Maximizing Profits and Enhancing Efficiency in Fashion Supply Chain Management: An Analytical and Numerical Model Addressing RFID Technology, Omnichannel Strategies, and Environmental and Social Aspects

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Abstract:

As technology and internet have been leaping forward, supply chains are subjected to numerous new opportunities and challenges with the rise of consumer choices and environmental and social concerns. Given the unique features exhibited by fashion supply chains (e.g., short product life cycles and unpredictable demand), selecting and implementing suitable strategies for increasing the profitability and efficiency of the supply chain while promoting green products and optimizing social welfare distribution turns out to be a topic that should be urgently investigated. This dissertation aims to address the above-mentioned research problems, striving to provide a theoretical basis for decision-making by a wide variety of stakeholders in the supply chain industry, including governments, suppliers, manufacturers, and retailers. Furthermore, this dissertation aims at gaining insights into the diversification of consumer choices and its potential impacts, exploring how to transform the above-described changes into benefits for supply chain members, and further considering their effects on the environment and overall social welfare.

Supply chains find broad application across a wide range of industries and encompass a multitude of stages. This dissertation places a major focus on three vital managerial aspects in fashion supply chains, explored progressively from differing perspectives through three key studies. The above-mentioned managerial aspects comprise inventory management (RFID technology), operational management (channel selection), and environmental and social considerations, such that the challenges in fashion supply chains are explored in depth. Under the above arrangement, the respective problem can be discussed more comprehensively and in depth, facilitating an individualized understanding of each issue's complexities. Each of the three studies employs a different mathematical decision-analysis model: the Newsvendor model, Stackelberg game model, and the Two-dimension Hoteling model. In all three studies, a comprehensive theoretical analysis is coupled with robust numerical analysis using computer simulations. This approach provides a clear and comprehensive perspective on the challenges fashion supply chains face and the potential solutions.

The first study of inventory is addressed in the initial paper, which focuses on contrasting the problem-solving capabilities of RFID technology (IT-method) and maintaining safety service levels (IE-method) in the context of fashion product inventory misplacement. The paper's findings reveal that RFID takes on critical significance in mitigating product

misplacement, particularly when RFID operating costs are low, and misplacement occurs frequently. Concurrently, the research suggested that increasing order sizes is ineffective at alleviating product misplacement when inventory managers aim to maximize profits.

The second operational issue is addressed in the second study, which investigates the integration of online and offline channels in a fashion supply chain through an omnichannel structure. The above-mentioned method aims at enhancing customer satisfaction by presenting a seamless shopping experience (e.g., buy online, pick-up in-store services, and home delivery options). As indicated by the analysis, under specific conditions (e.g., higher retail prices or inconvenience costs), an omnichannel strategy is confirmed to be more effective than a dual-channel one. However, the above advantage is not universally present; it is determined by factors (e.g., the in-store unit price and online retail price).

The third issue regarding environmental and social welfare is discussed in the final study, which falls into a two-echelon fashion supply chain where a manufacturer produces green products while selling them to competitive retailers. The paper examines the effects of retailer competition, government fiscal intervention, and consumer surplus on the decisions regarding the pricing of green products and green marketing efforts in the supply chain. As revealed by the findings, the government should offer more subsidies to companies to lower retail prices and attract more customers to purchase green products. The paper also suggests that both parties' profits and the development of green products can be enhanced by maintaining a proper level of competition between online and physical stores. However, overly aggressive competition (e.g., ongoing price wars) can harm both parties' profits. Finally, to increase social welfare (consumer surplus), the manufacturer should enhance the green grade of its products, the retailers should intensify their green marketing efforts, and the price of green products should be moderately reduced to compete with ordinary products.

In essence, this doctoral dissertation introduces novel theoretical constructs and pragmatic methodologies for fashion supply chains adjusting to technological, internet, and environmental shifts. It accomplishes this by scrutinizing pivotal studies such as inventory management, Omnichannel retailing, and environment-friendly production. All three papers collectively underscore the vital role of theoretical models in dissecting and mitigating challenges in the supply chain, offering decision-makers rich insights and implementable strategies that are invaluable in understanding, anticipating, and managing complex supply chain papers. Despite each of the three studies differing in their research focus and methodologies employed, they share a common thread: the utilization of theoretical models supported by numerical analysis to investigate practical papers. Their collective objective is to enhance supply chain efficiency and profitability through optimized decision-making. Moreover, the findings of this dissertation carry significant implications for policy-makers, particularly in stimulating green product sales and fostering sustainable supply chain development via government subsidies. This holistic examination of fashion supply chains thus provides a rich trove of decision-making resources for industry stakeholders.

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List of Abbreviations

2D Hotelling model	Two-dimension Hotelling model
BOPS	Buy-Online-Pickup-in-Store
CDF	Cumulative Distribution Function
CS	Consumer-Surplus
CS–M	Consumer-Surplus with Manufacturer
CS–R	Consumer-Surplus with Retailer
CSR	Corporate Social Responsibility
E-commerce	Electronic commerce
GDP	Gross Domestic Product
HD	Home-delivery
IE	Industrial Engineering
IT	Information Technology
MTO	Made-to-Order
MTS	Made-to-Stock
O2O	Online-to-Offline
P&G	Procter & Gamble
PDF	Probability Density Function
PET	Polyethylene Terephthalate
RFID	Radio Frequency Identification
R & D	Research and Development
ROI	Return to Investment
SMEs	Small- and medium-sized Enterprises

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Chapter 1 Introduction

The fashion supply chain takes on critical significance in the global economy. To be specific, the UN DESA (2017) published that the industry value of this supply chain reaches $30 trillion, taking up 2% of the world's Gross Domestic Product (GDP). The global fashion e-commerce market achieved an estimated value of $668.1 billion by 2021. FU (2021) stated the estimated worth of the global fashion industry reached nearly $1.5 trillion in the same year, constituting approximately 2% of the GDP worldwide. The above-mentioned significant contribution highlights the fashion industry's significance and effect on the global economic landscape.

Characterized by short product life cycles, volatile and unpredictable demand, extensive product diversity, lengthy and inflexible supply processes, as well as intricate supply chains, the fashion industry presents its unique set of challenges (Şen, A, 2008). Given the industry-specific factors such as short cycles and unpredictable demand, which necessitate high inventory requirements, and short product lifecycles that can lead to wastage, the fashion supply chain inherently grapples with many obstacles. Compounding the above-described inherent challenges are external factors arising from the widespread adoption of technology and the internet, environmental pollution, and imbalanced welfare distribution. The above-mentioned factors have introduced both opportunities and trials for the fashion supply chain.

The literature primarily focuses on supply chain studies aiming to enhance efficiency in terms of expected cost reductions or profit increases (Choi & Yan, 2008). New technologies, such as RFID and online shopping, can significantly elevate the shopping experience and optimize supply chain efficiency. However, it's worth noting that companies should not blindly follow these trends. Instead, they should assess these developmental trends based on their unique characteristics to bolster supply chain efficiency. However, these technologies can only bring maximum benefits when businesses thoroughly understand and consider their specific business models and customer needs. Therefore, despite these technologies and trends offering new opportunities to improve supply chain efficiency, companies still need to ensure effective utilization of these tools and strategies through continuous learning and adaptation. In summary, to achieve maximum efficiency and benefits, each company must customize and optimize its supply chain strategy according to its unique features and needs.

When considering supply chain efficiency, it's critical to remember that our goal is not only to enhance company profits but also to foster customer satisfaction, sustainable growth, and social development. A comprehensive approach is needed, taking into account all these factors. In particular, the fashion industry's supply chain embodies these complexities, presenting distinct challenges in areas such as inventory management, consumer purchasing via omnichannel, and environmental protection. Each of these aspects requires strategic planning and careful execution to not only maintain supply chain efficiency but also to maximize profits. This multifaceted approach makes the fashion industry supply chain an intricate and demanding domain, further emphasizing the necessity for comprehensive, profit-oriented strategies.

In this dissertation, the examination of the above-described three key supply chain managerial aspects takes on great significance. In general, the fashion industry serves as a significant global sector with immense effects on the environment, society, and the economy. Hence, addressing inventory management, Omnichannel consumption, and environmental and social responsibilities is pivotal for comprehending current challenges and developing sustainable solutions. Additionally, the above-mentioned problems offer a window to investigate different dimensions of the fashion supply chain, including operations, technology, sustainability, and social responsibility, thus providing a comprehensive understanding and practical solutions. Lastly, by zooming in on the above-described matters, this dissertation can deliver pragmatic strategies and suggestions to stakeholders in the fashion industry such as retailers, manufacturers, and policymakers. The findings from this dissertation can guide them towards informed decisions, implementing sustainable practices, and enrich the existing body of knowledge in this field, thereby potentially sparking further research. To approach the above-mentioned three papers systematically, I have partitioned this dissertation into three individual studies, each focusing intensely on one of the above-described three problems. The layout of this dissertation can facilitate a more profound and extensive understanding, thereby providing solutions to the above-mentioned critical papers plaguing the fashion supply chain.

Through the study on the above-described three papers, a novel theoretical framework is proposed, and the ongoing academic discourse around sustainable practices in the fashion industry can be facilitated. In general, my decision to focus on inventory management, channel selection (omnichannel shopping), and environment-friendly production stems from the practical significance and theoretical value of the above-mentioned papers in today's fashion supply chain. Insights and strategies on how to enhance the efficiency and profitability of fashion supply chains, as well as how to achieve environment-friendly production can be gained by thoroughly exploring the above-described matters.

To provide clarity and cohesion throughout this dissertation, each of the three primary research articles will be distinctly labeled and correspond to specific chapters. For example, 'Study I', related to our first paper, will be the focus of Chapter 3. Following this convention, 'Study II' and 'Study III', both of which have been accepted by academic journals (evidence of this acceptance can be found in Appendix D), will be respectively addressed in the subsequent chapters. This systematic approach will facilitate an easier understanding and comparison of the findings across all three papers.

1.1 Research Background

The fashion supply chain, an integral part of the global economy, takes on critical significance in fulfilling consumers' demands, driving economic growth, and promoting environmental protection. Nevertheless, this rapidly changing industry harbors several challenges and problems. The three papers mentioned earlier comprise difficulties in inventory management, the proliferation of sales channels, and concerns regarding investments in green products and the distribution of social resources.

Problems of inventory loss and inability to deliver products to customers quickly and accurately exist in the fashion supply chain. Moreover, the short life cycle of fashion supply chain products and unpredictable demand pose further complications. Since inventory management significantly affects cost, effective inventory management takes on vital significance in the fashion industry and its supply chain. Retailers are required to maintain high levels of inventory to prevent stock-outs, which can trigger immediate sales losses and long-term negative effects on store image and customer loyalty. Factors (e.g., demand uncertainty, theft, commodity spoilage, devaluation, and misplacement) can generally contribute to supply-demand imbalances. Study I extend a mathematical model based on the Newsvendor problem, focusing on the issue of misplacement in the fashion supply chain, and compares traditional safety stock levels maintenance solutions with information technology (RFID) solutions.

Study II is the increasing demand for shopping convenience due to technological advancements and customer diversion. For instance, can offering methods such as online purchase with in-store pickup improve customer satisfaction and bring additional profits to the store? The second paper addresses the advent of omnichannel sales in the fashion supply chain, which presents many challenges due to rapid network development compared to traditional sales channels. This paper introduces two innovative concepts: Buy-Online-Pickup-in-Store (BOPS) and Home-delivery (HD) services. I improve supply chain efficiency by comparing the profitability of online and offline retailers. This research employs a mathematical model based on the two-dimension Hoteling model to explore the above-mentioned aspects.

Study III involves the rapid updating of products in the fashion supply chain, which leads to environmental pollution and welfare distribution problems with government intervention that necessitating in-depth discussion and research. Study III investigates the significance of environment-friendly investments in the fashion supply chain, focusing on factors affecting the greenness of products and marketing efforts. The research investigates how competition among supply chain members, government intervention, and social welfare policies affect the development of green products in two-echelon supply chains, involving competitive retailers and manufacturers of green products. The third research problem uses mathematical modelling to simulate potential problems in economic activities and conducts corresponding numerical analyses. The research applies three standard mathematical models- the Newsvendor model, Hoteling's model, and Stackelberg game model to address inventory management, omnichannel sales, and environmental papers in the fashion supply chain.

The above-described studies are all related to the fashion supply chain, each contributing to a deeper understanding of its challenges and offering distinct solutions. There is interconnectivity among the three studies, where solving one problem can have a positive effect on the other two. For instances, improving inventory management can enhance the shopping experience, and reducing waste indirectly improves environmental protection. The above-mentioned three studies represent key challenges in the fashion supply chain and are research hotspots in this field. Through theoretical modeling and numerical analysis, more insights into the dissertation and propose effective solutions can be gained. Subsequent research can deepen the exploration of how to increase the efficiency, profitability, and sustainability of the fashion supply chain based on this dissertation, such that the development of the fashion industry can be boosted.

1.2 Practical Cases

Theories should be discussed in conjunction with practical applications during the exploration of a wide variety of papers in the fashion supply chain. This dissertation attempts to cite successful cases that are consistent with my theoretical models for validation. In fact, a considerable number of fashion companies have already focused on and applying concepts (e.g., RFID, omnichannel, and green sustainability) to increase supply chain management efficiency and enhance corporate performance. Accordingly, this research, when examining research papers like inventory management, Omnichannel sales, environmental sustainability, and social welfare, will discuss in conjunction with some specific business cases. The above-mentioned cases will help us gain more insights into how theories can be applied in practice and the challenges and solutions that may be encountered in practical operations.

Inventory management problems are exemplified by Adidas (Adidas Group, 2016) and Nike (Nike Group, 2021) in Study I. Both companies use RFID technology for strengthening inventory management, such that inventory loss can be more effectively reduced, and the efficiency of product tracking can be increased. Uniqlo, a Japanese fashion brand, has applied RFID management technology across all regions in Japan (Huayuan RFID, 2022).

Study II addresses the issue of omnichannel sales. Companies like ZARA (ZARA Group, 2023), Nike, and H&M (H&M Group, 2022) have successfully integrated online and offline channels, providing customers with a seamless shopping experience. Alibaba Group, China's largest online shopping platform, cooperates with Cainiao pickup stations, allowing customers to pick up items at their convenience (Xiao et al., 2017). GAP (GAP Group, 2023). and Uniqlo (UNIQLO, 2023) in Japan have developed their mobile apps, which not only allow inventory checks anytime but also enhance the shopping experience. Integration of Macys' online and in-store experiences resulted in sales increase by 1.8% up to $9.4 billion in 2015 (Forrester Research). Through the above-described companies' examples, we can see how Omnichannel sales can help improve customer satisfaction and store profits.

Study III consider environmental sustainability and social welfare are investigated. Companies (e.g., Zara, Nike, and H&M) employ considerable environment-friendly materials in product design and production processes, such that they become leaders in promoting environmental consciousness in the fashion industry. Particularly worth mentioning is Stella McCartney, a fashion designer famous for her sustainable design and manufacturing practices. Her brand firmly abstains from using real leather and fur, actively seeking and using environment-friendly and sustainable alternative materials (Moorhouse & Moorhouse, 2018). In addition to the efforts of the companies themselves, relevant government policies have profoundly impacted the environmental trends of the fashion industry. For instance, the UK Government (2022) has implemented a policy known as the "Green Tax", which encourages businesses to reduce CO2 emissions. Companies can enjoy tax benefits if proving that they are reducing CO2 emissions. According to the Ministry of the Environment, Government of Japan (2022), the Japanese government motivates companies to take proactive actions by setting up a wide range of environmental awards (e.g., the "Environment Minister Award" which is adopted to commend companies that have made outstanding contributions to the environmental field).

The secrets of their success will be revealed through the in-depth analysis of the above-mentioned successful fashion supply chain management strategies. Valuable conclusions about how to address challenges in the fashion supply chain will be drawn through comparing theoretical research and actual business cases. By referencing these fashion business cases, they can effectively support my arguments, demonstrate real-world successful practices, and facilitate comparative analysis with my research findings. Additionally, these cases can serve as a source of inspiration and provide practical guidance for other fashion companies in developing viable strategies for environmental sustainability and social responsibility.

1.3 General Research Motivation

This dissertation aims at addressing practical economic challenges observed in everyday life. The fashion industry holds a significant position in the global economy, thus significantly affecting the economy, society, and the environment. Given the challenges posed by the advancement of technology and the internet, it is essential to address key questions, such as how RFID transforms inventory management, how customer behavior can be predicted, how Omnichannel sales strategies can be optimized, and how effective integration of online and offline sales can be achieved. As detailed in Study I, effective inventory management strategies can significantly enhance supply chain efficiency. Study II further expands on this discussion by exploring the role of omnichannel sales in today's fashion industry. Lastly, Study III emphasizes the importance of green product manufacturing and welfare distribution for sustainable growth.

In existing literature, it is common to examine the fashion supply chain from a single perspective (related literature will be detailed in Chapter 2). However, the dissertation aims at integrating three studies to analyze existing papers from a more comprehensive and in-depth perspective. Each study places a focus on different links in the supply chain’s aspect, and this integration can provide us with an overarching view. It helps us examine deeper into the operations of this complex industry, identify possible solutions, and enhance the overall effectiveness of the fashion supply chain.

The insights and recommendations derived from this dissertation have practical application value for a wide variety of stakeholders in the fashion industry, such as retailers, manufacturers, and policy-makers. For instance, in Study III, I concluded that providing financial subsidies can incentivize companies to sell more green products. By resolving the above-described papers, this dissertation can assist them in making more informed decisions and adopting practices that improve business conditions, customer satisfaction, and environmental quality.

In brief, the dissertation is motivated by the significance of addressing the urgent challenges facing the fashion industry, enhancing the existing knowledge system, and providing practical and sustainable solutions for industry stakeholders.

1.4 General Research Goal

This dissertation is fundamentally aimed at conducting an in-depth exploration of the challenges and intricacies inherent within the fashion supply chain. While the principal goal remains the pursuit of maximal profits and the enhancement of efficiency for supply chain participants, such as manufacturers and retailers, this study also adopts a comprehensive, multifaceted approach to evaluating supply chain efficiency. Key perspectives incorporated into this analysis include inventory management, omnichannel strategies, and environmental considerations. Notably, a crucial aspect of this research involves understanding and integrating the customer's perspective, thereby adding another significant dimension to the discussion. Beyond these factors, the research extends its scrutiny to encompass environmental conservation efforts and the equitable distribution of social welfare within the fashion industry.

Notably, this dissertation also aims to enhance companies' profitability and supply chain efficiency by providing strategic insights and solutions. The interdependence of a wide range of Studies in the fashion supply chain will be recognized in this dissertation, and the result suggests that improvements in one area can take on great significance in the entire system. For instance, the application of RFID, as discussed in Chapter 3, not only enhances operational efficiency but also contributes to the establishment of a green supply chain, a topic elaborated upon in Chapter 5. The mutually beneficial outcomes derived from the synergies of these applications are individually summarized at the end of each chapter, thereby providing a cohesive understanding of their cumulative effects within the broader context of the fashion supply chain.

Therefore, this dissertation encourages industry participants to adopt a more integrated and collaborative method to improve the efficiency of the entire supply chain. Ultimately, this dissertation seeks to contribute to a more sustainable future for the fashion industry by proposing and implementing innovative solutions to tackle the challenges facing the industry. The research goal is to ensure the long-term success and resilience of the fashion supply chain by promoting the adoption of the above-mentioned strategies, providing theoretical support for a more environment-friendly and economically robust industry.

1.5 General Research Methodology

For the methodology employed in this dissertation, operations research-based modeling methods are adopted, combining theoretical analysis with extensive numerical experiments in a research design, for in-depth research on the problems and challenges in the fashion supply chain. By leveraging the robust analytical capabilities of operations research and numerical experimentation, this dissertation can probe deeper into the intricate dynamics of the fashion supply chain, unearthing fresh insights, and contributing valuable perspectives to the evolving discourse in this field.

In Study I, the classic Newsvendor model is employed to delve into optimizing inventory management using RFID technology, in comparison to traditional methods of maintaining safety stock levels. This exploration allows for a comparative analysis between modern technology and conventional practices in inventory management, offering insights into their respective efficiencies and profits. The above-mentioned model is employed for describing and optimizing inventory management decisions given the correlation between a retailer's order quantity, sales volume, and profits. Conclusions that provide meaningful guidance for retailers are drawn through theoretical analysis and numerical experiments.

In Study II, the 2D Hoteling model is expanded upon to analyze and optimize the impact of Omnichannel strategies on fashion retailers. This positional model is utilized to describe and analyze the placement of competitors (online vs. physical stores) within the same market. Through the application of this model, we can examine the effects of different Omnichannel strategies, including BOPS and HD, contrasting these with traditional sales strategies in terms of a retailer's profitability and competitiveness.

For Study III, I use the Stackelberg game model to research how retailers and the manufacture’s competition, government finance intervention, and consumer preferences impact the pricing and marketing of green products in the fashion supply chain under consideration of environmental factors. The Stackelberg game model allows us to consider hierarchical decisions and interactions among different participants and analyze their effect on green product pricing and market marketing strategies.

Although the mathematical models in the three studies differ, all model analyses have accompanied numerical experiments through multiple trials to ensure robustness, validate the effectiveness of theoretical analysis, reveal the sensitivity of model parameters, and assess the effects of implementing different strategies. In general, the methodology of this dissertation will provide a structured framework for understanding and addressing key studies in the fashion supply chain management.

1.6 Major Contributions

The three studies in this dissertation make significant contributions to the supply chain management in the fashion industry, addressing key managerial aspects such as inventory management, Omnichannel sales operation, and environmental and social concerns. The dissertation provides far-reaching insights for policymakers and relevant stakeholders in the industry, further promoting sustainable development in the fashion sector.

Study I's notable contribution lies in its revelation of the significance of RFID technology applications in the fashion supply chain for enhancing inventory management efficiency and reducing misplaced goods. Under certain conditions (e.g., high RFID costs), strategies of increasing the order quantity to boost the safety stock outperform those the implementation of RFID. On the other hand, if the product unit price can absorb RFID costs, I recommend employing RFID technology to reduce misplacement rate and improve customer satisfaction.

The contribution of Study II lies in its theoretical model comparison of two Omnichannel strategies: Buy-Online-Pickup-in-Store (BOPS) and Home-delivery (HD), thereby providing a new perspective on Omnichannel sales strategies for the fashion industry. This research makes the first attempt at such a comparison, suggesting that I recommend the adoption of Omnichannel strategies in the fashion supply chain to expand sales and enhance customer satisfaction when the operational costs of Omnichannel are low.

Study III's contribution lies in its exploration of the role of government intervention in the fashion supply chain, particularly when considering environmental papers. Through parameter analysis and numerical examples, the research reveals how government subsidies impact the retail price of green products and how they affect consumer purchasing behaviors towards green products. This paper can present more insights into government intervention in the fashion supply chain while providing useful practical guidelines for policymakers and industry stakeholders, such that the promotion and procurement of green products in the fashion industry can be expedited.

1.7 Dissertation Structure

In Chapter 2, a detailed literature review is presented, and the research contributions and innovations of this dissertation are outlined. In Chapter 3, Study I is explored in depth, offering an in-depth exploration of the Newsvendor model as adopted in the fashion supply chain. It covers its introduction, main assumptions, and a detailed discussion of its implications. The model's formulae and results are analyzed, especially in relation to the inventory management problem addressed. Furthermore, the insights derived from the first paper's findings are revealed to lay a basis for the second and third papers. In Chapter 4, Study II build the problem description, business background, and the application of the Hoteling model in the second paper are illustrated, while the model's formulae and numerical experiments are investigated. Besides, the findings of the second paper can be conducive to the Study I and III. In Chapter 5, Study III's application of the Stackelberg game model in dealing with green environmental and welfare distribution papers is introduced, while a particular focus is placed on its application in supply chain analysis. Besides, the connections among the results of the three Studies are discussed. In Chapter 6, the results from the three papers are summarized comprehensively, offering valuable managerial insights and suggestions. The connections between these three papers are also summarized, and how they collectively contribute to a comprehensive insight into the vital aspects and challenges of the fashion supply chain is outlined. Lastly, in Chapter 7, the research directions following the cross-application of the themes from the three articles are summarized.

Chapter 2 General Literature Review

In the second Chapter of this dissertation, I have carefully curated and incorporated five critical research themes. These themes collectively construct a comprehensive insight into the diversity and challenges of the fashion supply chain. These five themes are the unique characteristics of the fashion supply chain, strategies for its management, the implementation of RFID technology, the application of Omnichannel sales strategies, and the significance and impact of environmental factors within the fashion supply chain. In the conclusion of this chapter, I particularly emphasize the distinctiveness of my research compared to existing literature. Building upon the integration of existing knowledge, I am committed to providing original insights and innovative points of my doctoral research. I anticipate that these contributions can propel the future development direction of this vibrant field.

2.1 The Unique of Fashion Supply Chain

The global fashion industry has undergone pervasive change due to leaner economic times that have reduced consumer buying power. Discount retailers and verticals (international fashion chains, such as the GAP or Zara, with their own production facilities) have entered the market and gained remarkable market share. Customers increasingly expect individualized product offerings, personalized service, and regularly updated collections, often as frequently as every day. Traditionally, business secrecy has kept suppliers from inter-organizationally managing inventories and participating fully in warehouse and store space management and ‘seasonless’ retailing, that is, providing all products year-round. Over the last 20 years from 1980s, the fashion industry has undergone significant changes, including consolidation in retail, the majority of apparel manufacturing operations moving overseas, and more recently, increasing use of electronic commerce in retail and wholesale trade (Loebbecke & Palmer, 2006). Caro & Gallien (2010) highlight the unique challenges of fashion retailing, emphasizing the need for advanced forecasting, agile supply chain management, and real-time data analysis in optimizing inventory levels and minimizing costs. The fashion industry is unique in that it is constantly changing and evolving, with new trends and styles emerging every season.

Additionally, the fashion industry has a significant impact on the environment due to its use of resources and production processes. As such, there is a growing need for sustainable practices throughout the fashion supply chain to reduce its environmental impact (Chan & Wong, 2012). Shen (2014) asserts that sustainable fashion supply chain management involves a dynamic process engaging multiple stakeholders. The H&M case study offers valuable insights into adopting sustainable practices in the fashion sector. The fashion industry has a significant impact on the global environment due to its intensive use of chemical products, large quantities of water and pesticides, and other unsustainable practices. Therefore, it is crucial for fashion products to be produced in a sustainable manner and follow the guidelines of sustainability such as ISO 14000. Additionally, consumers are growing more socially and environmentally aware, which directly influences their eco-fashion consumption.

2.2 Fashion Supply Chain Management

The fashion supply chain involves all the activities in delivering product from raw material to the final customer. The supply chain activities span from internal organization to external trading partners of suppliers, manufacturers, third-party companies, and information system providers. The management of the supply chain is a complex process and involves trust, partnership and information sharing between the upstream and downstream supply chain partners (Lam & Postle, 2006). Implementing inventory control systems to reduce overproduction and minimize excess inventory, as well as using data analytics to forecast demand and optimize production levels. By improving inventory management practices, fashion companies can reduce their environmental impact and improve the sustainability of their supply chains (Loebbecke & Palmer, 2006). Operations managers have discussed the unintentional reduction in inventory due to misplacement, shrinkage, theft, and so on. A previous study, Rekik et al. (2008) analytically examined the impact of theft on the profit of the inventory inaccuracy in which lost products are never purchased by customers. They compared three scenarios, including the case in which RFID is adopted as a tool to improve inventory accuracy. The literature addressing inventory record inaccuracy stemming from the misplacement type errors is quite limited. Camdereli and Swaminathan (2010a) consider a supply chain under misplacement of inventory subject to uncertain demand. They show that the incentives of the parties for investing in the technology are not perfectly aligned in the existence of the fixed cost of investment. Shen et al. (2016) highlights several recent trends and innovations in fashion inventory management. These include the use of data analytics and machine learning to improve demand forecasting, the adoption of lean or agile supply chain management strategies, and the implementation of RFID technology to track inventory in real-time. Additionally, there is a growing interest in sustainable and ethical fashion practices, which may impact inventory management strategies in the future.

2.3 Fashion Supply Chain with RFID Technology

The Third stream that is relevant to my paper is RFID adoption in the fashion supply chain, which has proliferated significantly in practice and academic study in the last decade. Advanced identification and communication characteristics of the RFID can improve the product traceability and the visibility among supply chain (Sarac et al., 2010). Fan et al. (2014) conducted an analytical and numerical investigation using RFID to reduce the gap between physical information and IT information.

Zhang et al. (2018a) modelled the inventory shrinkage to evaluate how it could be resolved using RFID, comparing cases with and without RFID. Similarly, Biswal et al. (2020) analyzed how RFID can recover the negative effect of inventory misplacement and determined who should invest in RFID; a supplier, or a retailer, or both. By studying the application of RFID in the textile and apparel industry in Malaysia, it was found that RFID has a positive and important impact on the operation and maintenance of the industry chain. Loebbecke and Palmer (2006) proposed that falling transponder prices will drive demand, further lowering costs and making large-scale RFID adoption economically feasible. They also highlighted improvements in tag readability and data accuracy as contributors to RFID's economic viability in the fashion industry (Camdereli & Swaminathan, 2010). It was also assumed that RFID technology can be a strategic tool towards higher performance of supply chain operations in the textile and apparel industry of Malaysia, with the study finding that RFID has a significant role in improving supply chain operations through effective delivery time and better information communication technology (Ali & Haseeb, 2019).

New technology can increase customer satisfaction, but cannot bring additional benefits to the company, because the benefits brought by a high level cannot offset the cost of new technology (Sarac et al., 2008). Kärkkäinen (2003) concluded that when applied with recyclable transport containers, RFID investments can provide quick amortization of capital whilst offering a range of operational benefits. However, not all literature is positive about the application of RFID. There are many authors concerned about RFID data read rate, customer information protection, return on investment (ROI) and other issues. The value of RFID-based estimates of shelf inventories using pure backroom monitoring is severely influenced by imperfect read rates, which makes this policy acceptable only under optimal reader performance (Condea et al., 2012). Fan et al. (2014) suppose that only a part of shrinkage errors can be eliminated because RFID is imperfect. Application of RFID for small and medium-sized enterprises is cost-reflective, different types of companies should consider different applications to install RFID (Lee & Lee, 2010). This finding from the perspective of investment is consistent with my Study I.

2.4 Omnichannel Retail in the Fashion Industry

Omnichannel refers to a retail and marketing strategy that integrates multiple channels and touchpoints, such as brick-and-mortar stores, online websites, mobile applications, and social media, to create a seamless, consistent, and personalized customer experience. The goal of an Omnichannel approach is to ensure that customers can easily interact with a brand and make purchases, regardless of the channel they choose to use (Krafft & Mantrala, 2006). Omnichannel is a new topic, that is now more frequently discussed in academic articles and real-world economic life. Verhoef, Kannan, and Inman (2015) introduce studies on the development of multi-channel and omnichannel retailing and summarize how multi-channels are moving towards omnichannel. They discuss important research directions for omnichannel. Chopra (2016) proposes that omnichannel retail refers to the use of various channels to interact with customers and fulfill their orders. The author uses empirical data to show that store pick-up and home delivery in different consumer markets have different consumer outcomes. He also proposes that this hybrid structure is particularly effective in emerging markets, where new online players can work with existing local retailers to benefit themselves and the consumers. Hübner et al. (2016) introduced new concepts of forward and backward distribution in the omnichannel. They use empirical data to compare the differences between home delivery and store delivery in the omnichannel structure. Manser Payne et al. (2017) proposed that improving the contact point with customers (mobile phones, tablets) is key to achieving effective omnichannel disbursement. In addition, paying attention to the changing shopping patterns of customers, new shopping methods, and lifestyles is also important.

BOPS can expand in-store product offerings and attract omnichannel consumers who were previously reluctant to shop in-store. Online-only products can now be profitable in retail stores. Thus, industries with diverse products and strong online presence may benefit from incorporating BOPS into their omnichannel operations (Gao & Su, 2017a). With the onset of omnichannel shopping and improvements in information technology, the consumer's style of purchasing has also changed. Jin et al. (2018) compare consumer utility in a study on the BOPS service area. Kusuda (2019) follows Gao's model idea, considering that the retailer can select inventory levels to maximize inventory availability. In addition, the author suggests a tradeoff between profits and the additional cost incurred to reduce BOPS ordering lead time. However, this present study focuses on brick-and-mortar stores and does not cover the cross-effect of BOPS. As far as I know, few papers have discussed HD. Geunes et al. (2002) empirically suggest that store delivery may improve system performance by reducing system inventory levels. Customer reliance on public transport is a direct contributing factor to service levels: store delivery services are more common and more extensively used in this case (Burt et al., 2011). My study innovatively uses analytical methods to discuss the availability of the HD option as a major factor that influences customers' shopping behavior and market demand.

For instance, if consumers display a significant preference for HD services, brands may need to augment their inventory and bolster their delivery capabilities to meet this demand. Predicting the influence of home delivery services on market demand allows fashion supply chains to manage inventory more effectively, thus avoiding situations of surplus or shortage. Furthermore, if there is high demand for HD services, fashion brands may need to explore more efficient logistical solutions, such as partnering with third-party logistics firms, to ensure prompt and timely deliveries.

2.5 Green and Social Concerns in Fashion Supply Management

Addressing the environmental and social challenges faced by the fashion industry has become increasingly imperative, particularly due to the industry's substantial influence on global sustainability and its responsibility to uphold corporate social and environmental standards. This responsibility extends beyond mere compliance, as it involves actively promoting sustainable practices, adopting innovative solutions, and fostering a culture of ethical decision-making within the industry, ultimately contributing to a more sustainable and responsible global economy (Moraga-Gonzalez & Padron-Fumero, 2002). The authors show that government intervention can lead to less-polluting product variants, but reduced emissions may result in lower product differentiation. Chitra (2007) investigates green marketing, presenting a conceptual framework and classifying customers according to their eco-friendliness. It highlights stakeholders' concerns regarding green marketing and emphasizes the importance of addressing environmental challenges. Aguilar and Vlosky (2007) explain that consumers may be willing to pay a premium for environmentally certified products as a way to express their concerns about social and environmental stewardship. Bemporad and Baranowski (2007) suggest that consumers willingly engage in "easy" behaviors, such as recycling cans, bottles and newspapers, and using energy efficient appliances. Caniato et al. (2012) provide several examples of practices that fashion companies can use to improve their environmental sustainability. For example, they suggest using sustainable materials such as organic cotton, recycled polyester, and Tencel; Implementing closed-loop supply chain models; Reducing water usage in manufacturing processes; Implementing energy efficiency measures. Choi (2013) demonstrates the impact of a carbon footprint tax on retailers' sourcing decisions in fashion supply chains and suggests its potential for promoting sustainability. Sinayi and Rasti-Barzoki (2018) provide a framework for considering economic, environmental and social welfare policies simultaneously, for both supply chain and government level, and optimizing all three dimensions of sustainability. Their findings show that cooperation between the manufacture and retailer always leads to a greener product, increases the profit of the entire supply chain, and increases the consumer surplus of customers. Muthu (2020) depicts the character of fashion supply chain management as an interconnected network of processes that have significant environmental implications. The book emphasizes the importance of corporate social responsibility (CSR) and eco-friendly practices in the textile and clothing industry, promoting the adoption of sustainable strategies and initiatives.

2.6 The Novelty of the Dissertation

This dissertation contributes to the existing literature on supply chain management by considering both technology (RFID), channel selection and environmental welfare considerations. While previous studies have focused primarily on economic goals, this research recognizes the importance of environmental responsibility in the fashion industry. In addition, the study extends previous research by considering the impact of competitors' green marketing efforts on market demand, in addition to the effect of their own green marketing efforts. Furthermore, the research incorporates the manufacturer's input in producing green products and the retailer's utilization of green marketing techniques to expand the market. By integrating these factors into the analysis, this study provides a comprehensive understanding of the pricing decision-making process within a two-echelon supply chain. The results of this study highlight the importance of government intervention in promoting green product development and suggest that subsidies may be an effective way to encourage the adoption of sustainable practices within the fashion industry. Overall, this dissertation’s contribution is significant as it recognizes the need for sustainable practices within the fashion industry while also offering valuable insights into the pricing strategies of supply chain stakeholders.

Distinct from the literature I have listed, the dissertation also demonstrates the interconnections among the three key aspects of the fashion industry, closely reflecting the complexities of the real business world. By examining inventory management, channel selection, and environmental concerns, I provide a holistic perspective on the challenges faced by the fashion supply chain and their interconnected nature. Inventory management directly impacts the overall efficiency and effectiveness of the supply chain, while channel selection shapes the customer experience and the adaptability of businesses to evolving consumer preferences. Additionally, environmental concerns highlight the necessity for the industry to strike a balance between economic performance and environmental responsibility. By addressing these aspects in a cohesive manner, my research offers valuable insights into how the various components of the fashion industry interact and influence one another. This comprehensive approach enables stakeholders in the fashion supply chain to make more informed decisions, optimize their operations, and better navigate the complexities of the real business world. By recognizing the interplay between these critical aspects, my research contributes to the advancement of sustainable practices and helps fashion industry stakeholders address the challenges that arise from the interconnected nature of their business operations.

Chapter 3 Value of Product Tracking Information in Fashion Supply Chain: A Modelling Approach

In Chapter 3, I discuss the critical role that product assortment and display arrangement play in the success of fashion retail shops. However, literature related to item display and availability frequently arise, such as item misplacement on incorrect shelves or delays in product replenishment from the back of a shelf to the front. Consequently, fashion retailers experience unintentional sales losses when customers cannot find the desired items available in the shop.

Radio-frequency identification (RFID), an information technology often applied to logistics and supply chain management, can continuously track the locations of products within a facility. In this study, I analytically examine the value of information that a fashion retailer can obtain by installing RFID devices to track product movement in a retail facility to avoid item misplacement. On the other hand, I compare the RFID method with the target service-level approach in the fashion supply chain, employing Industrial Engineering (IE) methodologies. Through this comparative analysis, I aim to identify the most effective solution for addressing inventory management challenges within the fashion industry. By leveraging IE techniques, I can systematically evaluate the performance of both methods, taking into account their respective costs, benefits, and potential impact on customer satisfaction. I develop a mathematical model, an extension of the Newsvendor model, that captures fashion retail performance. Next, I establish three scenarios (a base scenario without resolution, a target service-level scenario, and an RFID scenario) and two goals: maximization of expected profit and maintenance of a given customer service level. I then examine the performance of each scenario concerning each goal and determine the conditions under which RFID is worth adopting for fashion retailers. I also propose managerial recommendations based on the analytical results, including when and how to implement RFID in the fashion industry.

3.1 Introduction

Adequate product assortment and guaranteed product availability on shop shelves are the key to retail business success. For example, managers of convenience stores with limited shop space and long business hours consider adequate product assortment and reliable availability essential for their business (Chanchaichujit et al,2020). Hence, retailers must keep service levels as high as possible to avoid product stockout because stockout can result in sales losses in the short run and eventually declines in customer perception and loyalty.

The maintenance of adequate product assortment and reliable availability faces added challenges from the demand side. In addition to uncertainties in demand, mismatches occur between supply and demand for various reasons beyond the control of the retailer, such as theft, spoilage, and depreciation. Item misplacement, i.e., placement of items in the wrong location, is another factor commonly contributing to the failure of inventories to satisfy demand. Item misplacement can occur due to the carelessness of shop staff, sudden changes of mind on the part of customers, or customer failure to properly turn in items of clothing after trying them on. Item misplacement causes unintentional sales losses when store management falsely believes that the products are available for sale. The difference between the actual on-hand inventory level and the IT system-recorded inventory level is also regarded as an inventory discrepancy. (Rekik et al., 2007) addressed that can similarly lead to unintentional sales losses. Here, we investigate business strategies for coping with item misplacement in retail shops.

Misplacement can lead to the incorrect confirmation of stock and may be mistaken as out-of-stock. Undesirable product stockout is traditionally prevented using safety stock, i.e., extra stock kept on hand in the case of stockout. A retail manager employing the safety stock approach increases the number of items ordered to eliminate undesirable sales losses. In contrast, modern radio-frequency identification (RFID) devices can trace the locations of products on shelves, and therefore store management can recognize unintentional item misplacement before stockout occurs. In addition, RFID can enhance inventory visibility, facilitating the rectification of any incorrect item locations (Camdereli and Swaminathan, 2010b; Zhang et al., 2018b) and enabling item-level tracking (Ovezmyradov and Kurata, 2022). Thonemann (2002) reported that, following the implementation of RFID technologies, both Procter & Gamble and Walmart improved their service levels to 99%. RFID not only mitigates misplacement but can also help reduce forecasting error (Zhang et al., 2018b). In a previous study, Ali and Haseeb (2019) reported that RFID has a positive and crucial impact on the operation and maintenance of the industry chain. However, the application of new technology to real-world businesses is challenging, and not all literature on RFID applications is positive. In one study, only 25% of the RFID tags on shipping containers containing water-filled bottles could be read, although jars filled with rice had a higher read rate (80.6%). Even empty boxes did not have a 100% read rate (Clarke et al., 2006). Other authors (Lee and Lee, 2010) analysed how RFID can mitigate the negative effects of inventory misplacement and provided a basis for deciding whether to invest in RFID.

Camdereli and Swaminathan (2010b) studied a supply chain under inventory misplacement subject to demand uncertainty. They found that the value of the information obtained from RFID-based estimates of shelf inventories using only backroom monitoring was significantly affected by imperfect read rates. As such, they deemed that backroom monitoring alone was only acceptable under optimal reader performance (Condea et al., 2012). Fan et al. (2014) suggested that, due to the imperfections of RFID technology, not all shrinkage errors could be eliminated. The cost-effectiveness of RFID application for small- and medium-sized enterprises was highlighted by Tao et al. (2022), suggesting that different types of companies should consider different RFID applications. They proposed that a manager might even consider adopting traditional industrial engineering techniques as alternatives to modern information technology. Thus, they emphasized the need for an evaluation of the trade-off between the inexpensive traditional method with moderate accuracy and the expensive state-of-the-art technology with excellent accuracy.

Study I consider a retail situation in which (i) customers' preferences for products affect the stockout of their preferred products, (ii) item prices are high enough to merit attachment of RFID tags, and (iii) the store deals with many items, so that the staff must make considerable effort to maintain adequate shelf display and product assortment. I examine the conditions under which a retail shop should adopt RFID to mitigate unintentional item misplacement. I construct a model considering the apparel industry, where apparel products are commonly tagged with RFID and customers bring their garments to trial rooms and leave them elsewhere rather than returning them to the proper shelf. For example, retailers such as UNIQLO, ZARA, and Right-on have successfully used RFID tags.

I solve the following questions using an analytical approach uses the extension of Newsvendor model:

(RQ 3.1) What is the value of information obtained by RFID in a retail store whose managerial goal is profit maximization?

(RQ 3.2) Which is more beneficial as a tool to cope with item misplacement, RFID, or safety stock?

(RQ 3.3) How does the service-level goal affect the effective value of information obtained using RFID and the consequent comparison between the two approaches, namely, RFID adoption and safety stock increases?

In this study 1, first, I set up two different business objectives, namely, profit maximization and service-level maintenance, and compare the information value provided by RFID under each of the two objectives. Second, I consider the choice between safety stock and RFID as tools to mitigate item misplacement; this choice can be regarded as a strategic selection between a simple, inexpensive, traditional method and a state-of-the-art, IT-based method. Hence, I provide insight regarding the strategic questions of whether modern high-priced technology is always necessary and when a simple and less expensive solution may suffice.

The major contribution of my research is the identification of a general relationship between the profitability of RFID adoption and the misplacement rate and RFID adoption adjustment cost. I also find that increasing safety stock is always ineffective for profit-maximization, although it can be effective for maintaining a particular service level. To establish a clear positioning for my work, I've summarized the differences between this study and the referenced literature in Table 3-1. This table provides a comparative analysis with existing literature closely related to my research. The novelty of this research is to address how the adoption of RFID as a tool to cope with item misplacement can improve the performance by setting two business goals and conclude that, under certain conditions, just increasing a safety stock by increasing the order size outperforms the adoption of RFID. In addition, I found that the adoption of RFID may increase the order size, which is a counterintuitive outcome because people believe that the installation of the state-of-the-art IT may reduce uncertainty, thereby reducing an extra-inventory. As a result, my analysis can give manager advice on when and how to set RFID adoption to retailers' shelf management.

Study I proceeds as follows: an extension of the Newsvendor model in Section 3.2, an analysis of the model with three scenarios in Section 3.3, I provide conclusions and directions for future studies in Section 3.4. I provide conclusions, managerial suggestions for real-world businesses and directions for future studies in Section 3.5. The results that how to influences other two papers are shown in the Section 3.6. All proofs are in the Appendix A.

Table.3-1:The comparison of literature review of Study I

	Lost sales due to misplacement	RFID adoption to retailers' shelf management	Keep service level in inventory	Newsvendor model
Lau (1980)			√	√
Thonemann (2002)	√			
Clarke., et al (2006	√	√		
Rekik.,et al (2008)	√		√	√
Lee and Lee (2010)	√	√		
Condea.,et al (2012)		√	√	
Fan., et al (2014)	√	√		√
Tao., et al (2018)	√	√		
Zhang (2018)	√	√		√
Chanchaichujit., et al (2020)	√	√		√
Ovezmyradov and Kurata (2022)	√	√		√
Tao., et al (2022)	√	√		√
Study I	√	√	√	√

3.2 Model Setting

The Newsvendor Model, also known as the Single-Period Inventory Model, is a classic optimization model utilized in operations management and supply chain management. It is particularly effective for determining optimal order quantities for perishable or short-life products, which characterizes many items in the fashion supply chain such as clothing, jewelry, handbags, and cosmetics. These items, which are the subject of my doctoral research, are distinguished by their short lifecycles and substantial demand fluctuations. As a result, applying the Newsvendor Model in managing these products within the fashion supply chain is highly pertinent. This model aids in effectively managing inventory by accounting for these fluctuations, thus avoiding situations of surplus or shortage. In Study I, I use the extended Newsvendor model to discuss the fashion supply chain problem.

3.2.1 Modelling background and assumptions

I assumed that item misplacement caused sales losses. This assumption is reasonable when consumers are highly heterogeneous and sensitive to their preferences. For instance, a customer who cannot find the desired item on a shop floor is expected to leave the store without buying any substitute or asking the sales staff about the availability of the product. Misplacement in the context of this study refers to the situation where items in a store are incorrectly placed, either by customers or staff, in locations other than their designated shelf spaces. This could lead to potential confusion for customers and may cause an unexpected decrease in sales as customers might not be able to find the products they need. Misplacement could also increase store operation costs due to additional efforts needed for repositioning items to their correct locations. I assume that item misplacement is caused by some customers after the products (order quantity: q) are properly displayed on the shop shelves. About the timing of the timing of product misplacement occurrence in my model initially assumes that the misplacement, occur before the store displays the ordered products on its shelf space. Consequently, even though the order size is q, the amount of products available for customers becomes $(1-\alpha)q$. Item misplacement is caused by a fraction of customers after the products (order quantity; q) are correctly displayed on the shop shelves. The misplaced items are stored somewhere in the store until the end of business. Therefore, misplaced products not only lead to an unexpected loss of sales but also generate overage costs.

To denote a situation in which a sales loss occurs even when the item exists in a store, I modified a traditional Newsvendor model to allow overage and shortage to occur simultaneously. The aim of the classical Newsvendor problem is to find the order quantity that maximizes profit under uncertain demand (Tao et al., 2022). (Sahin et al., 2008) evaluated the impact of inaccuracies on a simple inventory setting in which there are data capture errors. (Heese, 2007) extended the Newsvendor model to analyze how uncertainty in inventory records affects optimal stocking decisions in an integrated supply chain. In the model, I used the parameter α $[0 \leq \alpha \leq 0.5]$ to denote the proportion of displayed items that eventually result in lost sales due to misplacement. I assume that item misplacement is caused by some customers after the products (order quantity: q) are properly displayed on the shop shelves. The fixed parameters were the retail price r, wholesale price w, unit overage cost c_O, and unit shortage cost c_S. I assumed that the unit cost for RFID operations c_I was exogenously given and proportional to the misplacement rate α and order size q. I determined α^{β} ($\beta > 0$) as the cost of mitigating an item misplacement problem, since a problem causing more frequent misplacement is expected to result in a higher cost to detect and fix (Sahin et al., 2008). This β is related to the convexity and concavity of the cost function so that my cost term is flexible enough to describe various cost behavior. Thus, this metric also denotes the efficiency of potential RFID correction. All the notations in the Study I are shown in the Table 3-2.

In Analysis 3.1, the retailer maximizes the expected profit, while Analysis 3.2's goal is maintaining a certain service level. Below are some Assumptions settings to support my model:

Assumptions:

Assumption 3.1: When the sales start, the store has no information on how much misplacement will happen during business hours. Therefore, the store determines the order size as q and, correspondingly, q amount of the items is available at the shelves when business starts.

Assumption 3.2: The fixed cost for RFID installation was not included. The unit cost for RFID operations c_I was exogenously given and proportional to the misplacement rate α and order size q. The unit RFID tag cost is $c_I\alpha^{\beta}$. Different from the unit RFID tag cost is t (Rekik & Dallery, 2008), This setting is near to the real-business world. In the fashion industry, the operational cost of RFID is indeed related to the misplacement rate and order size, then the setting of $c_I\alpha^{\beta}$ would be closer to the real-world scenario. This might offer a more accurate cost estimation, thereby assisting companies in making better decisions.

Assumption 3.3: The demands for the products were assumed to be normally distributed $D{\sim}X(\mu, \sigma^2)$, and the retailer knew this distribution. $\pi(q)$ is the retailer's expected profit function. As mentioned in the book by Zipkin (2000), "If the demand is composed of many independent and identically distributed small effects, then the total demand will approach a normal distribution, even if these small effects themselves are not normally distributed." When combining many random variables, the total often follows a normal distribution regardless of their individual distributions. For inventory management, this means that even if individual demand factors aren't normally distributed, the total demand might be. Thus, the normal distribution is frequently used for modeling.

Assumption 3.4: $r > w > c_o, c_s$. This setting is commonly used in inventory management and pricing strategies. Businesses aim to establish a reasonable level of inventory and pricing strategies to maximize profits. Ideally, a company wants to achieve the highest sales volume with the lowest inventory costs while minimizing the risks of stockouts and excess inventory. This assumption helps businesses assess the risks and benefits under different circumstances, thereby making better inventory and pricing decisions.

Table.3-2:The Notations and meanings of Study I

Notations	Meanings
α	The proportion of displayed items that due to misplacement.
β	The cost of mitigating an item misplacement problem.
α^β	The efficiency of potential RFID correction.
r	Unit retail price.
w	Unit wholesale price.
c_O	Unit overage cost.
c_S	Unit shortage cost.
c_I	Exogenously given and proportional to the misplacement rate α and order size q.
i	Scenerio index, $i \in$ {3.I, 3.II, 3.III}.
3.I	Base scenario.
3.II	Increased safety stock scenario.
3.III	RFID scenario.
k	The exogenously given service level, the inventory factor.
μ	The mean of the demand distribution, which reflects the expected average demand.
σ	The standard deviation of demand distribution, reflecting the degree of demand fluctuation.
q_i	Order quantity of each scenario.
$\pi(q_i)$	The retailer's expected profit function.
q_i^*	Optimal order size in i. The asterisk (*) indicates the value is optimal.
π_i^*	Optimal profit in i.

3.2.2 Three scenarios and two business goals

I considered the following three scenarios to evaluate the value of information regarding item misplacement on a shop floor:

Scenario 3.I (base scenario): $100\alpha\%$ of the misplaced items are not purchased due to misplacement on shop shelves.

Scenario 3.II (increased safety stock scenario): the store increases order sizes so as to prevent sales losses due to misplacement.

Scenario 3.III (RFID scenario): the store installs an IT system to mitigate misplacement.

I set up two business goals regarding the inventory policy: (1) to maximize the expected profit (hereafter the profit-maximization goal) and (2) to maintain the exogenously given service level (hereafter the target service-level goal). For each goal, I computed the performance level in each of the three scenarios and determined whether the installation of RFID is a reasonable strategic choice for mitigating item misplacement. Then, I lay out the conditions under which even a traditional countermeasure for sales losses, namely, an extension of safety stock, suffices.

3.2.3 Profit functions

I develop a generic profit function for the case in which $100\alpha\%$ of the items are misplaced:

$$\pi(q) = (1-\alpha)r\left\{\int_{-\infty}^{q} xf(x)dx + \int_{q}^{\infty} qf(x)dx\right\} - \alpha(c_S + c_O)\left\{\int_{-\infty}^{q} xf(x)dx + \int_{q}^{\infty} qf(x)dx\right\} - c_S\int_{q}^{\infty}(x-q)f(q)dx - c_O\int_{-\infty}^{q}(q-x)f(x)dx - wq. \quad (3.1)$$

On the Eq. (3.1) above, $f(x)$ is the probability density function (PDF) of the sales quantity. The first term denotes the expected profit caused from sales, while the second term represents the second term represents the expected loss due to item misplacement. The misplaced products generate overage costs in addition to an unexpected loss of sales. The misplaced products generate overage costs in addition to an unexpected loss of sales. Note that the number of unsold items is expressed as an expected value. The third, fourth, and fifth terms denote the expected shortage cost, expected overage cost, and procurement cost, respectively. Note that if the misplacement rate α is zero, Eq. (3.1) becomes the traditional Newsvendor model. The misplacement rate α is exogenously set.

3.3 Model Analysis

3.3.1 Analysis 3.1: profit-maximization goal

This subsection considers the optimal order size and corresponding expected profit under the profit-maximization goal. The expected profit function for Scenarios 3.I and 3.II is the same as in Eq. (3.1). Since Scenario 3.II copes with item misplacement by increasing the order size, the optimal order size in Scenario 3.II is determined as $\mathrm{q}_{3.\mathrm{II}}^{*} = \mathrm{q}_{3.\mathrm{I}}^{*}/(1-\alpha)$. Here, $q_{3.\mathrm{I}}^{*}$ represents the optimal inventory level when the issue of product misplacement is not considered, and α denotes the proportion of products with sales losses due to misplacement. Using this formula, I can calculate the optimal order quantity $q_{3.II}^{*}$ when taking the product misplacement issue into account. This approach essentially compensates for sales losses caused by product misplacement by increasing the order quantity. In practical applications, this strategy may help improve the store's overall revenue but could also lead to increased inventory and storage costs.

The expected profit function for Scenario 3.III is defined by Eq. (3.2) below. In that equation, the installation of the IT system causes the misplacement ratio to become zero. The final term in Eq. (3.2) denotes the operational cost of the IT system, i.e., the effort of correcting all item misplacements revealed by the RFID system.

$$\pi_{3.\mathrm{III}}(q_{3.\mathrm{III}}^{*}) = r\left\{\int_{-\infty}^{q_{3.\mathrm{III}}} xf(x)dx + \int_{q_{3.\mathrm{III}}}^{\infty} q_{3.\mathrm{III}}f(x)dx\right\} - c_S\int_{q_{3.\mathrm{III}}}^{\infty}(x - q_{3.\mathrm{III}})\, f(q_{3.\mathrm{III}})dx - c_O\int_{-\infty}^{q_{3.\mathrm{III}}}(q_{3.\mathrm{III}} - x)f(x)dx - wq_{3.\mathrm{III}} - c_I\alpha^{\beta}q_{3.\mathrm{III}}. \quad (3.2)$$

The optimal order size that yields the maximum expected profit is determined for each scenario according to Lemma 3.1. All the proofs are given in the Appendix A.

Lemma 3.1 (optimal order size that maximizes expected profit)

$$q_{3.I}^{*} = F^{-1}\left(\frac{(1-\alpha)(r+c_S+c_O)-w}{(1-\alpha)(r+c_S+c_O)+c_O}\right),$$

$$q_{3.II}^{*} = \frac{1}{1-\alpha}F^{-1}\left(\frac{(1-\alpha)(r+c_S+c_O)-w}{(1-\alpha)(r+c_S+c_O)+c_O}\right),$$

$$q^*_{3.III} = F^{-1}\left(\frac{r+c_S-w-c_I\alpha^\beta}{r+c_S+c_O}\right).$$

In Lemma 3.1, the F^{-1} represents the inverse function of the probability density function (PDF), which is used to convert the values of the cumulative distribution function (CDF) back to the corresponding sales quantities. In this result, I find the optimal inventory level $q^*_{3.\mathrm{I}}$ by solving for F^{-1}. Using this equation, I can calculate the optimal inventory level $q^*_{3.\mathrm{I}}$ under given conditions to maximize the store's profit. In practical applications, stores can reduce costs and increase revenue by adjusting inventory levels, improving product placement, and implementing other strategies.

Proposition 3.1 (the order of the optimal order sizes)

(a) $q^*_{3.I} < q^*_{3.II}$.

(b) *When* $\alpha \geq 0$, *if* $0 < \beta < 1$, *there exists* $\tilde{\alpha} \in [0,0.5]$ *where* $q^*_{3.I} \geq q^*_{3.III}$ *if* $0 < \alpha < \tilde{\alpha}$; $q^*_{3.I} \leq q^*_{3.III}$ *if* $\tilde{\alpha} \leq \alpha \leq 0.5$. *Otherwise, analytical determination of whether is difficult* $q^*_{3.I} > q^*_{3.III}$. *Note that* $\tilde{\alpha} \in [0,0.5]$ *is defined as the value of* α *that satisfies* $\frac{(c_O+w)(r+c_S)}{(1-\alpha)(r+c_S)+c_O} = c_{3.I}\alpha^\beta$.

Proposition 3.1 shows that when the rate of item misplacement is relatively high, but the operation cost of the IT system does not increase much with increasing misplacement rate, the optimal order size under the IT system (i.e., Scenario 3.III) exceeds that in Scenario 3.I. This result sounds counterintuitive because, at first glance, the ability of RFID to provide real-time monitoring of products in a facility should prevent theft and mitigate misplacement, thus reducing the needed order size. However, I find that there is indeed a possibility that IT adoption may increase the optimal order size. Due to the economy of scale and learning effects, the operational cost of adopting RFID can be quite low. If so, cases in which RFID increases the optimal order size become more prevalent.

Proposition 3.2 (profit comparison)

(a) $q^*_{3.I} < q^*_{3.II}$.

(b) *When* $\alpha \geq 0$, *if* $0 < \beta < 1$, *there exists* $\tilde{\alpha} \in [0,0.5]$ *where* $q_I^* \geq q_{III}^*$ *if* $0 < \alpha < \tilde{\alpha}$; $q_I^* \leq q_{III}^*$ *if* $\tilde{\alpha} \leq \alpha \leq 0.5$. *Otherwise, analytical determination of whether is difficult* $q_I^* > q_{III}^*$. *Note that* $\tilde{\alpha} \in [0,0.5]$ *is defined as the value of* α *that satisfies* $\frac{(c_O+w)(r+c_S)}{(1-\alpha)(r+c_S)+c_O} = c_I\alpha^\beta$.

Proposition 3.2 shows that profit is expected to decrease if safety stock inflation is used as the sole tool for mitigation of unintended sales losses due to item misplacement. This finding implies that safety stock inflation alone could be an unreasonable strategic choice. However, increased order sizes may be welcomed by customers, since this strategy can reduce the actual frequency of unexpected stockouts. Hence, I conclude that safety stock inflation cannot simultaneously achieve the two goals of interest: profit maximization and service-level maintenance. Supply chain management in the fashion industry faces several challenges, including seasonal demand, rapidly changing fashion trends, and forecasting uncertainties. Relying solely on safety stock inflation is insufficient to address these complexities. To meet customer expectations of timely availability and reduce unexpected stockouts, supply chain managers need to employ a combination of strategies, tools, and flexible inventory control. Increasing order sizes and implementing timely replenishment can minimize the frequency of stockouts, leading to improved customer satisfaction and service levels. However, maintaining optimal inventory levels is essential to avoid excessive inventory and capital occupation while considering customer demands.

3.3.2 Numerical examples of analysis 3.1

Using numerical methods, I examined the effects of the cost-related parameters, α and β, on the optimal order size in Scenarios 3.I and 3.III. The other value of the parameters is shown in Table.3-3. Fig.3-1 shows the behavior of the order size for $0 < \beta < 1$, $\beta = 1$, and $\beta > 1$ in comparison with $q_{3.I}$ and $q_{3.III}$. When the value of α (misplacement rate) is low and $0 < \beta < 1$, $q_{3.I}$ exceeds $q_{3.III}$. When the $\beta < 1$, the order size of Scenario 3.III becomes small. However, I also consider the value of a simultaneously. Next, I compared the maximum profit among the three scenarios.

Table.3-3:Parameter values of Study I

Parameters	r	w	c_O	c_S	c_I	μ	σ
Value	20	5	2	3	0.15	30	10

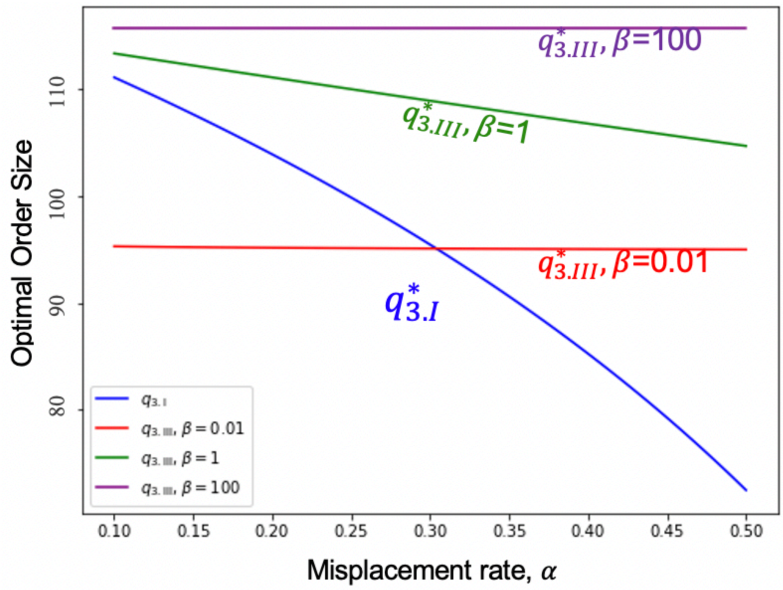

Fig.3-1: Misplacement rate influence on order size respect to β

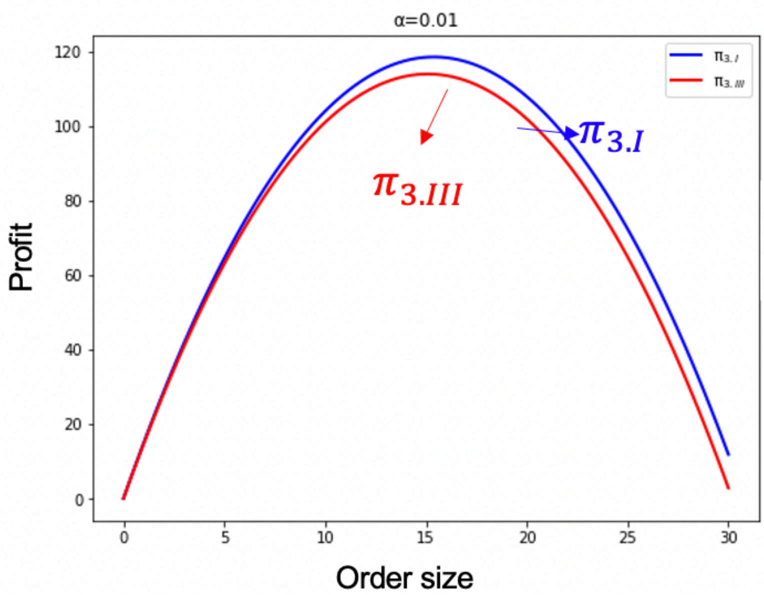

Fig.3-2: Order size impacts on profits for $\alpha = 0.01$

Fig.3-3: Order size impacts on profits for α = 0.5

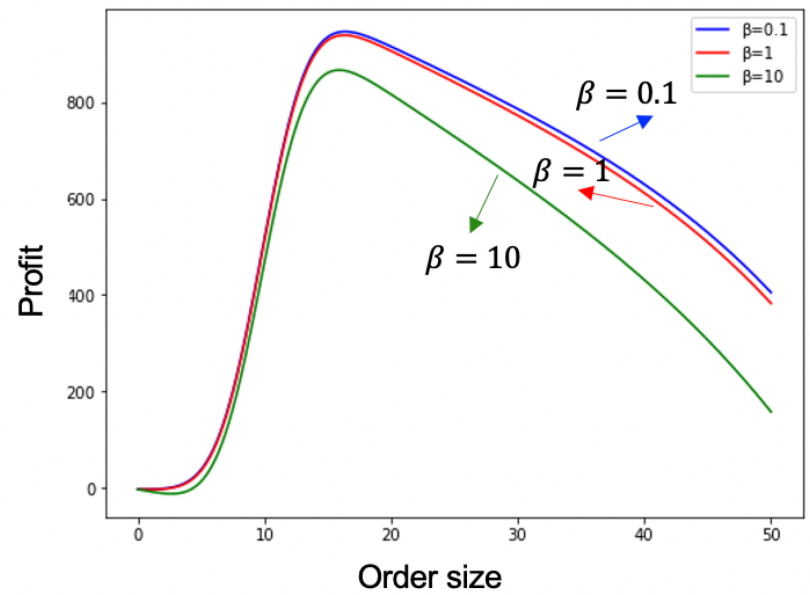

Fig.3-4: The behavior of the profit with respect to the parameter β

I examined (through numerical methods) the effects of the cost-related parameter α, β on the optimal profit associated with the scenarios. Fig.3-2 and Fig.3-3 show the results obtained for α levels of 0.01 and 0.5, respectively. For simplicity, I assumed that $\beta = 1$. As shown in Fig.3-2, when the misplacement rate α is extremely small, the profit difference between Scenario 3.I and Scenario 3.III is modest: the profit in Scenario I is larger than that in Scenario 3.III for small order sizes, and the reverse is true for large order sizes. This finding suggests that RFID operational costs can offset misplacement costs for large order sizes. When α is extremely large, as shown in Fig.3-3, the profits of Scenario 3.III are greater than those of scenario I. These behaviors indicate that RFID installation is more reasonable for high misplacement rate than for low misplacement rates.

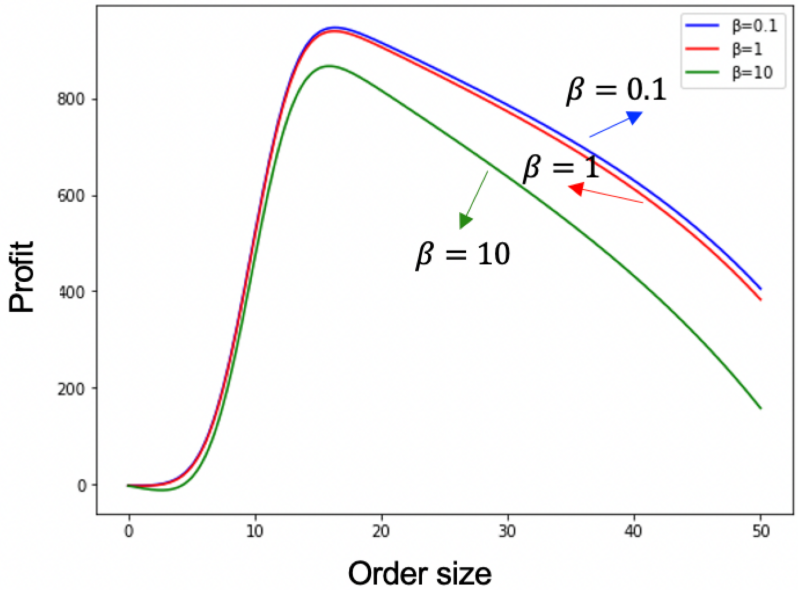

Fig.3-4 shows the results obtained for β levels of 0.1, 1, and 10 with $\alpha = 0.05$. Theoretically, the misplacement rate lies between 0 and 0.5 [$0 \le \alpha \le 0.5$], and hence increasing β leads to decreasing RFID operation cost and, consequently, increased profit.

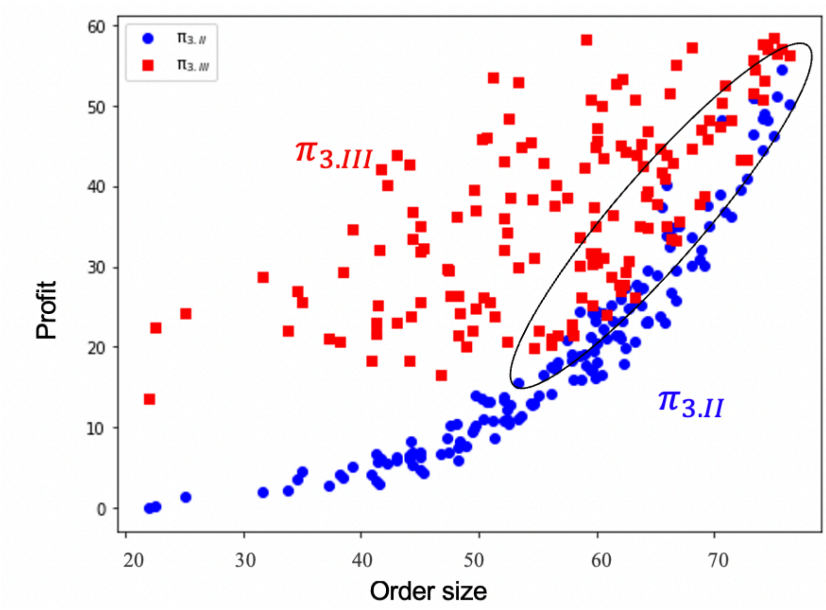

Fig.3-5: Impact of order size on profits: comparing scenario 3.II to 3.III.

Fig.3-5 illustrates that, under specific circumstances, the implementation of RFID technology proves more economically advantageous than sustaining safety stock. I performed a series of 150 random experiments to guarantee the robustness and stability of my data. The parameter ranges selected for these experiments align with real-business considerations, notably setting the retail price to exceed both the wholesale price and the shortage cost. Brands like ZARA, for instance, have a sufficiently high selling price for their clothing items to bear the cost of RFID chips. Additionally, for fashion brands, with shorter product lifecycles, the ability to respond quickly is crucial.

3.3.3 Analysis 3.2: target service-level goal

The target service-level approach is a method in inventory management and supply chain operations that focuses on maintaining a specific level of customer service to ensure customer satisfaction. In this context, service level refers to the ability of a retailer or supplier to meet customer demand and deliver products on time and without shortages. The target service-level approach typically involves setting a goal for the desired service level, usually expressed as a percentage, which represents the probability of not experiencing stockouts. For example, a target service level of 95% means that there is a 95% chance that a customer's demand for a particular product will be met without encountering a stockout. By adopting the target service-level approach, retailers and suppliers can make inventory management decisions, such as order quantities and safety stock levels, based on their desired service level. This method helps businesses balance the trade-offs between inventory holding costs, stockout costs, and customer satisfaction to optimize their supply chain operations. Analysis 3.2 considers the case in which the store attempts to maintain an exogenously set service level. In the Newsvendor approach, the exogenously given service level is denoted by the inventory factor k $(0 \leq k \leq 1)$ (Sahin et al., 2008). Under the target service-level goal, the optimal order sizes are determined as follows:

$$\bar{q}^*_{3.I} = \mu + k\sigma,\ \bar{q}^*_{3.II} = \frac{\mu + k\sigma}{1-\alpha}, \text{ and } \bar{q}^*_{3.III} = \mu + k\sigma. \tag{3.3}$$

This brief equation represents a simplified inventory management strategy, namely, the calculation of inventory levels based on a normal distribution. In Eq. (3.3), $\bar{q}^*_{3.III}$ denotes the optimal inventory level. μ represents the mean of the demand distribution, which reflects the expected average demand. σ indicates the standard deviation of the demand distribution, reflecting the degree of demand fluctuation. When demand fluctuates significantly, a higher safety stock is required to ensure the service level. I can calculate the optimal inventory level by considering both the average level and fluctuation of demand. Note that the bar over the symbol (i.e., $\bar{\ }$) indicates a model for a target service-level goal. The order size in Scenario 3.II is inflated to cover the loss of sales by misplacement, whereas the order size in Scenario 3.III is the same as that in Scenario 3.I because the IT system eliminates any sales losses due to misplacement. The following are the three order sizes:

Proposition 3.3 (comparison among the three scenarios under the target service-level goal)

(a) *Define* $\bar{\bar{q}}^*_{3.I}$ *as the value of* $q_{3.I}(\neq \bar{q}^*_{3.I})$ *that satisfies* $\pi_{3.I}(\bar{q}^*_{3.I}) = \pi_{3.I}(\bar{\bar{q}}^*_{3.I})$. *If* $\bar{q}^*_{3.I} \geq \bar{\bar{q}}^*_{3.I}$, *then* $\bar{\pi}^*_{3.I} \geq \bar{\pi}^*_{3.II}$: *if* $\bar{q}^*_{3.I} < \bar{\bar{q}}^*_{3.I}$, *and if* $\bar{q}^*_{3.I} < \bar{q}^*_{3.II} < \bar{\bar{q}}^*_{3.I}$, *then* $\bar{\pi}^*_{3.II} > \bar{\pi}^*_{3.I}$, *otherwise.*$\bar{\pi}^*_{3.II} \leq \bar{\pi}^*_{3.I}$.

(b) *If* $c_I > \frac{E(Sales)(r+c_S)}{q(\alpha^{\beta-1})}$, *then* $\bar{\pi}^*_{3.I} > \bar{\pi}^*_{3.III}$; *otherwise.*$\bar{\pi}^*_{3.I} \leq \bar{\pi}^*_{3.III}$.

Proposition 3.3 (a) implies that safety stock inflation alone is reasonable under certain conditions in which the optimal order size in Scenario 3.I is much smaller than the inventory level in Scenario 3.II that satisfies the given target service level. Proposition 3.3 (b) that the RFID installation does not always bring extra profit when its operational cost (c_I) is high enough. Hence, I conclude that a simple method for coping with item misplacement, such as safety stock inflation, may be more reasonable than the adoption of state-of-the-art technology when an inventory goal is to meet a particular service-level goal.

Fashion retailers need to carefully weigh the costs and profits, especially when dealing with high-value items, such as luxury bags, jewelry, and so on. As suggested by Proposition 3.3 (a), increasing the safety stock might be a reasonable strategy when there's a need to meet a specific service level. This implies that fashion retailers might consider inflating the safety stock to avoid stockouts and sales loss. If the company is deciding whether to adopt advanced technologies like RFID referred in Proposition 3.3 (b), fashion retailers need to meticulously assess their costs and profits.

In this Study I, to ensure the robustness of my model, I conducted 150 sets of parameter combinations for each figure's results. Apart from **错误!未找到引用源。**, where I wished to demonstrate the difficulty of comparing Scenario 3.II and Scenario 3.III and chose to present the combination of 150 points.

3.3.4 Additional sensitivity analyses

In the previous section, I primarily discussed the impact of decision variables and key parameter changes on the optimal order quantity and profit. To ensure the comprehensiveness of the discussion, I also calculated the effects of other variables on the decision-making process. The behavior of the solutions was explored through additional sensitivity analyses. The analysis of the optimal profit with respect to the parameters r, w, c_s, c_o, and c_I was easily performed based on the envelop theorem (refer Proposition 3.4 for a summary of the results).

Proposition 3.4

For all three scenarios, the optimal profit increases with the retail price r*, but decreases with the wholesale price* w*, shortage cost* c_s*, overage cost* c_o*, and the RFID operational cost* c_I*.*

This conclusion comprehensively considers various factors in decision-making within fashion supply chain management, such as pricing decisions, inventory management, and RFID investment decisions, all with the aim of maximizing company profits. Based on the Proposition 3.4 mentioned, increasing the retail price can enhance profitability. However, factors such as market demand, brand positioning, and competitive landscape need to be carefully considered. Expensive bags and jeweler often possess high value and uniqueness, allowing for a higher pricing strategy that reflects their scarcity and distinctiveness. Additionally, the proposition highlights that RFID operational costs have a negative impact on profits. Nevertheless, the application of RFID technology in the fashion supply chain can improve logistics and inventory management efficiency, thus reducing costs. When deciding whether to invest in RFID technology, a comprehensive evaluation of the costs associated with RFID tags, equipment, systems, and their corresponding benefits is necessary. This decision should be based on the scale, complexity, and expected business growth of the supply chain.

3.4 Conclusions

I developed a mathematical model and several numerical examples to help fashion retail managers decide between the RFID technology or traditional IE technique for mitigating product misplacement by considering two business goals: profit maximization (Scenarios 3.I and 3.III) and maintenance of a particular service level (Scenario 3.II).

3.4.1 Key findings

By exploring the impact of the relevant coefficients on decisions and profits, I can find new insights: (1) Model analysis elucidated the conditions under which RFID provided a better solution than the safety stock expansion. In general, RFID plays an important role in mitigating item misplacement when RFID operation costs are low and the misplacement occurs frequently; (2) When the inventory manager aims to maximize profit, order size inflation is ineffective in mitigating item misplacement, but can be effective for retailers aimed at maintaining a particular service level. (3) When the inventory manager aims to the target service level, the numerical analysis suggests that expanding safety stock is a more viable solution for item misplacement at higher target service levels than RFID installation. These findings offer practical insights for retailers. Strategy selection should balance factors such as inventory costs, product wastage, and technological investment costs. Choosing an appropriate service level is also vital as it directly affects profit margins.

3.5 Managerial Implications

I propose several managerial implications derived from the analytical results. First, Proposition 3.2 implies that RFID is a reasonable tool that can prevent item misplacement for profit-maximizing retailers when the operational cost of monitoring product locations within a shop by RFID is affordable. This is consistent with the fact that RFID is typically employed only in the sale of small, expensive products, such as books, DVDs, brand apparel, cosmetics, and electronic appliances. For example, as mentioned in the text, all the stores of UNIQLO in Japan have completed the installation of RFID devices. In addition, the price of RFID tags continues to decrease with growing economies of scale and learning-curve effects. Therefore, I expect RFID adoption to become more widespread (than current levels) as an effective tool for mitigating item misplacement. Second, retail companies sometimes distribute their products to their customers without considering profits. Loss leaders and traffic builders are common sales strategies. In such situations, I know from Proposition 3.3 that when the target service level is high enough, a simple increase in safety stock may be more profitable than RFID implementation as a product-misplacement mitigation method. When RFID operational cost is a managerial concern, perhaps for the case of selling commoditized products, I show that simple methods, such as safety stock inflation, remain practical in maintaining a particular service level for customers. Nike, during high-demand periods such as new shoe releases or major sporting events, also commonly employs the strategy of simply increasing safety stock. The findings of this study can be used to as a general guideline to assist retailers in choosing a strategy for mitigating product misplacement.

In summary, the inventory management goal is the main determinant of the selection between a simple way (i.e., more safety stock) and IT (i.e., adoption of RFID). A profit-maximizing manager should adopt safety stock inflation as one of the applicable measures.

However, if management aims to prioritize item fulfillment, then safety stock inflation is a viable option. I also note that, although the initial investment for an IT system is a crucial factor, the present work focuses on shop floor daily operations and has intentionally excluded the fixed IT system installation cost. Here, I suggest that, for decisions regarding RFID-system implementation, a manager should consider the balance between investment and the real-life expected returns, employing a simple method without the use of IT as the only option.

3.5.1 Future research

Based on several limitations mentioned in Study I, I propose some potential fields for future research. First, an extension of this study to include a classification problem of complementary goods would be interesting. Product assortment management often consider product substitutability, where a stockout of one product will result in lost sales of other complementary products in the store. Second, I need to apply my model to online-to-offline (O2O) dynamics. In the O2O setting, inadequate information on the online channel may negatively influence offline store sales. A third topic of interest could include examining the effect of timing on item misplacement. Study I assume that misplacement happens after the sales start, but some extant research assumes that misplacement occurs before sales. Elucidating the impact of misalignment timing supports practical decisions about RFID implementation.

3.6 Effect of Study I's Findings on the Other Two

Study I place a major focus on addressing the inventory challenges of fashion products and improving inventory accuracy and efficiency through the comparison of the strategies of adopting RFID technology and expanding safety stock. Although its primary concern is inventory management, Study I take on certain significance in addressing omnichannel and environmental aspects:

Implications for omnichannel in Study II: The analytical results of Study I reveal that RFID can address the problem of misplaced items when the operating cost of RFID is low and misplaced items occur frequently, such that the implementation of an omnichannel strategy can be affected markedly. In an omnichannel retail environment, inventory accuracy and real-time visibility are crucial. By implementing RFID technology, retailers are capable of tracking real-time inventory information and ensuring synchronization between online and offline channels, such that out-of-stock situations can be reduced, customer satisfaction can be improved, and omnichannel services (e.g., BOPS, HD) can be supported.

Implications for Environmental Concerns in Study III: Although Study I do not directly address environmental and social concerns, it indirectly has a positive effect on the environment by improving inventory management. Retailers using RFID technology can manage their inventory more accurately, thereby reducing excess inventory and unsold goods. Furthermore, maintaining an appropriate level of safety stock, instead of blindly increasing inventory levels, is conducive to reducing inventory waste, decreasing transportation costs and emissions, such that environmental effects can be reduced. Moreover, improving inventory accuracy can reduce unnecessary product returns, such that the carbon emissions produced during transportation can be curbed.

In conclusion, while Study III's focus is on inventory management, it has a positive effect on both omnichannel and environmental and social concerns. By enhancing inventory accuracy and real-time visibility, RFID technology provides support for the achievement of omnichannel strategies and environmental goals.

Chapter 4 Designing Omnichannel Fashion Retail Operations with Heterogenous Customer Preferences of Channel and Purchases Style

Chapter 4 discuss the Study II on omnichannel within the fashion industry, examining its distinctions and functions in relation to traditional sales models. The chapter explores the influence of consumer choices on decision-makers and their strategic approaches. As online shopping becomes more popular, it not only offers greater convenience to customers but also creates new modes of shopping. This presents both opportunities and challenges for fashion retailers, requiring them to make strategic choices. Customers can participate in various shopping experiences as online and offline channels are seamlessly connected via modern information and communication technology. An omnichannel shopping experience comprises the BOPS service, in which a customer orders a fashion product online and picks it up in a physical store; and the home-delivery (HD) option, in which the customer examines and purchases a product and then requests for delivery directly to an address of their choice. This Study II examines how providing BOPS and HD services can increase the profitability of online and offline fashion retailers that offer omnichannel disbursement. In addition to a decentralized supply chain, I examine whether supply chain contracts between the two channels can enhance system performance with model formulation and numerical experiments. I discovered that omnichannel adoption is not always desirable, and revenue-sharing ratios affect the decentralized channel’s performance in the fashion industry.

The fashion industry can enhance the sales and profitability of clothing, luxury accessories, and handbags by providing exceptional shopping experiences, strengthening supply chain collaborations, optimizing revenue distribution, and implementing personalized marketing strategies. By offering omnichannel services such as BOPS and HD, fashion brands can attract more customers and provide flexible shopping options. Establishing robust supply chain partnerships and equitable revenue allocation mechanisms can improve supply chain efficiency and maintain a balanced among partners. Through personalized marketing strategies, fashion brands can foster strong connections with consumers, increasing purchase intent and customer loyalty. By effectively implementing these strategies, the fashion industry can achieve sustainable growth and business success.

4.1 Introduction

Channel competition has increased with the rise of online shopping in the fashion supply chain. Channels compete based on price and product quality, marketing models used, and services provided. An omnichannel structure combines existing channels (i.e., online shops and brick-and-mortar stores), develops seamless links between them, and provides consumers with a convenient shopping experience. (Dumrongsiri et al., 2008) show that opening a direct channel of distribution increases total profit when the manufacturer and retailer collaborate and coordinate. (Chopra, 2016) proposes that omnichannel retail refers to the use of different channels to interact with customers and fulfill their orders. Supermarkets and furniture shops, including retail giants, Walmart and IKEA, have adopted omnichannel. Omnichannel is beneficial for retailers since it is flexible and satisfies the needs of consumers as market expansion occurs. However, in a comprehensive survey conducted by Fuentes-Blasco et al. (2014), it was found that only 6% of the 256 US and European retail and manufacturing decision-makers involved in digital commerce initiatives reported no significant barriers to becoming an integrated omnichannel company. This indicates the complexity and challenges faced by organizations in transitioning to an omnichannel approach. Integrated omnichannel distribution, according to the study, poses more organizational and ownership, technology and integration, and operational and execution problems than other channels.

The omnichannel develops a new product acquisition style where customers can buy a product online and pick it up at a physical store near their home and analyze BOPS initiative with strategic customers (Gao and Su, 2017). (Jin et al., 2018) compare consumer utility in a study on the BOPS service area. (Shi and Yan, 2017) investigated the BOPS approach with retailer pre-orders, in the presence of informed and uninformed consumers. BOPS is often employed by supermarkets (e.g., Walmart), electronic appliance shops (e.g., Apple Store, Best Buy), and furniture shops (e.g., Home Depot). Walmart had over 2,100 grocery pickup locations and approximately 800 grocery delivery locations as of January 31,2019 (Walmart, 2019). This BOPS service helps the company avoid the risk of secondary delivery and save money on transportation. It also offers customers more flexibility in choosing a suitable time and protecting their residential privacy.

HD is another emerging approach to enhancing retailer performance and improving customer convenience. When customers order goods from a brick-and-mortar store, the store can deliver the goods to the customers' homes, or a location specified by the customer. proposed new concepts of forward and backward distribution in omnichannel. They evaluate the differences between HD and store delivery in the omnichannel structure using empirical data. Customers' reliance on public transportation is often a contributing factor to the demand for such services and HD is more sought-after (Colombo and Matsushima, 2020). HD is often used by fashion stores (e.g., GAP), furniture shops (e.g., IKEA and NITORI), and even some small duty-free shops that can deliver products to hotels or airports for tourists' convenience. Some shops provide free shipping for a predetermined minimum value, which persuades travelers to buy more (i.e., shops at an airport in Japan offer free shipping for shopping worth 10,000 yen or more). HD also provides convenience to customers when the products are heavy or require careful delivery. Even if a product is out of stock, there will be no loss of sales because some customers would prefer to complete the purchase in-store and have it shipped to their home than go through the inconvenience of visiting another store. For example, fashion products giant, GAP guarantee customers that when ordering in-store, they can track down any style and hold it or ship it directly to them for free.

Since complex logistics systems and information exchange media are required for coordination between the two channels, setting up an omnichannel distribution initially entails intense effort and high costs for retail businesses. Thus, my primary question is whether it is profitable for a profit-maximizing retailer to offer omnichannel alternatives (i.e., BOPS and HD) in both offline and online shops. If yes, under what conditions would omnichannel adoption be reasonable? I compare the centralized and decentralized systems composed of brick-and-mortar stores and online shops for this purpose. The brick-and-mortar and online stores, both belong to the same retailer in the centralized model. In the decentralized model, the brick-and-mortar store and online shop are different companies that ally to participate in the Omnichannel and share the benefits, aiming at the global optimum. The primary assumption is that consumer preferences of the store (online advantageous or offline) and product acquisition style (store pickup or HD) are heterogeneous. This study is the first to analyze the profitability of an omnichannel approach in this setting.

This study evaluates the trade-off between profits and additional costs in an omnichannel approach. The research questions include the following:

(RQ 4.1) Is it profitable to develop an omnichannel approach by adding BOPS and HD in a centralized system? Under what conditions would omnichannel become a more profitable approach than a traditional channel?

(RQ 4.2) Is it profitable to establish an omnichannel shopping environment in a decentralized system? Next, I determine the factors that make an omnichannel more profitable than the traditional channel.

(RQ 4.3) Can a revenue-sharing contract coordinate the supply chain?

I numerically demonstrate how a profit-maximizing retailer determines the optimal charge for BOPS and HD for each product to answer these questions. Finally, I propose many numerically derived managerial implications for omnichannel approaches. The novelty of this study is in being the first to investigate HD from a theoretical viewpoint, and simultaneously compare BOPS and HD in an omnichannel framework.

Study II is structured as follows. Section 4.2 introduces the basic model, providing a foundation for the subsequent analysis. In Section 4.3, the profit functions and model formulations for various cases are presented. Section 4.4 conducts numerical experiments to examine the impact of uncertain parameter distributions on supply chains. Managerial insights and discussions are provided in Section 4.5. Section 4.6 presents the conclusions drawn from the study and highlights future research prospects. Finally, Section 4.7 summarizes the findings of Study II and explores its influence on Study I and Study III. More details about the numerical results are provided in the Appendix B.

Table.4-1:The literature comparison of Study II

	Channel competition	Omnichannel	BOPS purchasing	HD purchasing	Heterogeneity of consumers' preferences
Boxall et al., (2002)		+	+		
Khouja et al., (2010)	+				+
Xu et al., (2012)	+	+			+
Verhoef and Majeed (2015)		+	+		
Chopra (2016)	+	+			+
Gao and Su (2017)	+	+	+		
Chen et al., (2017)	+	+			+
Jin and Chen (2018)	+		+		+
Kusuda, (2019)		+			+
Zhang and Zhao (2019)	+	+			+
Study II	+	+	+	+	+

4.2 The Model

My first assumption is that in the fashion supply chain, a retailer owns both an online shop and a brick-and-mortar store in a market of a given size. A retailer can provide the product through both channels. I extended Hoteling's linear market model to disuse in this research. The 2D Hoteling model is a spatial competition model used in economics to analyze how firms differentiate themselves in terms of location and the impact of their location decisions on their competitiveness. All the notations and meanings in the Study II are shown in the Table.4-2.

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4.2.1 Sales structure and utility functions

In the dual-channel model, I assume that the brick-and-mortar store only provides traditional shopping (i.e., customers go to the physical store and buy the products directly), while the online store provides typical e-market shopping (i.e., customers order online and wait for delivery). In an Omnichannel model, the online shop also provides the BOPS option; and the brick-and-mortar store provides HD service when purchasing or ordering from the store.

The first step in a consumer's purchase decision-making process is deciding where to shop and then deciding on an acquisition style (BOPS or HD). It also suits my model if the customer first decides on an acquisition style before deciding where to buy. The customer chooses the product that provides him/her the highest positive utility. My model contains four different combinations of shopping behavior: traditional store shopping (4.I), typical e-business shopping (4.II), omnichannel with BOPS shopping (4.III), and omnichannel with HD shopping (4.IV) Note that all four behaviors are possible in an omnichannel situation. The notations and meanings of Study II are shown in the Table 4.2 above.

Table.4-2:The notations and meanings of Study II

Notations	Meaning
θ	A customer's preference for online shopping over offline shopping.
η	Customer's preference for BOPS over HD
v	Customer's potential evaluation or reservation price
r_s	Retail price in the brick-and-mortar store.
r_o	Retail price in an online shop.
w_2	The wholesale price.
t_c	"Unit external cost" associated with shopping in the dual-channel framework.
e_c	The cost of shop to providing omnichannel sales.
m	Unit inconvenience cost incurred by customer choosing omnichannel shopping service.
h_s	Additional payment made on visiting the brick-and-mortar store.
h_o	Additional payment/costs incurred by shopping online.
k_2	Inventory factor.
φ	The BOPS revenue share for the store using.
D_j	The number of potential consumers in each segment is represented by D_i
j	$j \in \{4.I, 4.II, 4.III, 4.IV\}$ and $\sum_i D_i = 1$
$\pi_j{}^*$	The optimal profit in j.
$\bar{\theta}$	The value of θ at which $U_I = U_{II}$.
$\hat{\eta}$	The value of η at which $U_{III} = 0$.
$\check{\eta}$	The value of η at which $U_{IV} = 0$.

The definition of the utility function in Study II deviates from traditional microeconomic interpretations. This is common in the Operations Management (OM) and Supply Chain SCM fields (Vandenbosch & Weinberg,1995; Conrad, 2005). In these fields, we occasionally focus on factors like prices and costs directly rather than consumption levels, as it provides specific insights for certain types of decision-making scenarios, such as evolving shopping behaviors in the age of traditional shopping and omnichannel experiences.

To develop a more detailed understanding of the market, I have chosen to extend Hoteling's linear market model (Schultz, 1929) into a two-dimensional (2D) one. In which the parameter θ describes a customer's preference for online shopping over offline shopping, and parameter η is a customer's preference for BOPS over HD. Increasing θ improves the preference for online shopping while increasing η reduces the preference for omnichannel shopping with BOPS.

Assumption 4.1. In operations and marketing research, a 2D square (or rectangular) market model is commonly used. Both θ and η are assumed to be uniformly distributed between 0 and 1 (Vandenbosch and Weinberg, 1995). For the utility functions in Study II, each utility function aims to represent a specific shopping behavior. Each component within these functions describes different aspects of a consumer's decision-making process when choosing between online and offline shopping. The parameter θ describes a consumer's preference for online shopping relative to traditional brick-and-mortar shopping. A higher value of θ indicates a stronger preference for online shopping and vice versa.

Following the Hotelling's horizontal differentiation modeling approach, we assume there's a heterogeneity in consumers' preferences towards the mode of shopping (online or offline). To capture this heterogeneity, I employ θ and $1-\theta$.

Assumption 4.2. I assume that the consumer chooses the option that provides him/her with the highest positive utility. I also assume that the potential market (i.e., the number of potential consumers in a specific market) is represented by a square with an area of one, that is divided into four segments. The number of potential consumers in each segment is represented by $D_j, j \in \{4.\mathrm{I}, 4.\mathrm{II}, 4.\mathrm{III}, 4.\mathrm{IV}\}$ and $\sum_i D_i = 1$.

Assumption 4.2. Different from Gao and Su (2017)' customers may encounter two possible outcomes:(1) if the store has inventory, then she can make a purchase on the spot and receive payoff $v - p$; (2) if the store is out of stock, she can go back to buying the product online and receive payoff $v - p - ho$. In economics and management research, utility functions are commonly used to depict a consumer's satisfaction or preference towards a product or service simultaneously. Here, the four given utility functions each represents the utility of four distinct shopping behaviors, specifically:

$$U_{4.\mathrm{I}} = v - r_s - t_c\theta. \tag{4.1}$$

This represents the utility function of shopping in a physical store.

$$U_{4.\mathrm{II}} = v - r_o - t_c(1-\theta). \tag{4.2}$$

This signifies the utility function for online shopping.

$$U_{4.\mathrm{III}} = v - h_o - m\eta. \tag{4.3}$$

This is the utility function when opting for omnichannel shopping services.

$$U_{4.\mathrm{IV}} = v - h_s - m(1-\eta). \tag{4.4}$$

This corresponds to the utility function of shopping in a physical store and choosing delivery.

The parameter v describes a customer's potential evaluation or reservation price; r_s is the retail price in the brick-and-mortar store; r_o is the retail price in an online shop. (Forman et al., 2009) concluded that the transportation costs of brick-and-mortar stores and the negative utilities of online shopping can influence customers' choice of channels using empirical data from Amazon and local brick-and-mortar bookstores. Thus, t_c is the unit transportation cost of a customer visiting the brick-and-mortar store (e.g., the time and money spent on going to the store); m is the unit inconvenience cost incurred by a customer choosing an Omnichannel shopping service (e.g., going to the shop for pickup, paying the extra delivery fee); h_o is the additional payment/costs incurred by shopping online (e.g., searching for information, spending time going to the store to pick up the product) when BOPS is chosen. h_s is the additional payment made on visiting the brick-and-mortar store (e.g., waiting for the product and paying for delivery). The value of h_o could be positive or negative. For example, if the pick-up store location is close to the customer and the product is always in stock, h_o will be positive for the customer; otherwise, h_o will be negative.

From a mathematical standpoint, these four utility functions are linear combinations of various variables, either added or subtracted. The values of these functions fluctuate with changes in these variables, thereby reflecting consumers' preferences towards different shopping behaviors. For instance, if the transportation cost t_c increases, the values of both $U_{4.\mathrm{I}}$ and $U_{4.\mathrm{II}}$ will decrease, indicating a reduced level of consumer satisfaction or preference for both physical store shopping and online shopping.

4.2.2 Dual-channel with a demand function

To clarify the result, I set up three cases:

Case 4.1: Dual-channel in the market (two traditional shopping behaviors).

Case 4.2: Omnichannel in the market (four shopping behaviors).

Case 4.3: Omnichannel in the market when the cross-profit exists (four shopping behaviors).

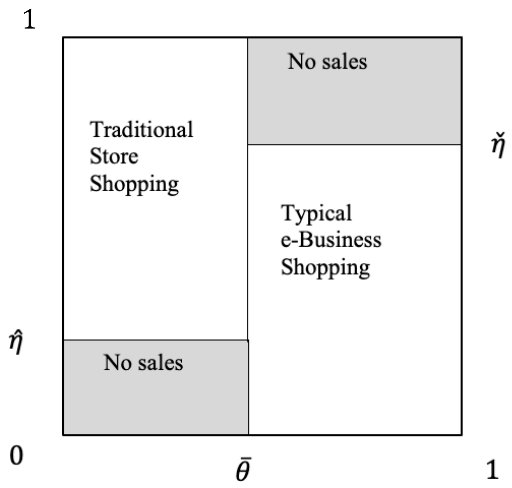

Fig.4-1:Market demand with dual-channel.

Fig.4-1 shows the market demands of case 4.1 under my utility settings. I define three thresholds $\bar{\theta}$, $\hat{\eta}$, and $\check{\eta}$ where $U_{4.\text{I}} = U_{4.\text{II}}$ at $\bar{\theta}$, $U_{4.\text{IV}} = 0\ at\ \check{\eta}$ and $U_{4.\text{III}} = 0\ at\ \hat{\eta}$. Thus, a consumer with a threshold value $\bar{\theta} = \frac{1}{2} + \frac{r_o - r_s}{2t_c}$ is indifferent to the two channels. $\check{\eta} = 1 - \frac{v - h_s}{m}$ represents a situation in which BOPS is not provided by the online shop, and customers will give up shopping. $\hat{\eta} = \frac{v - h_o}{m}$ indicates that when HD is not offered by the physical store, there will be no sale. The detail of how to derivate the three-threshold value ($\bar{\theta}, \check{\eta}, \hat{\eta}$) are show in the Appendix B.

It is common for the price setting of online stores to be lower than that of brick-and-mortar stores (Hsiao, 2009). This price differential often denoted as $r_o - r_s < 0$, so $\bar{\theta}$ is smaller than $\frac{1}{2}$. The demand functions of case 4.1, where subscripts 's' and 'o' stand for physical store and online shop in the dual channel:

$$D_s = \bar{\theta}\hat{\eta} = (\frac{1}{2} + \frac{r_o - r_s}{2t_c})(\frac{v - h_o}{m}). \tag{4.5}$$

$$D_o = (1 - \bar{\theta})(1 - \check{\eta}) = \left(\frac{1}{2} - \frac{r_o - r_s}{2t_c}\right)\left(\frac{v - h_s}{m}\right). \tag{4.6}$$

4.2.3 Omnichannel with a demand function

Fig.4-2 shows the market demands of omnichannel (case 4.2 and case 4.3) under my utility settings.

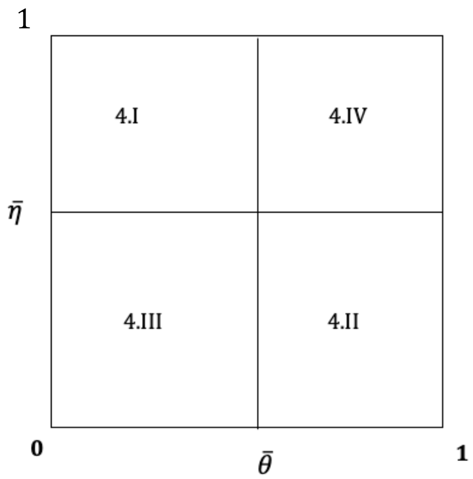

Fig.4-2: Market demand with omnichannel.

There are two thresholds $\bar{\theta}, \bar{\eta}$, where $U_{4.\mathrm{I}} = U_{4.\mathrm{II}}$ at $\bar{\theta}$ and $U_{4.\mathrm{III}} = U_{4.\mathrm{IV}}$ at $\bar{\eta}$. Thus, $\bar{\eta} = \frac{1}{2} + \frac{h_s - h_o}{2m}$ is indifferent between two-phase behaviors. In typical retail settings, the pricing strategy of online stores tends to be more competitive, often undercutting the prices found at brick-and-mortar stores (Hsiao, 2009). Given the lower cost of operations for online outlets, this results in a scenario where $r_o - r_s < 0$, so $\bar{\theta}$ is smaller than $\frac{1}{2}$. I set the inconvenience cost of brick-and-mortar stores to be higher than that of an online shop, $h_s - h_o > 0$, so $\bar{\eta} > \frac{1}{2}$. The detail of how to derivate the threshold value $\bar{\eta}$ are show in the Appendix B.

I could derive the demand functions of case 4.2 according to the four threshold values:

$$D_{4.\mathrm{I}} = \bar{\theta}\bar{\eta} = (\frac{1}{2} + \frac{r_o - r_s}{2t_c})(\frac{1}{2} + \frac{h_s - h_o}{2m}). \quad (4.7)$$

$$D_{4.\mathrm{II}} = (1 - \bar{\eta})\bar{\theta} = (\frac{1}{2} - \frac{h_s - h_o}{2m})(\frac{1}{2} + \frac{r_o - r_s}{2t_c}). \quad (4.8)$$

$$D_{4.\mathrm{III}} = (1 - \bar{\theta})\bar{\eta} = \left(\frac{1}{2} - \frac{r_o - r_s}{2t_c}\right)\left(\frac{1}{2} + \frac{h_s - h_o}{2m}\right). \quad (4.9)$$

$$D_{4.\mathrm{IV}} = (1 - \bar{\theta})(1 - \bar{\eta}) = (\frac{1}{2} + \frac{h_s - h_o}{2m})(\frac{1}{2} + \frac{r_o - r_s}{2t_c}). \quad (4.10)$$

I set $\Delta r = r_s - r_o$; $\Delta h = h_s - h_o$ for simplicity. To make each market demand greater than 0, then must meet:

$$\begin{cases} \left(\frac{1}{2}-\frac{\Delta r}{2t_c}\right)\left(\frac{1}{2}+\frac{\Delta h}{2m}\right) > 0; \\ \left(\frac{1}{2}+\frac{\Delta r}{2t_c}\right)\left(\frac{1}{2}+\frac{\Delta h}{2m}\right) > 0; \\ \left(\frac{1}{2}-\frac{\Delta r}{2m}\right)\left(\frac{1}{2}-\frac{\Delta h}{2t_c}\right) > 0; \\ \left(\frac{1}{2}+\frac{\Delta r}{2m}\right)\left(\frac{1}{2}-\frac{\Delta h}{2t_c}\right) > 0; \end{cases}$$

Proposition 4.1 (the condition to offer dual/omnichannel)

(a) *When* $\Delta r < t_c$ *and* $\Delta r < m$; $\Delta h < t_c$ *and* $\Delta h < m$, *all omnichannel purchasing styles exist.*

(b) *When* $\Delta r < t_c$, *only dual channel purchasing styles exist (i.e., there are no conditions to provide omnichannel).*

To ensure positive sales in the physical store and online shop, it must ensure that both channels are attractive to the customer. If Δr is greater than the transportation cost, the customer will choose the online store over the brick-and-mortar store. If Δh is greater than the extra Omnichannel cost, the customer will not choose the BOPS service. When customers are faced with the choice between transportation costs and convenience, fashion brands and retailers need to consider appropriate pricing and transportation strategies. If transportation costs are low and customers can easily obtain the products, they are more likely to choose online shopping. Fashion supply chain managers should focus on logistics efficiency and cost optimization to ensure the competitiveness of online channels.

4.2.4 Demand uncertainty setting

In my model setting, when a customer orders through BOPS, the order information is transferred from an online shop to a brick-and-mortar store, and the order is fulfilled on a made-to-order (MTO) basis. In the HD order situation, the product is taken from the store inventory and the order policy is based on made-to-stock (MTS). MTO and MTS are two different production strategies used by businesses to manage their inventory and fulfill customer orders. In the MTO strategy, products are manufactured only after a customer order is received. This approach allows for greater customization and flexibility, as each product can be tailored to the customer's specific requirements. MTO is particularly useful for businesses that offer customizable products or operate in industries where demand is unpredictable. However, MTO can lead to longer lead times, as the production process begins only after an order is placed. In contrast, the MTS strategy involves manufacturing products in advance, based on anticipated demand, and storing them in inventory until a customer order is received. This approach enables businesses to fulfill customer orders more quickly, as products are readily available in stock. MTS is suitable for businesses that deal with standardized products or experience stable demand patterns. However, MTS can result in higher inventory holding costs and the risk of overstocking or stock obsolescence if demand predictions are inaccurate.

In this research, I adopt the assumption that every consumer's purchasing decision aligns with a Poisson distribution, also referred to as Poisson purchasing. The Poisson distribution is a mathematical concept that expresses the probability of a given number of events occurring in a fixed interval of time or space if these events occur with a known constant mean rate and independently of the time since the last event. This approach models the randomness and unpredictability inherent in individual consumer behavior. As stated by Springall and Van Nieuwenhuyse (2005), to capture the purchasing behavior of retail customers accurately, the demand process ought to be represented as a compound Poisson process. This method involves the combination of two or more individual Poisson processes, where the quantities of purchases are also governed by a Poisson distribution. This compound model more precisely reflects the reality of retail consumer behavior, which often involves sporadic purchasing patterns and variable purchase quantities. One characteristic of a Poisson distribution is that its mean is equivalent to its variance. Thus, if the demand's mean is D_i, its standard deviation will be $D_i^{0.5}$.

The offline shop's stocking policies follow the MTS for 4.I and 4.IV consumers, and MTO for 4.II and 4.III consumers. Here, I assume that the online shop has abundant capacity such that the demand of 4.II and 4.III is always satisfied (i.e., no stockout occurs at the online shop).

Thus, for the MTS policy case of 4.I and 4.IV, the optimal order size q_I^* is calculated as $q_{4.\text{I}}^* = D_{4.\text{I}} + k_2 D_{4.\text{I}}^{0.5}$; $q_{4.\text{IV}}^* = D_{4.\text{IV}} + k_2 D_{4.\text{IV}}^{0.5}$, where the parameter k_2 is an inventory factor of Study II determined by a given service level. The optimal order for the MTO case is determined to be equivalent to the demand size, that is, $q_{4.\text{II}}^* = D_{4.\text{II}}$ and $q_{4.\text{IV}}^* = D_{4.\text{IV}}$. Another crucial difference between MTO and MTS is that MTS is more expensive than MTO because MTS may face higher inventory costs due to over- or under-stocking. Thus, I maintain that the retailer bears an over- or under-stock cost when ordering under MTS.

4.3 Profit Function Calculations

4.3.1 Case 4.1: Dual-channel in the market (two shopping behaviors)

The profit of the brick-and-mortar store:

$$\pi_S = r_s min(r_s, D_s) - w_2 r_s + maxv(q_s - D_s) - maxs(D_s - q_s). \quad (4.11)$$

The first two terms denote profits from selling the product, and the third term is the salvage value when the order is higher than the demand. The final term is the shortage cost (when the order is smaller than demand) that may result in a lost sale.

$$\pi_s{}^* = r_s D_s - w_2(D_s + k_2 D_s^{0.5}) + vk_2 D_s^{0.5},$$

$$D_s = (\frac{1}{2} + \frac{r_o - r_s}{2t_c})(\frac{v - h_o}{m}).$$

The profit of the online shop:

$$\pi_o = (r_o - w_2)D_o. \quad (4.12)$$

The two terms denote the profits from selling the product.

$$\pi_o{}^* = (r_o - w)D_o,\ D_o = (\frac{1}{2} - \frac{r_o - r_s}{2t_c})(\frac{v - h_s}{m}).$$

4.3.2 Case 4.2: Omnichannel in the market (four shopping behaviors)

(a) When the stocking policy is MTS, the profit function of 4.I, is calculated as follows:

$$\pi_I(q_I^{MTS}) = r_s min(q_I^{MTS}, D_I) - w_2 q_I^{MTS} + maxv(q_I^{MTS} – D_I) - maxs(D_I - q_I^{MTS}). \quad (4.13)$$

The first two terms denote profits from selling the product, and the third term is the salvage value when the order is higher than demand. The final term is the shortage cost (when the order is smaller than demand), which may cause a loss of sales.

$$q_I^* = D_I + k_2 D_I^{0.5} = \left(\frac{1}{2} + \frac{r_o - r_s}{2t_c}\right)\left(\frac{1}{2} + \frac{h_s - h_o}{2m}\right) + k_2\sqrt{\left(\frac{1}{2} + \frac{r_o - r_s}{2t_c}\right)\left(\frac{1}{2} + \frac{h_s - h_o}{2m}\right)}. \quad (4.14)$$

The following proposition is obtained with regard to the supply chain's demand uncertainty.

The optimal order quantity of 4.I *is* $q_I^* = D_I + k_2 D_I^{0.5}$. Then, the optimal profit is $\pi_{4.I}^* = r_s{}^* D_I - w_2{}^* q_I^* + v^* k_2 D_I^{0.5}$.

(b) Profit function of 4.II when the stocking policy is MTO

$$\pi_{4.\mathrm{II}}(q_{4.\mathrm{II}}^{MTO}) = (r_o - w_2)q_{4.\mathrm{II}}^{MTO}. \qquad (4.15)$$

These two terms are the profits from selling the product.

$$q_{4.\mathrm{II}}^{*} = D_{4.\mathrm{II}} = \left(\frac{1}{2} - \frac{h_s - h_o}{2m}\right)\left(\frac{1}{2} + \frac{r_o - r_s}{2t_c}\right), \pi_{4.\mathrm{II}}^{*} = (r_o - w_2)D_{4.\mathrm{II}}.$$

(c) Profit function of 4.III when the stocking policy is MTO

$$\pi_{4.III}(q_{4.\mathrm{III}}^{MTO}) = (r_o - w_2 - e_c + h_o)q_{4.\mathrm{III}}^{MTO}. \qquad (4.16)$$

The profits from selling the product are the first two terms, and the third term is the cost of providing Omnichannel sales. The final term is the additional revenue for offering the BOPS service to customers (e.g., saving the delivery fee).

$$q_{4.\mathrm{III}}^{*} = D_{4.\mathrm{III}} = \left(\frac{1}{2} + \frac{r_o - r_s}{2t_c}\right)\left(\frac{1}{2} + \frac{h_s - h_o}{2m}\right), \pi_{4.\mathrm{III}}^{*} = (r_o - w_2 - e_c + h_o)D_{4.\mathrm{III}}.$$

(d) Profit function of IV when the stocking policy is MTS

$$\pi_{\mathrm{IV}}(q_{IV}^{MTS}) = r_s min(q_{IV}^{MTS}, D_{IV}) - w_2 q_{IV}^{MTS} + maxv(q_{IV}^{MTS} - D_{IV}) - maxs(D_{IV} - q_{IV}^{MTS}) - e_c q_{IV}^{MTS} + h_s q_{IV}^{MTS}. \qquad (4.17)$$

The profits from selling the product are the first two terms, the third term is shortage cost, the fourth term is the salvage value, and the fifth term is the cost of offering omnichannel sales. The final term is the additional revenue for providing the BOPS service to customers from an online shop.

$$q_{IV}^{*} = D_{IV} + k_2 D_{IV}^{0.5} = \left(\frac{1}{2} + \frac{h_s - h_o}{2m}\right)\left(\frac{1}{2} + \frac{r_o - r_s}{2t_c}\right) + k_2\sqrt{\left(\frac{1}{2} + \frac{h_s - h_o}{2m}\right)\left(\frac{1}{2} + \frac{r_o - r_s}{2t_c}\right)},$$

$$\pi_{IV}^{*} = (p_s - w_2 - e_c + h_s)D_{IV} + k_2(v - w_2 - e_c + h_s)D_{IV}^{0.5}.$$

4.3.3 Case 4.3: Omnichannel with cross-profit (four shopping behaviors)

The key difference between centralized and decentralized systems is revenue sharing when physical stores offer BOPS service. This is a cross-selling sales strategy where a business encourages customers to purchase additional products or services related to their initial purchase. By offering complementary items, companies can increase their overall revenue and profit. As Gao and Su (2017b) have proposed, brick-and-mortar stores can benefit from not only sharing in the revenue from online sales, but also from the additional cross-selling opportunities that arise from increased foot traffic.

Store profit with BOPS (cross-selling exit):

$$\pi_{IV}^{r} = \varphi r_s min(q_{IV}^{MTS}, D_{IV}) + rD_{IV} - w_2 q_{IV}^{MTS} + \max v(q_{IV}^{MTS} - D_{IV}) - \max s(D_{IV} - q_{IV}^{MTS}) - e_c q_{IV}^{MTS} + h_s q_{IV}^{MTS}. \quad (4.18)$$

$$\pi_{II}^{r}(q_{II}^{MTO}) = (r_o - w_2 - e_c + h_o) q_{II}^{MTO} + (1-\varphi) r_s \min(q_{IV}^{MTS}, D_{IV}) \quad (4.19)$$

I represent the BOPS revenue share for the store using $\varphi \in [0,1]$, and r in the π_{IV}^{r} as the cross-selling profit for the store. If φ equals 0, the online shop retains all revenue, while the store only obtains cross-selling profit. When φ equals 1, the store receives all revenue from the online shop, making the store always willing to maintain inventory for BOPS customers to pick up their orders.

$$q_{IV}^{*} = D_{IV} + k_2 D_{IV}^{0.5}, \pi_{IV}^{*r} = (\varphi r_s + r - w_2 + v - e_c + h_s) q_{IV}^{*},$$

$$q_{IV}^{*} = D_{IV} + k_2 (v - w - e_c + h_s) D_{IV}^{0.5}.$$

Proposition 4.2 (profits comparison)

a) *When* $\frac{p_s - w}{w - v_c} \geq \frac{k_2}{D_I^{0.5}}$ *,the* π_I^{*} *will be a positive value.*

b) *When* $\frac{\varphi p_s - w - e_c + h_s}{v_c - w - e_c + h_s} \geq \frac{k_2}{D_{IV}^{0.5}}$ *, the* π_{IV}^{*} *will be a positive value.*

c) $\varphi \geq \frac{\Delta p}{p_s}$*, the* $\pi_{IV}^{*r} \geq \pi_{IV}^{*}$*, it is worth to implement revenue sharing contract.*

This Proposition 4.2 offers a formula to help determine the optimal order quantity in the fashion supply chain, considering not only current demand but also demand uncertainty, which is prevalent in the fashion industry due to factors such as seasonal shifts and changing trends. The optimal profit formula in this proposition offers insights into how various cost and revenue factors impact profitability. It could be a valuable reference for decisions related to pricing strategies, inventory cost reduction, and enhancing the value of product residuals. The condition provided in this proposition serves as a guideline to assess the feasibility of achieving positive profit. Adjustments in selling price, inventory cost, and product residual value can be made to meet this condition and therefore, realize a positive profit.

Proposition 4.2 (b) demonstrates the profit of omnichannel with BOPS and 4.2 (c) comparing the *IV* profit in the centralized and decentralized systems, I obtain the optimal value of φ. Proposition 4.2 provides critical insights for profit optimization in the fashion supply chain within an omnichannel context with BOPS services. It establishes a set of conditions to evaluate the potential for positive profit and compares the profitability between centralized and decentralized systems. By identifying the optimal value of φ, a decision variable or policy parameter, it guides supply chain managers in determining the most profitable system for their operations. Moreover, it illustrates different scenarios depending on the value of φ, which can aid strategic planning and decision making. However, the specifics of the fashion supply chain, such as demand variability, cost structure, operational capabilities, and the overall market scenario, must be considered when applying these insights.

4.4 Numerical Analysis

This section presents a numerical analysis of the three research questions of Study II, and I compare the numerical results to derive managerial insights on Omnichannel approaches. The parameters are set as, $w_2 = 50$, $v = 10$, $s = 8$, $e_c = 5, m = 2, t_c = 3$, and $k_2 = 0.8$. The figures and results are derived from the MATLAB and Python software.

The first research question of whether the introduction of Omnichannel could benefit the retailer is answered by comparing cases 4.1 and 4.2.

4.4.1 Comparing case 4.1 and case 4.2

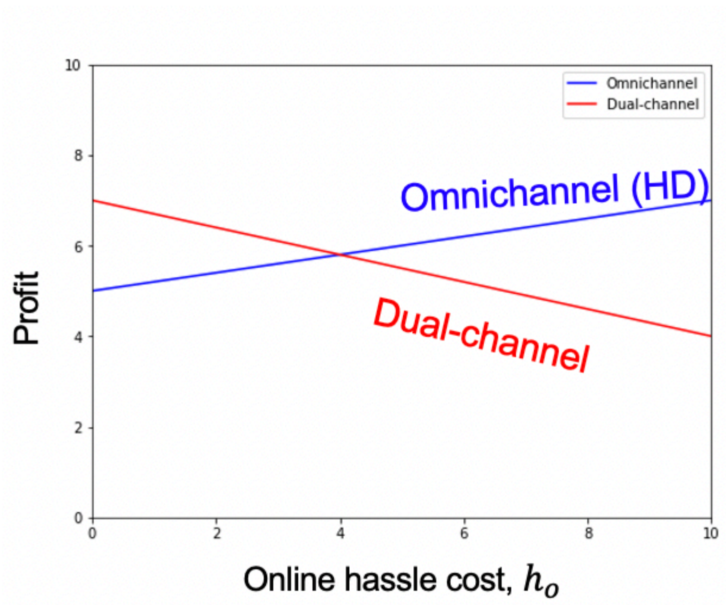

Fig.4-3: Online inconvenience cost impacts on profits

The inconvenience cost of online shops is lower than that of physical stores, as shown in Fig.4-3. The inconvenience cost of online shops is higher than that of physical stores, as shown in Fig.4-4. By setting the online retail price lower than the store retail price and keeping online inconvenience cost equal to the store inconvenience cost, Fig.4-3 demonstrates that Omnichannel firms yield higher total profits than dual-channel firms, provided that the online retail price isn't excessively low.

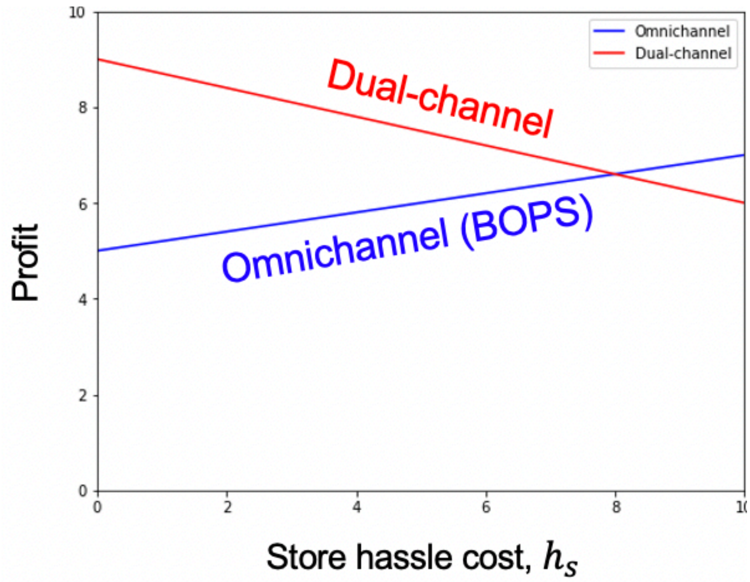

Fig.4-4: Store inconvenience costs impacts on profits.

In Fig.4-4, I set the store price to be lower than the online price, and the online retail price is the same as the store retail price. Omnichannel profits were greater than those of the dual-channel. Comparing Fig.4-3 and Fig.4-4 , it is more advantageous to use omnichannel than dual-channel, regardless of whether the retail price in an online store is greater than that of a brick-and-mortar store. The profit of omnichannel in Fig.4-4 is higher than that in Fig.4-3 in the omnichannel setting. Thus, I propose that when the inconvenience costs are the same, the brick-and-mortar store's retail price is greater than that of the online shop, and the online shop's retail price is not too low.

4.4.2 Comparing case 4.2 and case 4.3

In this analysis, I primarily answered the RQ 4.1 and RQ 4.2.

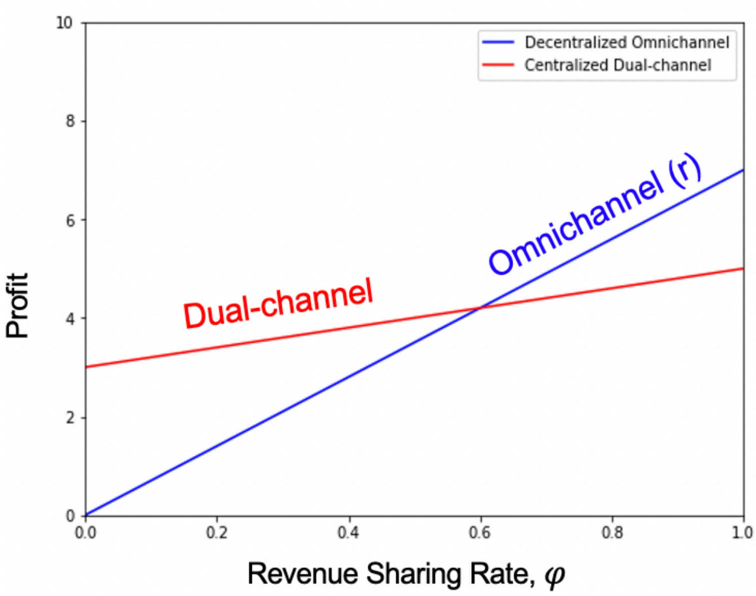

Fig.4-5: Revenue sharing rate impacts on profits

Fig.4-5 shows the common result that the centralized system's profit is always larger than that of the decentralized system when the value of revenue sharing is insignificant, regardless of how much φ is taken. This result can be applied in the fashion supply chain by suggesting that a centralized approach to managing operations, inventory, and revenue-sharing may yield higher profits compared to a decentralized system. Centralized systems can benefit from better coordination, improved information sharing, and streamlined decision-making processes. Fashion supply chain stakeholders may consider adopting centralized structures, where feasible, to enhance overall efficiency and profitability while managing multiple channels, suppliers, and retail partners.

This finding highlights the importance of strategic organization and collaboration in the fashion supply chain to optimize performance and competitiveness.

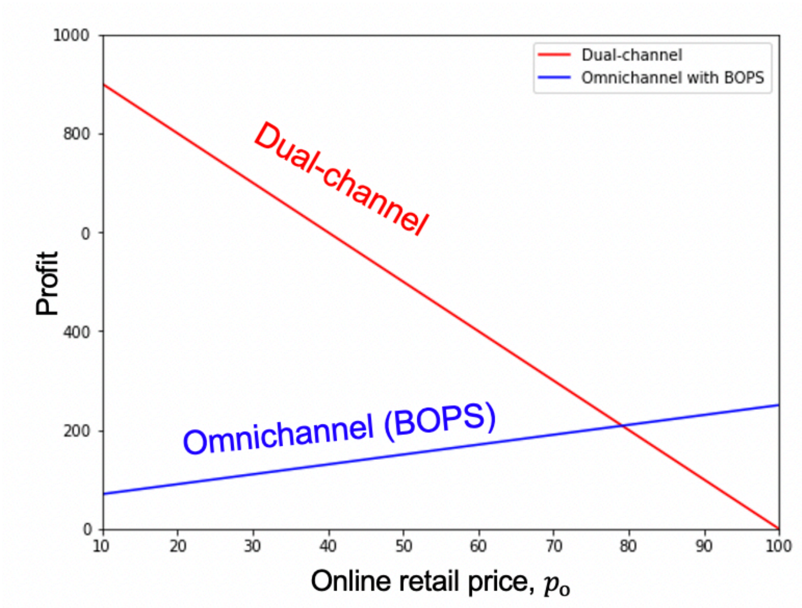

Fig.4-6: Online shop’s profit

As shown in Fig.4-6, omnichannel is not always beneficial for online shops. Thus, the BOPS service provided by the online store can bring benefits to the online shop only with an increase in unit prices. Fashion brands and retailers can use this finding to make more informed decisions about adopting an omnichannel strategy. It is not always beneficial for online stores to implement omnichannel approaches. Therefore, when formulating an omnichannel strategy, fashion brands should consider factors such as product characteristics, market demand, and competitive landscape. For specific product lines or market segments, online stores can derive benefits by offering BOPS services while simultaneously increasing product prices.

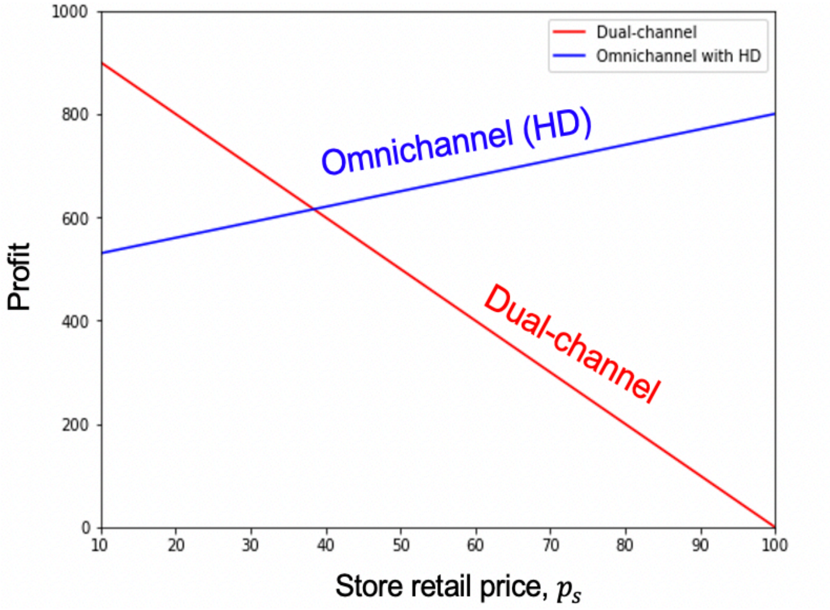

Fig.4-7: The store's profit

Fig.4-7 demonstrates that when the unit price of brick-and-mortar sales is very low, dual-channel sales are more beneficial than omnichannel. When the unit price rises, brick-and-mortar stores can provide HD services to exceed traditional channels. Considering the conclusion, fashion brands can analyze customer segments based on their preferences and purchasing behaviors. They can identify customer groups that are more likely to prefer brick-and-mortar shopping or online shopping. By tailoring marketing campaigns and experiences to these specific segments, brands can effectively target and engage their customers. This personalized approach can enhance customer loyalty and drive sales in the chosen channels.

4.4.3 Discussions

In light of the clarification, the novelty of this study lies in the HD services from a theoretical perspective, while concurrently comparing BOPS and HD services within an Omnichannel framework. This innovative approach offers a comprehensive understanding of the underlying dynamics and interplay between these two key services in the retail industry.

By examining HD services from a theoretical standpoint, the study contributes to the existing literature on retail strategies and customer preferences. It expands the knowledge base by delving into the critical factors that influence the adoption and effectiveness of HD services in a retail setting. The simultaneous comparison of BOPS and HD services in an Omnichannel context provides valuable insights into the potential synergies and trade-offs between the two services. This comparative analysis enables businesses to make informed decisions regarding the optimal integration of these services within their Omnichannel strategies. By considering the interdependencies and potential complementarities of BOPS and HD services, retailers can better adapt their business models to meet the evolving demands of consumers in an increasingly competitive market.

In summary, the study's novelty stems from its ground-breaking examination of home delivery services from a theoretical perspective and its unique comparison of BOPS and HD services within an Omnichannel framework. These contributions not only enhance my understanding of retail strategies and customer preferences but also provide actionable insights for businesses seeking to optimize their sales and profitability in the ever-changing retail landscape.

4.5 Conclusions

4.5.1 Key findings

In conclusion, this study emphasizes the importance of maintaining customer attractiveness in both physical and online stores for positive sales. Key findings reveal that Omnichannel strategies are more effective than dual-channel ones under specific conditions, such as higher retail prices or inconvenience costs. However, this advantage is not universal, as it depends on factors like in-store unit prices and online retail prices. Furthermore, the study indicates that BOPS services don't consistently provide benefits, only becoming advantageous when unit prices increase. As in-store unit prices rise, brick-and-mortar stores can offer high-definition services surpassing traditional channels.

4.5.2 Theoretical implication

Study II theoretical implications arise from the findings obtained through the 2D Hoteling model and numerical analysis in retail operations, enriching existing literature on retail strategies, customer preferences, and competitive dynamics. Firstly, the Hoteling model offers a valuable framework for understanding and predicting consumer behavior within retail operations. Applying the model to omnichannel and dual-channel strategies provides insights into how various factors impact customer preferences and decision-making. Secondly, the study's numerical analysis reveals specific conditions where one retail strategy might be more advantageous than another, enabling retailers to tailor their strategies to market contexts and customer preferences more effectively. The findings on the effectiveness of BOPS services and HD services in brick-and-mortar stores contribute to the ongoing discussion on the evolving retail landscape. These insights help industry practitioners and researchers better understand physical and digital retail channels' dynamics and potential synergies. Lastly, by extending the Hotelling model and numerical analysis to retail operations, Study II contributes to developing more comprehensive theories on retail strategy and consumer behavior. Consequently, future research can build upon these findings and further refine my understanding of retail operations and strategies in an ever-changing business environment, fostering new insights and innovations in the retail industry.

4.5.3 Managerial implications

Consequently, from a managerial perspective, it is suggested that online stores can implement the BOPS service while simultaneously increasing the unit sales price to ensure profitability. Customers may be amenable to paying a premium to reduce waiting times. In a managerial context, implementing BOPS and increasing unit sales prices can boost profitability as customers may pay premiums for reduced wait times. From Proposition 4.1 could know the omnichannel exit in the market that relationship with the hassle cots. Therefore, fashion supply chain managers should focus on logistics efficiency and cost optimization to ensure the competitiveness of traditional channels. Proposition 4.2 consider the profits comparison, helps fashion supply chain managers choose the most profitable system. When considering the creation of a SC contract, contemplate whether the revenue-sharing ratio allows for extra profitability. In-store pickups allow retailers to cross-sell, potentially enhancing profits. In the case of discount or chain stores, it is recommended not to offer BOPS or HD services, as price competition could lead to additional costs. Conversely, for boutique stores that specialize in high-value products, the unit price of BOPS or HD services may constitute a relatively small proportion of the total price, making the provision of these services an attractive option for drawing in customers.

4.6 Further Study

Despite significant progress in current research, it's essential to recognize existing limitations, which present opportunities for future directions to improve and broaden the investigation scope. First, exploring the influence of order quantity on sales and profitability is a crucial area for future research, potentially revealing valuable insights into the relationship between these factors. Second, examining more complex contractual agreements could be an intriguing area of study, helping researchers understand the possible consequences for various retail outlets within a decentralized distribution channel. Third, the claim that information impact is consistent across all distribution channels, as suggested in many scholarly articles, should be considered in future investigations. Consequently, it is recommended that future studies assume relative information completeness, allowing for a more sophisticated and thorough examination of information's role within the broader context of channel relationships.

4.7 Effect of Study II on the Study I and Study III

Study II primarily focuses on integrating the BOPS and HD channels in an omnichannel structure in the fashion industry supply chain to enhance customer convenience and satisfaction. While its emphasis is largely on omnichannel retail strategies, it also affects the first and third papers:

Positive effect on Study I: In an omnichannel environment, inventory management is especially crucial. The second paper underscores that retailers need to have accurate and real-time inventory information when offering a seamless shopping experience (e.g., BOPS and HD services). This resonates with the first paper's focus on the role of RFID technology in inventory management. By adopting RFID technology, retailers can implement an omnichannel strategy more effectively, ensuring synchronization of information between online and offline channels, thereby helping to increase customer satisfaction and reduce inventory waste and transportation costs. The key findings of the second paper further emphasize that an Omnichannel strategy can be more effective than a dual-channel strategy under specific conditions (e.g., higher retail prices or greater shopping inconvenience), providing significant implications for the inventory management and use of RFID technology discussed in the first paper.

Positive effect on Study III: The omnichannel structure examined in Study II plays a significant role in addressing the environmental and social concerns highlighted in Study III. By providing BOPS services, retailers can reduce the demand for home delivery services, thereby lowering transportation costs and carbon emissions. Omnichannel retail strategies indirectly enhance the sales and acceptance of green products by increasing customer satisfaction, aligning with the theme of Study III on green product pricing and green marketing strategies. If the sales channels for green products are supported by an omnichannel platform, it could potentially garner fiscal support from the government and ease customer purchase, thus promoting sales. This could enable retailers to reduce overstock and waste, ultimately contributing to a smaller environmental footprint. Simultaneously, the research results of Study II also indicate that BOPS services do not offer advantages in all situations. It only becomes advantageous when the unit price rises, which could have significant implications for the green product strategies in Study III.

In brief, although Study II mainly focuses on omnichannel retail strategies, it positively impacts Study I and Study III. Omnichannel strategies not only improve the accuracy of inventory management, but they also support the sustainable development of the fashion supply chain by implementing environment-friendly measures.

Chapter 5 Social-Welfare Aspects of Green Decision-Making in Channel Competition with Government Financial Intervention in Fashion Supply Chain

In this chapter, I describe in a two-echelon fashion supply chain that a manufacturer produces a green product and sells it to two competing retailers (one physical store and one online shop). I consider two factors that affect the green level of a product: the product's green level as produced by the manufacturer and the green-marketing effort made by the two retailers. Similar with Study II, I discuss the two retailers are one is online shop, the other is the physical store. The government charges a tax on or gives a subsidy to the final retail price. Using the Stackelberg game, I investigate how the competition between retailers, government financial intervention, and consumer surplus affect the pricing of a green product and the green-marketing effort-level decisions by members of the supply chains. The results show that consumer surplus is affected by the green decisions, and that government subsidies increase the profits of the two types of stores. The government should offer subsidies to increase the production of green fashion products. By incentivizing green initiatives through financial assistance, the government encourages the adoption of environmentally friendly practices and stimulates economic growth within the fashion supply chain.

This chapter sheds light on the intricate relationship between competition, government intervention, consumer surplus, and sustainability efforts within a two-echelon supply chain. The findings offer valuable insights for manufacturers, retailers, policymakers, and stakeholders, allowing them to make informed decisions that promote both profitability and environmental consciousness in the realm of green fashion product.

5.1 Introduction

Environmental concerns are increasing green activities from the top of the supply chain (i.e., from the government and from manufacturing companies) to the bottom, reflecting consumers' willingness to buy green products. The government and companies have adopted many measures to address the increasingly severe environmental problems. For example, beginning July 1, 2020, Japan has been charging for the use of plastic shopping bags in order to control the excessive use of plastics and to encourage their wise usen (Johnston, 2020). Further, IKEA has replaced virgin fossil-based polyesters with recycled materials, reducing the climate footprint from polyester by around 45% (IKEA,2022).

Chitra (2007) demonstrated that unique equilibrium prices exist, and that consumer awareness of the environment significantly influences market share. The higher a consumer's environmental awareness, the more willing is he/she to pay higher prices for eco-friendly products. The BBMG Conscious Consumer Report reveals that 87% of Americans identify with the term "conscious consumer" when it comes to their commitment to environmentally friendly practices, assuming products are of equal quality and price (Bemporad & Baranowski, 2007). Additionally, Liu et al. (2012) investigated the influence of consumers' environmental awareness and competitive intensity on the profitability of manufacturers and retailers from a supply-chain network perspective.

Generally, there are two significant types of green-level research and development (R & D) investments: green-product development and green-marketing efforts. Green Product is designed, manufactured, and distributed with a focus on minimizing its environmental impact throughout its entire lifecycle (Sinayi & Rasti-Barzoki, (2018). In fashion industry, the organic cotton is often used as green product. H&M spent 1.15 million USD in premiums received by farmers, supporting investment in organic farming (2019-2020). NIKE Apparel and Converse increased their sustainable cotton to 100% in FY20.

Green marketing, which takes into account the environmental impacts of traditional marketing activities and their social, economic, and political implications, has become a focus of many businesses (Chamorro et al., 2009). A consumer's actual green purchasing behavior is closely tied to their knowledge of green products, which is in part shaped by the green marketing efforts put forth by product providers (Hong & Guo, 2019). Retailers are increasingly deploying green promotional strategies, such as electronic ordering, to cater to consumers' environmental preferences. In an effort to bolster their image and draw in customers, many companies are underlining the importance of green products in their advertising efforts. Green marketing extends beyond television and newspaper advertising, often incorporating strategies like displaying a "green logo" on a company's website to promote eco-friendly products. For instance, the online retail giant Amazon uses a unique label, "Climate Pledge Friendly", as a strategy to incentivize customers to make environmentally friendly choices (Engleman, 2010). JIGSAW adverting on the subway walls to show the green marketing on the product materials. In another example, 'Ito En', a well-known tea company in Japan, made the announcement that it would launch the first label-free decaffeinated green tea beverage, with no label on the polyethylene terephthalate (PET) bottles. This product has been sold exclusively on e-commerce sites since November 16th, 2020 (ITO EN, 2021).

Strategies to encourage green product design have also been examined. Wang et al. (2021) utilized two reward strategies to promote such designs and explored the differences in their performance in enhancing product greenness. Additionally, retail promotion policies, which are common strategies in supply chain operations, have been proposed to increase a retailer's competitiveness. The performance of supply chains under such promotional strategies has been explored (He & Zhou, 2019). The green-product development and green-marketing promotions of manufacturers and retailers provide consumers with more detailed environmental information about products. This may motivate the actual purchasing behaviors of consumers and expand the market share of green products, increasing the competition between physical stores and online shops. However, the manufacturers and retailers must pay for the necessary green investment costs (Ji et al., 2017). The trade-off is between profit on the one hand and investments in improving the green level of products and green marketing on the other. The retailer faces decisions about the pricing of a green product and the level of green marketing. The manufacturer faces decisions about the green level of the product.

Taxes or subsidies are alternate strategies to safeguard our environment. These measures ensure that companies with polluting units and individuals bear the external environmental costs. In certain scenarios, economic incentives or financial support for pollution abatement can also be considered (Galera et al., 2019). Furthermore, as per economic theory, consumer surplus is a precise measure of welfare, reflecting consumers' willingness to pay. This is demonstrated by Sinayi and Rasti-Barzoki (2018), who show how consumer surplus may increase as the price of a product rises.

Prior research has discussed scenarios where manufacturers, in order to expand market demand, often open a direct channel to sell a product (Zhang, L.-H., et al., 2018b). In the current business climate, online stores have evolved into powerful, independent retailers, capable of competing with manufacturers and brick-and-mortar stores. In the model setting we consider here, a manufacturer produces green products, while an online store and a physical store undertake green-marketing efforts to promote these green products. Given the maturation of e-commerce and the growth of online stores, the latter are increasingly being seen as independent decision-makers. Therefore, we explore the green competition between retailers operating in different sales channels who make independent decisions regarding green product pricing and investment in green-marketing efforts.

The previous literature has focused almost exclusively on green-product development, with little concern for green marketing, which is also important in real business. Conversely, in the present article, I mainly emphasize the importance of green marketing, such as advertising to enable customers to recognize correctly the benefits of green products, which will increase sales. Alternatively, online stores can choose to use electric vehicles to deliver goods; thus, allowing people to buy products without considering carbon emissions. The value of the present study is that I fill in a research gap in that I consider not only the input of the manufacturer in producing a green product but also the use of green-marketing methods by retailers to expand the market.

The novelty of this Study III, I consider the impact on market demand of a retailer's green-marketing efforts, and I also consider the impact of competitors' green-marketing efforts. From the fashion industrial viewpoint, I are considering not only the economic goal, but also, I are incorporating environment and social-welfare goals. In a competitive environment, in addition to considering the impact of their green-marketing efforts on market demand, a company must also consider the impact of competitors' green-marketing efforts. Here I not only consider a manufacturer's input to produce green products but also consider retailers' use of green-marketing methods to expand the market.

My research goal of Study III is to promote the efficiency of the green supply chain and to help companies make appropriate green decisions in modern business (i.e., about the green level of a product and the green-marketing level) by taking advantage of competition among companies, governmental financial intervention, and making clear how to make the distribution of consumer surplus more reasonable. I also expect this study to provide valuable information to companies and operation managers for making appropriate decisions to achieve economic and environmental competitiveness. Enterprises make products greener and provide more environmental protection through the benefits they obtain, yielding increased social benefits. To this end, I consider the following research questions:

(RQ 5.1) How does retail competition (i.e., retail pricing and green-marketing efforts) influence the performance of the supply chain?

(RQ 5.2) What is the effect of government policy on the profits of a supply chain member?

(RQ 5.3) How do a product's green level, retail pricing, and green-marketing effort affect the consumer surplus?

The remainder of Study III is organized as follows. Section 5.2 formulates the problem description and states some assumptions. Section 5.3 presents the methodology I used for modeling and an equilibrium analysis of several models. Section 5.4 deals with results and numerical illustrations and offers some managerial suggestions. Finally, my conclusions and a future research direction are presented in Section 5.5. I build upon the contributions made in the other studies, presenting the findings and insights in Section 5.6.

Table.5-1: The literature comparison of Study III

Related papers	Selling channel	Pricing competition	Green product	Green marketing	Government intervention	Social welfare
Kurata et al (2007)	Dual	√	-	-	-	-
Panda (2014)	Single	√	-	-	-	√
Jamali&Rasti-Barzoki (2017)	Dual	√	√	-	√	-
Sinayi&Rasti-Barzoki (2018)	Single	-	-	√	√	
Hong&Guo (2019)	Single	-	√	√	-	√
Guo&Chen (2020)	Dual	√	√	-	-	-
Li et al (2021)	Dual	√	√	-	√	
Study III	Dual	√	√	√	√	√

5.2 Problem Description and Framework

In this Section, I establish six scenarios to illustrate my research questions on green decisions (i.e., the green level of a product, green-marketing efforts, and green-product pricing). I assume that a manufacturer produces green products and that two retailers undertake green-marketing efforts. I also assume that the government either charges a tax on or provides a subsidy for the final retail price. Consumers can buy the products through both channels. The framework of the considered supply chain is shown in Fig.5-1.

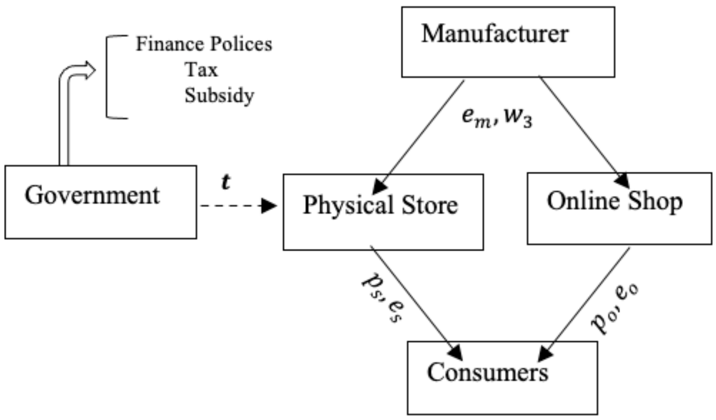

Fig.5-1: The supply chain framework of Study III

In creating this model, I made several assumptions in Table.5-2 below:

Table.5-2:The notations and meanings of Study III

Notations	Meanings
b	The basic market of green products.
p_i	The retail price of store i.
e_m	The green level of the manufactured product.
e_i	Increased by green-marketing efforts by i
w_3	Wholesale price.
c_3	Product cost.
β_1	The self-sensitivity of the marginal price per respective channel demand.
β_2	The cross-sensitivity of the marginal price per respective channel demand
ρ	The customers' preference for the online shop over the physical store, $(0 \leq \rho \leq 1)$.
δ	The coefficient of green level of product.
γ	The green-marketing effort of the competitor's product, $(0 \leq \gamma \leq 1)$.
s_c	The online shopping cost (i.e., the cost of searching and waiting for delivery).
x_c	The cost of shopping at the physical store.
t	The government imposes a tax on $(t > 0)$ or pays a subsidy for $(t < 0)$ the product.
k_3	The coefficient of investments in green technology.
η_c	The cost coefficient per unit of the degree of greenness.
D_i	Demand functions of i.
i	$i \in \{s, o\}$, s means the physical store, o means the online shop.

Assumption 5.1. The demands faced by the channel members are linear functions of the retail prices (p_o, p_s) and of the green level of the manufactured product (e_m); I assume that the demand is increased by green-marketing efforts (e_o, e_s) and is decreased by competitors' green-marketing efforts. The demand functions D_i can therefore be expressed as follows:

$$D_o(p_o, e_o, e_m) = \rho b - \beta_1 p_o + \beta_2 p_s + \delta e_m + e_o - \gamma e_s - s_c. \quad (5.1)$$

$$D_s(p_s, e_s, e_m) = (1-\rho) b - \beta_1 p_s + \beta_2 p_o + \delta e_m + e_s - \gamma e_o - x_c. \quad (5.2)$$

where the remaining quantities in these equations are defined below.

It is also assumed that the two competing retailers share the basic market demand b for green products. The quantity ρ $(0 \leq \rho \leq 1)$ is the customers' preference for the online shop over the physical store. The parameter β_1 is the self-sensitivity of the marginal price per respective channel demand, β_2 is the cross-sensitivity of the marginal price per respective channel demand, and the parameter γ $(0 \leq \gamma \leq 1)$ is the negative sensitivity of market demand with respect to the green-marketing effort of the competitor's product (Li et al., 2021). Here, s_c is the online shopping cost (i.e., the cost of searching and waiting for delivery). Conversely, x_c is the cost of shopping at the physical store (i.e., the cost of traveling to go to the store). s_c and x_c can help us understand why some consumers prefer online shopping, while others favor shopping in physical stores. These two parameters can be used to differentiate the characteristics and economic nature of brick-and-mortar stores versus online shops.

Chen and Chen (2019) explored the conditions under which an offline retailer should implement price matching. Their research has potential implications for our study, where we consider the pricing of green products, denoted by the coefficient δ representing the green level of the product.

Assumption 5.2 (Tax or subsidy)

I assume that the government imposes a tax on $(t > 0)$ or pays a subsidy for $(t < 0)$ the product, so that the final price of the product is $p_i + t$. Therefore, the demand for the product, including taxes or subsidies, can be written as:

$$D_o^t(p_o, e_o, e_m) = \rho b - \beta_1(p_o + t) + \beta_2(p_s + t) + \delta e_m + e_o - \gamma e_s - s_c. \quad (5.3)$$

$$D_s^t(p_s, e_s, e_m) = (1 - \rho)b - \beta_1(p_s + t) + \beta_2(p_o + t) + \delta e_m + e_s - \gamma e_o - x_c. \quad (5.4)$$

Assumption 5.3 (Two types of green costs)

For the manufacturer: For each green product, the manufacturer faces a unit cost $(c_3 + k_3 e_m)$.

For the two retailers: Retailer i incurs an extra cost for selling green products to the target market. The extra investment is the total cost $\frac{\eta_c e_i^2}{2}$, where η_c is the cost coefficient per unit of the degree of greenness. Such a quadratic-type function is frequently used by previous researchers (e.g. Chen, 2001; Zhang et al., 2015; Zhang & Yousaf, 2020).

Unlike other studies, we adopted two types of green investment costs. This setting is more aligned with the apparel industry. For instance, organic cotton used for clothing production is charged on a per-unit basis, while certain green marketing initiatives might involve one-time substantial investments, even though maintaining a green brand image can require ongoing efforts and expenditures.

Assumption 5.4 (Consumer surplus)

In Study III, I consider consumer surplus to be an indicator of social welfare. Consumer surplus (CS) is the difference between the total amount that a consumer is willing able to pay for a good or service and the total amount that they actually pay (i.e., the equilibrium price). A fraction of the consumer surplus is the socially responsible manufacturers and retailers' concern, and the amount of consumer surplus incorporated in their profit in the model is then (Sinayi & Rasti-Barzoki, 2018).

$$CS = \int_{equilibrium\ price}^{p_i} D(p_i, e_m, e_i)dp.$$

In Study III, I consider two CS situations. In one, the manufacturer has the social concern, and the retailers are profit-maximizing; hereafter I call this the consumer surplus with manufacturer (CS–M) scenario. In the other, the retailers have the social concerns, and the manufacturer is profit-maximizing; I call this the consumer surplus with retailer CS–R scenario. All the scenarios are shown in Table.5-3 below.

Table.5-3:The scenarios of Study III

Without government intervention ($t = 0$)	With government intervention ($t \neq 0$)
5.I Benchmark Scenario with $t = 0$ 5.II CS–M concerns 5.III CS–R concerns	5.IV Benchmark Scenario with $t \neq 0$ 5.V CS–M concerns 5.VI CS–R concerns

Assumptions 5.5:

1. $\beta_1 > \beta_2$: The demand for each retailer is more sensitive to its own price than to the competitor's price (Kurata et al., 2007). In other words, consumers are more responsive to changes in the price set by the retailer themselves than to changes in the prices set by competitors. This could inform the retailer's pricing strategy, suggesting they have some degree of pricing power and that their demand would be more significantly affected by their own price changes than by the price changes of their competitors.

2. $p_i > w_3 > c_3$: This represents a positive profit for both the retailers and the manufacturer.
3. $\beta_1 > \gamma$: The sensitivity of the retail price is greater than that of the green-marketing efforts (Hong and Guo, 2019). For businesses, this information could be crucial in strategizing their market approach. It might indicate that although investing in green marketing can positively affect demand, adjusting prices is likely to have a more immediate and stronger effect on sales volume. However, the long-term brand value and customer loyalty gained through green marketing could also be significant, even if it is less quantifiable in the short term.
4. $k_3 > \eta_c$: The investments in green technology are higher than the investments in green marketing, which implies that the cost rate of technology development is higher than that of green marketing (Hong and Guo, 2019). This comparison suggests that a company prioritizes or allocates more resources to developing and implementing green technologies than to promoting its green image. It could also reflect an understanding that long-term cost savings and competitive advantage are more likely to come from technological advancements rather than just marketing efforts.

5.3 Equilibrium Analysis of Scenarios

In this Study III, the Stackelberg game is employed, a strategic game in economics and game theory that models a hierarchical market structure. This game was named after the German economist Heinrich Freiherr von Stackelberg, who introduced the concept in his 1935 book "Market form and equilibrium" (Hicks, 1935). The Stackelberg game enables the study of strategic dynamics in hierarchical marketplaces, which can provide valuable insights into industry practices and competitive behaviors. According to the Myerson (1991), in the Stackelberg model, the "Equilibrium Value" refers to the strategy combination by which the leader (e.g., the manufacturer) can maximize its profit, given the strategies of the followers (e.g., retailers). Conversely, the followers will choose a strategy to maximize their profit, taking into account the strategy of the leader. The game is a type of sequential-move game and is a refinement of the more general Cournot competition model, which assumes that firms choose their output or price simultaneously.

In this model of Study III, each member of a supply chain optimizes its own decisions. For example, in the fashion industry, the manufacturer has the more powerful structure and makes the first decisions. In a Stackelberg game setting, the manufacturer is the leader who first decides the wholesale price and the green level of the product. The two retailers are the followers, playing a Nash game, each deciding its own retail price and green-marketing level simultaneously. "Optimal Retail Pricing" in Study III denotes the price strategy selected by the retailer to maximize its profit given the strategy of the manufacturer. To determine this optimal strategy, we differentiate the profit function first and second t derivative to ensure we achieve a maximum.

In the game sequence of the model, the manufacturer first determines the green level e_m of product and the wholesale price w_3. The two retailers then simultaneously decide the retail prices p_s and p_o and the green-marketing efforts e_s and e_o. Adopting the method of reverse induction, I first evaluate the derivatives of the demand functions of the two retailers with respect to p_s, p_o, e_s, and e_o and set them to 0.

5.3.1 Without government intervention

Scenario 5.I

I obtain the profit functions π_i for each of the three supply chain members from the demand functions (5.1) and (5.2):

$$\pi_m^{5.\mathrm{I}} = (w_3 - c_3 - ke_m)(D_o + D_s) = (w_3 - c_3 - ke_m)(b - (p_o + p_s)(\beta_1 - \beta_2) + 2\delta e_m + (e_s + e_o)(1 - \gamma) - s_c - x_c). \quad (5.5)$$

$$\pi_s^{5.\mathrm{I}} = (p_s - w_3)D_s = ((1 - \rho)b - \beta_1 p_s + \beta_2 p_o + \delta e_m + e_s - \gamma e_o - x_c) - \frac{\eta_c {e_s}^2}{2}. \quad (5.6)$$

$$\pi_o^{5.\mathrm{I}} = (p_o - w_3)D_o = (\rho b - \beta_1\, p_o + \beta_2 p_s + \delta e_m + e_o - \gamma e_s - s_c) - \frac{\eta {e_o}^2}{2}. \quad (5.7)$$

According to the Stackelberg game' backward solution, I first solve the first-order condition for $\pi_s^{5.\mathrm{I}}$ and $\pi_o^{5.\mathrm{I}}$ to obtain:

$$e_s^* = \frac{w_3\beta_1 + \gamma e_o + x_c - b(1-\rho) - \beta_2 p_o - \delta e_m}{1 - 2\beta_1\eta},$$

$$p_s^* = w_3 + \eta_c \frac{w\beta_1 + \gamma e_o + x_c - b(1-\rho) - \beta_2 p_o - \delta e_m}{1 - 2\beta_1\eta_c},$$

$$e_o^* = \frac{w_3\beta_1 + \gamma e_s + s_c - \rho b - \beta_2 p_s - \delta e_m}{1 - 2\beta_1\eta_c},$$

$p_o^* = w_3 + \eta_c \frac{w\beta_1+\gamma e_s+s_c-\rho b-\beta_2 p_s-\delta e_m}{1-2\beta_1\eta_c}.$

Then need to substitute the followers' (physical store and online store) reaction functions into the manufacturer's profit function. We then need to derive the partial derivatives with respect to w_3 *and* e_m, and set them to zero to find the optimal values. Since we already have the expressions for the followers' strategies, we can directly use these for taking the derivatives.

$$\frac{\partial \pi_m^{5.I}}{\partial w} = b - (p_o^* + p_s^*)(\beta_1 - \beta_2) + 2\delta e_m + (e_s^* + e_o^*)(1-\gamma) - s_c - x_c - c_3 - ke_m = 0$$

$$\frac{\partial \pi_m^{5.I}}{\partial e_m} = -k(b - (p_o^* + p_s^*)(\beta_1 - \beta_2) + 2\delta e_m + (e_s^* + e_o^*)(1-\gamma) - s_c - x_c) + 2\delta(w_3 - c_3 - ke_m) = 0.$$

The results are presented in Appendix C.

Scenario 5.II

In this scenario, the manufacturer has the social concerns, and the retailers are profit-maximizing. In all the consumer-surplus scenarios, I assume the use of a consistent price strategy to make the calculation simpler. Therefore, the retail prices and green-marketing efforts are the same: $p_o = p_s = p$ and $e_o = e_s = e$. The total supply chain demand is then:

$$D(p, e_m, e) = b - 2p(\beta_1 - \beta_2) + 2\delta e_m + 2e(1-\gamma) - s_c - x_c.$$

$$\lambda CS = \lambda \int_{p_{market}}^{p_{max}} D(p, e_m, e)dp$$

$$= \lambda \int_{p}^{\frac{b+2\delta e_m+2e(1-\gamma)-s_c-x_c}{2(\beta_1-\beta_2)}} [b - 2p(\beta_1 - \beta_2) + 2\delta e_m + 2e(1-\gamma) - s_c - x_c]dp$$

$$= \lambda[(p + (\beta_1 - \beta_2)\left(\frac{x_c-b+s_c+2e(\gamma-1)}{2}\right)\left(x_c - b + s_c - 2\delta e_m + 2e(\gamma-1)\right) - (\beta_1 - \beta_2)^3(\frac{x_c-b+s_c+2e(\gamma-1)}{2} - \delta e_m)^2 + p^2(\beta_1 - \beta_2)].$$

$$U_m^{5.I} = \pi_m^{5.I} + \lambda CS.\ U_s^{II} = \pi_s^{II};\ U_o^{II} = \pi_o^{II}\ . \quad (5.8)$$

In Eq. (5.8), note that when $\lambda = 0$ the manufacturer is a pure profit maximizer, whereas $\lambda = 1$ indicates that the manufacturer is a perfect welfare maximizer. In exist literature papers, consumer surplus is considered to be the social aspect of sustainability and corporate social responsibility (Panda, 2014; Sinayi & Rasti-Barzoki, 2018). The method of solution for this scenario is similar to that employed for Scenario 5.I, so I can obtain the optimal values of the decision variables and the profit functions for this case as well.

Scenario 5.III

In this scenario, the retailers have the social concern, and the manufacturer is profit-maximizing. In this case, I obtain:

$U_S^{5.III} = \pi_S^{5.III} + \lambda_1 CS, U_o^{5.III} = \pi_o^{5.III} + \lambda_2 CS. U_m^{II} = \pi_m^{II}.$

where these functions are shown in the Appendix C.

5.3.2 With government intervention

From the demand functions (5.3) and (5.4), I can obtain the profit functions for each of the three supply chain members for Scenarios 5. IV to 5.VI. I do not provide the calculational details in this section, because the logic and procedure of the calculation are similar to those employed in Section 5.3.1. I compare the results of numerical and sensitivity analyses in Section 5.4. More details about the numerical results are provided in the Appendix C.

5.4 Results and Discussion

In this section, I provide numerical examples and sensitivity analyses to illustrate the feasibility of the proposed problem solution.

Table.5-4:Parameter setting of Study III

Parameters	α	β_1	β_2	k	c	δ	ρ	η	s	θ	x	γ	t
Value	1000	0.5	0.4	1	50	1	0.5	0.8	2	3	2	1	2

5.4.1 Numerical analysis for RQ 5.1

RQ 5.1 considers the effect of the model parameters on the two retail competitors, as depicted bellow in Fig.5-2 and Fig.5-3.

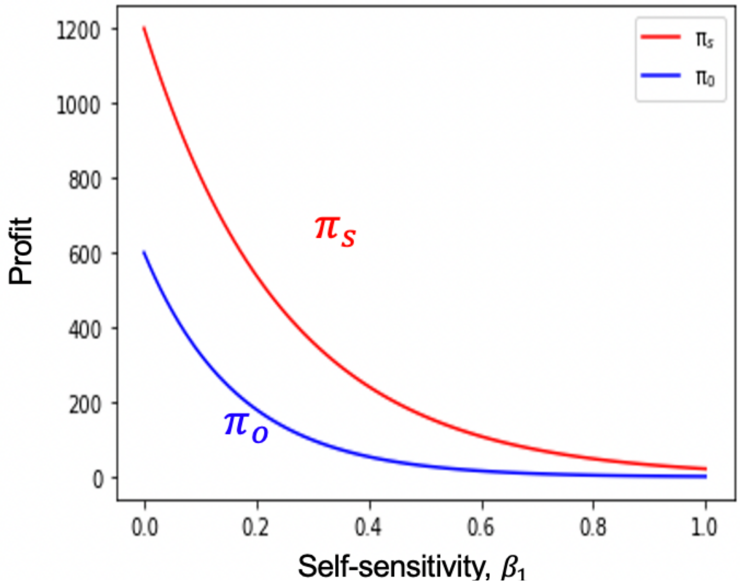

Fig.5-2: Self-sensitivity of retail price impact on profits

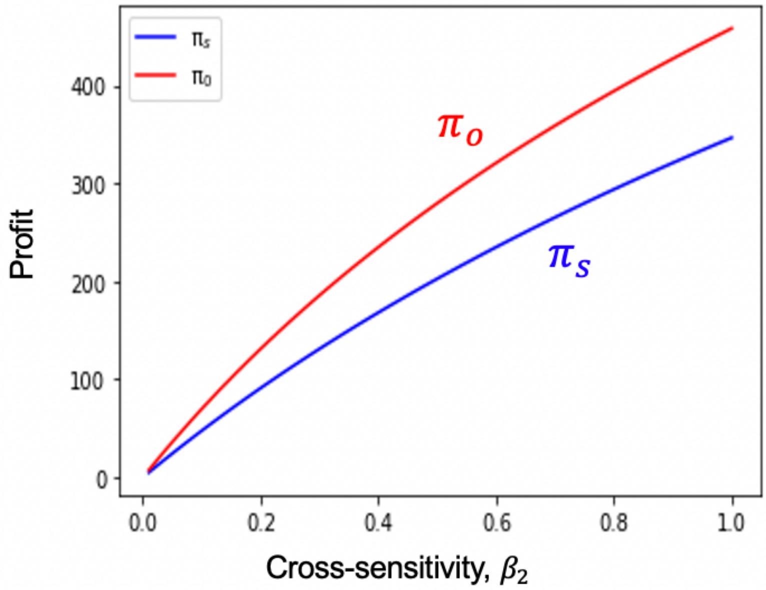

Fig.5-3: Cross-sensitivity of retail price impact on profits

Observation 5.2. *Weak competition can increase profits, but competition that is too strong decreases a retailer's profits.*

Observation 5.2 suggests that a moderate level of competition can enhance profitability. This implies that retailers should strive for a balanced competitive scenario. In the fashion industry, this might mean diversifying product offerings to minimize direct competition or focusing on unique selling propositions (USPs) that differentiate them from competitors.

Fig.5-2 shows that the retailers’ profits decrease with the self-sensitivity of the price. In the context of the fashion industry, this could mean that retailers with pricing power - the ability to raise prices without significantly affecting demand - could enjoy higher profits. This could be achieved by offering high-quality, unique, or luxury items that consumers perceive to be worth the higher price. On the other hand, Fig.5-3 shows that the retailers’ profits increase with the cross-sensitivity of the price. This underlines the importance of being aware of and managing the impact of price changes on cross-selling opportunities in the fashion supply chain. For instance, a steep price increase in one item may deter consumers from purchasing related products. In summary, these observations suggest that fashion retailers should aim to create a distinctive, attractive brand and product proposition, have a balanced approach to competition, and manage their pricing strategy effectively to maximize their profitability.

To provide a more comprehensive answer to question 5.1, an experiment was added to assess the combined impact of the two determinant variables on profit. The selection of parameters was informed by both academic literature and real-world examples to strike a balance between theory and practice. Specifically, Fig. 5-5, 6, and 7 drew inspiration from UNIQLO's green initiative titled "The Power of Clothing" (https://www.uniqlo.com/jp/en/contents/sustainability/jointpoc/).

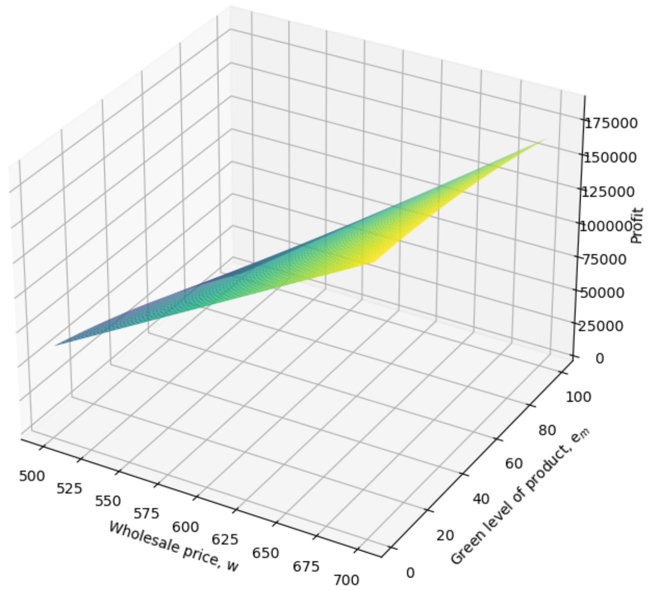

Fig.5-4: The combined effects of wholesale price and green level on the profits.

Fig.5-4 provided three-dimensional graph illustrates the relationship between the wholesale price, green level of a product, and the resulting profit. As the wholesale price increases, there's a notable increase in profit. This suggests that as products are priced higher at the wholesale level, profits also tend to rise, possibly due to a higher markup. As the green level of a product goes up, the profit also tends to increase, but not as dramatically as with wholesale price. This may imply that while eco-friendliness or sustainability of a product does play a role in profitability, its effect isn't as pronounced as the w. The peak of the surface (the yellowest part) suggests the optimal combination of w and e_o that yields the highest profit. It seems the profit is maximized at a higher wholesale price range combined with a higher green level.

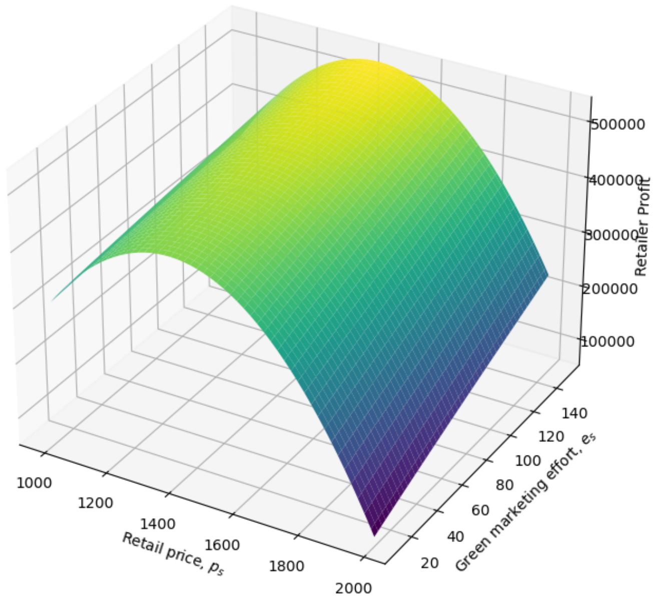

Fig.5-5: The impact of retail price and green marketing in physical store.

From Fig.5-5, at lower levels of e_s, profits experience a significant increase when p_s rises from around 1000 to approximately 1600. However, as p_s further increases to 2000, the profits start to decline. This might suggest that for low green marketing efforts, there exists an optimal retail price range (around 1600), beyond which consumers might perceive the price as too high, consequently reducing their willingness to purchase. For lower and medium p_s, profits increase with the rise of e_s. When e_s hits the 80-100 range, profits begin to drop. This indicates that excessive green marketing might result in diminishing marginal returns, possibly because consumers feel fatigued by the overemphasis on green initiatives or perceive it as a marketing gimmick. In the higher p_s range (around 1800-2000), profits remain almost unchanged or slightly decrease even with increased e_s. This suggests that for higher-priced products, ramping up green marketing efforts may not yield additional profit gains, likely because consumers expect high-priced items to be of superior quality inherently, thus additional green This suggests that for higher prices, ramping up green marketing efforts may not yield additional profit gains. It's possible that consumers feel that high-priced products should inherently be of high quality, so extra green marketing efforts don't enhance their buying intent.

From the Fig.5-5, the highest profit seems to occur when p_s is around 1600 and e_s falls within the 70-80 range. This implies that, given the current market and consumer preferences, this might be the best combination of price and green marketing effort.

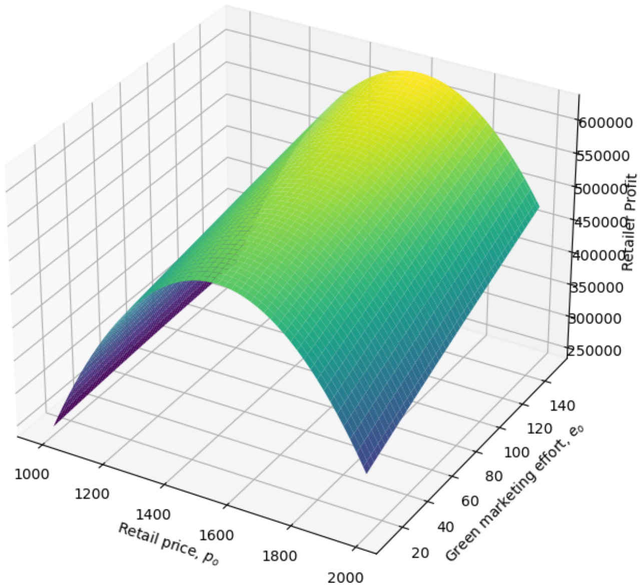

Fig.5-6:The impact of retail price and green marketing in online shop

From Fig.5-6, in the lower online retail price range, profits are relatively low. As p_o increases, profits gradually rise, peaking at a certain point before declining again. In the lower range of green marketing efforts, profits are relatively high. However, as e_o increases, profits decline significantly. This could be due to the costs of excessive green marketing effort outweighing the additional revenue generated. To maximize profits, businesses should opt for a retail price situated between the yellow and green regions on the Fig.5-6 and maintain a moderate investment in green marketing. The surface plot exhibits an inverted U-shape, suggesting the existence of a point of maximum profit.

5.4.2 Numerical analysis for RQ 5.2

RQ 5.2 considers the effect of financial intervention by the government (i.e., as taxes or subsidies) on the profits of the two competing stores as depicted bellow in Fig.5-7.

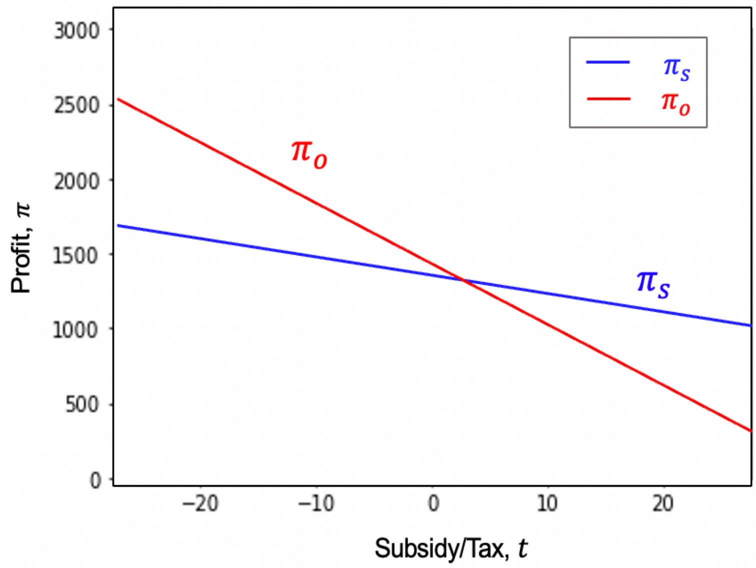

Fig.5-7: Financial intervention impacts on profits.

Observation 5.3. *Government subsidies increase the profits of stores, and taxes reduce them.*

The results shown in Fig.5-7 are consistent with the natural economic environment in the fashion supply chain. Subsidies bring certain benefits to companies, but the effects are different for online shops and physical stores. Brick-and-mortar stores are more sensitive to government subsidies, and the same subsidies impact the profit growth of brick-and-mortar stores more significantly. Conversely, taxes impact the income for both types of stores, but not as much as subsidies do. Study III suggests that the government should consider increasing subsidies to lower the retail prices of green products to attract more customers to buy them and to stimulate sales in the two types of stores. This achieves the original intention of protecting the environment.

5.4.3 Numerical analysis for RQ 5.3

RQ 5.3 considers the effect of green decisions on the consumer surplus, as depicted bellow in.

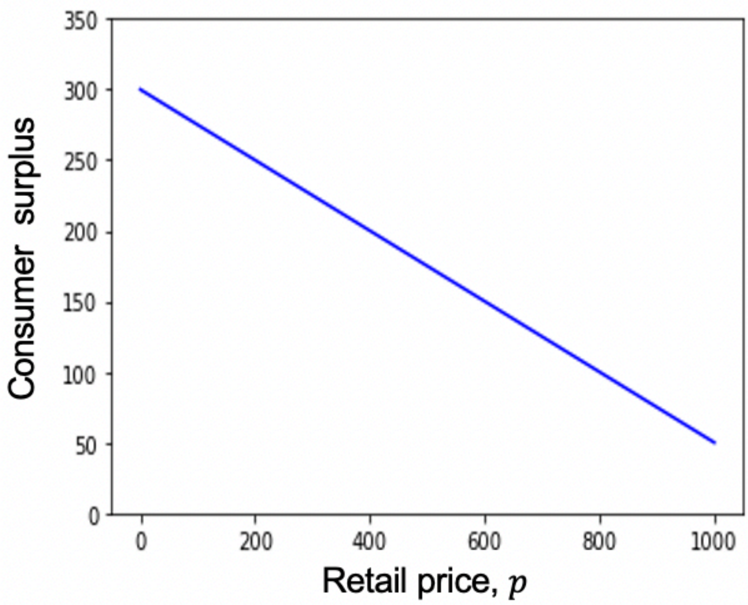

Fig.5-8: Retail price impacts on CS

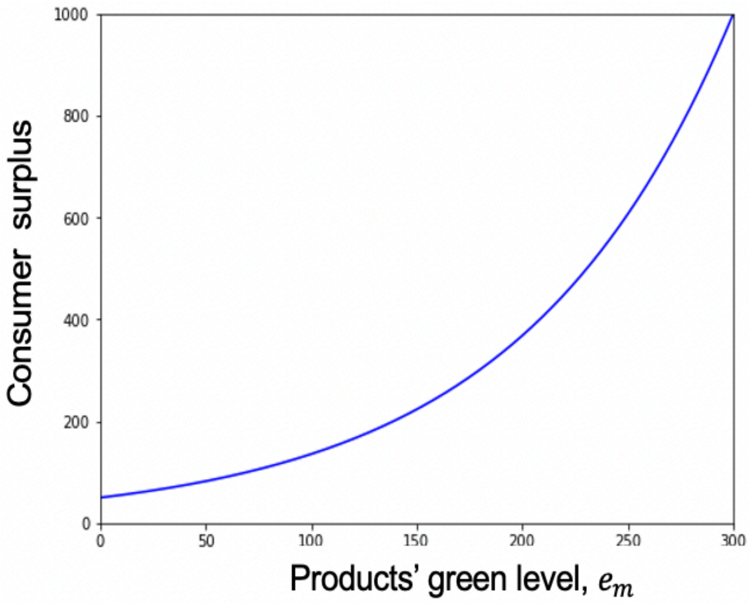

Fig.5-9: Product's green level impacts on CS

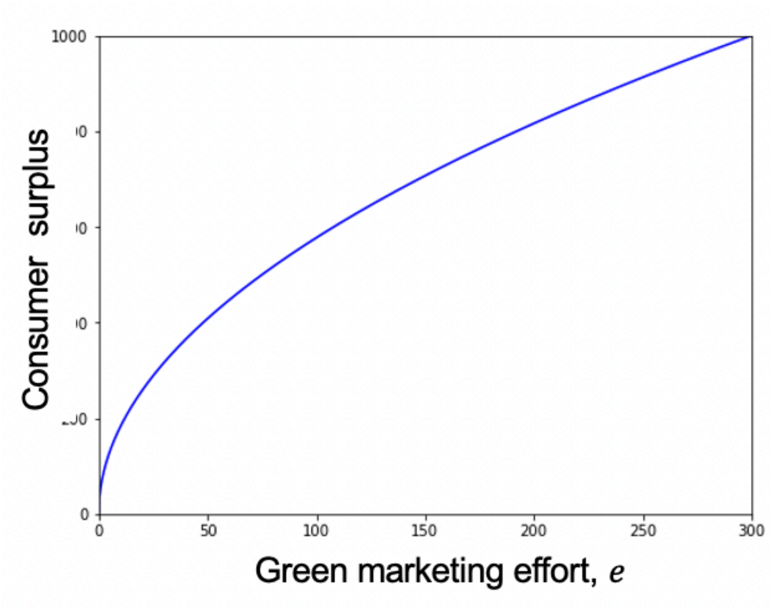

Fig.5-10: Green marketing effort impacts on CS

Observation 5.4. *Consumer surplus is distinctly influenced by the green decisions (i.e., the green-marketing efforts, a product's retail pricing, and its green level).*

Observation 5.5. *When a manufacturer/retailer incorporates a fraction of the consumer surplus into its profit function, I suggest that the manufacturer should increase the green level of the product, and the retailer should decrease the retail price and increase the green-marketing effort.*

Fig.5-8 shows that the consumer surplus decreases as the retail price increases. Conversely, the consumer surplus increases with the green level of the product (Fig.5-10) and with the green-marketing efforts (Fig.5-11). Therefore, improving the green level of a product and increasing the green marketing generates more social welfare. In the context of the fashion supply chain, these results have significant implications. The fashion industry is well-known for its environmental impact, including resource consumption, pollution, and waste generation. By improving the green level of products and investing in green marketing efforts, fashion brands can contribute to greater social welfare and a more sustainable supply chain. Improving the green level of a product in the fashion supply chain can involve various strategies, such as using more eco-friendly materials, adopting energy-efficient production methods, and minimizing waste during manufacturing. Additionally, brands can collaborate with suppliers to ensure that they adhere to sustainable practices throughout the supply chain. Green marketing efforts in the fashion industry can include promoting the use of sustainable materials, highlighting environmentally friendly production processes, and encouraging consumers to make more responsible purchasing decisions. By raising awareness about the environmental impact of the fashion industry, green marketing can influence consumer behavior and preferences, ultimately leading to increased demand for more sustainable products. In conclusion, enhancing the green level of products and investing in green marketing efforts can generate more social welfare in the fashion supply chain. By adopting these strategies, fashion brands can not only reduce their environmental footprint but also appeal to a growing consumer base that values sustainability and ethical practices. It can also lead to improved brand reputation, customer loyalty, and long-term business success.

5.5 Managerial Implications and a Future Study

The production of green products is increasing today because supply chain members (i.e., customers, manufacturers, and retailers) are taking the environment into consideration. Also, improvements in peoples' knowledge resulting from green marketing have led them to buy more green products. Consequently, manufacturers are looking to produce green products to attract eco-friendly customers and address environmental concerns. Observation 5.2 show that the increase in self-sensitivity leads to a decrease in profit, while the increase in cross-sensitivity leads to an increase in profit. When setting retail prices for green fashion products, it is essential to strike a balance between these two sensitivities. Observation 5.3 and 5.4 indicted when a manufacturer/retailer incorporates a fraction of the consumer surplus into its profit function, the manufacturer should increase the green level of the product, and the retailer should decrease the retail price and increase the green marketing effort.

Therefore, making optimal decisions about the appropriate green level of a product, green-marketing efforts, and analyzing the competitive conditions of the market are necessary. There is also competition between the two types of retailers in determining the appropriate selling prices. Pricing strategies and the green marketing of products are being discussed, and equilibrium decisions for players in both supply chains are being studied.

In this study, I solved the pricing problem in two different situations: with and without government intervention. I evaluated each scenario using parametric analyses and numerical examples. My results suggest that the government should offer more subsidies to companies in order to decrease retail prices and attract more customers to buy green products. In a future study, the government could also be considered as a decision-maker that participates in supply chain decisions.

5.6 Effect of Study III on the Study I and Study II

Study III investigates aspects such as green marketing, government intervention, and social welfare distribution in the fashion supply chain, paying particular attention to the effect of consumer surplus, product green ratings, and retail pricing.

1. Effect on Study I: Observation 5.4 indicates that consumer surplus is significantly affected by green decisions (i.e., the strength of green marketing, retail pricing of products, and their green ratings). Accordingly, retailers may be encouraged to more actively adopt RFID technology to increase the accuracy and efficiency of inventory management while maintaining consumer surplus and conforming to the needs of green decisions. Moreover, government subsidies and tax policies (Observation 5.3) may affect the adoption of RFID technology.

2. Effect on Study II: As indicated by Observation 5.5, manufacturers should raise the green rating of products, and retailers should lower retail prices and intensify green marketing efforts, with the aim of incorporating a portion of consumer surplus into their profit function. Thus, when formulating an omnichannel strategy, retailers should consider the green rating of products and the strength of green marketing. Accordingly, the use of online shopping, BOPS services, and HD services can be boosted, such that transportation costs and carbon emissions can be reduced. Furthermore, the degree of competition (Observation 5.2) may exert a certain effect on the success of an omnichannel strategy.

As revealed by the above discussions, the themes of green marketing, government intervention, and social welfare distribution in Study III can exert positive effects on the Study I and Study II. The above-described elements are capable of collectively stimulating the sustainable development of the fashion supply chain while strengthening the intrinsic connections among the dissertations.

Chapter 6 Conclusions

6.1 Key Findings

I underscored the significance of precise and timely product provision for consumers in the fashion supply chain management in three Chapters of this dissertation. This research revealed that the use of modern technologies, such as RFID, not only enhances decision-making efficiency, shortens delivery times, and reduces inventory costs but also improves the shopping experience for consumers. Especially in situations with high misplacement rates and low RFID operational costs, RFID plays a vital role in improving inventory management, reducing misplacement, and enhancing sales performance. However, in scenarios where RFID costs are high, increasing safety stock can also be a good method.

As indicated by Chapter 4, Omnichannel strategy is not always the optimal choice. To be specific, implementing an Omnichannel strategy only yields significant advantages when retail prices or pickup inconvenience costs reach over the costs of a dual-channel system. Furthermore, the BOPS service offered by online retailers cannot be constantly beneficial. Thus, retailers are recommended to adjust product prices while offering BOPS service for ensuring profitability and providing more shopping choices to satisfy consumers' demand.

In Chapter 5, the pricing of green products is explored from two different perspectives, i.e., one with government intervention and the other without. As indicated by the analysis, appropriate government subsidies are capable of effectively lowering the retail price of environment-friendly products, such that more consumers can be attracted to switch to green products. The above-mentioned finding suggests the vital role of the government in promoting the shift towards sustainable development in the fashion industry.

From the summaries of the above-mentioned three Studies, some common findings can also be discussed, such as:

1. Enhancing consumer satisfaction and supply chain profits: All three Studies underscore the importance of supply chain strategies and technology in enhancing consumer satisfaction and emphasize the direct impact of this on improving supply chain benefits. Whether through RFID technology to optimize inventory management and shorten delivery times, offering more

shopping choices through omnichannel sales strategies, or meeting consumer demand for sustainability by providing environmentally friendly products, these strategies all contribute to enhancing the consumer shopping experience, thereby increasing sales and expanding supply chain benefits.

2. Enhancing supply chain efficiency: The three Studies all highlight the importance of enhancing supply chain efficiency. For instance, RFID technology can reduce waste and improve inventory management, omnichannel sales strategies can increase resource utilization, and government subsidies can lower the price of environmentally friendly products and promote market acceptance. These strategies all contribute to pushing the supply chain towards greener transformations, enhancing supply chain efficiency.

3. Emphasizing mathematical model-driven decisions to enhance supply chain profits and efficiency: All three Studies emphasize the importance of mathematical models, analyses, and experiments in the decision-making process. Data collected through RFID technology for inventory, consumer behavior collected through omnichannel sales strategies, and green product sales are all used to drive effective decision-making, thereby enhancing supply chain benefits and efficiency.

These common findings provide a framework for understanding how these strategies and technologies can be applied to fashion supply chain management to achieve the best balance of supply chain benefits and efficiency, while also improving consumer satisfaction.

6.2 Theoretical Implications

This dissertation has made contributions to the development of related theories by solving specific problems in the fashion supply chain through unique mathematical models, numerical examples to implicate to the fashion industry.

Study I, the Newsvendor model is adopted to deeply explore the role of RFID technology in inventory management, such that more insights can be gained into the application of the Newsvendor model in fashion supply chain management from the perspective of traditional mathematical models. Study II, using the 2D Hoteling model, reveals the mutual effects between retail strategies and consumer behaviors, providing a novel theoretical perspective for understanding consumer purchasing decisions and retail strategy choices. Study III, through the application of the Stackelberg game model, explores the balance between environmental protection and economic benefits, opening up new areas for the application of game theory in supply chain management.

Besides the above-mentioned specific models, all three Studies have used numerical examples for simulation verification and carried out a large amount of data simulation and sensitivity analysis to ensure the robustness of the results. The above-described empirical examples demonstrate the utility of each model in practical application and provide valuable tools for understanding the complexity of the fashion supply chain.

By comprehensively applying the Newsvendor model, Hoteling model, and Stackelberg game model, coupled with numerical examples, this dissertation provides a comprehensive and powerful theoretical framework for gaining insights into a wide variety of aspects of sustainable development in the fashion industry chain. This integrated method contributes to the development of a more comprehensive theory of inventory management, retail strategies, and supply chain sustainability, providing a solid theoretical foundation for future research.

6.3 Managerial Implications

To apply the insights from the above-mentioned three studies to the fashion supply chain, the following strategies should be considered by businesses:

A) RFID technology can be implemented for inventory management. In the fashion industry where inventory turnover may be high, and loss of items can lead to significant losses, the use of RFID technology can be conducive to increasing the accuracy and efficiency of inventory. Take Zara as an example. This fast fashion brand has extensively used RFID technology to track its inventory and products, such that its inventory loss has been reduced, and its inventory accuracy has been increased. Thus, it can respond to market changes more swiftly. By tracking items across the entire supply chain, fashion retailers are capable of minimizing lost or misplaced inventory, optimizing inventory levels, and reducing operational costs.

B) Omnichannel retail strategies can be developed. Fashion retailers should consider adopting an Omnichannel method to satisfy diversified customer needs. For instance, Nordstrom has successfully implemented an Omnichannel retail strategy, such that online and offline sales channels have been seamlessly integrated, a consistent customer experience has been provided, and the profitability of BOPS services can be ensured by regulating price structures. Retailers can provide a consistent shopping experience at all touchpoints by seamlessly integrating physical and digital channels. However, before implementing such a strategy, it is key to carefully evaluate price structures and customer preferences. Offering services (e.g., BOPS, HD) can be beneficial if prices are adjusted properly to ensure profitability and customer satisfaction.

C) Sustainable practices in the fashion supply chain can be promoted. To encourage green decision-making in the fashion industry, it is imperative for companies to prioritize sustainable practices in procurement, production, and distribution processes. Companies (e.g., Patagonia) have extensively adopted sustainable practices in their production, procurement, and distribution processes (e.g., the use of environment-friendly materials, energy-efficient production processes, and waste reduction in packaging and transportation). Furthermore, fashion retailers can collaborate with the government to take advantage of fiscal incentives and support programs that are capable of encouraging environment-friendly practices.

D) Government intervention and cooperation. Governments can play a significant role in encouraging sustainable practices in the fashion industry. By providing fiscal incentives, such as subsidies or tax breaks, governments can help businesses lower the retail prices of environment-friendly products, making them more attractive to customers. In some countries, like Denmark, governments are encouraging sustainable practices in the fashion industry by offering fiscal incentives, such as subsidies or tax breaks. Moreover, governments can participate in supply chain decision-making by setting industry standards, promoting optimal practices, and establishing partnerships between businesses and environmental organizations.

In brief, to increase the efficiency, profitability, and sustainability of the fashion supply chain, businesses are required to implement RFID technology for inventory management, implement Omnichannel retail strategies, prioritize sustainable practices, and cooperate with the government to exploit fiscal incentives and support programs.

6.4 Interconnection Between the Three Studies

In this dissertation, the aspects of inventory management, Omnichannel consumption, and environmental and social concerns in the fashion supply chain are thoroughly discussed through three distinct yet inherently relevant Studies. The above-described three Studies share numerous similarities (e.g., using mathematical models to simulate real-life problems and consistently focusing on the fashion supply chain). The three critical interrelationships that I believe are worth emphasizing are primarily introduced:

1. Analyzing the interrelationship of the above-mentioned models from a mathematical perspective. All three Studies use mathematical modelling to analyze and solve problems in the fashion supply chain. Through the construction of mathematical models, the relationships between different factors can be quantified, thereby providing more in-depth insights and targeted recommendations. These models serve as powerful tools in understanding and managing complex supply chain interactions, leading to increased efficiency and overall benefit. Furthermore, mathematical models assist in validating the effectiveness of a wide range of strategies and assumptions, thereby enhancing the reliability and applicability of the research. More specifically, how the similarities and differences between the Newsvendor model and the Hoteling model affect the strategies and results of this dissertation in problem-solving.

2. Seeking win-win solutions. All parties playing a certain role in the fashion supply chain can achieve mutual benefits by seeking balance and coordination, which is conducive to achieving environmental sustainability while protecting economic interests. For instance, using RFID technology can improve company efficiency while alleviating environmental pressures. Besides, governments can balance economic benefits and environmental requirements more effectively through subsidies, thereby promoting the realization of the objectives in Study I and Study II.

3. Focusing on satisfying ever-changing customer needs and improving customer satisfaction. In the fashion supply chain, customer needs and satisfaction take on critical significance in maintaining competitive advantages and achieving sustainable growth. All three Studies focus heavily on satisfying customer needs and improving customer satisfaction. With the rise of green consumerism, customers might be more inclined to purchase environment-

friendly products, which will have a profound effect on fashion supply chain management. The dissertation provides valuable insights and suggestions for the sustainable development of the fashion supply chain by strengthening inventory management, implementing omnichannel retail strategies, emphasizing the manufacture and promotion of green products.

Chapter 7 Research Limitations and Future Directions

Although this dissertation aims to thoroughly investigate key managerial aspects in the fashion supply chain, there remain many unexplored territories worth studying. Given the constraints of the current research, some particularly promising directions for future exploration related to the fashion supply chain have been identified. While each Study concludes with future research directions for their respective areas at the end of the Chapters, it would be interesting to further examine the intersections between the three Studies. This added layer of analysis could provide additional insights, potentially revealing unexplored synergies and interdependencies within the field of fashion supply chain management.

Future research in the realm of fashion supply chain management might consider several fascinating intersections between the themes examined in the dissertation. The marriage of RFID technology with sustainable supply chain practices can be one such area of exploration. This line of research would study into how the capabilities of RFID for inventory management and tracking could be extended to lifecycle management to meet broader environmental objectives. Moreover, the incorporation of RFID technology within sustainable supply chain management can aid in enhancing operational efficiency. By improving accuracy and reducing errors in inventory management, RFID can minimize waste, leading to more environmentally friendly operations. Researchers could investigate this potential along with challenges in implementation and solutions to overcome these barriers.

Integrating the concept of omnichannel retail strategies with environmental themes should prove interesting. For instance, exploring how retailers can utilize the seamless integration of various shopping channels to enhance and heighten consumer awareness of environmentally friendly products. It would be worthwhile to further investigate how such strategies can be developed to increase customer satisfaction and cultivate sustainable consumption behaviors. Omnichannel retail strategy is a significant trend in the current retail industry, holding tremendous potential in promoting environmentally friendly products. By integrating various online and offline channels, retailers can provide a more personalized and convenient shopping experience, which is vital for steering consumers towards environmentally friendly products. Simultaneously, the omnichannel retail strategy can also help retailers gain a better understanding of consumers' shopping habits and needs, enabling precise promotion of environmentally friendly products and enhancing their market acceptance. In this future, it's crucial to delve deeper into understanding how, through the omnichannel retail strategy, we can enhance consumer recognition and acceptance of environmentally friendly products. As well as how such strategies can increase customer satisfaction and foster a culture of sustainable consumption. This research could provide valuable strategic guidance for the retail industry, playing a pivotal role in promoting the popularity of environmentally friendly products and advancing sustainable consumption.

Investigating the role played by government policies and regulations in incentivizing sustainable practices in the fashion supply chain has been confirmed as another promising direction. Understanding how government interventions can shape the competitive landscape, such that the adoption of RFID technology, Omnichannel retail strategies, and sustainable practices will be a significant contribution.

Lastly, it will be conducive to understanding the cross-cultural implications of the above-described strategies, particularly in emerging markets. As the above-mentioned economies are characterized by rapidly evolving consumer preferences and business landscapes, how the strategies proposed in this dissertation translate across different cultural and economic contexts should be recognized. Such research will be academically intriguing and practically useful in devising tailored supply chain strategies for diverse markets.

Subsequent research can make substantial contributions to the scholarly literature and provide valuable by addressing the above-described research limitations and pursuing themes that crosscut the topics, such that more holistic guidance can be provided to businesses operating in the fashion supply chain. Incorporating the above-mentioned findings into the dissertation can enhance its relevance and impact, ultimately improving understanding of inventory management, channel coordination, and sustainable practices in the fashion industry.

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Appendices (A, B, C, D)

All the numerical examples shown in the three papers are derived from the MATLAB and Python software.

Appendix A

This Appendix A is added information for Study I (Chapter 3).

Proof of Lemma 3.1. All components of Propositions 3.1, 3.2, and 3.3 can be derived from the profit functions using simple mathematical operations.

Proof of Proposition 3.1. (a). The proof follows directly from the assumption. (b) Define $h(\alpha) = \frac{(1-\alpha)(r+c_S+c_O)-w}{(1-\alpha)(r+c_S+c_O)+c_O}$ and $g(\alpha) = \frac{r+c_S-w-c_I\alpha^\beta}{r+c_S+c_O}$. Then, because $h'(\alpha) < 0$ and $h''(\alpha) > 0$, q_I^* is a monotonically decreasing function of α that is everywhere concave-up. In addition, because $g'(\alpha) < 0$ and $g''(\alpha) = -\frac{\beta(\beta-1)c_I^{\beta-2}}{\{r+c_S+c_O-\alpha(r+c_S)\}^4}$, $g(\alpha)$ is also monotonically decreasing, but its concavity depends on the value of β. Also, $\lim_{\alpha\to1} q_{3.I}^* = -\infty$ and $\lim_{\alpha\to1} q_{3.III}^* > 0$. If $0 < \beta < 1$, then $g(\alpha)$ is convex-up. Hence, $g(\alpha) < h(\alpha)$ between $\alpha = 0$ and $\alpha = \tilde{\alpha}$. However, if $\beta \geq 1$, it is difficult to analytically define whether $g(\alpha) > h(\alpha)$. Consequently, I obtain Proposition 3.1-(b). (QED).

Proof of Proposition 3.2. (a) The proof follows directly from the definition. (b) Define $\Delta\pi \equiv \pi_{3.I}(q) - \pi_{3.III}(q)$. Then $\frac{\partial\pi_{3.I}}{\partial\alpha} = -(r+c_S)\mathrm{E}(Sales)$ and $\frac{\partial\pi_{3.III}}{\partial\alpha} = -\beta c_I\alpha^{\beta-1}q$, where E(Sales) denotes the expected sales when the order size is q. Thus, the sign of $\partial\Delta\pi/\partial\alpha$ depends on whether $\frac{\Delta\pi}{\partial\alpha} = -(r+c_S)E(Sales) + \beta c_I\alpha^{\beta-1}q < 0$, equivalently $c_{3.I} < \frac{E(Sales)(r+c_S)}{\beta q\alpha^{\beta-1}}$. If $\partial\Delta\pi/\partial\alpha$ is negative, then $\pi_{3.I}(q_{3.I}^*) < \pi_{3.III}(q_{3.I}^*) < \pi_{3.III}(q_{3.III}^*)$. I use the same logic for positive $\partial\Delta\pi/\partial\alpha$. Hence, I obtain Proposition 2-(b). (QED).

Proof of Proposition 3.3. (a) the profit function of Scenario 3.I, $\pi_{3.I}(q)$, is concave-up with respect to q and is maximized at $q_{3.I}^*$. Since $\bar{q}_{3.I}^*$ is not an optimal value unless $\bar{q}_{3.I}^* = q_{3.I}^*$, there exists such $\bar{\bar{q}}_{3.I}^*(\neq \bar{q}_{3.I}^*)$ that satisfies $\pi_{3.I}(\bar{\bar{q}}_{3.I}^*) = \pi_{3.I}(\bar{q}_{3.I}^*)$. Considering the relationship among $\bar{q}_{3.I}^*$, $\bar{\bar{q}}_{3.I}^*$, and $q_{3.I}^*$, I obtain Proposition 3.3-(a). (b) Note that from the definition, $\bar{q}_{3.I}^{*} = \bar{q}_{3.III}^{*}$. Define $\Delta\bar{\pi} = \pi_{3.I}(\bar{q}_{3.I}^{*}) - \pi_{3.III}(\bar{q}_{3.I}^{*})$. From Eqs. (3.1) and (3.2), $\Delta\bar{\pi} = -\alpha(r + c_S)\mathrm{E}(Sales) + c_I\alpha^{\beta}q$. Hence, I obtain Proposition 3.3-(b). (QED)

Appendix B

This Appendix B is added information for Study II (Chapter 4).

The detailed derivation of the demand functions (three threshold values) in dual channel.

1. Threshold $\bar{\theta}$: For $U_{4.I} = U_{4.II}$ at $\bar{\theta}$. From the equations:
   $U_{4.I} = v - r_s - t_c\theta$.
   $U_{4.II} = v - r_o - t_c(1 - \theta)$.
   Step-by-step for $\bar{\theta}$:
   a. Set $U_{4.I}$ equal to $U_{4.II}$: $v - r_s - t_c\theta = v - r_o - t_c + t_c\theta$.
   b. Simplify and combine like terms: $2t_c\theta = r_o - r_s + t_c$.
   c. Solve for θ : $\bar{\theta} = \frac{1}{2} + \frac{r_o - r_s}{2t_c}$.
2. Threshold $\hat{\eta}$: For $U_{4.III} = 0$ at $\hat{\eta}$. From the equation: $U_{4.III} = v - h_o - m\eta$.
   Step-by-step for $\hat{\eta}$: a. Set $U_{4.III}$ equal to zero: $v - h_o - m\hat{\eta} = 0$.
3. Threshold $\check{\eta}$: For $U_{4.IV} = 0$ at $\check{\eta}$. From the equation: $U_{4.IV} = v - h_s - m(1 - \eta)$.
   Step-by-step for $\check{\eta}$:
   a. Set $U_{4.IV}$ equal to zero: $v - h_s - m(1 - \check{\eta}) = 0$.
   b. Solve for η : $\check{\eta} = 1 - \frac{v - h_s}{m}$.
4. Threshold $\bar{\eta}$: For $U_{4.III} = U_{4.IV}$ at $\bar{\eta}$. From the equations:
   $U_{4.III} = v - h_o - m\eta$.
   $U_{4.IV} = v - h_s - m(1 - \eta)$.
   Step-by-step for $\bar{\eta}$:
   a. Set $U_{4.III}$ equal to $U_{4.IV}$:
   $v - h_o - m\eta = v - h_s - m + m\eta$.
   b. Simplify and combine like terms: $2m\eta = h_s - h_o + m$.
   c. Solve for η : $\bar{\eta} = \frac{h_s - h_o + m}{2m}$.

Proof of Proposition 4.1. For part (a) of Proposition 4.1, let's assume that $\triangle r < t_c$, $\triangle r < m$, $\triangle h < t_c, and$ $\triangle h < m$.Given these conditions, we consider each of the market demand functions (4.7-4.10). Since $\triangle r < t_c$ and $\triangle r < m$, in Eqs. (4.7) and (4.8), both terms $\left(\frac{1}{2} - \frac{\Delta r}{2t_c}\right)$ and $\left(\frac{1}{2} + \frac{\Delta r}{2t_c}\right)$ are greater than 0, while in Eqs. (4.9) and (4.10), both $\left(\frac{1}{2} - \frac{\Delta r}{2m}\right)$ and $\left(\frac{1}{2} + \frac{\Delta r}{2m}\right)$ are also greater than 0. Similarly, because $\triangle h < t_c$ and $\triangle h < m$, in Eqs. (4.7) and (4.9), both $\left(\frac{1}{2} + \frac{\Delta h}{2m}\right)$ and $\left(\frac{1}{2} - \frac{\Delta h}{2t_c}\right)$ are greater than 0, while in Eqs. (4.8) and (4.10), both $\left(\frac{1}{2}+\frac{\Delta h}{2m}\right)$ and $\left(\frac{1}{2}-\frac{\Delta h}{2t_c}\right)$ are also greater than 0. Therefore, when $\Delta r < t_c$ and $\Delta r < m$; $\Delta h < t_c$ and $\Delta h < m$, all Omnichannel purchasing styles exist, which verifies part (a) of Proposition 4.1.

For part (b) of Proposition 4.1, we aim to prove that when $\Delta r < t_c$, only dual channel purchasing styles exist. If we assume that $\Delta r < t_c$, but $\Delta h >= t_c$ or $\Delta h >= m$. In this case, in Eqs. (4.7) and (4.9), one of the terms $\left(\frac{1}{2}+\frac{\Delta h}{2m}\right)$ or $\left(\frac{1}{2}-\frac{\Delta h}{2t_c}\right)$ will be less than 0. This implies that at least one of the functions results in a value less than 0, which does not satisfy the existence conditions for Omnichannel purchasing styles. Therefore, when $\Delta r < t_c$, only Dual channel purchasing styles exist, verifying part (b) of Proposition 4.1. (QED)

Proof of Proposition 4.2, 4.3. The proof of Propositions 4.2 and 4.3 are straightforward derivations from our earlier analyses. Specifically, Proposition 4.2 is derived directly from our examination of case 4.2 (a) and its associated Eqs. (4.13) and (4.14). Analogously, Proposition 4.3 is directly derived from Eqs. (4.18) and (4.19). (QED)

Appendix C

This Appendix C is added information for Study III (Chapter 5).

(a) The optimal decision variables of scenario 5.I

$$w_3^{5.I^*} = (-(b - c_3\delta + k_3(x_c - \gamma s) + c_3(\gamma^2\delta + \eta_c\delta) - bk_3(\rho + \gamma + \eta_c(\rho + \gamma)) - k_3\eta_c s(1 - 2\beta_1^2 1 + \beta_2^2 + 2\beta_{1\beta_2}) - b\beta_1 k_3(1 - 2\beta_1\eta_c) + b\beta_2 k_3(\eta_c(1 + \rho) + \rho - \gamma(1 + \rho\gamma)) - k_3 x_c(\beta_1 - \beta_2) + c_3\delta(\beta_2 - \beta_1) + k_3\gamma^2 s - c_3\eta_c\gamma^2\delta + k_3\eta_c\gamma^2 x_c + 2bk_3\rho\gamma(1 - \eta_c\gamma) + 3\beta_1 k_3\eta_c.$$

$$e_m^{5.I*} = (b(\rho + \gamma) + c_3(1 + \gamma - \gamma^3) + x_c(1 + \beta_1 - \beta_2 - \gamma) - b(\beta_1 - \beta_2) + \eta_c(s - \gamma s - \gamma x_c - b\rho - b\gamma - 2b(\beta_1 - \beta_2)\eta_c) + (\beta_1^2 - \beta_1\beta_2) + \beta_2^2)c_3 + 2(\beta_1 - \beta_2)(\eta_c(s - x_c) + b\eta_c^2 - c_3\eta_c^2) - \eta_c\gamma(s - x_c)) + \eta_c^2(s(\beta_1^2 - 2\beta_1\beta_2) + \beta_2^2) - x_c(2\beta_1^2 - 3\beta_1\beta_2) + \beta_2^2) - b\rho\gamma^2))/(k_3 + \delta + \beta_1\delta - \beta_2\delta - 2k_3\gamma - \eta_c(\delta - \gamma\delta - \beta_1^2 k) - \beta_2^2 k) + k_3\gamma^2 + 2\beta_1\beta_2 k_3)) - \beta_1 k_3\eta_c)) - 3\beta_1\eta_c\delta) + \beta_2\eta_c\delta + \eta_c\gamma\delta + \beta_1 k_3) + \beta_1 k_3\eta_c\gamma)) - \beta_1\beta_2 k_3\eta_c)).$$

$$p_o^{5.I*} = (b(\delta - k_3 + k_3\rho + k_3\gamma) + k_3(x_c - \gamma x_c + \gamma s) - c_3(\gamma^2\delta - 4\beta_1\eta_c\delta - \beta_2\eta_c\delta + \beta_1\gamma\delta - \beta_2\gamma\delta + \beta_1\delta - \beta_2\delta) - \beta_1 k_3(2\eta_c s + 2\eta_c x_c - \gamma s + x_c - \eta_c - 3\eta_c\delta) + \beta_2 k_3(-\eta_c x_c + \gamma s + x_c + \eta_c\delta) + b\eta_c(\delta - \beta_2\delta - 2\rho\delta - \gamma\delta) + \beta_1\eta_c(-s\delta + x_c\delta) - \beta_2\eta_c(s\delta - x_c\delta) + \eta_c(\gamma x_c\delta - \gamma s\delta) - k_3\gamma^2 s - 2bk_3\rho\gamma - b\beta_1^2(k_3\eta_c + \eta_c^2\delta - k_3\eta_c^2) + \beta_2^2(c_3\eta_c\delta - k_3\eta_c x_c + k_3\eta_c) + 2b(\beta_1 k_3\eta_c - \beta_1\eta_c\rho\delta + \beta_2\eta_c\rho\delta + \eta_c\rho\gamma\delta) - 2b\beta_1\beta_2(k_3\eta_c^2 - \eta_c^2\delta + k_3\eta_c\rho) + 2\beta_1\beta_2(c_3\eta_c^2\delta + k_3\eta_c^2 x_c))/(\gamma - 2\beta_1\eta_c - \beta_2\eta_c + 1)(k_3 + \delta + \beta_1\delta - \beta_2\delta - 2k_3\gamma - \eta_c\delta - \gamma\delta - \beta_1^2 k_3 - \beta_2^2 k_3 + k_3\gamma^2 + 2\beta_1\beta_2 k_3 - \beta_1 k_3\eta_c).$$

$p_s^{5.I*} = (bk_3\rho - bk_3\eta_c\gamma + 2bk_3\eta_c\rho - 4bk_3\eta_c\rho\gamma + bk_3\rho\gamma^2 + \eta_c^2 s\delta - \eta_c^2 x_c\delta - 4\beta_1 c_3\eta_c\delta -$
$\beta_2 c_3\eta_c\delta + \beta_1 c_3\gamma\delta - \beta_2 c_3\gamma\delta - b\eta_c^2\gamma\delta + 2b\beta_1^2 k\eta_c - 2b\beta_1\beta_2 k\eta_c + b\beta_2 k_3\eta_c + 2\beta_1\beta_2 c_3\eta_c\delta -$
$2b\beta_1 k_3\eta_c^2\rho - 2b\beta_1^2 k_3\eta_c\rho - b\beta_2^2 k_3\eta_c\rho + \beta_1\beta_2 k_3\eta_c^2 s - b\beta_1\beta_2 k_3\eta_c^2 + 2\beta_1\beta_2 c_3\eta_c^2\delta - k\gamma^2 s +$
$k_3\gamma s - k_3\gamma x_c + k_3 x_c - k_3\eta_c s + k_3\eta_c x_c + 2k_3\eta_c\gamma s - 2k_3\eta_c\gamma x_c + \beta_1 k_3\gamma s - \beta_2 k_3\gamma s -$
$\beta_1 k_3\eta_c s - 2\beta_1 k_3\eta_c x_c - \beta_2 k_3\eta_c x_c + \beta_1 k_3\eta_c^2 s - \beta_1 k_3\eta_c^2 x_c - k_3 k_3\eta_c\gamma^2 s + k_3 k_3\eta_c\gamma^2 x_c -$
$2b\beta_1^2 k_3\eta_c^2 + 4\beta_1^2 c_3\eta_c^2\delta + 2\beta_1^2 k_3\eta_c^2 s + 2\beta_1^2 k_3\eta_c^2 x_c + b\beta_1 k_3\eta_c^2 - b\beta_1 k_3\eta_c^2\gamma)$.

$e_s^{5.I*} = (b + c_3)\delta + (k_3 - x_c)\delta s + (\beta_1^2 + \beta_2^2)k_3 x_c - (b\beta_1 - b\beta_2)k_3 + (b\beta_1 - \beta_1^2 - \beta_2^2)\delta - (b\beta_2 +$
$\beta_1^2 + \beta_2^2)\gamma - (b - \beta_1^2 - \beta_2^2)k_3 s + (b - \beta_1^2 - \beta_2^2)k_3 x_c + (\beta_1^2 - \beta_2^2)\eta_c\delta + (b\beta_1 - 2\beta_1^2 -$
$2\beta_2^2)\rho\delta + (\beta_1 - \beta_2)(c_3\delta - c_3\eta_c\delta - c_3\gamma\delta) + (b - \beta_1^2 - \beta_2^2)\gamma x_c\delta + (b - \beta_1^2 - \beta_2^2)\rho\gamma\delta + (\beta_1 -$
$\beta_2)(s\delta - \eta_c s\delta + \eta_c x_c\delta) + (b\beta_1^2 - b\beta_2^2 - \beta_1^2 k_3 - \beta_2^2 k_3 + 2\beta_1\beta_2 k_3)/(k_3 + \delta + \beta_1\delta - \beta_2\delta -$
$\gamma(\beta_1 - 2\eta_c) + k_3(1 - \gamma + x_c) - \beta_1^2 k_3 - \beta_2^2 k_3 + 2\beta_1\beta_2 k_3 - 2\beta_1\beta_2 x_c)$.

$e_o^{5.I*} = \delta(c_3 - \eta_c^2 - 2b\eta_c^2\rho - b\eta_c^2\gamma + 2\beta_1\eta_c^2 s - \beta_2\eta_c^2 s - 2\beta_1\eta_c^2 x_c + \beta_2\eta_c^2 x_c + 4\beta_1^2 c_3\eta_c^2 - \eta_c^2\gamma s +$
$\eta_c^2\gamma x_c) + k_3(-b\beta_1 + x_c(-\eta_c^2 - b\beta_2 + k_3) + \beta_1 c_3 + k_3\gamma - \beta_2 c_3) + \rho(-b - k_3\gamma^2 + \eta_c^2 s -$
$\eta_c^2 x_c\gamma) + \gamma(-bk_3\eta_c + \beta_1 c_3 - \beta_2 c_3 + bk_3\gamma + \beta_1 k_3 x_c - \beta_2 k_3 x_c + \eta_c^2 s\gamma - \eta_c^2\gamma x_c) +$
$\eta_c(-4\beta_1 c_3 - \beta_2 c_3 - 2k_3\rho\gamma - \beta_1^2 k_3 - \beta_2^2 k_3 - \beta_1 c_3\gamma + \beta_2 c_3\gamma - 2\beta_1 k_3 x_c - \beta_2 k_3 x_c + 2k_3\gamma s -$
$2k_3\gamma x_c + 2b\beta_1\eta_c^2 - b\beta_2\eta_c^2 + 2b\beta_1^2 k_3 - b\beta_1 k_3\gamma^2 - bk_3\gamma^2 - \beta_1 k_3 x_c - \beta_2 k_3 s + 2\beta_1^2 c_3\eta_c^2\delta +$
$2\beta_1^2 k_3\eta_c^2 s + 2\beta_1^2 k_3\eta_c^2 x_c + 2b\beta_1 k_3\eta_c + b\beta_2 k_3\eta_c + b\beta_1 k_3\rho - b\beta_2 k_3\rho - 2b\beta_1\beta_2 k_3\eta_c +$
$\beta_1\beta_2 c_3\eta_c\delta - b\beta_2 k_3\rho\gamma - b\beta_2 k_3\gamma - b\beta_1 k_3\rho\gamma + b\beta_2 k_3\rho\gamma - \beta_1\beta_2 k_3\eta_c s + 2\beta_1\beta_2 k_3\eta_c x_c +$
$\beta_2 c_3\eta_c\gamma\delta - 4bk_3\rho\gamma + \beta_2 k_3\gamma x_c)$.

(b) The profit functions of scenario 5.II - 5.VI.

Scenario 5.II

$$\pi_m^{5.II}(w_3, e_m) = (w_3 - c_3 - ke_m)(D_s(p_s, e_s) + D_o(p_o, e_o)) + \lambda CS.$$
$$\pi_s^{5.II}(p_s, e_s) = (p_s - w_3)D_s(p_s, e_s) - \eta_c {e_s}^2/2.$$
$$\pi_o^{5.II}(p_o, e_o) = (p_o - w_3)D_o(p_o, e_o) - \eta_c {e_o}^2/2.$$

Scenario 5.III

$$\pi_m^{5.III}(w_3, e_m) = (w_3 - c_3 - ke_m)(D_s(p_s, e_s) + D_o(p_o, e_o).$$
$$\pi_s^{5.III}(p_s, e_s) = (p_s - w_3)D_s(p_s, e_s) - \eta_c {e_s}^2/2 + \lambda_1 CS.$$
$$\pi_o^{5.III}(p_o, e_o) = (p_o - w_3)D_o(p_o, e_o) - \eta_c {e_o}^2/2 + \lambda_2 CS.$$

Scenario 5.IV

$$\pi_m^{5.IV}(w_3, e_m) = (w_3 - c_3 - ke_m)\left(D_s^t(p_s, e_s) + D_o^t(p_o, e_o)\right).$$
$$\pi_o^{5.IV}(p_o, e_o) = (p_o - w_3)D_o^t(p_o, e_o) - \eta_c {e_o}^2/2.$$
$$\pi_s^{5.IV}(p_s, e_s) = (p_s - w_3)D_s^t(p_s, e_s) - \eta_c {e_s}^2/2.$$

Scenario 5.V

$$\pi_m^{5.V}(w_3, e_m) = (w_3 - c_3 - ke_m)\left(D_s^t(p_s, e_s) + D_o^t(p_o, e_o)\right) + \lambda CS.$$
$$\pi_s^{5.V}(p_s, e_s) = (p_s - w_3)D_s^t(p_s, e_s) - \eta_c {e_s}^2/2.$$
$$\pi_o^{5.V}(p_o, e_o) = (p_o - w_3)D_o^t(p_o, e_o) - \eta_c {e_o}^2/2.$$

Scenario 5.VI

$$\pi_m^{5.VI}(w_3, e_m) = (w_3 - c_3 - ke_m)\big(D_s^t(p_s, e_s) + D_o^t(p_o, e_o)\big).$$

$$\pi_s^{5.VI}(p_s, e_s) = (p_s - w_3)D_s^t(p_s, e_s) - \eta_c {e_s}^2/2 + \lambda_1 CS.$$

$$\pi_o^{5.VI}(p_o, e_o) = (p_o - w_3)D_o^t(p_o, e_o) - \eta_c {e_o}^2/2 + \lambda_2 CS.$$

Appendix D

This Appendix D documents my achievements:

1. Zhang, L., & Kurata, H. (2023). Designing Omnichannel Retail Operations with Heterogenous Customer Preferences of Channel and Purchase Style. *International Journal of Japan Society for Management Systems.* 15(1), 53-60. (Peer-reviewed)
2. Zhang, L., & Kurata, H. (2023). Social-Welfare Aspects of Green Decision-Making in Channel Competition with Government Financial Intervention. *International Journal of Japan Association for Management Systems*, 15(1), 23-31. (Peer-reviewed)
3. Zhang, L., & Kurata, H. (2023). Applying Mean-Variance Method to an Analytical Model of Green Dual-Channel Supply Chain with Risk Aversion. *In Proceedings of the 5th International Conference on Production Management (ICPM 2023),* Session No.C-13, September 10, Tokyo, Japan. (Peer-reviewed)
4. Value of Product Tracking Information: A Modelling Approach Style. LU ZHANG, Hisashi KURATA, *Japan Industry Management Association.* Under review.