy:

$$\int_0^{Q_{jo}^*} f_i'(x)F_j'(Q_{io}^* + Q_{jo}^* - x)dx = \frac{r_i - c_i}{r_i}\Delta Q_{j2} = \frac{\partial Q_j}{\partial \lambda_j}|_{Q_j(Q_i)} * (-\Delta\lambda_j) = \frac{Q_j(1-e^{-\alpha Q_i})}{\alpha(1-e^{-\alpha Q_i}+\alpha Q_j e^{-\alpha Q_i})} \cdot (-\Delta\lambda_j) \quad (4.7)$$

Figure. 4.4 shows the movement of the Nash equilibrium. Since the two players are stealing demand from each other according to Proposition 4.1, at most one newsvendor experiences equilibrium order reduction. The equilibrium (Q_{io}^*, Q_{jo}^*) with overestimation may be located in region I where newsvendor j has order decrease, in region II where both newsvendors have order increase, or in region III where newsvendor i has its equilibrium order reduced.

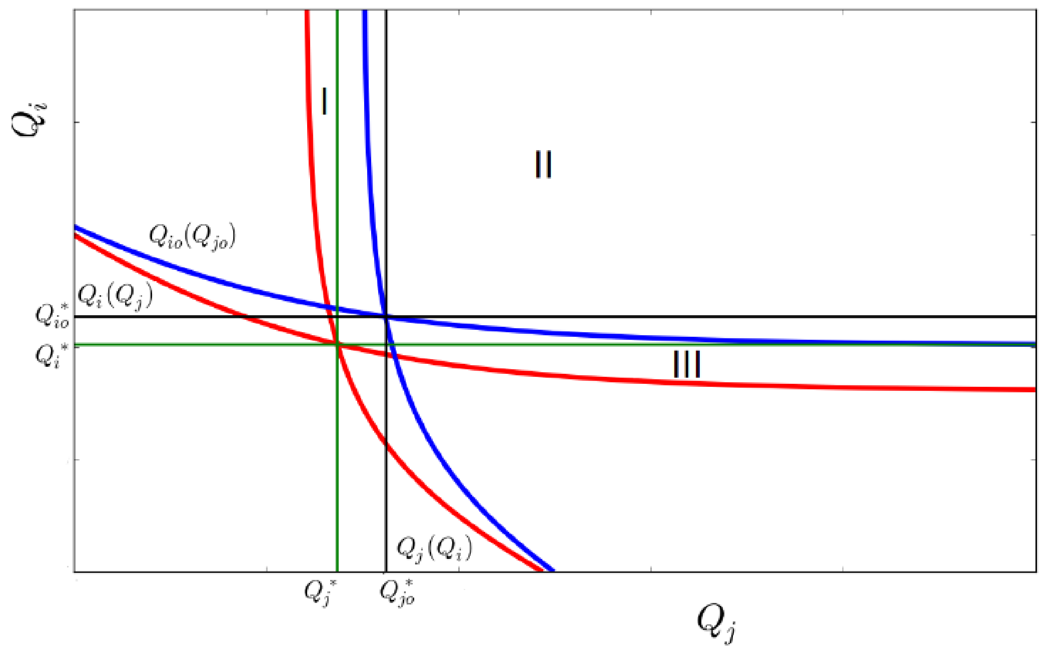

Figure 4.4 Nash equilibrium with both overestimating newsvendors

Proposition 4.2 *When both newsvendors have the same unbiased demand* $(\lambda_i = \lambda_j = \alpha)$*, overestimating newsvendor j's equilibrium order decreases when* *their ratio of overestimation level is larger than a threshold value shown in Equation (4.8). Besides, overestimating newsvendor j's equilibrium order decreases with newsvendor i 's critical fractile (c_i/p_i) and increases with newsvendor j's critical fractile (c_j/p_j).*

$$\frac{OL_i}{OL_j} \geq \frac{e^{\alpha Q_i^*}-1}{\alpha Q_i^*} + \frac{e^{\alpha Q_i^*}-1}{e^{\alpha Q_j^*}-1} = l \tag{4.8}$$

Proof. Denote l as the right-hand side of Equation (4.8). Let ΔQ_{j1} be the change of equilibrium order of newsvendor j caused by newsvendor i's overestimation. Let ΔQ_{j2} be newsvendor j's equilibrium order change due to newsvendor j's overestimation.

$$\Delta Q_{j1} = \frac{\partial Q_i}{\partial \lambda_i}|_{Q_i(Q_j)} * (-\Delta\lambda_i) * \frac{\partial Q_j}{\partial Q_i}|_{Q_i(Q_j)} = \frac{Q_i\left(1-e^{-\alpha Q_j}\right)}{\alpha\left(1-e^{-\alpha Q_j}+\alpha Q_i e^{-\alpha Q_j}\right)} \cdot \frac{\alpha Q_j e^{-\alpha Q_i}}{\left(1-e^{-\alpha Q_i}+\alpha Q_j e^{-\alpha Q_i}\right)} \cdot (-\Delta\lambda_i) \tag{4.9}$$

$$\Delta Q_{j2} = \frac{\partial Q_j}{\partial \lambda_j}|_{Q_j(Q_i)} * \left(-\Delta\lambda_j\right) = \frac{Q_j(1-e^{-\alpha Q_i})}{\alpha(1-e^{-\alpha Q_i}+\alpha Q_j e^{-\alpha Q_i})} \cdot \left(-\Delta\lambda_j\right) \tag{4.10}$$

The total change of newsvendor j 's equilibrium order is ($\Delta Q_{j1} + \Delta Q_{j2}$). Substitute Equations (4.9) and (4.10) into $\Delta Q_{j1} + \Delta Q_{j2} < 0$: Take this boundary condition with respect to Q_i^*:

$$\frac{\partial l}{\partial Q_i^*} = \frac{(\alpha^2 Q_i^* e^{\alpha Q_i^*} - \alpha e^{\alpha Q_i^*} + \alpha)}{\left(\alpha Q_i^*\right)^2} + \frac{e^{\alpha Q_i^*}\left(e^{\alpha Q_j^*}-1\right) - \alpha Q_j'\left(Q_j^*\right) * e^{\alpha Q_j^*} * e^{\alpha Q_i^*} - 1}{\left(e^{\alpha Q_j^*}-1\right)^2} \tag{4.11}$$

With $Q_j'\left(Q_j^*\right) < 0$, the second term of Equation (4.11) is always larger than zero, so we can only discuss the second term of the right-hand side.

$$\lim_{Q_i^* \to 0} (\alpha^2 Q_i^* e^{\alpha Q_i^*} - \alpha e^{\alpha Q_i^*} + \alpha) = 0 \tag{4.12}$$

$$\frac{\partial(\alpha^2 Q_i^* e^{\alpha Q_i^*} - \alpha e^{\alpha Q_i^*} + \alpha)}{\partial Q_i^*} = \alpha^3 Q_i^* e^{\alpha Q_i^*} > 0 \tag{4.13}$$

Therefore, $\partial \frac{OL_i}{OL_j} / \partial Q_i^* > 0$ always holds. With the relationships $\partial Q_i^* / \partial(\frac{r_i - c_i}{r_i}) > 0$ and $\partial Q_i^* / \partial(\frac{r_j - c_j}{r_j}) > 0$, it can be determined that:

$$\frac{\partial l}{\partial\left(\frac{r_i - c_i}{r_i}\right)} > 0 \quad , \quad \frac{\partial l}{\partial\left(\frac{r_j - c_j}{r_j}\right)} < 0 \tag{4.14}$$

When both newsvendors have the same demand forecast by a third party, Proposition 4.2 shows whether the equilibrium order reduction is dependent on the ratio of overestimation levels. The newsvendor who has a higher critical fractile has a lower obstacle for equilibrium order decreasing. With a lower critical fractile, a lower overestimation level ratio is needed for reduced equilibrium order of the other newsvendor.

As shown in Figure 4.4 (page 93), the model of two overestimating competitive newsvendors could lead to both newsvendors increasing the supply. When both newsvendors have the same demand forecast by a third party ($\lambda_i = \lambda_j = \alpha$), the condition of newsvendor j has a higher order increase than newsvendor j $\Delta Q_j - \Delta Q_i > 0$ is (4.15).

$$\frac{OL_i}{OL_j} < \frac{\alpha Q_j^* Q_i^* e^{-\alpha Q_j^*}\left(1-e^{-\alpha Q_i^*}\right)+Q_j^*(1-e^{-\alpha Q_i^*})(1-e^{-\alpha Q_j^*}+\alpha Q_j^* e^{-\alpha Q_i^*})}{\alpha Q_j^* Q_i^* e^{-\alpha Q_i^*}\left(1-e^{-\alpha Q_j^*}\right)+Q_i^*(1-e^{-\alpha Q_j^*})(1-e^{-\alpha Q_i}+\alpha Q_i^* e^{-\alpha Q_j^*})} \tag{4.15}$$

Denote the right-hand side of (4.15) as k. Since the expression of k is complex but asymmetric, a case study is conducted to illustrate how the value of k correlates with original equilibrium orders. The results are shown in Figure 4.5.

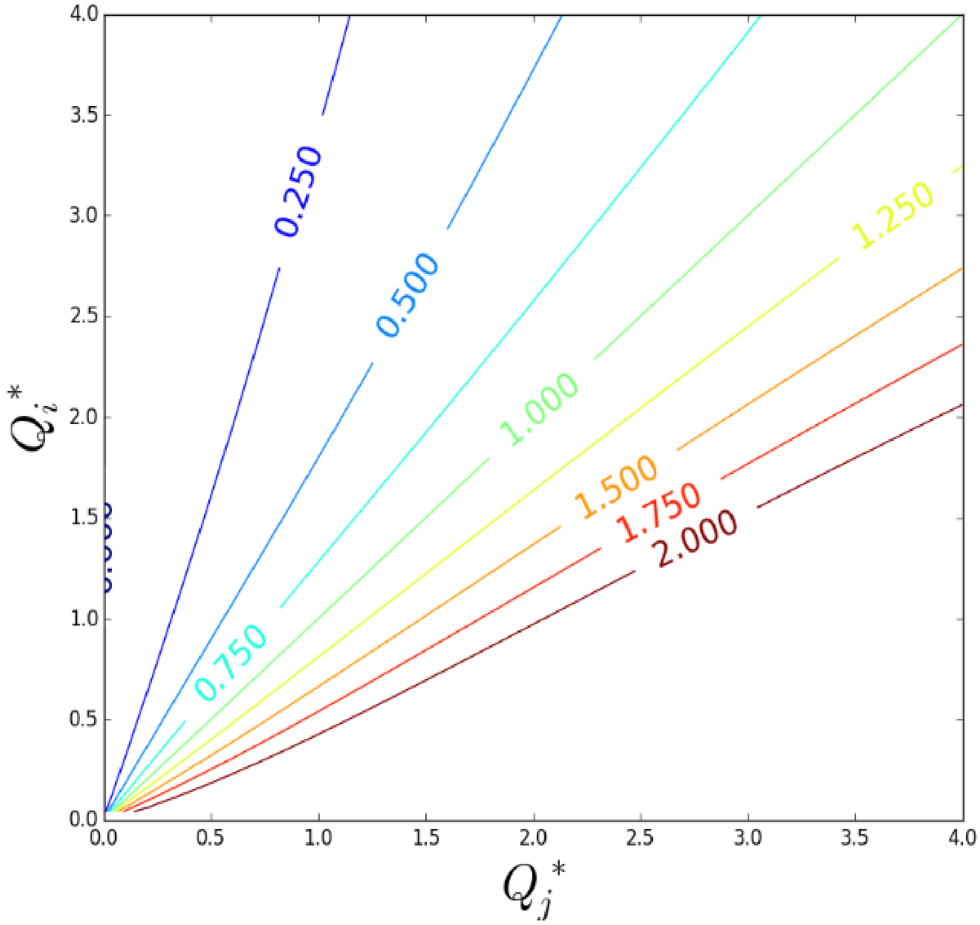

Figure 4.5 The value of k in respect to order quantities

Figure 4.5 shows that the value of k increases with the ratio of the original equilibrium order (Q_j^*/Q_i^*). The newsvendor who has a larger original equilibrium order still has an advantage in the overestimation effect. With the same overestimation level, the newsvendor who had a larger original equilibrium order would have a larger equilibrium order increase than the newsvendor who has a smaller equilibrium order. Additionally, if both newsvendors had the same original equilibrium order value, the newsvendor with a larger overestimation level will have more equilibrium order increase.

4.4. Summary

This part of the study examines the impact of overestimation of demand on the competitive newsvendor game. Firstly, Section 4.2 discusses the case where one player overestimates his demand. The Nash equilibrium solution shows that the biased newsvendor has a larger equilibrium order compared with the unbiased competitive newsvendor. At the same time, the other unbiased newsvendor has a lower equilibrium order quantity but the overall supply of the product by two newsvendors increases. Then, let both newsvendors overestimate the demand. In this case, it leads to two outcomes: 1) both newsvendors experience an equilibrium order increase; and 2) one newsvendor experiences an order fall while the other newsvendor's order increases. It has been found that the boundary condition of the newsvendor's equilibrium order increases with its critical fractile and decreases with the other newsvendor's critical fractile. This indicates that the newsvendor with a higher critical fractile is more likely to have an equilibrium order drop. In both situations, the total product supply rises and it may also lead to losses for overestimating newsvendors.

5. Pricing Strategy of a Dual-Channel Supply Chain with Overconfident Consumers

Caused by cognitive bias, consumers tend to be overconfident and are overprecise in their valuation of products, which directly affects product demand and prices. Many manufacturers nowadays sell products to consumers not only through retailers but also through the Internet, which leads to the formation of the dual-channel supply chain. Determining the optimal wholesale, direct, and retail prices present itself as one of the important issues in dual-channel supply chains. In this study, we investigate the optimal pricing strategies of both a manufacturer and retailer in a dual-channel supply chain with overconfident consumers. We first introduce concepts of consumers' overconfidence level and consumers' channel preference. Then, we develop a consumer utility function to model the demand. We then characterize the manufacturer's and the retailer's pricing strategies in centralized and decentralized dual-channel supply chains and derive closed-form solutions to explore the impacts of consumers' overconfidence on demand, and chain members' pricing decisions and profits. The results highlight that (1) the decentralized dual-channel supply chain demand decreases along with the increases of consumers' overconfidence level; (2) the manufacturer and retailer should set lower prices when consumers are overconfident; (3) the manufacturer should set equal direct and retail prices in the decentralized dual-channel supply chain; and (4) the profits of the manufacturer and retailer are reduced due to consumers' overconfidence. Based on the numerical examples, we suggest several approaches to reduce consumers' overconfidence, e.g., providing better retail services, in the hope of increasing the profits of the manufacturer and the retailer.

In Section 5.1, we analyze demand in the dual-channel supply chain when consumers are overconfident. In Section 5.2, we determine the pricing strategy of the centralized dual-channel supply chain. In Section 5.3, we analyze the pricing strategy of the decentralized dual-channel supply chain. In Section 5.4, a numerical example is presented. Finally, in Section 5.5, a summary is provided.

5.1. Demand in the dual-channel supply chain

When consumers' overconfidence is not considered in the pricing strategy of a dual-channel supply chain (as in most of the available literature), modeling demand is relatively easy. This is because, besides prices, the other main consideration is the consumers' channel preference. When overconfident consumers are considered, demand modeling is not as straightforward as the impact of their being overprecise in product valuation has to be taken into account. In this regard, we introduce consumers' overconfidence level in regard to modeling demand.

Let v be a consumer's valuation of a product. For simplicity, without losing generality, all parameters are normalized in this study. We assume that consumers' valuation follows a uniform distribution in [0, 1]. Therefore, unbiased consumers perceive the product to be worth v in the retail channel. Consistent with the literature (Chiang et al., 2003), consumers value the product from the direct channel as θv, where θ is the channel preference between the direct and the retail channels. In practice, consumers prefer the retail channel to the direct channel for many products, e.g., kitchenware, apparel (Statista.com, 2017a). Thus, we assume $\theta < 1$.

Researchers, such as Grubb (2009), Ren and Croson (2013), and Li et al. (2016), use a measure of overconfidence level, α, in modeling overconfident participants. In this study, we thus adopt α in the modeling of an overconfident consumer's biased valuation of the product, v_b, as follows:

$$v_b = \alpha E(v) + (1-\alpha)v \tag{5.1}$$

where $\alpha \in [0,1]$ is the measure of a consumer's overconfidence level and $E(v)$ is the expectation of the unbiased distribution of consumers' valuation and follows a uniform distribution with a mean of 0.5. If $\alpha = 0$, the consumer is not biased and $v_b = v$. If $\alpha = 1$, the consumer is extremely overconfident, and his valuation equals the expectation of valuation distribution.

Let r and d denote the retail channel and the direct channels and p is the product's price. The utility of an overconfident consumer is his valuation of the product minus the product's price: $v_b - p$. Thus, the overconfident consumer's utilities, U_r *and* U_d, from purchasing the product in the direct channel and the retail channel are modeled as follows:

$$\begin{aligned} U_r &= v_b - p_r = 0.5\alpha + (1-\alpha)v - p_r \\ U_d &= \theta v_b - p_d = 0.5\theta\alpha + (1-\alpha)\theta v - p_d \end{aligned} \tag{5.2}$$

where p_r *and* p_d are the product's prices in the retail channel and direct channel, respectively. As we assume that the consumer's valuation distribution is uniformly distributed in [0,1], we use the mean expectation of 0.5 in modeling the overconfident consumer's utility. If $U_r > U_d$, overconfident consumers prefer the retail channel over the direct channel.

In the channel selection mechanism, overconfident consumers try to maximize their utilities when purchasing the product. They compare the utility of the direct channel with that of the retail channel and choose the channel contributing to a larger positive utility. If both channels incur negative utilities, overconfident consumers will walk away without buying products. The breakeven valuation for positive utilities in the retail channel, v_{br}, is $\frac{p_r}{1-\alpha}-\frac{\alpha}{2(1-\alpha)}$ and that in the direct channel online, v_{bd}, is $\frac{p_d}{\theta(1-\alpha)}-\frac{\alpha}{2(1-\alpha)}$. Consider the case, $U_r > U_d$: an overconfident consumer who values the product higher than $v_{rd}=\frac{p_r-p_d}{(1-\theta)(1-\alpha)}-\frac{\alpha}{2(1-\alpha)}$ prefers to purchase the product via the retail channel.

First, let $v_{bd} < v_{br}$ and further obtain $\frac{p_d}{p_r}<\theta$. In this case, $v_{rd}-v_{br}$ is $\frac{\theta p_r - p_d}{\theta(1-\theta)(1-\alpha)}>0$. Therefore, when $\frac{p_d}{p_r}<\theta$, we obtain $v_{bd} < v_{br} < v_{rd}$. As shown in Figure 5.1(a) (page 104), the demand of the direct channel, D_d, is the number of consumers whose product valuation falls in $[v_{bd}, v_{rd}]$ and can be modeled as $\int_{v_{bd}}^{v_{rd}} f(v)dv$; the demand of the retail channel, D_r, is the cumulative number of consumers whose product valuation falls in $[v_{rd},1]$ and can be modeled as $\int_{v_{rd}}^{1} f(v)dv$.

Similarly, when $\frac{p_d}{p_r}>\theta$, we obtain $v_{rd} < v_{br} < v_{bd}$. In this case, overconfident consumers whose product valuation falls in $[v_{br},1]$ will purchase the product via the retail channel, while others walk away. The demand of the retail channel is $\int_{v_{rd}}^{1} f(v)dv$, and the demand in the direct channel is 0, as shown in Figure

5.1 (b).

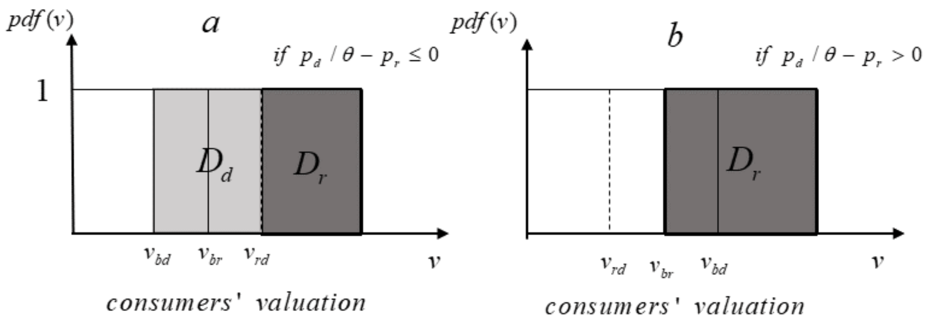

Figure 5.1 Demand in the dual-channel supply chain

Based on the above analysis, the demand for the dual-channel supply chain is stated below in the case of $\frac{p_d}{\theta} - p_r \geq 0$ or $\frac{p_d}{\theta} - p_r \leq 0$.

$$D:\begin{cases} D_r = 1 - \dfrac{p_r - p_d}{(1-\theta)(1-\alpha)} + \dfrac{\alpha}{2(1-\alpha)} \\ D_d = \dfrac{p_r - p_d}{(1-\theta)(1-\alpha)} - \dfrac{p_d}{\theta(1-\alpha)} \end{cases} ,if \ \frac{p_d}{\theta} - p_r \leq 0$$

$$D:\begin{cases} D_r = 1 - \dfrac{p_r}{1-\alpha} + \dfrac{\alpha}{2(1-\alpha)} \\ D_d = 0 \end{cases} ,if \ p_r - \frac{p_d}{\theta} \leq 0 \qquad (5.3)$$

5.2. The centralized dual-channel supply chain

Referring to the literature on pricing strategy, in the centralized dual-channel supply chain, the manufacturer and the retailer are vertically integrated into the retail channel. More specifically, the manufacturer owns the supply chain and sets the direct price and the retail price simultaneously. The manufacturer produces the product and distributes it to the retail channel at an average cost, c_1. The product distributed in the direct channel has an average cost, c_2. We assume that $c_1 > c_2$ as the manufacturer pays less cost in running the direct channel. The product is sold in the retail channel at p_r and in the direct channel at p_d. Figure 5.2 indicates the structure of the centralized dual-channel supply chain.

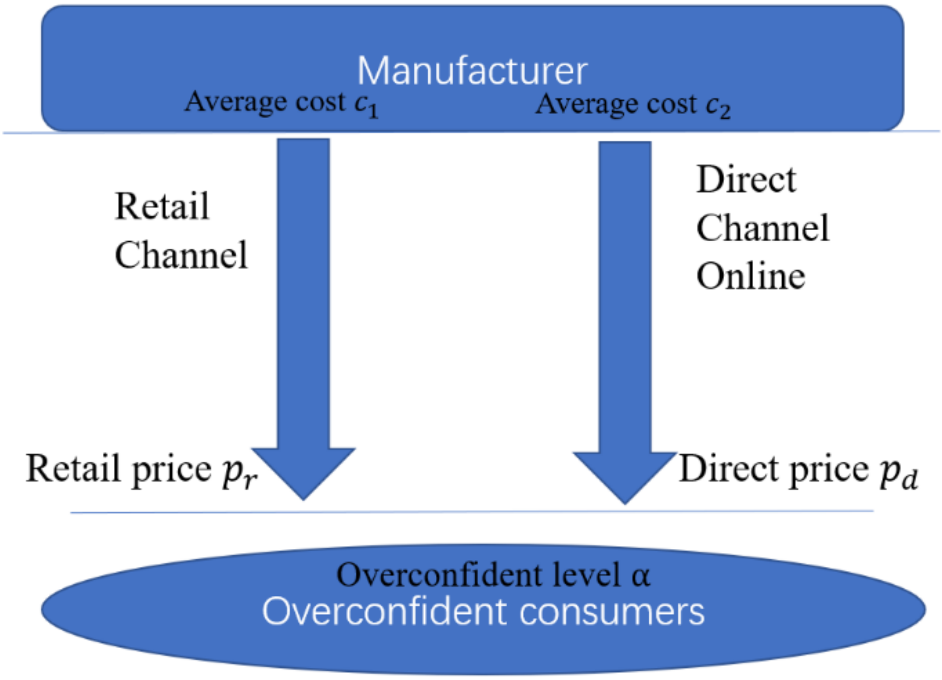

Figure 5.2 Centralized dual-channel supply with overconfident consumers

In the centralized supply chain, the profit of the manufacturer, π_{cm}, is $D_r(p_r - c_1) + D_d(p_d - c_2)$. We discuss below several cases where the manufacturer can maximize his profit by setting the suitable retail price.

5.2.1 $p_r - p_d / \theta < 0$

When $p_r - p_d / \theta < 0$, the centralized supply chain is, in fact, an integrated traditional single retail channel supply chain as there is no demand in the direct channel. The manufacturer can maximize his profit based on the model below.

$$\begin{aligned} &\pi_{cm} = (1 - \frac{p_r}{1-\alpha} + \frac{\alpha}{2(1-\alpha)})(p_r - c_1) \\ &s.t. \quad \frac{p_d}{\theta} - p_r > 0 \end{aligned} \tag{5.4}$$

Proposition 5.1. *The optimal retail channel price is* $p_r^* = 1/2 + c_1/2 - \alpha/4$ *when the direct channel online has no positive s*ale.

The last term in p_r^*: $-\alpha/4$ indicates the impact of the consumer's overconfidence level on the retail price. The higher the consumer's overconfidence level is, the lower the retail price should be to maximize the manufacturer's profit.

5.2.2 $p_d / \theta - p_r \le 0$

In the case: $p_d / \theta - p_r \le 0$, the direct channel has a positive demand. The manufacturer can maximize his profit: π_{cm} as follows:

$$\pi_{cm} = (1 - \frac{p_r - p_d}{(1-\theta)(1-\alpha)} + \frac{\alpha}{2(1-\alpha)})(p_r - c_1) + (\frac{p_r - p_d}{(1-\theta)(1-\alpha)} - \frac{p_d}{\theta(1-\alpha)})(p_d - c_2) \quad (5.5)$$
$$s.t. \quad p_d / \theta - p_r \le 0$$

Proposition 5.2. *When* $p_d / \theta - p_r \le 0$ *, and the cost of the product and consumers' channel preference satisfy,* $\theta c_1 - c_2 \le 0$ *, the optimal pricing strategy is:*

$$(p_r^*, p_d^*) = (1/2 + c_1/2 - \alpha/4, \theta/2 + \theta c_1/2 - \alpha\theta/4) \quad (5.6)$$

Otherwise ($\theta c_1 - c_2 > 0$*):*

$$(p_r^*, p_d^*) = (1/2 + c_1/2 - \alpha/4, \theta/2 - 3\theta\alpha/4 + c_2/2) \quad (5.7)$$

See proof in Appendix 3.

We summarize the manufacturer's profit in the above two cases in the centralized dual-channel supply in Table 5.1. The relevant information, e.g., retail, direct prices, demand, is also provided.

Table 5.1 Manufacturer's profit in the centralized dual-channel supply chain

	$p_r - p_d / \theta < 0$	$p_d / \theta - p_r \le 0$	
		$\theta c_1 - c_2 \le 0$	$\theta c_1 - c_2 > 0$
Retail price	$1/2 + c_1/2 - \alpha/4$	$1/2 + c_1/2 - \alpha/4$	$1/2 + c_1/2 - \alpha\theta/4$
Direct price	$\frac{\theta}{2} - \frac{\theta\alpha}{4} + \frac{c_2}{2}$	$\theta/2 + \theta c_1/2 - \alpha\theta/4$	$\frac{\theta}{2} - \frac{3\theta\alpha}{4} + \frac{c_2}{2}$
Retail demand	$\frac{1-c_1}{2(1-\alpha)} - \frac{\alpha}{4(1-\alpha)}$	$\frac{1-c_1}{2(1-\alpha)} - \frac{\alpha}{4(1-\alpha)}$	$1 - \frac{c_1 - c_2}{2(1-\theta)(1-\alpha)} + \frac{2(1-\theta)-\alpha}{4(1-\alpha)}$
Direct demand	0	0	$\cdot \frac{\alpha\theta + c_1 - c_2}{2(1-\theta)(1-\alpha)} + \frac{3\theta\alpha - 2c_2}{4\theta(1-\alpha)}$
Manufacturer profit	$(\frac{1-c_1}{2(1-\alpha)} - \frac{\alpha}{4(1-\alpha)})$ $*(\frac{1-c_1}{2} - \frac{\alpha}{4})$	$(\frac{1-c_1}{2(1-\alpha)} - \frac{\alpha}{4(1-\alpha)})$ $*(\frac{1-c_1}{2} - \frac{\alpha}{4})$	$(\frac{1}{2} - \frac{\alpha\theta + c_1 - c_2}{2(1-\theta)(1-\alpha)})(\frac{1-c_1}{2} - \frac{\theta\alpha}{4}) +$ $(\frac{\alpha\theta + c_1 - c_2}{2(1-\theta)(1-\alpha)} + \frac{3\theta\alpha - 2c_2}{4\theta(1-\alpha)})(\frac{\theta - c_2}{2} - \frac{3\theta\alpha}{4})$

Based on Table 5.1, we obtain Theorem 5.1 below:

Theorem 5.1. *The optimal pricing strategy for the centralized dual-channel supply chain with overconfident consumers is:*

$$p_r^* = \begin{cases} 1/2 + c_1/2 - \alpha/4 & \text{if } \theta c_1 - c_2 \le 0 \\ 1/2 + c_1/2 - \alpha\theta/4 & \text{if } \theta c_1 - c_2 > 0 \end{cases}$$
$$p_d^* = \begin{cases} \theta/2 + \theta c_1/2 - \alpha\theta/4 & \text{if } \theta c_1 - c_2 \le 0 \\ \frac{\theta}{2} - \frac{3\theta\alpha}{4} + \frac{c_2}{2} & \text{if } \theta c_1 - c_2 > 0 \end{cases} \tag{5.8}$$

As shown in Theorem 5.1, when the costs of the product and the consumer channel preference satisfy the relationship $\theta c_1 > c_2$, the direct channel has positive demand, i.e., $D_d > 0$, thus being active.

In Equation (5.8), as $dp^*_{r,d} / d\alpha < 0$, we can conclude that the overconfidence of consumers leads to lower optimal prices in both channels. In addition, as $|dp^*_d| = 3\theta/4 > |dp^*_r| = \theta/4, if\, \theta c_1 - c_2 > 0$, consumers' overconfidence has a negative effect on the direct price when the direct channel has positive demand.

Further insights about the profit of the manufacturer in the centralized dual-channel supply chain are discussed based on a numerical experiment. In this experiment, we set the average cost of the product in the retail channel as $c_1 = 0.4$. The average cost of the product in the direct channel online, $c_2 = 0.35$.

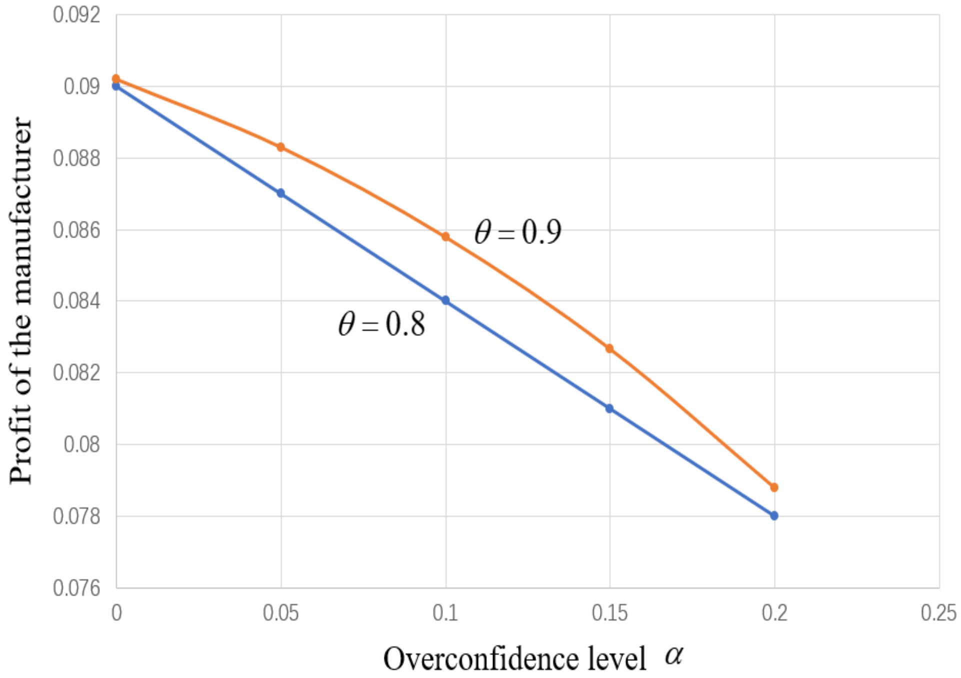

Figure 5.3 Profit of the manufacturer in the centralized dual-channel supply chain

Figure 5.3 presents the profit of the manufacturer in the centralized dual-channel supply chain with respect to consumers and overconfidence level. When consumers have a channel preference of $\theta = 0.8$, $\theta c_1 - c_2 \le 0$ is satisfied. In this case, the direct channel has no demand. The dual-channel strategy turns out to be the same as the single channel case. The profit of the manufacturer decreases with consumers' overconfidence level. At the same time, when consumers have a channel preference of $\theta = 0.9$, the direct channel has positive demand. In this case, the profit of the manufacturer still decreases with consumers' overconfidence level. This indicates that the manufacturer suffers losses due to consumers' overconfidence. Comparing the profit of the manufacturer when only the retail channel works ($\theta = 0.8$), the profit of the manufacturer is higher when the direct channel has positive demand ($\theta = 0.9$). This implies that the dual-channel strategy can reduce the losses due to consumers' overconfidence. Therefore, the direct channel online is an effective tool to deal with overconfident consumers.

5.3. The decentralized dual-channel supply chain

In practice, many manufacturers cooperate with independent retailers when selling products, e.g., IBM and Best Buy, forming decentralized dual-channel supply chains. Thus, we analyze pricing decisions in the decentralized dual-channel supply chains. As shown in Figure 5.4, in the decentralized dual-channel supply chain considered in this study, the manufacturer produces a single product and distributes it in the retail channel at an average cost: c_1 and a wholesale price per unit: ω. The retailer offers the product to overconfident consumers at a price: p_r. At the same time, the manufacturer directly sells the product to overconfident consumers at a price: p_d and an average cost: c_2. Similarly, we assume that $c_1 > c_2$. In addition, the wholesale price is no larger than the direct channel price, i.e., $\omega \le p_d$. Alternatively, the retailer will purchase the product via the direct

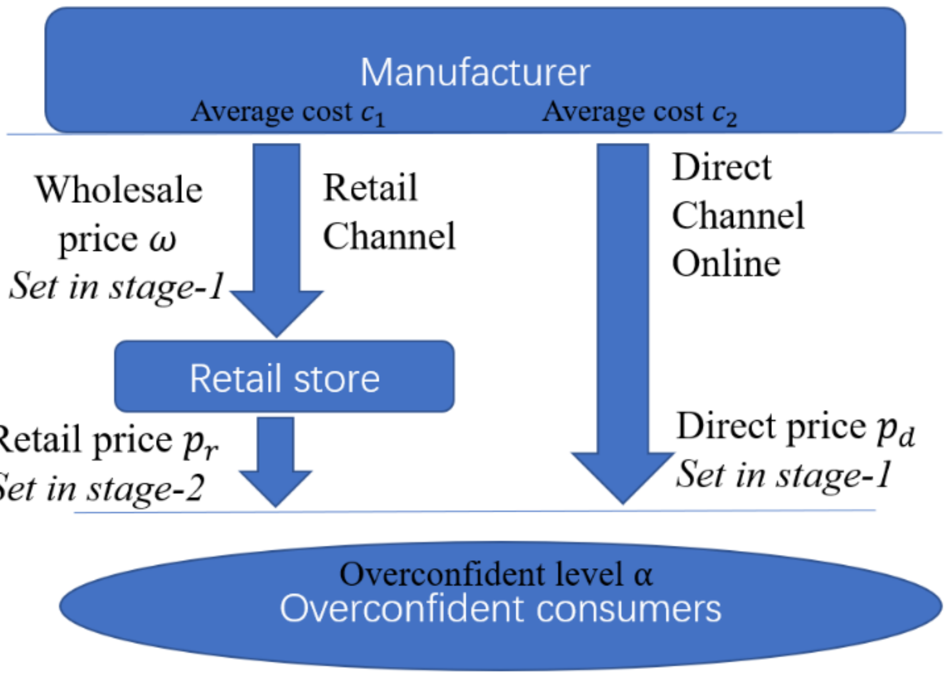

Figure 5.4 Decentralized dual-channel supply chain with overconfident consumers

channel, instead of buying the product at the wholesale price from the manufacturer.

Consistent with the related studies (e.g., Chiang et al., 2003; Li et al., 2014), we adopt the Stackelberg game theory to analyze the pricing decision making in the decentralized dual-channel supply chain. In the Stackelberg game framework, the manufacturer (the Stackelberg leader) and the retail (the Stackelberg follower) make their pricing decisions in sequence. More specifically, the manufacturer first sets the wholesale price: ω and the direct price: p_d to maximize his total profit: π_m while taking the retailer's reaction into account. His profit is computed as follows: $\pi_m = D_r(\omega - c_1) + D_d(p_d - c_2)$. By responding to the pricing decisions of the manufacturer, the retailer sets the retail price: p_r to maximize his profit: π_r, i.e., $\pi_r = D_r(p_r - \omega)$.

5.3.1.Pricing strategy of the retailer

In analyzing the pricing strategy of the manufacturer, the retailer's pricing decision has to be studied first. With the demand (in Equations (5.3)), the retailer determines the retail price in the way to maximize his profit: π_r , i.e., $\pi_r = D_r(p_r - \omega)$. There are two cases. In the first case, $p_r > p_d / \theta$, while in the second case, $p_r < p_d / \theta$.

When $p_r > p_d / \theta$, the retailer's profit function is formulated as follows: $\pi_r = (1 - \frac{p_r - p_d}{(1-\theta)(1-\alpha)} + \frac{\alpha}{2(1-\alpha)})(p_r - \omega)$. According to the first-order condition, we obtain the optimal retail price $p_r^* = (1 - \theta + \omega + p_d)/2 + (1-\theta)\alpha$. This retail price is optimal only if the direct price and wholesale price set by the manufacturer are in region S_1 :(as shown in Figure 5.5 (page 114))

$$S_1 = \left\{ (\omega, p_d) \mid \omega > \frac{2-\theta}{\theta} p_d - (1-2\alpha)(1-\theta), \omega < p_d \right\} \tag{5.9}$$

When $p_r < p_d / \theta$, the retailer's profit function is $\pi_r = (1 - \frac{1-p_r}{1-\alpha} + \frac{\alpha}{2(1-\alpha)})(p_r - \omega)$. Similarly, the optimal retail price can be obtained: $p_r^* = \frac{1+\omega}{2} - \frac{\alpha}{4}$. The corresponding direct price and wholesale price from the manufacturer should be in region S_2 :(as shown in Figure 5.5 (page 114))

$$S_2 = \{(\omega, p_d) \mid \omega < \frac{2p_d}{\theta} + \frac{\alpha}{2} - 1, \omega < p_d\} \tag{5.10}$$

As shown in Figure 5.5, there is a region S_3 between S_1 and S_2. The optimal retail price in this region is $p_r^* = \frac{p_d}{\theta}$.

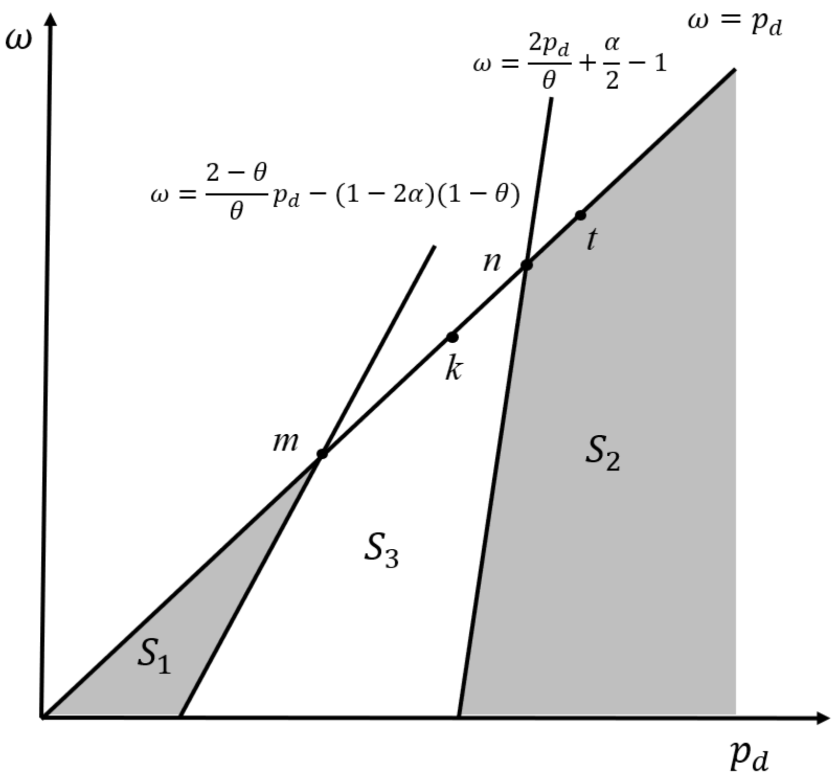

Figure 5.5 Feasible region of wholesale price and direct price

$$S_3 = \{(\omega, p_d) \mid \omega > \frac{2p_d}{\theta} + \frac{\alpha}{2} - 1, \omega < \frac{2-\theta}{\theta} p_d - (1-\theta) - 2\alpha(1-\theta), \omega < p_d\} \tag{5.11}$$

Figure 5.5 illustrates the feasible region of the manufacturer's decision variables: wholesale price and direct price. According to the discussion above, the optimal retail price strategy of the retailer is summarised in Theorem 5.2.

Theorem 5.2. *With overconfident consumers, the optimal retail price in regard to the manufacturer's decision of wholesale price,* ω, *and the direct price,* p_d, *are:*

$$p_r^* = \begin{cases} \dfrac{1-\theta+\omega+p_d}{2}+(1-\theta)\alpha & (\omega, p_d) \in S_1 \\ \dfrac{1+\omega}{2}-\dfrac{\alpha}{4} & (\omega, p_d) \in S_2 \\ \dfrac{p_d}{\theta} & (\omega, p_d) \in S_3 \end{cases} \tag{5.12}$$

As shown in Equation (5.12), the effect of consumers' overconfidence on the retailer's reaction to the manufacturer's wholesale and direct prices depends on the specific situations of the dual-channel supply chain. When both channels are active, thus having positive demands and when the wholesale and direct prices are in the region S_1, the retail price increases along with the increase of consumer's overconfidence level. If only the retail channel is active and has positive demand (in this situation, the wholesale price and direct price are in the region S_2), the retail price decreases along with the increase of consumer's overconfidence level. Unlike the above two situations, at the breakeven point for the positive direct channel demand (in this situation, the wholesale price and direct price are in the region S_3), the retail price is independent of the consumer's overconfidence level.

5.3.2.Pricing strategy of the manufacturer

Given the retailer's optimal pricing strategy, this study analyzes below how the manufacturer can optimize his wholesale price ω and direct price p_d.

When the manufacturer sets the wholesale price and direct price in S_1, the demand of the dual-channel can be obtained based on Equation (5.3). With the demand and wholesale and direct prices, the manufacturer can maximize his profit as follows:

$$\begin{aligned} Max \quad \pi_m &= (1-\frac{1}{2(1-\alpha)}+\frac{p_d-\omega}{2(1-\theta)(1-\alpha)})(\omega-c_1) \\ &+(\frac{1-2\alpha}{2(1-\alpha)}+\frac{\theta\omega-(2-\theta)p_d}{2\theta(1-\theta)(1-\alpha)})(p_d-c_2) \qquad (5.13) \\ s.t. \quad & -\omega+\frac{2-\theta}{\theta}p_d-(1-\theta)(1+2\alpha)<0 \\ & \omega-p_d<0 \end{aligned}$$

Using Karush–Kuhn–Tucker conditions, proposition regarding the manufacturer's optimal pricing strategy can be obtained.

Proposition 5.3. *The optimal solution for the manufacturer in the region* S_1 *is at point "m"(in Figure 5.5).*

$$(\omega^*, p_d^*)=(\frac{\theta}{2}+\theta\alpha, \frac{\theta}{2}+\theta\alpha) \qquad (5.14)$$

As shown in Theorem 5.2, the direct channel is active and has positive demand when the wholesale and direct prices are in the region S_1 only. In the region S_2, the retail channel is the only source for the manufacturer's profit. With the retail price set by the retailer, the manufacturer's sub-optimal problem is formulated below.

$$\begin{aligned} &Max \quad \pi_m = (\frac{1}{2} - \frac{\omega}{2(1-\alpha)} + \frac{3\alpha}{4(1-\alpha)})(\omega - c_1) \\ &s.t. \qquad \omega - p_d < 0 \\ &\qquad \frac{1+\omega}{2} - \frac{\alpha}{4} - \frac{p_d}{\theta} < 0 \end{aligned} \tag{5.15}$$

By solving Model (5.15) above, it can be obtained that the optimal wholesale and direct prices for the manufacturer as follows:

Proposition 5.4. *In the region S_2, the manufacturer's optimal prices should be set as the point "t" (in Figure 5.5).*

$$(\omega^*, p_d^*) = (\frac{1}{2} + \frac{c_1}{2} - \frac{\alpha}{4}, \frac{1}{2} + \frac{c_1}{2} - \frac{\alpha}{4}) \tag{5.16}$$

As shown in Figure 5.5, the region S_3 provides the breakeven point for the positive demand of the direct channel. Based on the retail price: $p_r = p_d / \theta$, the manufacturer's profit maximization model is formulated:

$$\begin{aligned} &Max \quad \pi_m = (1 - \frac{p_d}{\theta(1-\alpha)} + \frac{\alpha}{2(1-\alpha)})(\omega - c_1) \\ &s.t. \qquad \frac{2p_d}{\theta} + \frac{\alpha}{2} - 1 - \omega < 0 \\ &\qquad \omega - \frac{2-\theta}{\theta} p_d + (1-\theta) + 2\alpha(1-\theta) < 0 \\ &\qquad -\omega + p_d < 0 \end{aligned} \tag{5.17}$$

Similarly, by applying the Karush–Kuhn–Tucker conditions, solve Model (5.17) and obtain the solution for the manufacturer.

Proposition 5.5. *In the region* S_3, *if* $\alpha < \frac{\theta^2 - (2-\theta)c_1}{\theta - \theta^2}$, *the manufacturer's optimal prices should be set at point "k" (in Figure 5.5).*

$$(\omega^*, p_d^*) = (\frac{\theta + c_1}{2} - \frac{\theta\alpha}{4}, \frac{\theta + c_1}{2} - \frac{\theta\alpha}{4}) \tag{5.18}$$

Otherwise, point "n" (in Figure5.5) is optimal:

$$(\omega^*, p_d^*) = (\frac{2\theta - \alpha\theta}{2(2-\theta)}, \frac{2\theta - \alpha\theta}{2(2-\theta)}) \tag{5.19}$$

Appendix 4 provides the proofs of Propositions 5.3, 5.4, and 5.5. In summary, there are four candidate points, "t", "k", "m", and "n", for the global profit maximization of the manufacturer. As shown in Figure 4, the optimal point of the region S_1, "m", is on the boundary of S_3. Therefore, only the optimal points of region S_3 and region S_2 should be compared.

As "n" is on the boundary of S_2, "t", which is inside S_2, it provides a higher profit for the manufacturer. Thus, this study further compares $\pi_m(k)$ corresponding to "k" and $\pi_m(t)$ corresponding to "t" to determine the global optimal point. The result is that when $\alpha < \bar{\alpha}$, $\pi_m(k) > \pi_m(t)$ where the threshold value, $\bar{\alpha}$, is defined as follows:

$$\bar{\alpha} = \frac{4\theta^2 - 2\theta c_1 - 2\theta - 2(1-\theta)c_1\sqrt{2\theta}}{2\theta^2 - \theta} \tag{5.20}$$

According to the discussion above, the optimal pricing strategy of the manufacturer can be found:

Theorem 5.3. *With overconfident consumers, the optimal direct channel price should be equal to the optimal wholesale price. The optimal pricing strategy of the manufacturer in the decentralized dual-channel supply chain is:*

$$(\omega^*, p_d^*) = \begin{cases} (\frac{\theta + c_1}{2} - \frac{\theta\alpha}{4}, \frac{\theta + c_1}{2} - \frac{\theta\alpha}{4}) & if\, \alpha < \overline{\alpha} \\ (\frac{1 + c_1}{2} - \frac{\alpha}{4}, \frac{1 + c_1}{2} - \frac{\alpha}{4}) & if\, \alpha \geq \overline{\alpha} \end{cases} \tag{5.21}$$

Table 2 summarizes the optimal pricing strategies of the manufacturer and the retailer in the decentralized dual-channel supply chain. Also provided are the relevant results, such as profits of the manufacturer and the retailer.

Table 5.2 Profit of the decentralized the dual-channel supply chain with overconfident consumers

Consumers' Overconfidence level	$\alpha < \overline{\alpha}$	$\alpha \geq \overline{\alpha}$
Wholesale price	$\frac{\theta + c_1}{2} - \frac{\theta\alpha}{4}$	$\frac{1 + c_1}{2} - \frac{\alpha}{4}$
Direct price	$\frac{\theta + c_1}{2} - \frac{\theta\alpha}{4}$	$\frac{1 + c_1}{2} - \frac{\alpha}{4}$
Retail price	$\frac{\theta + c_1}{2\theta} - \frac{\alpha}{4}$	$\frac{3 + c_1}{4} - \frac{3\alpha}{8}$
Retail demand	$1 - \frac{\theta + c_1}{2\theta(1-\alpha)} + \frac{3\alpha}{4(1-\alpha)}$	$1 - \frac{3 + c_1}{4(1-\alpha)} + \frac{7\alpha}{8(1-\alpha)}$
Direct demand	0	0
Retailer profit	$(1 - \frac{\theta + c_1}{2\theta(1-\alpha)} + \frac{3\alpha}{4(1-\alpha)})$ $(\frac{(1-\theta)(\theta + c_1)}{2\theta} - \frac{(1-\theta)\alpha}{4})$	$(1 - \frac{3 + c_1}{4(1-\alpha)} + \frac{7\alpha}{8(1-\alpha)})(\frac{1 - c_1}{4} - \frac{\alpha}{8})$
Manufacturer profit	$(1 - \frac{\theta + c_1}{2\theta(1-\alpha)} + \frac{3\alpha}{4(1-\alpha)})$ $(\frac{\theta - c_1}{2} - \frac{\theta\alpha}{4})$	$(1 - \frac{3 + c_1}{4(1-\alpha)} + \frac{7\alpha}{8(1-\alpha)})(\frac{1 - c_1}{2} - \frac{\alpha}{4})$

As shown in Table 5.2, both the direct price and the retail price decrease along with the increase of the consumer's overconfidence level. The managerial implication is that in practice, the manufacturers and the retailers in dual-channel supply chains should set lower direct prices and lower retail prices to overconfident consumers to attract them.

Figure 5.6 shows the relationships between the retail price, direct price and consumers' overconfidence level. Below the threshold value, $\bar{\alpha}$, both the direct and retail prices decrease along with the increase of the consumer's overconfidence level. Once the consumer's overconfidence level reaches the threshold value, the direct and retail prices jump to a higher level. This $\bar{\alpha}$ price jumping is caused by the marketing effect of the direct channel (see analysis below). However, above the threshold value, the direct and retail prices decrease again along with the increase of the consumer's overconfidence level. To conclude, in decentralized dual-channel supply chains, consumers benefit from their overconfidence as lower direct prices and retail prices will be offered.

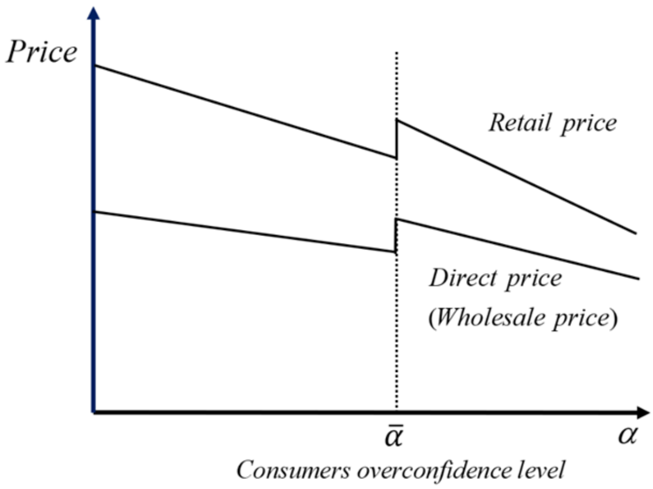

Figure 5.6 Retail price and wholesale price with respect to overconfidence level

As shown in Table 5.2, the retail demand (i.e., demand of the retail channel) increases along with the increase of the consumer's confidence level in certain conditions. When the consumer's confidence level is below $\bar{\alpha}$ and when $\theta > 2c_1$, the retail demand increases. However, when the confidence level reaches $\bar{\alpha}$, the retail demand drops to a lower level, as shown in Figure 5.7. When the confidence level is larger than $\bar{\alpha}$, the retail demand increases again along with the increase of the consumers' confidence level. In regard to the direct demand (i.e., the demand of the direct channel), it is always zero, as shown in Table 2. This finding is consistent with that of Chiang et al. (2003): The direct channel has zero demand and mainly functions as a marketing tool to increase the retail demand. Further, the fact that when the confidence level reaches $\bar{\alpha}$, the retail demand drops, indicates that the marketing effect of the direct channel diminishes when the confidence level reaches a certain value.

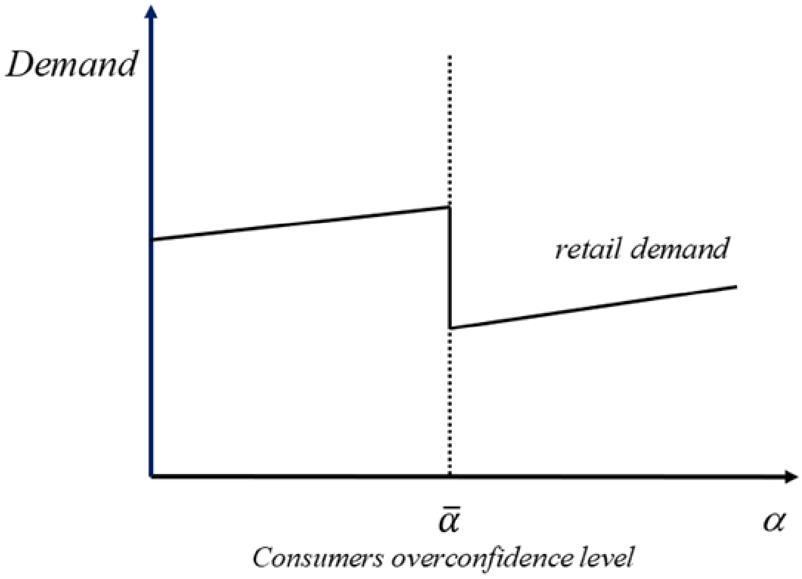

Figure 5.7 Demand of the manufacturer when $\theta > 2c_1$

Along with the changes of the consumer's confidence level and retail demand, the manufacturer's profit changes as well, as shown in Figure 5.8 (page 123). When the consumer's confidence level is lower than $\bar{\alpha}$, the direct channel functions as a marketing tool to stimulate retail demand. In this regard, the dual-channel strategy still works. When the confidence level is larger than $\bar{\alpha}$, the manufacturer's profit is lower than his profit from a single retail channel strategy. This is caused by the diminished marketing effect of the direct channel on the retail demand. The figure also shows that the manufacturer's profit from the single retail channel strategy decreases along with the increase of the consumer's confidence level. These findings suggest that the consumer's overconfidence level is a negative force in the decentralized dual-channel supply chain as the manufacturer's profit decreases along with the increase of the level. Moreover, when the consumer's confidence level is higher than $\bar{\alpha}$, the single retail channel strategy can bring a higher profit to the manufacturer than the dual-channel strategy. Thus, the manufacturer should adopt the single retail channel strategy for selling his product when the potential consumers are too overconfident.

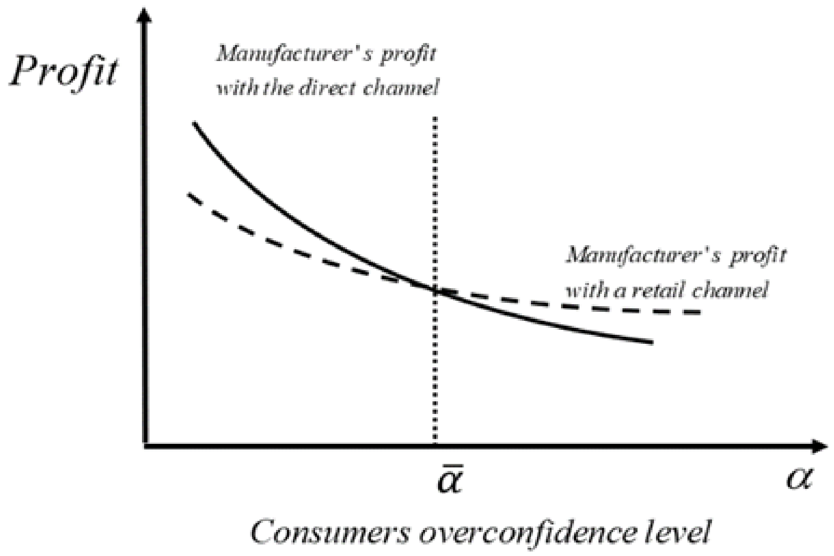

Figure 5.8 The manufacturer’s profits from the dual-channel and single retail channel strategies

From the retailer’s viewpoint, the profit margin becomes narrower when consumers become more overconfident. Although the demand increases (see Figure 5.7), due to the decrease of the retail price (see Figure 5.6), the retailer’s profit decreases along with the increase of the consumer’s overconfidence level, as shown in Figure 5.9 (page 124). This finding may suggest an independent retailer not to join the manufacturer’s supply chain, be it a dual-channel or a single retail channel, if the potential consumers are overconfident.

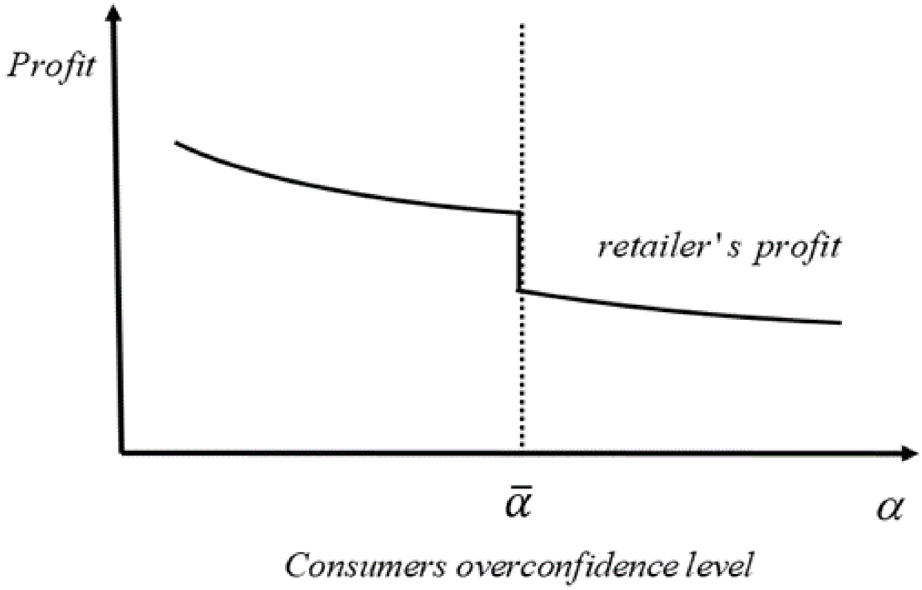

Figure 5.9 Profit of the retailer

5.4. Numerical example

We carry out numerical examples to demonstrate the impacts of consumer's overconfidence and the application of the proposed models in obtaining the optimal wholesale, direct, and retail prices in a dual-channel supply chain. In the numerical examples for both the centralized and decentralized supply chains, the costs for the manufacturer to distribute the product in the retail channel and in the direct channel are $4.50 and $3.00, respectively. The consumer's channel preferences and the total number of consumers are 0.85 and 10,000, respectively.

In the centralized dual-channel supply chain, to show the effect of the changes of the overconfidence levels on the prices, demand, and profits, this study used different values of the overconfidence level in the calculation, including 0 (indicating the consumers are not overconfident), 0.1, 0.2, etc. Based on the common data above, the condition: $\theta c_1 - c_2 > 0$ is satisfied. Therefore, the direct channel is active and has demand. Based on Table 1, this study computes the prices, demand, and profits. The results are provided in Table 5.3.

Table 5.3 Results for the centralized dual-channel supply chain

	Centralized dual-channel supply chain		
Overconfidence level	0	0.1	0.2
Retail price	$7.25	$7.00 (-3.33%)*	$6.75 (-6.66%)*
Direct price	$6.50	$6.30 (-3.08%)*	$6.10 (-6.18%)*
Retail demand	1,250 units	1,111units (-11.1%)*	937 units (-25%)*
Direct demand	1,875 units	2,083units (11.1%)*	2,343 umits (25%)*
Manufacturer profit	$10,000	$9,651 (-3.49%)*	$9,371 (-6.29%)*

*Reduced percentage compared to no overconfidence case (i.e., the case: $\alpha = 0$)

As shown in Table 5.3, both the retail price and the direct price decrease along with the increase of consumers' overconfidence level. In fact, they decrease linearly. More specifically, each time the consumer's overconfidence level increases by 0.1, the retail price and the direct price decrease by $0.25 and $0.2, respectively, as shown in the table. (Note: For illustrative simplicity, this study provides in the table the results corresponding to the overconfidence levels of 0.1 and 0.2.)

Although lower retail prices are offered to overconfident consumers, the retail demand decreases along with the increase of consumers' overconfidence level. When consumers are not overconfident, the retail demand is 1,250 units. It decreases to 1,111 units when consumers' overconfidence level increases to 0.1 and decreases to 937 units when consumers' overconfidence level becomes 0.2. On the contrary, the direct demand benefits from consumers' overconfidence. As shown in the table, the direct demand increases by 11.1% to 2,083 units when consumers' overconfidence level increases from 0 to 0.1. When consumers' overconfidence level reaches 0.2, it increases to 2,343 units. In spite of the direct demand increase, the profit of the manufacturer decreases along with the increase of consumers' overconfidence level. The profit of the manufacturer is $10,000 when consumers are not overconfident. It decreases to $9,651 and $9,371 when consumers' overconfidence level increases to 0.1 and 0.2, respectively. This is caused by the decrease of both the retail and direct prices.

To conclude, consumers' overconfidence presents itself as a negative force in relation to the manufacturer in a centralized dual-channel supply chain. Though the direct demand increases, both the retail and direct prices are lower. These lower prices reduce the manufacturer's profit.

In the decentralized supply chain where the manufacturer and the retailer make decisions independently, with the above common data, the threshold value of the consumer's overconfidence level is computed as 0.42 based on Equation (5.20). Similarly, to show the effect of the changes of the overconfidence levels on the prices, demand, and profits in the decentralized dual-channel supply chain, This study use different values of the overconfidence level in the calculation, including 0 (the consumers are not overconfident), 0.4, 0.45, etc. The results, including optimal prices, demand, and profits obtained are shown in Table 5.4.

Table 5.4 Pricing and profits of the dual-channel supply chain with overconfident consumers

	Decentralized dual-channel supply chain		
Overconfidence level	0	0.4	0.45
Retail price	$7.65	$6.65 (-13.1%)*	$6.90 (-9.8%)*
Wholesale price	$6.50	$5.65 (-13.1%)*	$6.12 (-8.0%)*
Direct price	$6.50	$5.65 (-13.1%)*	$6.12 (-8.0%)*
Retail channel demand	2,354 units	2,255units (-4.2%)*	1,477 units (-37.3%)*
Direct channel demand	0	0	0
Retail profit	$2,709	$2,255 (-16.7%)*	$1,152 (-57.5%)*
Manufacturer profit	$4,708	$2,593 (-45.0%)*	$2,392 (-49.1%)*

*Percentage change compared to no overconfidence case($\alpha = 0$)

As shown in Table 4, when the consumers are not overconfident (i.e., when

$\alpha = 0$), the optimal prices are all higher than the two cases when $\alpha = 0.4$ *and* $\alpha = 0.45$ where the consumers are overconfident. (Note: For illustrative simplicity, in the table, we provide the results corresponding to one overconfidence level value of 0.4 which is below the threshold value of 0.42 and one overconfidence level value of 0.45 which is above the threshold value.) This confirms our further analysis: in the decentralized dual-channel supply chain, both the manufacturer and the retailer need to offer a lower direct price and a lower retail price to overconfident consumers. The direct demand is 0 in all three cases. This demonstrates that the direct channel in the decentralized dual-channel supply chain functions as a promotion tool to increase the retail demand. However, due to the presence of consumers' overconfidence, the retail demand in the latter two cases is lower than the demand when consumers are not overconfident. With the lower prices and lower demand, both the manufacturer and the retailer receive lower profits in the latter two cases.

More specifically, in the case when $\alpha = 4.0$, which is lower than the threshold value $\overline{\alpha} = 0.42$, the retail price drops to \$6.65 by 13.1%. Similarly, the direct and wholesale prices both decrease to \$5.65. Although lower prices have been offered to consumers, the retail demand still decreases by 4.2% to 2,255 units as $\theta < 2c_1$ is satisfied. Caused by the lower demand and prices, the retailer's profit decreases to \$2,255 and the manufacturer's profit decreases to \$2,593. In the case when $\alpha = 4.5$, which is above the threshold value $\overline{\alpha} = 0.42$, all the prices are higher than those in the case when $\alpha = 4.0$. This result confirms the further analysis (see Figure 5.6 in subsection 5.3). As the marketing effect of the direct online channel is reduced, the retail demand of 1,477 is much lower than in the case when $\alpha = 4.0$. Similarly, both the manufacturer and retailer receive lower profits in this case. To summarize, instead of gaining higher profits, both the manufacturer and retailer suffer from the existence of consumers' overconfidence.

In view of the above results and analysis, in practice, manufacturers and retailers should try to reduce consumers' overconfidence. Some approaches suggested might include (1) providing more information about the products online or in promotion activities, (2) displaying the products in the online channel using cutting-edge information technologies, (3) providing better retail services in the retail channel to prevent consumers' overconfident valuation of the product in the purchasing process.

In view of the above results and analysis, in practice, manufacturers and retailers should try to reduce consumers' overconfidence. Some approaches suggested might include (1) providing more information about the products online or in promotion activities, (2) displaying the products in the online channel using cutting-edge information technologies, (3) providing better retail services in the retail channel to prevent consumers overconfident valuation of the product in the purchasing process.

5.5. Summary

Recognizing the negative effects of human's overconfidence in the decision making processes in different fields, researchers started investigating the role and effect that overconfidence has in decision-making. In this section, this study analyzed how consumers' overconfidence affects demand, prices, and profits in a dual-channel supply chain by developing closed-form solutions and proposed optimal pricing strategies for both the manufacturer and the retailer.

This study characterized the pricing problems in both centralized and decentralized dual-channel supply chains with overconfident consumers. In the analysis, this study modeled demand based on consumers' utility and introduced a concept of consumers' overconfidence level. In the centralized dual-channel supply chain, the manufacturer is the owner and sets retail and direct prices at the same time, whilst in the decentralized supply chain, the manufacturer and the retailer are two independent units and set their own prices. In both cases, the objective is to maximize the profits of both the manufacturer and retailer. Stackelberg game theory was adopted to analyze the pricing strategies in the decentralized dual-channel supply chain.

Several interesting results were obtained. First, consumers' overconfidence affects demand, prices, and profits of chain members in a dual-channel supply chain. Second, the direct channel has demand only in the centralized dual-channel supply chain. It does not have demand in the decentralized dual-channel supply chain. However, it helps stimulate demand in the retail channel. Third, in the decentralized dual-channel supply chain, the manufacturer should adopt a pricing strategy where the direct price and the wholesale price should be equal. Fourth, in both centralized and decentralized dual-channel supply chains, a lower direct price and retail price should be set in response to consumers' overconfidence. Fifth, the profits of both the manufacturer and the retailer are reduced with the presence of consumers' overconfidence. Sixth, there exists a threshold value of consumers' overconfidence level. Once the threshold value is reached, the direct channel will not be active for stimulating demand in the retail channel.

To summarize, consumers' overconfidence negatively affects demand, prices, and profits in the dual-channel supply chains. In this regard, manufacturers and retailers should reduce consumers' overconfidence or avoid overconfident consumers by, e.g., providing better retail services.

In this section, the dual-channel supply chain with overconfident consumers, who are overprecise in the valuation of products, is studied. In the future, consumers with more complex features should be considered, e.g., consumers who tend to overestimate the valuation of products. As consumers nowadays are becoming more and more environmentally concerned and prefer to buy green products even at relatively higher prices, it is interesting to see how their environmental consciousness coupled with overconfidence/overestimation affect the pricing decision-making and chain members' profits. Besides, both the retailer and the manufacturer can be overconfident. It seems like an interesting case when consumers, the manufacturer, and the retailer are all overconfident. It is an interesting question who can make profit gains in this case.

6. Pricing Strategy in a Dual-Channel Supply Chains with Loss-Averse Consumers

This chapter introduces the idea of "loss aversion" in the study of the dual-channel supply chain. Loss aversion, which indicates people's preference to avoid losses rather than earn a profit when making decisions under uncertainties, was first considered by Kahneman and Tversky (1979) in experiments. While the expected utility theory cannot explain loss aversion, the prospect theory has been developed (Kahneman and Tversky, 1979). Since loss aversion was introduced, it has been discussed in various fields, such as finance (Benartzi and Thaler, 1993; Barberis et al., 1999; Meng, 2014) and industrial organizations (Kőszegi and Rabin, 2009; Heidhues and Kőszegi, 2014). Based on the idea of loss aversion, behavioral operations research has been introduced as "the study of potentially non-hyper-rational actors in operational contexts" (Croson et al., 2013).

In this research, loss-averse consumer behavior is modeled in the dual-channel supply chain. this study determines utility for consumers who are considered loss-averse. Since loss aversion is reference point-dependent, the products are generally classified into two categories: 1) basic product which has a lower reference utility for consumers and 2) luxury goods which have a higher reference utility for consumers. The demand of each channel is found out according to loss-averse consumers' utility. The pricing strategies of the retailer and manufacturer are determined based on demand forecasting. The effects of loss aversion on the profit of the manufacturer and retailer are investigated.

The chapter is arranged as follows: Section 6.1 introduces consumers' valuation model with loss aversion. Section 6.2 analyzes the demand for the dual-channel supply chain. Section 6.3 illustrates the optimal pricing strategy in the dual-channel supply chain and discusses the results. Section 6.4 presents the findings by a numerical example. The conclusion is drawn in Section 6.5.

6.1. Consumers' valuation of products with loss aversion

As consumers cannot physically examine a product before making a purchase, they need to deal with larger uncertainty in the direct channel online. Therefore, this study assumes that consumers' valuation is more likely to be affected by loss aversion online. In the following part, the model of consumers' valuation of the product in the retail channel is introduced. Then, this study develops a basic model of loss-averse online consumers' valuation. The demand for each channel is forecast by comparing utilities in different channels.

It is assumed that consumers' valuation of a product is heterogeneous and uniformly distributed. Let the value that the product gives to the consumer be v. For simplicity, this study normalizes consumers' valuation to a uniform distribution between 0 and 1.

The retailer sets the retail price as p_r. The consumer who has a valuation of v can obtain utility of $u_r = v - p_r$. Assuming that there is no other retailer and no substitute for consumers, consumers who have positive utility in the transaction will buy a product. Therefore, consumers who make a valuation of the product in the interval $[p_r, 1]$ will buy the product from the retailer, $D_r = 1 - p_r$

Then, this study introduces loss-averse valuation of the product in the direct channel online, as shown in Figure 6.1. Let the set price be p_d and the utility that consumers can obtain from the direct channel online is $v - p_d$. Since loss aversion is reference-dependent, this study sets the reference position of consumers as a. The reference point is essential for distinguishing between gains and losses where the utility above a is a gain, and the utility below a is a loss. While loss-averse consumers would like to avoid losses rather than obtain gains, this study gives a lower weight to the utility above the reference point. Therefore, the cumulative distribution of utility is bent at an angle γ, where $\tan\gamma = k$ as shown in Figure 6.1.

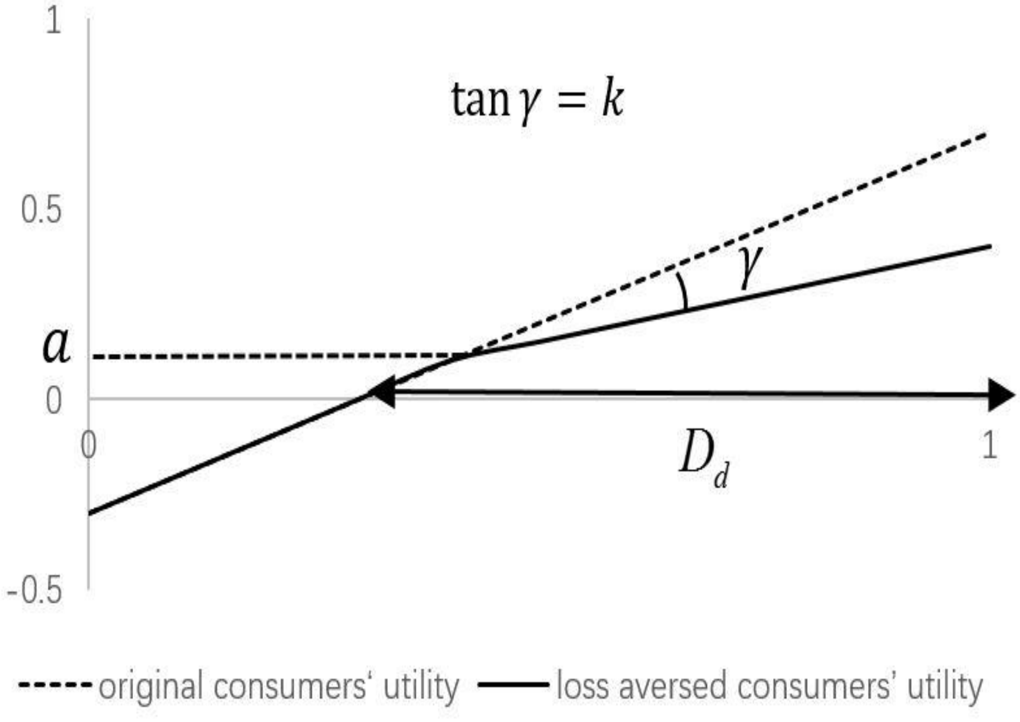

Figure 6.1 Normalized loss-averse cumulative consumers' valuation of a product

The cumulative distribution function of the loss-averse direct channel online consumers' utility u_d is determined. Reference point a indicates the consumers' position relative to the product. Higher k shows a deeper degree of loss aversion.

$$u_d = \begin{cases} v - p_d & , if\ v < a + p_d \\ \frac{1-k}{1+k} v - \frac{1-k}{1+k} p_d + \frac{2k}{1+k} a & , if\ v \geq a + p_d \end{cases} \tag{6.1}$$

The reference point indicates the utility that consumers expect from the transaction. Reference points vary according to the features of the goods. This study classifies products into luxury goods and basic goods. This study follows the definition of the luxury product by Wiedmann et al. (2007), "*the highest level of prestigious brands encompassing several physical and psychological values*". Consumers' value perception of luxury goods has four dimensions: 1) financial dimension; 2) functional dimension; 3) individual dimension; and 4) social dimension (Wiedmann et al., 2007). This study defines basic products where most buyers focus on their physical values. Consumers have a higher utility expectation of luxury goods due to the additional psychological value on the social dimension. The functional value is the main factor driving consumers to buy basic goods. Based on the above observation, luxury goods have a higher reference point of loss aversion and basic goods have a lower reference point of loss aversion.

6.2. Demand for the dual-channel supply chain

The utilities of buying a product through different channels are given. This study define consumers' channel selection mechanism as follows: let consumers maximize their utility by choosing the channel which provides higher utility. If neither channel has positive utility, consumers walk away. When the consumer perceives the same utility in two channels, consumers will remain in the retail channel due to the conventional preference for the retail store. Comparisons of utilities in the direct channel online and retail channel are shown in Figure 6.2 (page 139). If the retail price is less than the direct channel online price, $p_r < p_d$, all consumers are better off in the retail channel as shown in Figure 6.2(a). Demand in the retail channel is $1 - p_r$ while no consumers choose the direct channel online. Figure 6.2(b) shows the situation when the retail price equals the direct channel online price. Regarding $\overline{AB}$, there is no difference between consumers in the direct channel online and the retail channel regarding purchases. It is assumed that they would remain in the retail channel due to consumer loyalty in the segment $\overline{AB}$ (consumers are used to purchasing via the retail channel and there is no incentive for them to change). The same utility between direct channel online and retail channel gives no incentive for consumers to purchase online. Regarding $\overline{CD}$, the retail channel gives higher utility to consumers due to loss aversion in the direct channel online. As a result, all consumers who have positive utility would place orders in the retail channel.

When the retail price is higher than the direct price, $p_r > p_d$, consumers who give a relatively high valuation to a product will choose the direct channel online where the loss aversion effect is larger than the price difference effect. According to u_r and u_d the breakeven point C is $\frac{1+k}{2k}p_r - \frac{1-k}{2k}p_d + a$. In Figure 6.2(c), the length of $\overline{AC'}$ represents demand in the direct channel online, $D_d = \frac{1+k}{2k}(p_r - p_d) + a$. The length of $\overline{C'D'}$ indicates demand in the retail channel, $D_r = 1 - a - \frac{1+k}{2k}p_r + \frac{1-k}{2k}p_d$. However, when the breakeven point is larger than 1, $\frac{1+k}{2k}p_r - \frac{1-k}{2k}p_d + a \geq 1$, the price difference cannot eliminate the effect of loss aversion on consumers as shown in Figure 6.2(d). In this case, all consumers are better off in the direct channel online through an online store, $D_d = 1 - p_d$.

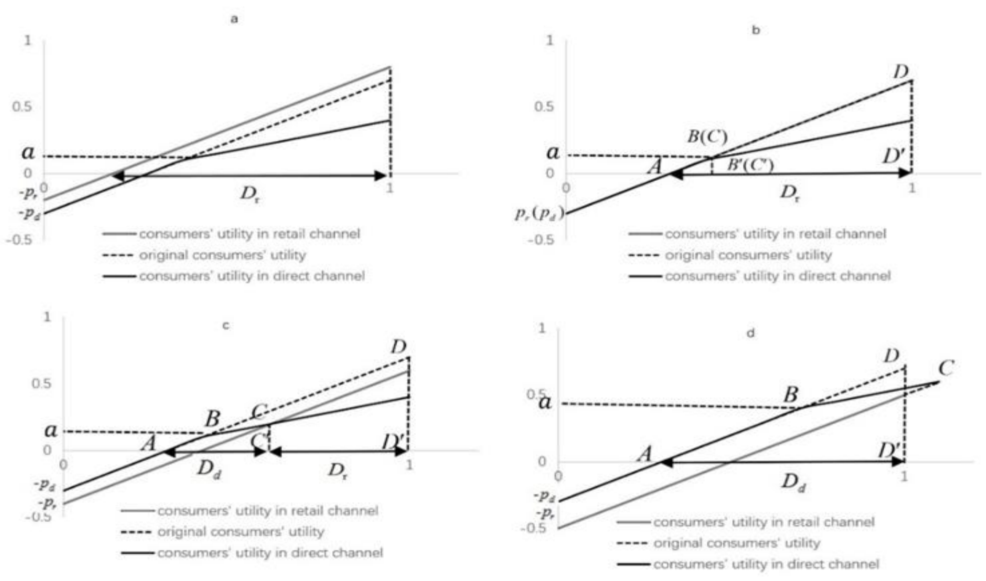

Figure 6.2 Utilities of consumers in the dual channel supply chain

Therefore, according to different combinations of the direct channel online price and the retail channel price, three regions of demand can be observed in Figure 6.3.

In summary, demand functions with respect to the direct price and the retail price are shown as follows:

$$D_r = \begin{cases} 0 & ,(p_d, p_r) \in R_1 \\ 1-a-\dfrac{1+k}{2k}p_r + \dfrac{1-k}{2k}p_d & ,(p_d, p_r) \in R_2 \\ 1-p_r & ,(p_d, p_r) \in R_3 \end{cases}$$

$$D_d = \begin{cases} 1-p_d & ,(p_d, p_r) \in R_1 \\ \dfrac{1+k}{2k}(p_r - p_d) + a & ,(p_d, p_r) \in R_2 \\ 0 & ,(p_d, p_r) \in R_3 \end{cases}$$

$$\begin{aligned} where:\ R_1 &= \{(p_d, p_r) \mid p_r > p_d, p_r > \tfrac{1-k}{1+k}p_d + (1-a)\tfrac{2k}{1+k}\}, \\ R_2 &= \{(p_d, p_r) \mid p_r > p_d, p_r < \tfrac{1-k}{1+k}p_d + (1-a)\tfrac{2k}{1+k}\}, \\ R_3 &= \{(p_d, p_r) \mid p_r > p_d\} \end{aligned} \qquad (6.2)$$

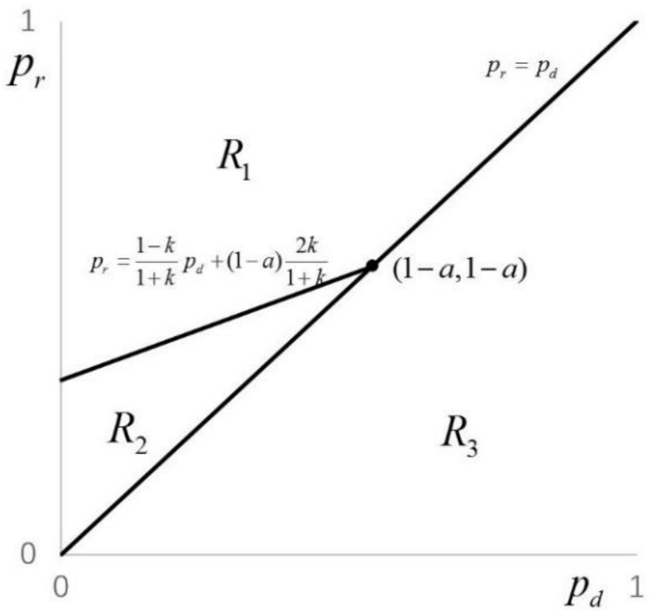

Figure 6.3 Regions of demand in respect to prices

6.3. Pricing in the dual-channel supply chain

The Stackelberg dual-channel supply chain competition model was developed for the case in which there is a monopolist manufacturer with an independent retailer in the market (Figure 6.4). Assume that the manufacturer has opened an online direct channel already. The manufacturer and the retailer independently maximize profit by setting the prices. The overlap effect of prices across channels is ignored.

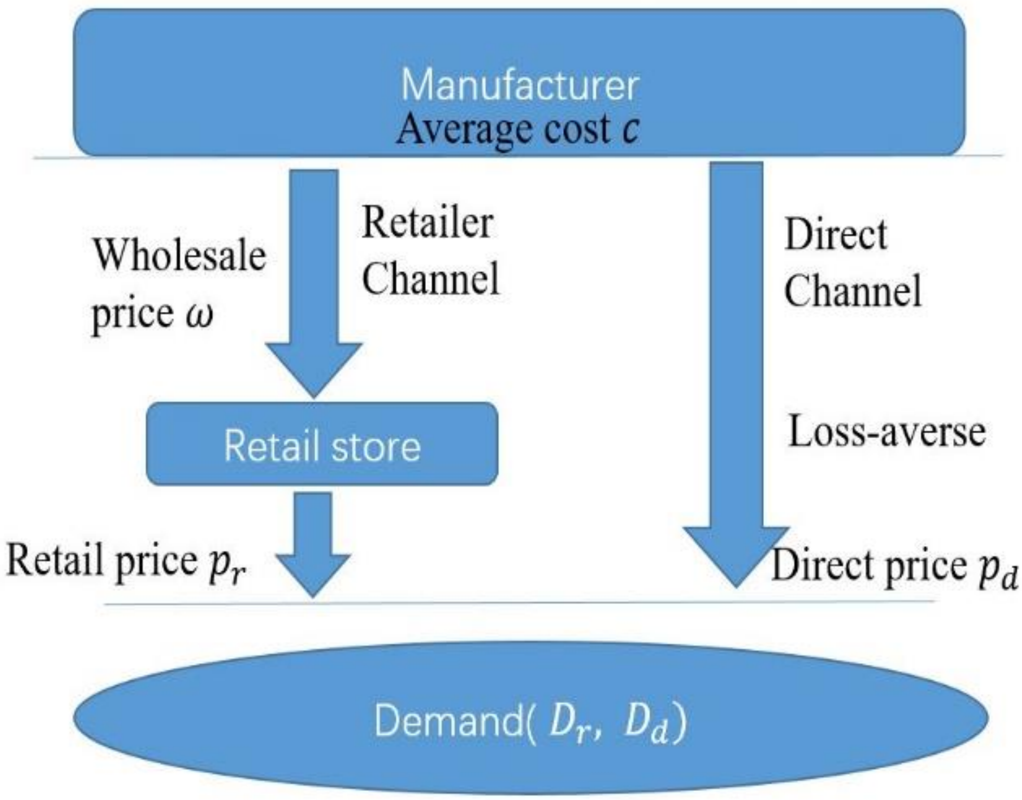

Figure 6.4 Stackelberg dual-channel supply chain with loss aversion

Let the manufacturer set the cost of the product as c. Let the game move in the following sequence. In the first place, the manufacturer, as the Stackelberg leader, sets the wholesale price ω, and the direct channel online price p_d. Then, the retailer, as the Stackelberg follower, sets the retail channel price p_r. Assuming no arbitrage opportunity for the retailer, the wholesale price should be less than or equal to the direct channel price, $\omega \leq p_d$. Otherwise, the retailer will purchase the product via the direct channel online instead of through a wholesale contract.

As discussed above, consumers tend to be loss-averse in the direct channel online. The manufacturer offers a direct channel online price and wholesale price to maximize its profit, $\pi_m = (p_d - c)D_d + (\omega - c)D_r$. Since demand is influenced by the retail channel price, the manufacturer needs to forecast the retailer's price.

6.3.1.The retailers' pricing problem

Only one variable is set by the retailer, which is the retail price p_r , to maximize its profit. In the following part, the optimal retail price p_r^* is examined region by region in R_1, R_2, and R_3. First, this study considers the situation where all consumers choose the direct channel online, $(p_d, p_r) \in R_1$. In this case, the demand for the retail channel is 0 which leads to the nonprofit of the retailer regardless of the retail channel price. No optimal retail price can be obtained. Since the nonprofit situation is not preferred, the retailer, as a Stackelberg follower, can always set a lower retail price to let (p_d, p_r) fall into R_2 or R_3 and avoid this scenario. Therefore, this case can be ignored in the Stackelberg dual-channel supply chain. If $(p_d, p_r) \in R_2$, consumers can be divided into two channels, where $D_r = 1 - a - \frac{1+k}{2k} p_r + \frac{1-k}{2k} p_d$. The corresponding optimal direct price of $p_r^* = \frac{1-k}{2(1+k)} p_d + \frac{w}{2} + \frac{k}{1+k}(1-a)$ is given by the first-order condition of the retailer's profit. In this case, the wholesale ω and the direct channel online price p_d should be in the region S_1.

$$S_1 = \{(\omega, p_d) \,\middle|\, \omega \le p_d, \frac{1+k}{1+3k}\omega + \frac{2k}{1+3k}(1-a) > p_d\} \tag{6.3}$$

When the optimal retail price is in the region R_3, the direct channel online is inefficient due to consumers' loyalty to the retail channel, and the optimal retail price follows $p_r^* = (1+\omega)/2$. The retailer will set this optimal price when the wholesale price ω and direct channel online price p_d are in the region S_2.

$$S_2 = \{(\omega, p_d) \middle| \omega \le p_d, \frac{1+\omega}{2} < p_d\} \quad (6.4)$$

Apart from S_1 and S_2, there is a possible region . Points in the region S_3 are on the boundary between R_2 and R_3, where $p_r^* = p_d$

$$S_3=\{(\omega, p_d) \middle| \omega \le p_d, \frac{1+k}{1+3k}\omega + \frac{2k}{1+3k}(1-a) < p_d, \frac{1+\omega}{2} > p_d\} \quad (6.5)$$

Figure 6.5 shows the retailer's optimal price region S_1, S_2, and S_3. According to the discussion above, the optimal retail price strategy is aggregated by regions as Theorem 6.1.

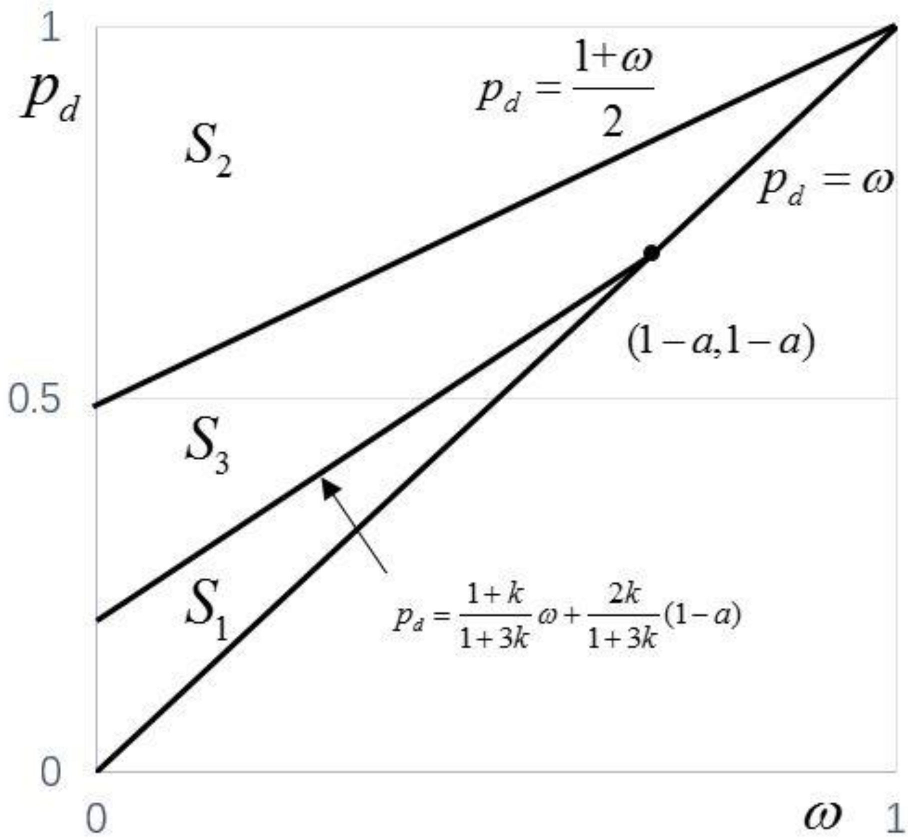

Figure 6.5 Feasible prices region for the retailer

Theorem 6.1 *The optimal retailer's pricing strategy given the manufacturer's settlement of wholesale price* ω *and direct channel online price* p_d *is*

$$p_r^* = \begin{cases} \frac{1-k}{2(1+k)} p_d + \frac{w}{2} + \frac{k}{1+k}(1-a) & ,(\omega, p_d) \in S_1 \\ \frac{1+\omega}{2} & ,(\omega, p_d) \in S_2 \\ p_d & ,(\omega, p_d) \in S_3 \end{cases} \tag{6.6}$$

6.3.2.The manufacturer's pricing problem

Since the Stackelberg leader acts in the first place, the manufacturer has to determine the optimal pricing strategy of the wholesale price and the direct price with respect to the retailer's pricing strategy. There is an important constraint that the wholesale price ω should be no larger than the direct price p_d. This guarantees that the retailer won't turn down the wholesale contract.

Following the logic above, the optimal strategy, (ω^*, p_d^*) is analyzed region by region from S_1 to S_3. In the first place, the region S_1 is discussed, where the direct price is relatively low. The retailer and the manufacturer share the total demand as shown in Figure 6.2(a).

Proposition 6.1. *In the region* S_1, *the optimal price is reference point* a *independently shown as follows:*

$$(p_d^*, \omega^*) = \begin{cases} (1-a, 1-a) & if\ a > \dfrac{1-c}{2} \\ (\dfrac{1+c}{2}, \dfrac{1+c}{2}) & if\ a \le \dfrac{1-c}{2} \end{cases} \tag{6.7}$$

Appendix 5 indicates the proof of Proposition 1 using the method of the Lagrangian multiplier. It should be mentioned that the optimal direct price equals the optimal retail price in both cases. The optimal prices are dependent on the reference point.

It is interesting that the optimal prices lead to a lower profit margin of the manufacturer when consumers have a high reference point.[1] As shown in Figure 6.5, the point $(1-a, 1-a)$ at the peak of the region, leads to no sales in the direct channel online, with a corresponding optimal retail price $p_r^* = 1-a$. The demand for the direct channel online should be zero when demand for the retail channel is a. The demand for each channel is shown as follows:

$$\begin{aligned} D_d &= \begin{cases} \dfrac{3}{4} + \dfrac{a}{2} - \dfrac{c}{4} & if\ a < \dfrac{1-c}{2} \\ 0 & if\ a > \dfrac{1-c}{2} \end{cases} \\ D_r &= \begin{cases} \dfrac{1}{4} - \dfrac{a}{2} - \dfrac{c}{4} & if\ a < \dfrac{1-c}{2} \\ a & if\ a > \dfrac{1-c}{2} \end{cases} \end{aligned} \tag{6.8}$$

[1] Profit margin (if $a > \frac{1-c}{2}$) $= \frac{1-a}{c} < \frac{1-\frac{1-c}{2}}{c} = \frac{1+c}{2c} =$ profit margin (if $a \le \frac{1-c}{2}$)

From the equation above, it can be concluded that the direct channel online is efficient only if consumers' reference point is relatively low, $a \le 0.5 - 0.5c$. While both channels are efficient, demand in the direct channel online is always larger than demand in the retail channel.

Then, the region S_2 is discussed, where $p_r^* = \frac{1+c}{2}$. The direct channel online is not efficient in this case. The dual-channel supply chain becomes a single retailer supply chain, which is familiar to researchers. The manufacturer maximizes its profit $\pi_m = (0.5 - 0.5\omega)(\omega - c)$. By the first-order condition, the optimal wholesale price is $\omega^* = \frac{1+c}{2}$ and the corresponding retail price is $p_r^* = \frac{3+c}{4}$. Therefore, the direct channel online price can be any price larger or equal to the retail price, $p_d^* \ge p_r^* = \frac{3+c}{4}$.

Finally, the region S_3 is studied; $\pi_m = (1 - p_d)(\omega - c)$, which shows that the optimal strategy of the manufacturer is:

Proposition 6.2 *In the region S_3, the optimal prices of the manufacturer are:*

$$(p_d^*, \omega^*) = (\frac{3}{4} + \frac{c}{4}, \frac{1+c}{2}) \tag{6.9}$$

The proof of Proposition 6.2 is shown in Appendix 6.

In region S_3, $p_r^* = p_d^* = \frac{3+c}{4}$. It can be observed that while the constraint, $p_d - 0.5\omega - 0.5 = 0$, is active, the optimal point is located on the boundary between the regions S_2 and S_3. Additionally, the optimal wholesale price and the optimal retail price in both regions are the same. It can be concluded that $(p_d^*,\omega^*)=(\frac{3}{4}+\frac{c}{4},\frac{1+c}{2})$ is the optimal strategy in regions S_2 and S_3 .

However, the optimal point of S_1, $(1-a,1-a)$, is on the boundary of S_2. Therefore, the global optimal prices are $(p_d^*,\omega^*)=(\frac{3}{4}+\frac{c}{4},\frac{1+c}{2})$ when the reference point is larger than the threshold $a>\frac{1-c}{2}$. When the reference point is lower than the threshold $a<\frac{1-c}{2}$, it can be shown that $\pi_{m,}(in\ S_1)=\frac{(1+c)^2}{4}>\frac{(1+c)^2}{8}=\pi_{m,}(in\ S_2\ and\ S_3)$ using the demand function above. This indicates that the global optimal point is $(p_d^*,\omega^*)=(\frac{1+c}{2},\frac{1+c}{2})$ if $a<\frac{1-c}{2}$. Therefore, Theorem 6.2 can be concluded.

Theorem 6.2 *The optimal pricing strategy of the manufacturer is dependent on its reference point under the loss aversion of consumers:*

$$(p_d^*,\omega^*)=\begin{cases}(\frac{3}{4}+\frac{c}{4},\frac{1+c}{2}) & if\ a\geq\frac{1-c}{2}\\ (\frac{1+c}{2},\frac{1+c}{2}) & if\ a<\frac{1-c}{2}\end{cases} \tag{6.10}$$

From the optimal strategy of the manufacturer, the direct channel online is effective only if the reference point is lower than the threshold $\frac{1-c}{2}$. The prices for the wholesale contract and direct channel online are applied. Therefore, the dual-channel supply chain is efficient for basic goods. However, for luxury goods, the dual-channel supply chain is not suggested while all consumers will stick to the retail channel due to loss aversion. Interestingly, the optimal wholesale price is fixed as $\frac{1+c}{2}$ regardless of the reference point. Besides, the level of loss aversion does not have an impact on the pricing by the manufacturer.

Obtained the optimal price of the retail price, wholesales price, and direct price, the profit of the manufacturer and the retailer in the dual-channel supply chain is presented as follows:

Table 6.1 The optimal strategy and outcome respect to the reference point

	The Dual-channel supply chain		Retail channel only
Product type	Basic goods	Luxury goods	-
Reference point, a	$a < \frac{1-c}{2}$	$a > \frac{1-c}{2}$	-
Optimal direct price, p_d^*	$\frac{1+c}{2}$	$\frac{3+c}{4}$	-
Optimal wholesale price, ω^*	$\frac{1+c}{2}$	$\frac{1+c}{2}$	$\frac{1+c}{2}$
Optimal retail price, p_r^*	$\frac{1}{2(1+k)}(1+c)+\frac{k}{1+k}(1-a)$	$\frac{3+c}{4}$	$\frac{3+c}{4}$
Demand in the direct channel online, D_d	$\frac{1+2a-c}{4}$	0	-
Demand in the retail channel, D_r	$\frac{1-2a-c}{4}$	$\frac{1-c}{4}$	$\frac{1-c}{4}$
Total demand, D_r+D_d	$\frac{1-c}{2}$	$\frac{1-c}{4}$	-
Profit of the manufacturer, π_m	$0.25(1-c)^2$	$0.125(1-c)^2$	$0.125(1-c)^2$
Profit of the retailer, π_r	$(\frac{1+c+2k-2ka}{2(1+k)}-\frac{1+c}{2})(\frac{1-2a-c}{4})$	$0.125(1-c)^2$	$0.125(1-c)^2$

From Table 6.1, following propositions can be summarised:

Proposition 6.3. *For basic goods, equilibrium demand of the direct channel online is larger than the retail channel,*

$$D_d^* = \frac{1+2a-c}{4} \geq \frac{1-2a-c}{4} = D_r^*,$$

Proposition 3 implies that the direct channel online will be more important to the manufacturer than the retail channel because the direct channel will contribute larger sales volume in the future. Emarketer.com (2017) reported that e-commerce sales accounted for 8.7 percent of global retail sales in 2016, with a growth rate of 17.6% and it is expected to reach 15.5% of global retail sales. One the one hand, this conclusion explains the booming of direct channels online with loss aversion of consumers. On the other hand, it encourages basic goods manufacturers to apply a dual-channel strategy and deploy more resources on the direct channel online.

Proposition 6.4. For basic goods, the dual-channel strategy can reduce the "double marginalization" effect to the manufacturer when consumers are loss-averse:

$$\pi_m(\textit{basic goods}) = \pi_m(\textit{ integrated retail channel only}) = 0.25(1-c)^2,$$

"Double marginalization" is the phenomenon where the manufacturer and retailer apply their markups in price in a vertical supply chain. This happens when only a retail channel strategy is applied, and it will result in two deadweight losses.

"Double marginalization" is well-known and commonly exists in various industries. To handle "double marginalization", vertical integration of the supply chain is suggested to reduce one of the deadweights. The total profit of the manufacturer is $0.25(1-c)^2$ when the supply chain is vertically integrated. Proposition 6.4 suggests that the dual-channel strategy can effectively reduce the effect of "double marginalization" to the manufacturer of basic goods. A direct channel online plays a significant role to reduce the effect of "double marginalization":

Proposition 6.5. The dual-channel strategy is not beneficial for the manufacturer and retailer of luxury products when there is no positive demand in the direct channel and the retail channel is the only channel for loss-averse consumers.

$$D_d(luxury\ goods) = 0$$
$$\pi_r(Dual - chennel) = \pi_r(retail\ channel\ only)$$
$$\pi_m(Dual - chennel) = \pi_m(retail\ channel\ only)$$

Table 1 illustrates that the demand for a direct channel online for luxury goods is zero. Compared with the case of the retail channel only, the dual-channel supply chain for luxury goods has the same demand for the retail channel. At the same time, profits of the manufacturer and retailer remain at the same level. Therefore, the dual-channel strategy is not suitable for luxury goods because loss-averse consumers avoid purchasing luxury goods from direct channels online.

Proposition 6.6. Considering the loss-averse behavior of consumers, the retailer's revenues are reduced by the dual-channel strategy for both luxury goods and basic goods.

In case 1: Basic Goods

$$\pi_r(\text{dual}) < \pi_r(retail\ only)$$

In case 2: Luxury Goods

$$\pi_r(\text{dual}) = \pi_r(retail\ only)$$

This indicates that the dual-channel strategy is not preferred by the retailer regardless of product type. For basic goods, the dual channel benefits the manufacturer by sacrificing the profit of the retailer, although overall, the total profit of the manufacturer and retailer is increased. For luxury goods, the dual-channel strategy lets the profit of the retailer remains the same as the retail channel only strategy. Therefore, there is no motivation for the retailer to support the direct channel established by the manufacturer when consumers are loss-averse.

6.4. Numerical example

In this section, a numerical example of the pricing of the dual-channel supply chain is presented. The cost of the product, c, is \$5.00. This study normalizes the price from \$0 to \$10. Let consumers' degree of loss aversion $k = 0.2$. Then this study discusses the optimal prices at different reference points of the utility $a = 0.5$, for luxury goods such as a luxury handbag, and $a = 0$, for basic goods such as groceries. The threshold reference point is 0.4. Let the total number of consumers be 1,000.

Table 6.2 Numerical example of the dual-channel supply chain with loss-averse consumer

	Dual-channel supply chain		Retail channel only	Integrated retail channel only
	Basic goods	Luxury goods	-	-
Reference point, a	0	0.5	-	-
Optimal direct price, p_d^*	\$7.50	\$8.75	-	--
Optimal wholesale price, ω^*	\$7.50	\$7.50	\$7.50	-
Optimal retail price, p_r^*	\$7.92	\$8.75	\$8.75	\$7.50

Demand in direct channel online, D_d	125 units	0	-	-
Demand in retail channel, D_r	125units	125 units	125 units	250 units
Total demand, D_r+D_d	250 units	125 units	-	-
Profit of the manufacturer, π_m	\$625.00	\$312.50	\$312.50	\$625.00
Profit of the retailer, π_r	\$52.50	\$156.25	\$156.25	-
Total profit, $\pi_m+\pi_r$	\$677.50	\$468.75	\$468.75	-

For basic goods with a reference point of zero, Table 6.2 illustrates that the demand for the direct channel online is 125 units, which is the same as the demand for 125 units in the retail channel. It shows that the direct channel online contributes to half of the total sales volume. It fits the conclusion of Proposition 3 that the direct channel online will be more important than the retail channel for basic goods manufacturers in the future. The higher the level of loss aversion, the higher the sales volume will be in the direct channel online. Managers of basic goods production firms should further develop direct channels to prepare for higher sales volume in the future, such as improving the shopping experience and delivery time. It has been found that the profit obtained by basic goods manufacturers, USD625, is much higher than the profit of the retail channel, USD312.50. This supports the conclusion that the dual-channel strategy can reduce the effect of “double marginalization”.

Through examining the data of luxury goods, Table 6.2 indicates that profit of the manufacturer remains the same at USD312.50 with the retail channel only strategy. At the same time, the retailer’s profit remains USD156.25. Therefore, the dual-channel strategy provides no advantage for luxury goods.

Compare the profit of the retailer in three scenarios (in Table 6.2), it shows that selling basic goods with the dual-channel strategy gives the lowest profit to the retailer, which is USD52.50. At the same time, selling luxury goods with the dual-channel strategy gives the same profit level of USD156.25 with the retail channel strategy. Therefore, there is no motivation for the retailer to support the dual-channel strategy.

The direct channel online is effective for basic goods. When the consumer’s reference point of loss aversion is 0, the demand for the retail channel drops 50% from 250 units to 125 units compared to an integrated supply chain. The reduced amount of demand is transferred to the direct channel online, with the sales of 125 units. In this case, the profit of the manufacturer is USD625 which is the same as the profit in the integrated retail-only supply chain.

6.5. Summary

Since the previous research on the dual-channel supply chain was built on the assumption that all involved parties aim to maximize their utility, what would happen if consumers' decision is biased by behavioral patterns such as loss aversion? This research indicates the suitability and pricing strategy of the dual-channel supply chain when consumers are loss-averse. It contributes to the literature on the dual-channel supply chain with people's non-hyper-rational behavior patterns while most of the previous research only considered rational participants.

In this research, manufacturers of basic goods are encouraged to deploy more resources for the direct channel online. For example, a shorter delivery time, better online website design, and more online marketing effort are required.

However, for the luxury goods manufacturer, the dual-channel online is not suitable when there are loss-averse consumers. This fits the observations in real life. Most top-tier luxury brands such as Louis Vuitton Malletier do not provide a direct channel or online sales. Major luxury brands use the direct channel online only as a marketing channel to present products. Deloitte (2017) reported that luxury goods manufacturers have been focused on expanding their physical stores in the past ten years. This study suggests that the luxury goods industry should continue to focus on the retail channel as consumers are loss-averse.

7. Conclusions

In this chapter, the conclusions of this study are established. In Section 7.1, a summary of the study is provided based on the pricing strategies and insights that were found in the chapters above, and the contribution of the study is discussed in Section 7.2. Then, the limitations of this study and the future research areas are identified in Section 7.3. These limitations could restrict the implications of the pricing strategies and insights. The future research directions are provided in order to extend the current knowledge with new and promising research topics.

7.1. Summary of the research

The dual-channel supply chain structure has been widely applied in business operations and has become an important field of research. This study has extended the literature on behavioral operations research in the dual-channel supply chain.

In the first stage of the study, the sales efforts deployment problem in the dual-channel supply chain has been studied in order to explore the basic features of the dual-channel supply chain. This study fulfilled the first research objective and second research objectives in this stage. The first objective is to determine the optimal sales effort deployment for both the manufacturer and the retailer in a dual-channel supply chain. This study built a dual-channel supply chain model that had a monopoly manufacturer. The manufacturer had both a retailer and a direct channel online for its sales, where the retailer and the manufacturer deployed their sales efforts independently. It has been found that the channel preference of the consumers was the key parameter for the sales efforts deployment. Interestingly, the optimal sales effort and the profit of the manufacturer and retailer can be limited by the other party's efficiency in the sales effort. This finding suggests that the manufacturer and retailer should collaborate to enhance the efficiency of their sales effort. It also shows that the manufacturer can utilize the direct channel as an important marketing channel, even when no profit is obtained through the direct channel.

In the latter part of the first stage of the study, the dual-channel model was extended in dual-channel operations research. This study explored the features of overconfidence in the classical operations research problem of the competing newsvendor game, where this study assumed that the newsvendor would overestimate his demand and keep this overestimated information private. The second research objective is fulfilled, which is to discuss overconfidence in a competing newsvendor game which is a classical operation research problem and is less complex than the dual-channel supply chain. It has been found that, if only one newsvendor overestimates his demand, a biased newsvendor will place an order that is higher than the optimal value. Then, when both newsvendors make overestimations, there might be two outcomes: 1) both newsvendors experience an equilibrium order increase; or 2) one newsvendor experiences a fall in orders while the other newsvendor’s orders increase. It was found that the boundary conditions of the newsvendor’s equilibrium order amount increase with its own critical fractile and decreases with the other newsvendor’s critical fractile. This indicates that the newsvendor with a higher critical fractile is more likely to have a drop in the equilibrium order amount. However, in both situations, the overall product supply rises, which may also lead to losses for the overestimating newsvendors.

In the second stage of the research, this study extended the literature on dual-channel supply chains with overconfident consumers and loss-averse consumers one by one. In this stage, third and fourth research objectives are fulfilled. The third objective is to examine the pricing strategy for the dual-channel supply chain with overconfident consumers who have overprecise valuations of the product.

This study modeled overconfident consumers who are overprecise on the valuation of a product. The demand analysis considered the consumers' channel preferences in the dual-channel supply chain. The manufacturer and the retailer were indicated in a Stackelberg game to set the prices and to maximize the profits (where the manufacturer was the Stackelberg leader). It turned out that overconfidence can be a positive force for the consumers, as a lower direct price and a lower retail price will be offered to overconfident consumers. Therefore, the manufacturer and the retailer both suffer losses when the consumers are overconfident.

In the later part of the second stage of research, the fourth research objective is fulfilled. The fourth objective is to determine the optimal prices in the dual-channel supply chain with loss-averse consumers who are more sensitive to "losses" than "gains". Since loss aversion is reference point-dependent, the products were classified into two categories: 1) basic goods; and 2) luxury goods. For the basic goods, only a physical value is expected by the consumers; but for luxury goods, an additional psychological value is expected such as psychological satisfaction and a social value. A Stackelberg game model was developed for the manufacturer (the Stackelberg leader) and the retailer (the Stackelberg follower) in the dual-channel supply chain. The results indicated that if there are loss-averse consumers, the dual-channel strategy is best for the manufacturer who produces basic goods, for which the consumers have a lower reference utility value for the loss aversion. These results may explain the booming online sales of goods in the fashion industry and for general merchandise among those who have a lower reference point for the product. The main benefit of a dual-channel strategy to the manufacturer is that the effect of "double marginalization" is reduced. Furthermore, it was shown that the direct channel will have a larger sales volume than the retail channel.

In summary, this study first developed a dual-channel supply chain model and determined the optimal sales efforts deployment strategy in the early stage of the study. The results suggested that a collaboration is needed between the direct and retail channels in order to maximize the profits for the manufacturer and retailer in a dual-channel supply chain. Based on the model of the dual-channel supply chain that has been developed, this study focused on the consumers' non-hyper-rational behavioral patterns in the main stage of the study. The optimal pricing strategy and the impacts of overconfident consumers were discussed, where it was suggested that a lower direct price and a lower retail price will be offered to overconfident consumers, leading to losses for both manufacturers and retailers. For loss-averse consumers, the traditional strategy of a retail channel only is recommended for luxury goods, for which the consumers have a high reference utility value. On the other hand, the dual-channel supply chain strategy is more suitable for basic goods, for which the consumers have a low reference utility value.

7.2. The contribution of the research

The contributions of this research consist of the following:

First, in this research study, a comprehensive and extensive literature review of the dual-channel supply chain and of behavioral operations research is provided. The dual-channel supply chain is an important topic for businesses and for research. The issues of competition and coordination, which were summarized in the literature review, contributed to identifying the potential future research direction. The frameworks and major works on behavioral operations research were also discussed. Since behavioral operations research is in the early stages and is developing at a high pace, the review included in this study allows us to gain a better understanding of the ideas involved in behavioral operations research. Based on this review, the future research directions of behavior operations research can be suggested.

Secondly, this study provides a new method for modeling the sales efforts in the dual channel supply chain. The overlap of the sales efforts between the direct channel and the retail channel were considered in the model, and the optimal sales efforts based on the consumer behavior were determined. The study results will provide a useful framework for the deployment of sales efforts under the consumer preferences for different channels in the dual-channel distribution system. The finding suggests that the manufacturer and the retailer should collaborate to enhance the efficiency of their sales efforts. It also shows that the manufacturer can utilize the direct channel as an important marketing channel even though no profit is acquired through the direct channel. This research contributes to a better understanding of the demand in the dual-channel supply chain under sales efforts. Additionally, the research results provide a useful framework for sales efforts deployment under different consumers' channel

Thirdly, this study contributes to behavioral operations research by demonstrating the behavior of an overestimating newsvendor in the competitive newsvendor game. In the study, an overestimated newsvendor model was developed with an exponentially distributed demand. The Nash equilibrium solution showed that the biased newsvendor had a larger equilibrium order amount when compared with the unbiased competitive newsvendor. The relationship between the boundary conditions and the newsvendor's critical fractal was also investigated.

Fourthly, this study provided a model of overconfident consumers in the dual-channel supply chain, characterized by overconfident consumers who make overprecise valuations of the product. The optimal pricing strategy indicated the impact of overconfidence on the dual-channel supply chain. Several interesting results were obtained. First, consumers' overconfidence affects demand, prices, and profits of chain members in a dual-channel supply chain. Second, the direct channel has demand only in the centralized dual-channel supply chain. It does not have demand in the decentralized dual-channel supply chain. However, it helps stimulate demand in the retail channel. Third, in the decentralized dual-channel supply chain, the manufacturer should adopt a pricing strategy where the direct price and the wholesale price should be equal. Fourth, in both centralized and decentralized dual-channel supply chains, a lower direct price and retail price should be set in response to consumers' overconfidence. Fifth, the profits of both the manufacturer and the retailer are reduced with the presence of consumers' overconfidence. Sixth, there exists a threshold value of consumers' overconfidence level. Once the threshold value is reached, the direct channel will not be active for stimulating demand in the retail channel.

Fifth, this study developed a model that characterizes loss-averse consumers in the dual-channel. Since loss aversion is reference point-dependent, this study classified the goods based on their reference utility value as: 1) basic goods; and 2) luxury goods. As a result, the manufacturers of basic goods and luxury goods can apply the corresponding pricing strategy, and managers can learn about the effects of loss-averse consumers in the dual-channel supply chain. It has been found that manufacturers of basic goods are encouraged to deploy more resources for the direct channel online. For example, a shorter delivery time, better online website design, and more online marketing effort are required. However, for the luxury goods manufacturer, the dual-channel online is not suitable when there are loss-averse consumers. This fits the observations in real life. Most top-tier luxury brands such as Louis Vuitton Malletier do not provide a direct channel or online sales. Major luxury brands use the direct channel online only as a marketing channel to present products. Deloitte (2017) reported that luxury goods manufacturers have been focused on expanding their physical stores in the past ten years. This study suggests that the luxury goods industry should continue to focus on the retail channel as consumers are loss-averse

Lastly, since this study is a pioneering work in discussing non-hyper-rational behaviors in the dual-channel supply chain, the models presented in this study could inspire others undertaking future research in the area of behavioral operations in dual-channel supply chains.

7.3. Limitations and future research

In this study, this study made a number of assumptions when modeling the behavioral operations research in the dual-channel supply chain. However, some limitations have restricted the implications of this study and could be improved in future research. These limitations and future research directions are as follows:

First, this study assumed that the consumers would have a uniform distribution, for the purpose of simplicity. However, more complex and detailed distributions could be adopted in future research, such as a normal distribution.

Secondly, study mainly discussed a decentralized dual-channel supply chain where the manufacturer is the Stackelberg leader. However, there are some powerful retailers that can negotiate with the manufacturer to set the wholesale price, such as Walmart. In such cases, the retailer can be the Stackelberg leader.

Thirdly, this study only considered the factors of overconfidence and loss aversion in consumers. Questions remain, such as: what if the managers of the retailer and the manufacturer are biased? There is evidence supporting the overconfidence and loss aversion of managers in the literature review; and moreover, there could be more than one bias influencing the decision-making process at the same time. There could also be a partial portion of consumers who are overconfident and a portion of consumers who are loss-averse. In these cases, the optimal pricing strategy should be reinvestigated.

In addition, there are a larger number of non-hyperrational behavioral patterns in existence, but only overconfidence and loss aversion were discussed in this study. Future research could focus on modeling other non-hyper-rational behavioral patterns, such as arching effect and mental accounting.

In the literature review, the anchoring effect was introduced as a non-hyper-rational behavioral pattern. However, the current studies on the anchoring effect are empirical studies. The mathematical modeling is lacking. In future research, the anchoring effect will be modeled and analyzed.

8. Appendices

Appendix 1 The proof of uniqueness and existence of the Results in Table 3.1

Considering the scenario that consumers prefer the direct channel to the retail channel, the profit of the retailer is zero as there is no demand in the retail channel according to the demand analysis above. The profit of the manufacturer can be set as follows:

$$\pi_m = (p - c)\left(1 - N\left(\frac{p + c_d}{\theta}\right)\right)(1 + s_d) - \frac{\eta_d s_d^2}{2}$$

The maximum profit can be obtained by the first-order condition where the first-order derivative of the profit with respect to the sales effort is zero ($\frac{\partial \pi_m}{\partial s_d} = 0$)

$$(p - c)\left(1 - N\left(\frac{p + c_d}{\theta}\right)\right) - \eta_d s_d = 0$$

Furthermore, the uniqueness of the optimal sales effort can be proved by the second-order condition where the second-order derivative should always less than zero. For the manufacturer, $\frac{\partial^2 \pi_m}{\partial s_d^2} = -\eta_d \leq 0$, uniqueness can be guaranteed since the cost of the sales effort always has a positive value.

When consumers prefer the retail channel and the preference is larger than $\frac{p+c_d}{p+c_r}$, there is demand in both the retail and direct channels. The profits for the retailer and the profit of the manufacturer are listed below:

$$\pi_r = (p-\omega)(1-N(\frac{c_r-c_d}{1-\theta}))(1+s_r+s_d-s_d s_r)-\frac{\eta_r s_r^2}{2}$$

$$\pi_m = (p-c)\left(N\left(\frac{c_r-c_d}{1-\theta}\right)-N\left(\frac{p+c_d}{\theta}\right)\right)(1+s_r+s_d-s_d s_r)$$

$$+(\omega-c)\left(1-N\left(\frac{c_r-c_d}{1-\theta}\right)\right)(1+s_r+s_d-s_d s_r)-\frac{\eta_d s_d^2}{2}$$

Determination of the optimal sales effort follows the same approach mentioned above. The first-order condition of equilibrium is shown below:

$$\frac{\partial \pi_r}{\partial s_r} = (p-\omega)\left(1-N\left(\frac{c_r-c_d}{1-\theta}\right)\right)(1-s_d)-\ \eta_r s_r = 0$$

$$\frac{\partial \pi_m}{\partial S_d} = (p-c)\left(N\left(\frac{c_r-c_d}{1-\theta}\right)-N\left(\frac{p+c_d}{\theta}\right)\right)(1-s_r)$$

$$+(\omega-c)\left(1-N\left(\frac{c_r-c_d}{1-\theta}\right)\right)(1-s_r)-\ \eta_d s_d = 0$$

The second-order condition of the profits of the manufacturer and the retailer are $\frac{\partial^2 \pi_m}{\partial s_d^2} = -\eta_d \le 0$ and$\frac{\partial^2 \pi_r}{\partial s_r^2} = -\eta_r \le 0$, which ensures the uniqueness of the optimal sales effort.

Eventually, when customers prefer the retail channel over the direct channel (online sales), with a channel preference lower than $\frac{p+c_d}{p+c_r}$, consumers only choose the retail channel. Although there is no demand in the direct channel, sales effort in the direct channel could benefit the manufacturer by increasing demand in the retail channel. The profit functions of the retailer and manufacturer are shown as follows:

$$\pi_r = (p-\omega)(1-N(p+c_r))(1+s_r+s_d-s_d s_r\ ) - \frac{\eta_r s_r^2}{2}$$

$$\pi_m = (\omega-c)\big(1-N(p+c_r)\big)(1+s_r+s_d-s_d s_r\ ) - \frac{\eta_d s_d^2}{2}$$

The first-order condition for equilibrium is:

$$\frac{\partial \pi_r}{\partial s_r} = (p-\omega)\big(D-N(p+c_r)\big)(1-s_d\ ) - \ \eta_r s_r = 0$$

$$\frac{\partial \pi_m}{\partial s_d} = (p-\omega)\big(F-N(p+c_r)\big)(1-s_r\ ) - \ \eta_d s_d = 0$$

Following the same proof above, the uniqueness of optimal sales effort is guaranteed, with the positive cost of the sales effort ($\frac{\partial^2 \pi_m}{\partial s_d^2} = -\,\eta_d \le 0\ \ , \frac{\partial^2 \pi_r}{\partial s_r^2} = -\,\eta_r \le 0$).

Appendix 2 Proof of $Q'_{io}(\lambda_i) < 0$ in Proposition 4.1

If $\lambda_i = \lambda_j$:

$$\frac{\partial B_i(Q_j)}{\partial \lambda_i} = Q_i e^{-\lambda_i Q_i} - Q_i e^{-\lambda_j (Q_i + Q_j)} = Q_i e^{-\lambda_i Q_i}\left(1 - e^{-\lambda_i Q_j}\right) \geq 0$$

It also can be observed that $\frac{\partial B_i(Q_j)}{\partial \lambda_i} = 0$ when $Q_j = 0$.

If $\lambda_i \neq \lambda_j$:

$$\frac{\partial B_i(Q_j)}{\partial \lambda_i} = Q_i e^{-\lambda_i Q_i} + \frac{\lambda_j}{\left(\lambda_i - \lambda_j\right)^2} e^{-\lambda_j (Q_i + Q_j)} - \frac{\lambda_j}{\left(\lambda_i - \lambda_j\right)^2} e^{-\lambda_i Q_i - \lambda_j Q_j} - \frac{\lambda_i Q_i}{\lambda_i - \lambda_j} e^{-\lambda_i Q_i - \lambda_j Q_j}$$

Let $z = \frac{\partial B_i(Q_j)}{\partial \lambda_i}$

When newsvendor j does order the product with

$$z|_{Q_j=0} = -\frac{\lambda_j Q_i}{\lambda_i - \lambda_j} e^{-\lambda_i Q_i} + \frac{\lambda_j}{\left(\lambda_i - \lambda_j\right)^2} e^{-\lambda_j Q_i} - \frac{\lambda_j}{\left(\lambda_i - \lambda_j\right)^2} e^{-\lambda_i Q_i} = \frac{\lambda_j}{\lambda_i - \lambda_j}\left(\frac{e^{-\lambda_j Q_i} - e^{-\lambda_i Q_i}}{\lambda_i - \lambda_j} - Q_i e^{-\lambda_i Q_i}\right)$$
$$> 0$$

Assume newsvendor j order an infinite number of product:

$$z|_{Q_j=\infty} = Q_i e^{-\lambda_i Q_i} > 0$$

The change of the value of z is:

$$\Delta z = \left(\frac{\partial z}{\partial Q_i}, \frac{\partial z}{\partial Q_i}\right) \cdot (\Delta Q_i, \Delta Q_j)$$

With $-1 < \frac{\Delta Q_i}{\Delta Q_j} < 0$, and $\Delta Q_i < 0$, consider the case where Q_j is increasing, and the value of Δz satisfies the following equation:

$$\Delta z \geq (\lambda_j Q_i - \frac{\lambda_i}{\lambda_i - \lambda_j})\left(e^{-\lambda_i Q_i} - e^{-\lambda_i Q_i - \lambda_j Q_j}\right)(-\Delta Q_i)$$

If $\lambda_i - \lambda_j > 0$, $\Delta z > 0$.

If $\lambda_i - \lambda_j < 0$ and $Q_i > \frac{1}{\lambda_i - \lambda_j}$, then$\Delta z > 0$.

If $\lambda_i - \lambda_j < 0$, $Q_i < \frac{1}{\lambda_i - \lambda_j}$ $\Delta z < 0$. However, since $\lim_{Q_i \to \infty} z > 0$, it can be concluded that $\Delta z > 0$. Therefore $Q_{io}'(\lambda_i) < 0$ always holds.

Appendix 3 Proof of Proposition 5.2

The manufacturer's profit can be obtained by solving the below model:

$$
\begin{aligned}
Max \quad \pi_{cm} &= (1 - \frac{p_r - p_d}{(1-\theta)(1-\alpha)} + \frac{\alpha}{2(1-\alpha)})(p_r - c_1) \\
&+ (\frac{p_r - p_d}{(1-\theta)(1-\alpha)} - \frac{p_d}{\theta(1-\alpha)})(p_d - c_2) \\
s.t. \quad & p_d / \theta - p_r \le 0
\end{aligned}
$$

In solving the model, first obtain the Karush–Kuhn–Tucker conditions as follows:

$$
\begin{aligned}
Max \quad & U_{cm} = (1 - \frac{p_r - p_d}{(1-\theta)(1-\alpha)} + \frac{\alpha}{2(1-\alpha)})(p_r - c_1) \\
& + (\frac{p_r - p_d}{(1-\theta)(1-\alpha)} - \frac{p_d}{\theta(1-\alpha)})(p_d - c_2) + \lambda(p_d / \theta - p_r) \\
s.t. \quad & \lambda(p_d / \theta - p_r) = 0 \\
& \lambda \le 0
\end{aligned}
$$

If the constraint $p_d / \theta - p_r = 0$ is true, we obtain the equations below.

$$
\frac{\partial U_{cm}}{\partial p_r} = -\frac{p_r - c_1}{(1-\theta)(1-\alpha)} + 1 - \frac{p_r - p_d}{(1-\theta)(1-\alpha)} + \frac{\alpha}{2(1-\alpha)} + \frac{p_d - c_2}{(1-\theta)(1-\alpha)} - \lambda = 0
$$

$$
\frac{\partial U_{cm}}{\partial p_d} = \frac{p_r - c_1}{(1-\theta)(1-\alpha)} + \frac{p_r - p_d}{(1-\theta)(1-\alpha)} - \frac{p_d}{\theta(1-\alpha)} - \frac{p_d - c_2}{\theta(1-\theta)(1-\alpha)} + \frac{\lambda}{\theta} = 0
$$

Solving the equations above, we have optimal prices:

$$
\begin{aligned}
\lambda &= \frac{\theta c_1 - c_2}{\theta(1-\theta))(1-\alpha)} \\
p_r^* &= 1/2 + c_1/2 - \alpha/4 \\
p_d^* &= \theta/2 + c_1\theta/2 - \alpha\theta/4
\end{aligned}
$$

It is optimal only when $\lambda < 0$, which is $\theta c_1 - c_2 < 0$

Therefore, if $\theta c_1 - c_2 > 0$, the constraint $p_d / \theta - p_r \leq 0$ is not active. In this case, $\lambda = 0$.

$$\frac{\partial U_{cm}}{\partial p_r} = -\frac{p_r - c_1}{(1-\theta)(1-\alpha)} + 1 - \frac{p_r - p_d}{(1-\theta)(1-\alpha)} + \frac{\alpha}{2(1-\alpha)} + \frac{p_d - c_2}{(1-\theta)(1-\alpha)} = 0$$
$$\frac{\partial U_{cm}}{\partial p_d} = \frac{p_r - c_1}{(1-\theta)(1-\alpha)} + \frac{p_r - p_d}{(1-\theta)(1-\alpha)} - \frac{p_d}{\theta(1-\alpha)} - \frac{p_d - c_2}{\theta(1-\theta)(1-\alpha)} = 0$$

Corresponding the optimal retail price and direct price:

$$p_r^* = 1/2 + c_1/2 - \alpha\theta/4,$$
$$p_d^* = \theta/2 - 3\theta\alpha/4 + c_2/2$$

Appendix 4 Proof of Proposition 5.3:

To solve optimal pricing in S_1. The Karush–Kuhn–Tucker conditions are

$$
\begin{aligned}
\max\ U_m &= (1-\frac{1}{2(1-\alpha)}+\frac{p_d-\omega}{2(1-\theta)(1-\alpha)})(\omega-c_1)+(\frac{1-2\alpha}{2(1-\alpha)}+\frac{\theta\omega-(2-\theta)p_d}{2\theta(1-\theta)(1-\alpha)})(p_d-c_2) \\
&\quad +\lambda_1(\omega-p_d)+\lambda_2(-\omega+\frac{2-\theta}{\theta}p_d-(1-\theta)(1+2\alpha)) \\
s.t.\quad & \lambda_2(-\omega+\frac{2-\theta}{\theta}p_d-(1-\theta)(1+2\alpha))=0 \\
& \lambda_1(\omega-p_d)=0 \\
& \lambda_1,\lambda_2\le 0
\end{aligned}
$$

We let $\lambda_2=0$ in the first place, which implies $\omega-p_d=0$ is active. We have:

$$
\begin{aligned}
\frac{\partial U_{cm}}{\partial\omega} &= -\frac{\omega-c_1}{2(1-\theta)(1-\alpha)}+1-\frac{p_d-\omega}{(1-\theta)(1-\alpha)}-\frac{1}{2(1-\alpha)}+\frac{p_d-c_2}{2(1-\theta)(1-\alpha)}+\lambda=0 \\
\frac{\partial U_{cm}}{\partial p_d} &= \frac{\omega-c_1}{(1-\theta)(1-\alpha)}+\frac{\theta\omega-(2-\theta)p_d}{2\theta(1-\theta)(1-\alpha)}-\frac{p_d}{\theta(1-\alpha)}-\frac{(2-\theta)p_d-c_2}{2\theta(1-\theta)(1-\alpha)}+\frac{1-2\alpha}{2(1-\alpha)}-\lambda=0
\end{aligned}
$$

We have a value of $\lambda_1=-1-\frac{c_1-c_2}{2(1-\theta)(1-\alpha)}<0$. Therefore, the optimal direct channel price and wholesale price should be: $(\omega^*,p_d^*)=(\frac{\theta}{2}+\theta\alpha,\frac{\theta}{2}+\theta\alpha)$

Proof of Proposition 5.4:

In the region S_2, the objective function does not have a direct price involved. Therefore, we can maximize the profit by setting the wholesale price directly. The direct price is set on the boundary of the feasible region. The first-order condition of optimization is:

$$
\frac{\partial\pi_m}{\partial\omega}=\frac{1}{2}-\frac{\omega}{2(1-\alpha)}+\frac{\alpha}{4(1-\alpha)}-\frac{\omega-c_1}{2(1-\alpha)}=0
$$

The optimal wholesale price is $\omega^* = \frac{1}{2} + \frac{c_1}{2} - \frac{\alpha}{4}$. The corresponding lowest direct price is $p_d^* = \frac{1}{2} + \frac{c_1}{2} - \frac{\alpha}{4}$. Therefore, we have optimal prices in the region:

$$(\omega^*, p_d^*) = (\frac{1}{2} + \frac{c_1}{2} - \frac{\alpha}{4}, \frac{1}{2} + \frac{c_1}{2} - \frac{\alpha}{4})$$

Proof of Proposition 5.5:

Then, by analyzing the region S_3, we have The Karush–Kuhn–Tucker conditions:

$$\begin{aligned} Max \quad U_m = {} & (1 - \frac{p_d}{\theta(1-\alpha)} + \frac{\alpha}{2(1-\alpha)})(\omega - c_1) + \lambda_1(\frac{2p_d}{\theta} + \frac{\alpha}{2} - 1 - \omega) + \lambda_2(-\omega + p_d) \\ & + \lambda_3(\omega - \frac{2-\theta}{\theta} p_d + (1-\theta) + 2\alpha(1-\theta)) \\ s.t. \quad & \lambda_1(\frac{2p_d}{\theta} + \frac{\alpha}{2} - 1 - \omega) = 0 \\ & \lambda_2(-\omega + p_d) = 0 \\ & \lambda_3(\omega - \frac{2-\theta}{\theta} p_d + (1-\theta) + 2\alpha(1-\theta)) = 0 \\ & \lambda_1, \lambda_2, \lambda_3 \le 0 \end{aligned}$$

The objective function indicates that if both retail and direct channel prices increase, it leads to higher manufacturer's profit. Therefore, with the lower boundary of a feasible solution, the constraint $\omega - \frac{2-\theta}{\theta} p_d + (1-\theta) + 2\alpha(1-\theta) < 0$ is redundant.

When both constraints are active, the optimal point is $(\omega^*, p_d^*) = (\frac{\theta + c_1}{2} - \frac{\theta\alpha}{4}, \frac{\theta + c_1}{2} - \frac{\theta\alpha}{4})$. At the same time, $\lambda_1, \lambda_2 > 0$ should be satisfied. The first-order conditions are:

$$\frac{\partial U_m}{\partial \omega}=(1-\frac{p_d}{\theta(1-\alpha)}+\frac{\alpha}{2(1-\alpha)})-\lambda_1-\lambda_2=0$$
$$\frac{\partial U_m}{\partial p_d}=-\frac{\omega-c_1}{\theta(1-\alpha)}-\lambda_1\frac{2}{\theta}-\lambda_2=0$$

Input the optimal wholesale price and direct price into first order conditions.

We have $\lambda_2=1-\frac{(2-\alpha)}{(1-\alpha)(2-\theta)}+\frac{c_1+\theta\alpha}{\theta(1-\alpha)}<0$ which should be satisfied. Otherwise, only $p_d-\omega=0$ is active. In this case, we have first-order conditions:

$$\frac{\partial U_m}{\partial \omega}=(1-\frac{p_d}{\theta(1-\alpha)}+\frac{\alpha}{2(1-\alpha)})-\lambda_2=0$$
$$\frac{\partial U_m}{\partial p_d}=-\frac{\omega-c_1}{\theta(1-\alpha)}+\lambda_2=0$$

The optimal pricing is:

$$(\omega^*,p_d^*)=(\frac{2\theta-\alpha\theta}{2(2-\theta)},\frac{2\theta-\alpha\theta}{2(2-\theta)})$$

Appendix 5 Proof of Proposition 6.1

By introducing $p_r^* = \frac{1-k}{2(1+k)} p_d + \frac{\omega}{2} + \frac{k}{1+k}(1-a)$ in the demand function of R_2, we have:

$$D_r = \frac{1}{2}(1-a) + \frac{1-k}{4k} p_d - \frac{1+k}{4k}\omega$$
$$D_d = \frac{1}{2}(1+a) - \frac{1+3k}{4k} p_d + \frac{1+k}{4k}\omega$$

Therefore, we have the profit of the manufacturer as:

$$\pi_m = (\frac{1}{2}(1-a) + \frac{1-k}{4k} p_d - \frac{1+k}{4k}\omega)\left(\omega - c\right) + (\frac{1}{2}(1+a) - \frac{1+3k}{4k} p_d + \frac{1+k}{4k}\omega)(p_d - c)$$

subject to $p_d \ge \omega$ and $p_d \le \frac{1+k}{1+3k}\omega + \frac{2k}{1+3k}(1-a)$

We transfer the objective function and constraints into matrix form as:

$$\begin{aligned} &Max \quad \pi_m = \frac{1}{2} x^T Q x + c^T x - d^T \\ &s.t. \qquad\quad Ax \le b \end{aligned}$$

where: $x = \begin{bmatrix} p_d \\ \omega \end{bmatrix}$, $Q = \begin{bmatrix} -\frac{1+3k}{4k} & \frac{1-k}{4k} \\ \frac{1+k}{4k} & -\frac{1+k}{4k} \end{bmatrix}$, $c = \begin{bmatrix} \frac{1+a}{2} \\ \frac{1-a}{2} \end{bmatrix}$, $d = \begin{bmatrix} -c \\ 0 \end{bmatrix}$,

$A = \begin{bmatrix} -1 & 1 \\ -\frac{1+3k}{2(1+k)} & -\frac{1}{2} \end{bmatrix}$, $b = \begin{bmatrix} 0 \\ \frac{k}{1+k}(1+a) \end{bmatrix}$

The eigenvalue of Q : $\begin{bmatrix} -\frac{1+3k}{4k} & 0 \\ 0 & -\frac{1+k}{1+3k} \end{bmatrix}$; therefore, Q is negative definite.

The corresponding Lagrangian problem is:

$$\begin{aligned} &Max \quad \pi_m = \frac{1}{2}x^T Qx + c^T x - d^T + \mu(Ax-b) \\ &s.t. \qquad \mu(Ax-b) = 0, \mu \le 0 \end{aligned}$$

To maximize the objective function, we have:

$$\begin{bmatrix} -\frac{1+3k}{2k} & \frac{1}{2k} \\ \frac{1}{2k} & -\frac{1+k}{2k} \end{bmatrix} \begin{bmatrix} p_d^* \\ \omega \end{bmatrix} + \begin{bmatrix} -1 & 1 \\ 1 & -\frac{2k}{1+3k} \end{bmatrix} \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} + \begin{bmatrix} \frac{1+a}{2}+c \\ \frac{1-a}{2} \end{bmatrix} = 0$$

$$\begin{aligned} s.t. \qquad & \mu_1(-p_d+\omega) = 0 \\ & \mu_2(p_d - \frac{1+k}{1+3k}\omega - \frac{2k}{1+3k}(1-a)) = 0 \\ & \mu_1 \le 0 \\ & \mu_2 \le 0 \end{aligned}$$

In the first place, we assume $\mu_2 = 0$. Therefore $-p_d + \omega = 0$ is active. We have $(p_d^*, \omega^*) = (\frac{1+c}{2}, \frac{1+c}{2})$. To guarantee this, the value of a should satisfy $a < \frac{1-c}{2}$.

Then, assume $\mu_1 < 0, \mu_2 < 0$.

Therefore, $-p_d + \omega = 0, p_d - \frac{1+k}{1+3k}\omega - \frac{2k}{1+3k}(1-a) = 0$ are active. We have an optimal solution at $(p_d^*, \omega^*) = (1-a, 1-a)$.

To guarantee $\mu_1=(1-c-2a)\frac{2k}{1+k}<0, \mu_2=(1-c-2a)\frac{1+3k}{1+k}<0$, the value of a should satisfy $a>\frac{1-c}{2}$.

If $\mu_1=0$, $p_d-\frac{1+k}{1+3k}\omega-\frac{2k}{1+3k}(1-a)=0$ is active; however, in this case, $\mu_1<0$ cannot be guaranteed.

In conclusion, we have:

$$(p_d^*,\omega^*)=\begin{cases}(1-a,1-a) & if\ a>\frac{1-c}{2}\\ (\frac{1+c}{2},\frac{1+c}{2}) & if\ a\le\frac{1-c}{2}\end{cases}$$

Appendix 6 Proof of Proposition 6.2

In the region S_3, we have $p_r^* = p_d^*$. Demand in the retail channel is $1 - p_d^*$ while demand in the direct channel online is zero. $\pi_m = (1 - p_d)(\omega - c)$, constrained to $\omega \le p_d, \frac{1+k}{1+3k}\omega + \frac{2k}{1+3k}(1-a) < p_d, \frac{1+\omega}{2} > p_d$.

Applying the Lagrangian problem, we have:

$$\begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix} \begin{bmatrix} p_d \\ \omega \end{bmatrix} + \begin{bmatrix} c \\ 1 \end{bmatrix} + \begin{bmatrix} -1 & 1 & -1 \\ 1 & -\frac{1}{2} & \frac{1+k}{1+3k} \end{bmatrix} \begin{bmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \end{bmatrix} = 0$$

$$\mu_1(-p_d + \omega) = 0$$
$$\mu_2(p_d - \frac{\omega}{2} - \frac{1}{2}) = 0$$
$$\mu_3(-p_d + \frac{1+k}{1+3k}\omega + \frac{2k}{1+3k}(1-a)) = 0$$
$$\mu_1, \mu_2, \mu_3 \le 0$$

We first assume that $p_d - \frac{\omega}{2} - \frac{1}{2} = 0$ is active; we have $(p_d^*, \omega^*) = (\frac{3}{4} + \frac{c}{4}, \frac{1+c}{2})$. At the same time, $\mu_2 = \frac{c-1}{2} < 0$ is satisfied.

Therefore, the optimal pricing strategy in S_3 is:

$$(p_d^*, \omega^*) = (\frac{3}{4} + \frac{c}{4}, \frac{1+c}{2})$$

9. References

Alpert M and Raiffa H. (1982) A progress report on the training of probability assessors. In: Kahneman D, Slovic P and Tversky A (eds) *Judgment Under Uncertainty: Heuristics and Biases.* Cambridge University Press, 294--305.

Ancarani A, Di Mauro C and D'Urso D. (2016) Measuring overconfidence in inventory management decisions. *Journal of Purchasing and Supply Management* 22: 171-180.

AnthemMarketingSolutions. (2015) *Online VS. In-Store: Price Advantage Continues to Increase for Online Channel*. Available at: http://www.anthemedge.com/index.php?/news/pr/online-instore-pricewars-version8#.VdWBpbKqpBc.

Ariely D, Loewenstein G and Prelec D. (2003) "Coherent arbitrariness": Stable demand curves without stable preferences. *The Quarterly Journal of Economics* 118: 73-106.

Arrow KJ, Harris T and Marschak J. (1951) Optimal inventory policy. *Econometrica: Journal of the Econometric Society*: 250-272.

Balasubramanian S. (1998) Mail versus mall: A strategic analysis of competition between direct marketers and conventional retailers. *Marketing Science* 17: 181-195.

Barber BM and Odean T. (2001) Boys will be boys: Gender, overconfidence, and common stock investment. *The Quarterly Journal of Economics* 116: 261-292.

Barberis N and Huang M. (2008) Stocks as lotteries: The implications of probability weighting for security prices. *American Economic Review* 98: 2066-2100.

Barberis N, Huang M and Santos T. (1999) Prospect theory and asset prices. National bureau of economic research.

Benartzi S and Thaler RH. (1993) Myopic loss aversion and the equity premium puzzle. National Bureau of Economic Research.

Benartzi S and Thaler RH. (1995) Myopic loss aversion and the equity premium puzzle. *The Quarterly Journal of Economics* 110: 73-92.

Bendoly E, Croson R, Goncalves P, et al. (2010) Bodies of Knowledge for Research in Behavioral Operations. *Production and Operations Management* 19: 434-452.

Bendoly E and Swink M. (2007) Moderating effects of information access on project management behavior, performance and perceptions. *Journal of Operations Management* 25: 604-622.

Blankenship KL, Wegener DT, Petty RE, et al. (2008) Elaboration and consequences of anchored estimates: An attitudinal perspective on numerical anchoring. *Journal of Experimental Social Psychology* 44: 1465-1476.

Bokhari S and Geltner D. (2011) Loss aversion and anchoring in commercial real estate pricing: Empirical evidence and price index implications. *Real Estate Economics* 39: 635-670.

Boyaci T. (2005) Competitive stocking and coordination in a multiple-channel distribution system. *IIE transactions* 37: 407-427.

Braun PA and Yaniv I. (1992) A case study of expert judgment: Economists' probabilities versus base-rate model forecasts. *Journal of Behavioral Decision Making* 5: 217-231.

Brooker K. (1999) E-rivals Seem to Have Home Depot Awfully Nervous. *Fortune* 57: 28-29.

Burnside C, Han B, Hirshleifer D, et al. (2011) Investor overconfidence and the forward premium puzzle. *The Review of Economic Studies* 78: 523-558.

Busenitz LW and Barney JB. (1997) Differences between entrepreneurs and managers in large organizations: Biases and heuristics in strategic decision-making. *Journal of Business Venturing* 12: 9-30.

Cai GG. (2010) Channel selection and coordination in dual-channel supply chains. *Journal of Retailing* 86: 22-36.

Cai GG, Zhang ZG and Zhang M. (2009) Game theoretical perspectives on dual-channel supply chain competition with price discounts and pricing schemes. *International Journal of Production Economics* 117: 80-96.

Camerer C and Lovallo D. (1999) Overconfidence and excess entry: An experimental approach. *The American Economic Review* 89: 306-318.

Cameron D, Gregory C and Battaglia D. (2012) Nielsen personalizes the mobile shopping app. *Journal of Advertising Research* 52: 333-338.

Campbell SD and Sharpe SA. (2009) Anchoring bias in consensus forecasts and its effect on market prices. *Journal of Financial and Quantitative Analysis* 44: 369-390.

Campion MA and Lord RG. (1982) A control systems conceptualization of the goal-setting and changing process. *Organizational behavior and human performance* 30: 265-287.

Cao E. (2014) Coordination of dual-channel supply chains under demand disruptions management decisions. *International Journal of Production Research* 52: 7114-7131.

Carrillo JE, Vakharia AJ and Wang R. (2014) Environmental implications for online retailing. *European Journal of Operational Research* 239: 744-755.

Cattani K, Gilland W, Heese HS, et al. (2006) Boiling frogs: Pricing strategies for a manufacturer adding a direct channel that competes with the traditional channel. *Production and Operations Management* 15: 40.

Chapman GB and Johnson EJ. (1999) Anchoring, activation, and the construction of values. *Organizational Behavior and Human Decision Processes* 79: 115-153.

Chen J, Zhang H and Sun Y. (2012) Implementing coordination contracts in a manufacturer Stackelberg dual-channel supply chain. *Omega* 40: 571-583.

Chiang W-y and Monahan GE. (2005) Managing inventories in a two-echelon dual-channel supply chain. *European Journal of Operational Research* 162: 325-341.

Chiang W-yK. (2010) Product availability in competitive and cooperative dual-channel distribution with stock-out based substitution. *European Journal of Operational Research* 200: 111-126.

Chiang W-yK, Chhajed D and Hess JD. (2003) Direct marketing, indirect profits: A strategic analysis of dual-channel supply-chain design. *Management science* 49: 1-20.

Chuang W-I and Susmel R. (2011) Who is the more overconfident trader? Individual vs. institutional investors. *Journal of Banking & Finance* 35: 1626-1644.

Clark AJ and Scarf H. (1960) Optimal policies for a multi-echelon inventory problem. *Management science* 6: 475-490.

Coelho F, Easingwood C and Coelho A. (2003) Exploratory evidence of channel performance in single vs multiple channel strategies. *International Journal of Retail & Distribution Management* 31: 561-573.

Collett S. (1999) Channel conflicts push Levi to halt Web sales. *Computerworld* 33: 8.

Critcher CR and Gilovich T. (2008) Incidental environmental anchors. *Journal of Behavioral Decision Making* 21: 241-251.

Croson R, Schultz K, Siemsen E, et al. (2013) Behavioral operations: the state of the field. *Journal of Operations Management* 31: 1-5.

Dan B, Xu G and Liu C. (2012) Pricing policies in a dual-channel supply chain with retail services. *International Journal of Production Economics* 139: 312-320.

Dana Jr JD and Petruzzi NC. (2001) Note: The newsvendor model with endogenous demand. *Management science* 47: 1488-1497.

Daniel KD, Hirshleifer D and Subrahmanyam A. (2001) Overconfidence, arbitrage, and equilibrium asset pricing. *The journal of finance* 56: 921-965.

David A and Adida E. (2015) Competition and Coordination in a Two-Channel Supply Chain. *Production and Operations Management* 24: 1358-1370.

DellaVigna S and Malmendier U. (2006) Paying not to go to the gym. *American Economic Review* 96: 694-719.

Deloitte. (2017) *Global Powers of luxury Goods 2017*. Available at: https://www2.deloitte.com/content/dam/Deloitte/global/Documents/consumer-industrial-products/gx-cip-global-powers-luxury-2017.pdf.

Devaraj S, Fan M and Kohli R. (2002) Antecedents of B2C channel satisfaction and preference: validating e-commerce metrics. *Information Systems Research* 13: 316-333.

Diaz A and Fu MC. (1997) Models for multi-echelon repairable item inventory systems with limited repair capacity. *European Journal of Operational Research* 97: 480-492.

Dimmock SG and Kouwenberg R. (2010) Loss-aversion and household portfolio choice. *Journal of Empirical Finance* 17: 441-459.

Ding Q, Dong C and Pan Z. (2016) A hierarchical pricing decision process on a dual-channel problem with one manufacturer and one retailer. *International Journal of Production Economics* 175: 197-212.

Dumrongsiri A, Fan M, Jain A, et al. (2008) A supply chain model with direct and retail channels. *European Journal of Operational Research* 187: 691-718.

Easley D and Yang L. (2015) Loss aversion, survival and asset prices. *Journal of Economic Theory* 160: 494-516.

Emarketer.com. (2017) *A Brief Overview of the Global Ecommerce Market*. Available at: https://retail.emarketer.com/article/brief-overview-of-global-ecommerce-market/59690010ebd40005284d5cc5?ecid=NL1014.

Fruchter GE and Tapiero CS. (2005) Dynamic online and offline channel pricing for heterogeneous customers in virtual acceptance. *International Game Theory Review* 7: 137-150.

Gallego G and Moon I. (1993) The Distribution Free Newsboy Problem: Review and Extensions. *The Journal of the Operational Research Society* 44: 825-834.

Genesove D and Mayer C. (2001) Loss aversion and seller behavior: Evidence from the housing market. *The Quarterly Journal of Economics* 116: 1233-1260.

Gervais S and Odean T. (2001) Learning to be overconfident. *Review of Financial Studies* 14: 1-27.

Geyskens I, Gielens K and Dekimpe MG. (2002) The market valuation of internet channel additions. *Journal of marketing* 66: 102-119.

Goel AM and Thakor AV. (2008) Overconfidence, CEO selection, and corporate governance. *The journal of finance* 63: 2737-2784.

Grahovac J and Chakravarty A. (2001) Sharing and lateral transshipment of inventory in a supply chain with expensive low-demand items. *Management science* 47: 579-594.

Grimes PW. (2002) The overconfident principles of economics student: An examination of a metacognitive skill. *The Journal of Economic Education* 33: 15-30.

Grubb MD and Osborne M. (2015) Cellular service demand: Biased beliefs, learning, and bill shock. *American Economic Review* 105: 234-271.

Haigh MS and List JA. (2005) Do professional traders exhibit myopic loss aversion? An experimental analysis. *The journal of finance* 60: 523-534.

Heidhues P and Kőszegi B. (2014) Regular prices and sales. *Theoretical Economics* 9: 217-251.

Heidhues P, x and szegi B. (2008) Competition and Price Variation When Consumers Are Loss Averse. *The American Economic Review* 98: 1245-1268.

Helson H. (1964) Adaptation-level theory.

Herweg F and Müller D. (2016) Overconfidence in the Markets for Lemons. *The Scandinavian Journal of Economics* 118: 354-371.

Hilary G and Menzly L. (2006) Does past success lead analysts to become overconfident? *Management science* 52: 489-500.

Hirshleifer D, Low A and Teoh SH. (2012) Are overconfident CEOs better innovators? *The journal of finance* 67: 1457-1498.

Hu W and Li Y. (2012) Retail service for mixed retail and E-tail channels. *Annals of Operations Research* 192: 151-171.

Hua G, Wang S and Cheng TCE. (2010) Price and lead time decisions in dual-channel supply chains. *European Journal of Operational Research* 205: 113-126.

Huang J and Kisgen DJ. (2013) Gender and corporate finance: Are male executives overconfident relative to female executives? *Journal of Financial Economics* 108: 822-839.

Huang S, Yang C and Liu H. (2013) Pricing and production decisions in a dual-channel supply chain when production costs are disrupted. *Economic Modelling* 30: 521-538.

Huang S, Yang C and Zhang X. (2012) Pricing and production decisions in dual-channel supply chains with demand disruptions. *Computers & Industrial Engineering* 62: 70-83.

Huang W and Swaminathan JM. (2009) Introduction of a second channel: Implications for pricing and profits. *European Journal of Operational Research* 194: 258-279.

Iyer G. (1998) Coordinating channels under price and nonprice competition. *Marketing Science* 17: 338-355.

Janis IL. (1982) Groupthink: Psychological studies of policy decisions and fiascoes.

Jeuland AP and Shugan SM. (1983) Managing channel profits. *Marketing Science* 2: 239-272.

Kacen JJ, Hess JD and Chiang W-yK. (2013) Bricks or clicks? Consumer attitudes toward traditional stores and online stores. *Global Economics and Management Review* 18: 12-21.

Kahneman D and Tversky A. (1979) Prospect theory: An analysis of decision under risk. *Econometrica: Journal of the Econometric Society*: 263-291.

Kalyanaram G and Winer RS. (1995) Empirical generalizations from reference price research. *Marketing Science* 14: G161-G169.

Keenan W. (1999) E-commerce impacts channel partners. *industry Week* 248: 18.

Kőszegi B and Rabin M. (2009a) Reference-dependent consumption plans. *The American Economic Review* 99: 909-936.

Kőszegi B and Rabin M. (2009b) Reference-dependent consumption plans. *American Economic Review* 99: 909-936.

Kovalchik S, Camerer CF, Grether DM, et al. (2005) Aging and decision making: a comparison between neurologically healthy elderly and young individuals. *Journal of Economic Behavior & Organization* 58: 79-94.

Latham GP and Locke EA. (1991) Self-regulation through goal setting. *Organizational Behavior and Human Decision Processes* 50: 212-247.

Lau AHL, Lau H-S and Wang J-C. (2010) Usefulness of resale price maintenance under different levels of sales-effort cost and system-parameter uncertainties. *European Journal of Operational Research* 203: 513-525.

Lee H and Wu J. (2006) A study on inventory replenishment policies in a two-echelon supply chain system. *Computers & Industrial Engineering* 51: 257-263.

Li B, Chen P, Li Q, et al. (2014a) Dual-channel supply chain pricing decisions with a risk-averse retailer. *International Journal of Production Research* 52: 7132-7147.

Li B, Zhu M, Jiang Y, et al. (2016a) Pricing policies of a competitive dual-channel green supply chain. *Journal of Cleaner Production* 112, Part 3: 2029-2042.

Li L, He J and Shi Q. (2014b) Dual-channel pricing strategies for small and medium-sized enterprises. *International Journal of Services, Technology and Management* 20: 47-70.

Li M, Petruzzi NC and Zhang J. (2016b) Overconfident competing newsvendors. *Management science* 63: 2637-2646.

Li QH and Li B. (2016) Dual-channel supply chain equilibrium problems regarding retail services and fairness concerns. *Applied Mathematical Modelling* 40: 7349-7367.

Liao P, Ye F, Tayi GK, et al. (2015) Competition and coordination in online and offline hotel distribution channels under commission override model. *International Journal of Revenue Management* 8: 193-217.

Lippman SA and McCardle KF. (1997) The competitive newsboy. *Operations research* 45: 54-65.

Liu W, Song S and Wu C. (2013a) Impact of loss aversion on the newsvendor game with product substitution. *International Journal of Production Economics* 141: 352-359.

Liu Y, Sun Y and Hu J. (2013b) Channel selection in e-commerce age: A strategic analysis of co-op advertising models. *Journal of Industrial Engineering and Management* 6: 89-103.

Loch CH and Wu Y. (2007) Behavioral operations management. *Foundations and Trends® in Technology, Information and Operations Management* 1: 121-232.

Long X and Nasiry J. (2014) Prospect theory explains newsvendor behavior: the role of reference points. *Management science* 61: 3009-3012.

Lundeberg MA, Fox PW, Brown AC, et al. (2000) Cultural influences on confidence: Country and gender. *Journal of Educational Psychology* 92: 152.

Luo M, Li G and Cheng T. (2016) Free riding and coordination in a dual-channel supply chain in e-commerce. *International Journal of Shipping and Transport Logistics* 8: 223-249.

Ma J, Li Q and Bao B. (2016) Study on Complex Advertising and Price Competition Dual-Channel Supply Chain Models Considering the Overconfidence Manufacturer. *Mathematical Problems in Engineering* 2016.

Ma W-m, Zhao Z and Ke H. (2013) Dual-channel closed-loop supply chain with government consumption-subsidy. *European Journal of Operational Research* 226: 221-227.

Malmendier U and Tate G. (2005) CEO overconfidence and corporate investment. *The journal of finance* 60: 2661-2700.

Malmendier U, Tate G and Yan J. (2007) Corporate financial policies with overconfident managers. National Bureau of Economic Research.

Martín-Herrán G and Taboubi S. (2015) Price coordination in distribution channels: A dynamic perspective. *European Journal of Operational Research* 240: 401-414.

McElroy T and Dowd K. (2007) Susceptibility to anchoring effects: How openness-to-experience influences responses to anchoring cues. *Judgment and decision making* 2: 48.

Melewar T, Lim LL and Yan R. (2010) Product brand differentiation and dual-channel store performances of a multi-channel retailer. *European Journal of Marketing* 44: 672-692.

Meng J. (2014) Can prospect theory explain the disposition effect? A new perspective on reference points. *A New Perspective on Reference Points (March 1, 2014).*

Mitra S. (2009) Analysis of a two-echelon inventory system with returns. *Omega* 37: 106-115.

Moon Y, Yao T and Friesz TL. (2010) Dynamic pricing and inventory policies: A strategic analysis of dual channel supply chain design. *Service Science* 2: 196-215.

Mussweiler T. (2001) Sentencing under uncertainty: Anchoring effects in the courtroom. *Journal of applied social psychology* 31: 1535-1551.

Mussweiler T and Englich B. (2005) Subliminal anchoring: Judgmental consequences and underlying mechanisms. *Organizational Behavior and Human Decision Processes* 98: 133-143.

Mussweiler T and Strack F. (1999) Hypothesis-Consistent Testing and Semantic Priming in the Anchoring Paradigm: A Selective Accessibility Model. *Journal of Experimental Social Psychology* 35: 136-164.

Nicolau JL. (2013) Direct versus indirect channels: Differentiated loss aversion in a high-involvement, non-frequently purchased hedonic product. *European Journal of Marketing* 47: 260-278.

Northcraft GB and Neale MA. (1987) Experts, amateurs, and real estate: An anchoring-and-adjustment perspective on property pricing decisions. *Organizational Behavior and Human Decision Processes* 39: 84-97.

Odean T. (1998) Are investors reluctant to realize their losses? *The journal of finance* 53: 1775-1798.

Paich M and Sterman JD. (1993) Boom, bust, and failures to learn in experimental markets. *Management science* 39: 1439-1458.

Panda S, Modak NM, Sana SS, et al. (2015) Pricing and replenishment policies in dual-channel supply chain under continuous unit cost decrease. *Applied Mathematics and Computation* 256: 913-929.

Park JH, MacLachlan DL and Love E. (2011) New product pricing strategy under customer asymmetric anchoring. *International Journal of Research in Marketing* 28: 309-318.

Parlar M. (1988) Game theoretic analysis of the substitutable product inventory problem with random demands. *Naval Research Logistics (NRL)* 35: 397-409.

Parvini M, Atashi A, Husseini SMM, et al. (2014) A two-echelon inventory model with product returns considering demands dependent return rates. *The International Journal of Advanced Manufacturing Technology* 72: 107-118.

Pei Z and Yan R. (2015) Do channel members value supportive retail services? Why? *Journal of Business Research* 68: 1350-1358.

Pope DG and Schweitzer ME. (2011) Is Tiger Woods loss averse? Persistent bias in the face of experience, competition, and high stakes. *American Economic Review* 101: 129-157.

Ren Y and Croson R. (2013) Overconfidence in newsvendor orders: An experimental study. *Management science* 59: 2502-2517.

Rhee B-D and Park S-Y. (2000) Online store as a new direct channel and emerging hybrid channel system.

Rodríguez B and Aydın G. (2015) Pricing and assortment decisions for a manufacturer selling through dual channels. *European Journal of Operational Research* 242: 901-909.

Ronis DL and Yates JF. (1987) Components of probability judgment accuracy: Individual consistency and effects of subject matter and assessment method. *Organizational Behavior and Human Decision Processes* 40: 193-218.

Russo JE and Schoemaker PJ. (1992) Managing overconfidence. *Sloan management review* 33: 7.

Ryan JK, Sun D and Zhao X. (2013) Coordinating a supply chain with a manufacturer-owned online channel: A dual channel model under price competition. *Engineering Management, IEEE Transactions on* 60: 247-259.

Saha S. (2016) Channel characteristics and coordination in three-echelon dual-channel supply chain. *International Journal of Systems Science* 47: 740-754.

Samuelson PA. (1963) Risk and uncertainty: a fallacy of large numbers. *Scientia* 57: 108.

Schmidt U and Traub S. (2002) An experimental test of loss aversion. *Journal of Risk and Uncertainty* 25: 233-249.

Schweitzer ME and Cachon GP. (2000) Decision bias in the newsvendor problem with a known demand distribution: Experimental evidence. *Management science* 46: 404-420.

Sevier AJ. (1992) Managing employee resistance to JIT: Creating an atmosphere that facilitates implementation. *Production and Inventory Management Journal* 33: 83.

Shang W and Yang L. (2015) Contract negotiation and risk preferences in dual-channel supply chain coordination. *International Journal of Production Research* 53: 4837-4856.

Sherbrooke CC. (1968) METRIC: A multi-echelon technique for recoverable item control. *Operations research* 16: 122-141.

Shi K and Xiao T. (2008) Coordination of a supply chain with a loss-averse retailer under two types of contracts. *International Journal of Information and Decision Sciences* 1: 5-25.

Simon HA. (1986) Rationality in psychology and economics. *Journal of Business*: S209-S224.

Spengler JJ. (1950) Vertical integration and antitrust policy. *The Journal of Political Economy*: 347-352.

Statista.com. (2017a) *Online vs. in-store shopping preferences of consumers in the United States as of February 2017, by product category*. Available at: https://www.c/statistics/311459/us-online-in-person-shopping-preferences-product-category/.

Statista.com. (2017b) *Retail e-commerce sales in the United States from 2015 to 2021 (in billion U.S. dollars)*. Available at:

https://www.statista.com/statistics/272391/us-retail-e-commerce-sales-forecast/.

Statman M, Thorley S and Vorkink K. (2006) Investor overconfidence and trading volume. *The Review of Financial Studies* 19: 1531-1565.

Stern LW, El-Ansary AI and Coughlan AT. (1996) *Marketing channels*: Prentice Hall Upper Saddle River, NJ.

Sydnor J. (2010) (Over) insuring modest risks. *American Economic Journal: Applied Economics* 2: 177-199.

Takahashi K, Aoi T, Hirotani D, et al. (2011) Inventory control in a two-echelon dual-channel supply chain with setup of production and delivery. *International Journal of Production Economics* 133: 403-415.

Thaler RH, Tversky A, Kahneman D, et al. (1997) The effect of myopia and loss aversion on risk taking: An experimental test. *The Quarterly Journal of Economics* 112: 647-661.

Tsao Y-C and Su P-Y. (2012) A dual-channel supply chain model under price and warranty competition. *International Journal of Innovative Computing, Information and Control* 8: 2125-2135.

Tsay AA and Agrawal N. (2004) Channel conflict and coordination in the e-commerce age. *Production and Operations Management* 13: 93-110.

Tversky A and Kahneman D. (1974) Judgment under uncertainty: Heuristics and biases. *science* 185: 1124-1131.

Urban GL, Weinberg BD and Hauser JR. (1996) Premarket forecasting of really-new products. *The Journal of Marketing*: 47-60.

Van Loon M, de Bruin A, Leppink J, et al. (2017) Why are children overconfident? Developmental differences in the implementation of accessibility cues when judging concept learning. *Journal of Experimental Child Psychology* 158: 77-94.

Wagenaar WA and Sagaria SD. (1975) Misperception of exponential growth. *Perception & Psychophysics* 18: 416-422.

Wallace DW, Giese JL and Johnson JL. (2004) Customer retailer loyalty in the context of multiple channel strategies. *Journal of Retailing* 80: 249-263.

Wang CX. (2010) The loss-averse newsvendor game. *International Journal of Production Economics* 124: 448-452.

Wang CX and Webster S. (2009) The loss-averse newsvendor problem. *Omega* 37: 93-105.

Wang Z, Zhang Z, Li C, et al. (2015) Optimal ordering and disposing policies in the presence of an overconfident retailer: a Stackelberg game. *Mathematical Problems in Engineering* 2015.

Wansink B, Kent RJ and Hoch SJ. (1998) An Anchoring and Adjustment Model of Purchase Quantity Decisions. *Journal of Marketing Research* 35: 71-81.

Weber R, Camerer C, Rottenstreich Y, et al. (2001) The illusion of leadership: Misattribution of cause in coordination games. *Organization science* 12: 582-598.

Wegener DT, Petty RE, Blankenship KL, et al. (2010) Elaboration and numerical anchoring: Implications of attitude theories for consumer judgment and decision making. *Journal of Consumer Psychology* 20: 5-16.

Wiedmann K-P, Hennigs N and Siebels A. (2007) Measuring consumers' luxury value perception: a cross-cultural framework. *Academy of Marketing Science Review* 2007: 1.

Xiao T and Shi J. (2016) Pricing and supply priority in a dual-channel supply chain. *European Journal of Operational Research* 254: 813-823.

Xu G, Dan B, Zhang X, et al. (2014) Coordinating a dual-channel supply chain with risk-averse under a two-way revenue sharing contract. *International Journal of Production Economics* 147, Part A: 171-179.

Xu H, Liu ZZ and Zhang SH. (2012) A strategic analysis of dual-channel supply chain design with price and delivery lead time considerations. *International Journal of Production Economics* 139: 654-663.

Yan R. (2008a) Pricing strategy for companies with mixed online and traditional retailing distribution markets. *Journal of Product & Brand Management* 17: 48-56.

Yan R. (2008b) Profit sharing and firm performance in the manufacturer-retailer dual-channel supply chain. *Electronic Commerce Research* 8: 155-172.

Yan R and Ghose S. (2010) Forecast information and traditional retailer performance in a dual-channel competitive market. *Journal of Business Research* 63: 77-83.

Yan R and Pei Z. (2009) Retail services and firm profit in a dual-channel market. *Journal of Retailing and Consumer Services* 16: 306-314.

Yao D-Q and Liu JJ. (2005) Competitive pricing of mixed retail and e-tail distribution channels. *Omega* 33: 235-247.

Yao D-Q, Yue X, Mukhopadhyay SK, et al. (2009) Strategic inventory deployment for retail and e-tail stores. *Omega* 37: 646-658.

Yu JCP, Wang KJ and Lin YS. (2015) Managing dual warehouses with an incentive policy for deteriorating items. *International Journal of Systems Science* 47: 586-602.

Zacharakis AL and Shepherd DA. (2001) The nature of information and overconfidence on venture capitalists' decision making. *Journal of Business Venturing* 16: 311-332.

Zhang P, Xiong Y and Xiong Z. (2015) Coordination of a dual-channel supply chain after demand or production cost disruptions. *International Journal of Production Research* 53: 3141-3160.

Zhao D-z and Lv X. (2011) Vender Managed Inventory Model Based on Overconfident Suppliers under Stochastic Demand [J]. *Systems Engineering* 8: 000.