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Abstract

The omnichannel strategy that integrates online channels and traditional brick-and-mortar stores has been broadly utilised in retailing practices to deliver a seamless shopping experience. Early empirical studies have demonstrated its benefits: for physical stores, it brings footfall and increases the opportunity of cross-sells; for online channels, it allows customers to inspect the merchandise before purchase, thereby reducing the return rate. However, the relevant operating costs and the investment of channel integration can be substantial, yet the discussion on the pricing of omnichannel services is scarce. This thesis aims to provide insights to address the dilemmas omnichannel retailers face in the pre-purchase and post-purchase stages and identify the optimal pricing of omnichannel shipment.

In the ex-ante stage, omnichannel retailers face a dilemma: charging omnichannel service at a low price could attract online traffic, yet financial loss may occur when stores are less profitable and integration costs outweigh cross-sales in-store. Hence, a stylised model is developed to study the shipping policy, especially the shipping fee for omnichannel service, and their impacts on customer demand and overall profitability. Three scenarios are considered: (1) shipment fee is consistent across channels; (2) omnichannel service is charged at a discounted rate or (3) free of charge. The results show that omnichannel positively convert online traffic into footfall in-store but does not always grow total demands or boost overall profitability; charging a discounted rate could help retailers shift demands to a more profitable channel. This study identifies the optimal shipping policy that depends on the retailer's operational efficiency and distribution costs. When the distribution cost is low, the retailer can offer free omnichannel shipment or charge a discounted rate if the cost is medium. Finally, the home delivery fee should be adjusted jointly with the omnichannel shipping fee.

In the ex-post stage, customers need to decide whether and where they return the purchased product. Retailers face a trade-off: allowing cross-channel returns could reduce the shipment cost and potentially increase cross-sales in-store; however, handling returned products in-store means extra labour costs, such as inspecting, re-packing, re-storing. Moreover, stores potentially face financial loss if the returned product is re-sold in-store at a discounted price. Therefore, the features of omnichannel operations are incorporated in the post-purchase stage. A stylised model is built to characterise omnichannel operations and study how return policies impact customer channel choices and the retailer's profitability. This study differentiates online channels with stores based on customer return behaviours. When customers purchase online, they need to bear the risk of receiving a product that does not match their expectations. Distinctively, store customers can inspect the product before purchase. Customers are assumed not to return a product if they purchase in-store. Hence, this model focuses on four return policies depending on return fees and whether cross-channel is available. The unit selling price is consistent across channels, and the retailer offers a full refund. In this model setting, purchase decision and return channel decisions are endogenous. The results suggest that cross-channel returns are not recommended if online returns are free, whereas retailers with a larger customer base and efficient in-store operations or wide store networks could benefit from omnichannel returns. Last, the optimal omnichannel return policy should be jointly considered with the existing online return policy.

Overall, this thesis extends utility theory in understanding the customer's cross-channel behaviours and use decision theory to analyse the omnichannel retailer's service pricing in pre-and post-purchase stages. This analysis helps retailing practitioners to understand the scenario when the retailer should allow omnichannel implementations, such as buy online and collect or return in-store, and the condition of optimal shipment pricing.

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Preface

Retailing plays a crucial role in everyday life, domestically and in commercial trading, and spans diversely across merchandises, services, sectors and business scales. In the last decade, the boost of e-commerce, enabling technologies and changes in consumer behaviour have re-shaped the retailing landscape globally: the retailing model is developing drastically from single channel to multiple channels, and now to an omnichannel model, wherein consumers seamlessly shop and return through various online and offline channels. In the single-channel stage, brick-and-mortar stores and pure-online retailers focused on penetrating their target market and audiences with a limited intersection. With the development and widespread enabling technologies (e.g. smart devices, social media, warehouse automation, Internet of things), the market share of online retailing has boosted (e.g. Amazon, ASOS). Online retailers converted customers who used to shop in conventional physical stores to online purchasing, which has put substantial pressure on store retailers, and thereby they embraced the multichannel retailing model. In the multichannel phase, retailers operate their channels in a silo managerial approach. This duplicates processes and generates channel-specific focuses, leading to inefficient operations and unsatisfied consumers. On the other hand, pure-online retailers used to have advantages in operating costs as they do not have physical presences, but now have to compete with e-commerce, and multichannel retails to attract online traffic and face the operational challenges of increasing costs of delivery and handling customer returns. The benefit of having a physical presence is back in the spotlight, and both online and traditional retailers started to transform into the omnichannel model, wherein the identities of channels will be blurred.

However, implementing the omnichannel model should be re-thought, re-examined, and re-developed according to the retailer's operations and capabilities. In other words, retailers need to re-think the functionalities of physical stores, which has been evolving from single to multiple functions. For example, online retailers can open showrooms demonstrating merchandise samples and allow customers to inspect and experience products before purchase, or partner with third-party businesses with a physical presence. Likewise, brick-and-mortar stores can develop their online platforms or work with manufacturers and third-party online retailing platforms that enable them to expand their portfolio without the restriction of time and locations. Moreover, stores can leverage their offline touchpoints and re-structure traditional stores into multi-functional centres with showrooms for customer experience enhancement and fulfilment centres to ease last-mile delivery pressures. Hence, in retailing practices, firms face various decisions to balance the operational efficiency and satisfactory level of seamless customer services. A successful omnichannel function for one retailer may be an operational nightmare for another. What omnichannel functionalities should retailers incorporate in their existing operations? How do brick-and-mortar retailers re-design their store layouts and prioritise when adding the new omnichannel functionalities? How many physical stores are online retailers going to open, and where? How can online retailers maintain its advantages in costs and prices after adding new physical stores? How do retailers manage customer demand cannibalised by their own channels? How do retailers amplify the cross-selling effect? How do retailers decide their revenue-sharing scheme for cross-channel orders? In the omnichannel implementation arena, there are so many unsolved challenges.

The motivation of this research is to provide managerial insights to retailers that consider omnichannel implementation in two stages: pre-and post-purchase. From personal experience, after working for years within the retail-related industries (e.g. fast-moving customer goods brands and packaging manufacturers), I am particularly passionate about studying the operational challenges in retailing practices. Therefore, my research aims to extend the theoretical framework to understand omnichannel operational trade-offs in practices and provide managerial insights to retailing practitioners in helping their omnichannel decisions. The purpose of this thesis is to introduce the pricing decision of shipping services under the omnichannel context, which has been neglected in the academic literature, but impacts customer choices and retailer's operating costs. The thesis starts with briefly presenting the operational dilemmas when applying omnichannel functionalities and reviewing the relevant academic literature, and then it discusses the methodology chosen in the study. Two stylised models have been developed to study relevant research questions, and the analytical results will provide managerial insights. In Chapter 4 and 5, the shipping and return policies were reviewed in the model backgrounds and discussed in our model, excluding the impact of national lockdown in the United Kingdom due to COVID-19. We observed that many retailers, including single-channel and omnichannel businesses, embraced home deliveries and the Click & Collect service in response to the UK government decisions of local or national lockdowns during the global pandemic.

This thesis reflects my research journey in the past four years, starting with curiosity, through to a steep learning curve of developing and honing my research skills, and finally, the jubilation of seeking knowledge and completing each milestone.

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students. It was such a special and satisfactory experience in inspiring and working with young and talented minds. Thank you to Dr Jane Brown, who has taught me and demonstrated high-standard teaching skills. The teaching experience extends my understanding of the research audiences, my research communication has been influenced accordingly. I particularly thankful to Dr Kay Rogage for advising on writing a funding proposal for a cross-discipline project. These experiences allow me to reflect on my own research and thesis, especially on the research impact.

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Declaration

I declare that the work contained in this thesis has not been submitted for any other award and that it is all my own work. I also confirm that this work fully acknowledges opinions, ideas and contributions from the work of others.

Any ethical clearance for the research presented in this thesis has been approved. Approval has been sought and granted by the *[Faculty Ethics Committee]* on *[3rd February 2018]*.

I declare that the Word Count of this thesis is 76,162.

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Chapter 1

Introduction

1.1 Background

A channel refers to a customer contact or touchpoint where firms and customers interact (Neslin et al., 2006). Selling channels are those points where transactions are completed (Beck and Rygl, 2015). Traditionally, brick and mortar with a physical presence are known as offline channels. Retailers, such as Aldi and Lidi, are leading brick-and-mortar supermarkets in the UK. Physical stores allow customers to touch and feel products before purchases and provide them with "instant gratification" that instantly buy and receive a product (Brynjolfsson et al., 2013). However, stores usually attract customers locally due to the geographic and opening-hour restrictions and limited product assortment scale due to the restricted shelve and in-store inventory spaces. With the advent of internet technology and ongoing digitalisation, selling products through internet platforms without geographic and time restrictions (also known as the online channel), such as e-commerce, has boosted the overall retailing market. The online channel is complementary to conventional stores in three ways. First, it breaks the barriers in store opening time so that customers can shop online at any time. Second, it attracts customers, regardless of geographic location. Third, it allows businesses to offer a broader range of products without being restricted by traditional shelf spaces, thanks to the centralised supply chain (Brynjolfsson et al., 2013). As the usage of smart devices in the younger generation is growing, the online channel moves further into the mobile platform, where retailers and brands develop their own applications on smart devices and design a customised shopping experience (Mintel, 2020*a*). When online and offline channels are operated separately, the nature of their independence will provoke channel competitions (Brynjolfsson et al., 2009). As a result, it caused fragmented supply chains, such as data mismatch, product and order information inconsistency, and inefficient inventory management. The silo effects became the obstacle to deliver a reliable consumer experience (Saghiri et al., 2017). There is a real need for the combination and coordination between offline and online channels.

1.2 Omnichannel

Hence, businesses are embracing an omnichannel model that involves in selling products or services through all widespread channels. Customers can trigger full channel interaction, or the retailer controls full channel integration (Levy and Weitz, 2013; Beck and Rygl, 2015). Channel integration is the degree to which a firm coordinates its channels' objectives, design, and deployment in creating synergies for the firm and offering benefits to its consumers (Cao and Li, 2018). *Omnichannel* is a fully integrated approach that allows customers to purchase and return products across channels and allows retailers to fulfil orders flexibly from any available channel, thus empowering customers with flexibility and a consistent shopping experience (Bayram and Cesaret, 2020). For example, consumers can easily switch from one channel to another in their buying experience. They may find a product in one channel (e.g. a physical store), place the order via another channel (e.g. a website or a mobile app), and have the product delivered from a third-party (e.g. home delivery), or pick up in a chosen store. Omnichannel vanishes the boundary between online and offline through integrating traditional brick-and-mortar stores with digital platforms to deliver a seamless and consistent customer experience (Brynjolfsson et al., 2013).

1.2.1 Implementation

Omnichannel requires cross-channel coordination and integration in processes and technologies, as well as synergises customer touchpoints to optimise the shopping experience and retailer performance (Verhoef et al., 2015). It endeavours to integrate channels in the customer journey that starts well before the Point of Sale (POS) and continues long after (Wilding, 2003). Omnichannel can be applied in each stage of the journey: pre-purchase, payment, delivery, and return (Chaffey et al., 2009; Frambach et al., 2007; Lamb et al., 2015).

As soon as a customer needs a product, s/he starts collecting product information through available information channels, such as stores, websites, social media, catalogue, TV, and referrals. Channels can be integrated within the pre-purchase stage in the way that customers can collect product information through various channels while inspecting the product in another. For example, John Lewis provides internet access points and WiFi, which help customers to inspect the product in-store and order it online through an in-store tablet if it is not available in the store. Omnichannel potentially transforms traditional stores into showrooms for display purposes and help reduce the return rate of online orders.

In the payment stage, channel integration allows customers to pay flexibly through various methods (e.g. online transactions on websites or mobile apps, POS payment in-store, or pay through post or via phone), as well as accept cross-channel payment. For example, Sainsbury's has introduced cross-channel coupons that customers can redeem in-store or online (Sainsbury's, 2017). When products are not available in-store, staff in Zara can help customers check stock online and order it through a tablet (ZARA, 2020).

Followed by the delivery, channel integration caters for customers choosing a delivery method (e.g. home delivery, collect in-store, pick up from a third-party) that mostly meets their needs regardless of where they purchase. Thus, customers can order online and collect in s selected location, i.e. Click & Collect (C&C). The implementation of C&C can vary depending on the retailer's networks: 1) customers can pay online and pick the order up in a store, known as Buy Online and Pick-up In-store (BOPS); 2) customers can also book it online, pay and pick up in a store, known as Reserve Online Pay in Store (ROPS); 3) customers can also order online and pick up near a store, such as drive-through, or pick up from third-party locations, such as local post offices or convenience stores.

After the purchase, if the order does not meet the customer's expectation, the journey will extend further to the return stage. The return options (post, pick up at home, drop off at a selected third-party point, or return in-store) may satisfy customers distinctively, depending on their availability, convenience, cost or speed. Like the delivery stage, channel integration allows customers to choose a return option no matter where the purchase or delivery happens. Customers can Buy Online and Return In-store (BORS) or return to a third-party location, or buy in-store and return via post. For example, H&M accepts online orders to be returned in-store or dropped off at third-party points (e.g. convenient stores, parcel shops or post offices), or via home collection operated by third-party couriers (H&M, 2020). Besides, cross-channel refunds are allowed, e.g. if the item is purchase in-store and paid through a physical gift card, H&M will issue an e-gift card via Email as a refund.

1.2.2 Fulfilment

When asked about omnichannel priorities, the retailers surveyed by Forrester Research reported that fulfilment initiatives ranked higher than any other channel integration program (Gao and Su, 2017). Conventional online fulfilment, including online order picking, packing, and shipping to individual customers, is commonly cited as one of the most expensive and critical operations of e-commerce (De Koster, 2002*b*; Lummus and Vokurka, 2002; Acimovic and Graves, 2015). Among these fulfilment elements, outbound shipment (also known as last-mile delivery) can incur considerable costs by itself (Acimovic and Graves, 2015). On the other hand, Omnichannel fulfilment converts brick-and-mortar stores or third-party locations into last-mile fulfilment centres to minimise the shipping cost (Chen, Liu and Wan, 2016; MacCarthy et al., 2019).

For retailers, omnichannel fulfilment relieves them from the responsibility of managing last-mile deliveries and returns. Depending on the networks and operations, retailers can fulfil omnichannel orders in two ways. One delivers omnichannel orders from Distribution Centre (DC) to stores or third-party locations, known as Ship to Store (STS). The other uses the stock in a nearby store for fulfilment, known as Ship from Store (SFS) (Kämäräinen and Punakivi, 2002). Reversely, stores could also become the drop-off centres for returning online orders. Under the STS model, once orders are returned in-store or at a third-party location, they will be shipped back to DC inventory, while under the SFS model, they will be added to store inventory and re-sell from or in-store. Therefore, STS and SFS are the terms describing how retailer fulfils omnichannel orders internally. Externally, omnichannel fulfilment are perceived as shipment services, such as BOPS, ROPS and BORS. When customers collect or return orders in-store, it triggers opportunities for cross-selling and cross-promoting products, which increases store footfall and revenue (Cao and Li, 2015; MacCarthy et al., 2019). Omnichannel services are offered by many retailers (Forrester, 2014) and are likely to become more prevalent as the landscape for omnichannel retailing is highly competitive (Ishfaq and Raja, 2018; MacCarthy et al., 2019). It is estimated that, on average, when a customer comes to the store intending to buy \$100 worth of merchandise, they leave with \$120 to $125 worth of merchandise (Halzack, 2015). Many retailers regard BOPS as a way to reach new customers, as this new fulfilment option has become increasingly popular among shoppers (Rovner, 2011).

For customers, omnichannel fulfilment offers several benefits: i) it empowers customers with more flexibility than home deliveries as they do not have to wait for standard delivery or worry about missing parcels (MacCarthy et al., 2019); ii) it reduces the uncertainty of online purchases by allowing customers to evaluate received products in-store and return or replace them straight away if unmatched (Gao and Su, 2017); iii) it offers stock certainty for collection and eliminates the risk of Out of Stock (OOS) in comparison to conventional store shopping; iv) it may also be more economical as most of the C&C services are free of charge (Witcher, 2020; MacCarthy et al., 2019); v) it allows customers to access to a broader range of portfolio compared to conventional store channel that is restricted by the shelf spaces. In KPMG's report (KPMG, 2018), Over 22% of surveyed UK respondents who shop online opted for BOPS, ROPS, or Locker delivery. In Nielsen's global survey, over 55% of respondents are willing to use BOPS for online shopping (Nielsen, 2017).

To avoid confusion, the terms used in this study will be further distinguished. From retailers' internal operational view, STS and SFS refer to operating approaches to fulfil omnichannel orders. From retailers' external view, C&C, BOPS, ROPS, and BORS are omnichannel services offered to customers. C&C is the term widely used in the UK retailing marketing communication and does not limit to picking up in-store, like BOPS and ROPS. It emphasises the forward logistics, shipping from retailers to customers, while BORS highlights the reverse logistics, returning from customers to retailers. Most relevant studies are not trying to research their differences. Thus, this thesis will not focus on differentiating these terms (e.g. BOPS, and ROPS, C&C). Instead, they will be used as alternative terms to avoid a frequent repeat and represent orders generated online but fulfilled offline.

1.2.3 Trade-offs

Omnichannel fulfilment provides various benefits such as last-mile cost reduction, flexibility in fulfilment options, trust enhancement, and differentiation through value-added service (Kumar and Venkatesan, 2005; Stringer, 2004; Tate et al., 2005). Still, it provokes several dilemmas. On the one hand, demands are influenced by how C&C is implemented. On the other hand, additional operational costs and investments are involved in fulfilling omnichannel orders as a free alternative delivery option. It is unknown whether the benefit of shifting demand will cover the uncertainty of growing costs.

1.2.3.1 Demand Cannibalisation

Despite these advantages, it is arguable whether C&C implementation brings new customers. Some argue that omnichannel implementations convert existing online shoppers to stores other than generating new customers (Gao and Su, 2017). Gallino et al. (2014) empirically found that the implementation of BOPS is associated with a reduction in online sales and an increase in-store sales and traffic. Customer cannibalisation can vary along with the C&C fulfilment methods and shopper characteristics (Gielens et al., 2020). For instance, new customers could be reached if C&C fulfilment offers convenience, such as flexible pick-up time windows and wide coverage of pick-up locations. Also, C&C provides information that avoids the disappointment of OOS (Gielens et al., 2020), resulting in converting store customers. Besides, store customers who value collection convenience will be shifted to use C&C services, such as rural shoppers who purchase large basket sizes, as the store staff completes the effort of searching, picking, and packing. Likewise, C&C can attract online shoppers who demand instant gratification without risks of OOS or have a low bearing of return risks. Customers can return or adjust their online orders upon collection or returns. For example, customers can try and replace or return fashion products in-store. As a result, C&C would potentially cannibalise online customers.

Customer demand could be affected by the convenience of C&C (Avery et al., 2012) and how C&C is implemented. For example, when the collection point in-store is close to the entrance, customers may use stores as the destination of collection, that is, walking in and collecting online orders straightaway without shopping in-store. Conversely, if the collection point is located where customers have to pass through shelves on multiple floors, C&C may become less attractive for customers who want collection convenience. Furthermore, allowing customers to pick up at free-standing locations or near-store locations could expand the fulfilment coverage and potentially reach new customers. However, this implementation may lead to more systematic/planned buying and less cross-selling. As a result, C&C may shift customers from stores to third-party locations, boost planned buying behaviour, and attenuate consumer order sizes (Gielens et al., 2020). Potentially, BOPS might even increase online spending thanks to less shopping time and effort. As Bronnenberg (2018) indicates, travel time is a fixed cost, and consumers will only travel to a store when their basket size is large enough to amortise this cost. Thus, as the time cost drops, households would increase their shopping frequency (Gielens et al., 2020).

It is unclear how C&C is implemented would cannibalise sales from the existing store and online customers (Cao et al., 2016). Thus, it is vital to distinguish between demand cannibalisation and demand creations (Gao and Su, 2017). Liu et al. (2018) conclude that finding the right balance between channel cannibalisation and cross-channel convenience is a major unresolved issue.

1.2.3.2 Additional Fulfilment Costs

Cross-channel fulfilment brings operational complexities and additional costs. Nevertheless, most retailers offer C&C services free of charge with the belief that it will potentially reach new customers and grow in-store footfall and boost cross-sales.

Compared to traditional stores, fulfilling C&C generates additional cost of in-store operations, varying based on the fulfilment networks and processes. Under the STS shipping model, retailers will generate additional shipping costs to fulfil omnichannel orders from DC to a store compared to serve walk-in customers. Under the SFS model, retailers will need to invest in inventory transparency, as inaccurate store inventories will hinder cross-channel fulfilment and increase OOS possibilities for walk-in customers (Forrester, 2014; MacCarthy et al., 2019). When retailers have small store networks, to make omnichannel more flexible and reach more customers, online orders can be collected at free-standing locations, such as drive-through (Cao et al., 2016), self-service lockers or third-party locations. Therefore, additional set-up, commissions and labour costs are involved, but impulsive customer purchase will reduce (Gielens et al., 2020). Also, additional footfalls are not converted to stores. Thus, cross-selling opportunities are missing in this implementation. Additionally, extra costs are still provoked in fulfilling omnichannel orders even if a product is available both online and in-store.

Compared to pure online orders, although the shipment cost is reduced, using in-store items to fulfil online orders generally involves intense labour due to lower in-store efficiency in sorting, storing, picking, packing and shipping. Omnichannel orders generate manual operations to pick and pack in-store (Cao et al., 2016). Insufficient store staffing levels can lead to unsatisfied online customers (Mahar and Wright, 2017; MacCarthy et al., 2019) while overstaffing will burden the retailer with higher operational costs. Also, the loss of sales could happen when omnichannel orders are cancelled or when items are reserved for online customers but not available for walk-in customers. The fulfilment flexibility potentially results in more order cancellations, lost sales opportunities or returns (Karp, 2017).

Therefore, there is an uncertainty of additional costs involving in omnichannel fulfilment. It is challenging to strategically leverage stores for omnichannel fulfilment while balancing the need for walk-in and online customers.

1.2.3.3 Shipment Trade-off

Customer demands are cannibalistic or synergistic, depending on how C&C orders are fulfilled (Gielens et al., 2020). Likewise, the handling cost per order varies across channels in response to the retailer's fulfilment processes. Shipment is a pivotal stage and customer touchpoint in the fulfilment process, and accounts for a large portion of fulfilment costs.

For example, a walk-in customer buys a small pack of chocolate bar in-store and takes it home immediately. The retailer will receive a profit, that is, a unit selling price minors a handling cost that includes distribution from DC to stores, labour, and in-store storage. The average handling cost is relatively low because store inventory is managed and re-filled at an optimal scale. The stock of chocolate bars will be re-filled with other items that have low stock, and the shipment will be planned and arranged with optimal efficiency. Hence, shipment cost per item is low from DC to the store. Therefore, there is no shipping fee required as the customer completes last-mile delivery.

Differently, an online order needs to be picked and packed based on an individual scale in DC with efficient processes and economic inventory holding and shipped to the individual customer. Usually, the handling cost in DC per item is lower than that in-store due to the different process efficiency and scale. Even retailers can avoid store handling costs and effort, they have to complete the last-mile delivery, and it is not profitable for them to send just one small chocolate bar to customers via post. Therefore, retailers will charge customers a delivery fee to compensate for the fulfilment cost if the order is not profitable. However, this becomes one obstacle to online shopping, as customers are reluctant to pay delivery fees (Choi et al., 2010; Gielens et al., 2020), but expect to receive products with brief or no waiting (e.g. next-day or same-day delivery). In response, retailers can subsidise the fulfilment cost by offering free standard delivery if each order size meets a profitable threshold.

As C&C orders are generated online but fulfilled in a selected location, the additional fulfilment costs compared to online orders will depend on retailers' fulfilment networks and processes. Under the STS model, the chocolate bar is picked and packed in the DC like regular online orders, yet shipped to a store other than home delivery. Although the transport cost might be saved for the last-mile delivery, the extra in-store handling cost will incur, such as offloading and storing in the limited space. When under the SFS model, the chocolate will be picked and packed in-store with lower efficiency (Hübner, Holzapfel and Kuhn, 2016), and there will be higher labour costs involved than STS. Additionally, retailers need an adequate IT system for exchanging real-time Stock Keeping Unit (SKU) inventory data. With these additional costs, retailers also choose to charge customers with a delivery fee or set a minimum order size that is profitable. Unlike home delivery, C&C services offer an alternative delivery option for people with needs of convenience and flexibility, and customers expect C&C services to be free of charge because they complete the last-mile shipment. Therefore, most retailers do not charge for C&C services (Hübner, Holzapfel and Kuhn, 2016).

For products with a low retail price, shipping costs are not uncommon to be higher than the purchase price (Cao et al., 2016). For retailers, the additional fulfilment costs vary due to uncertainties in customer locations and the channel choices they make. Some retailers believe that the additional costs will be justified as they expect customers to increase their purchase frequency and cross-selling opportunities if they visit stores (Hübner, Holzapfel and Kuhn, 2016). Arguably, the delivery fee for online orders could impact their channel choices, such as shift online customers to stores, yet not necessarily increase the overall customer base. The trade-off is between demand uncertainty and additional variable costs depending on the fulfilment methods. Some retailers use shipping policies to purposely shift customer demands across channels to optimise overall profits (MacCarthy et al., 2019) and balance the additional costs and potential growing revenues depending. Another driver for retailers to charge shipping fees is to generate significant additional revenue (Hübner, Holzapfel and Kuhn, 2016), as long as customers are willing to pay. Shipment fees depend on operational costs, competitive environment, and market-specific culture regarding direct deliveries (Hübner, Holzapfel and Kuhn, 2016).

Thus, retailers need to have an efficient delivery policy to minimise the uncertainties on profits, and carefully consider various factors and market characteristics in selecting the appropriate products to offer free delivery. Otherwise, the implementation of omnichannel might not necessarily increase the overall profitability of the retailer (Cao et al., 2016).

1.2.3.4 Return Trade-off

A similar trade-off will also incur in the after-sales stage. The drawback of home delivery is that customers face the uncertainty of product inspection and the likelihood of dissatisfaction. Pure online retailers are challenging to deliver after-sales services with immediate gratification, such as returns and exchanges. For online retailers, offering after-sales services could incur substantial additional costs. For instance, the transportation cost from customer's home to DC, the labour of unpacking, checking and re-filling into the inventory system, the effort of re-selling, and potential loss of sales opportunities if returned items cannot be sold at full-prices (Gielens et al., 2020). According to China IRN (China Industry Research Net) report, the average return rate of online channels is approximately 30%, and this rate even reaches 40% in garment products (Du et al., 2019). In 2018, the loss from product returns in the American retail industry reached $369 billion (Federation, 2018; Huang and Jin, 2020). The total value of returned products has been calculated at £5.75 bn within the UK retail sector (Bernon and Cullen, 2007; Bernon et al., 2016). Half of the returned goods are often sold through third-party retailers, such as liquidators and discounters, with a discounted rate of as low as 10% - 20% of the original value (Stock et al., 2006; Huang and Jin, 2020). The high return rate has become a considerable concern that online retailers cannot ignore (Huang and Jin, 2020). Therefore, some e-commences increase customers' hassle of returning a product to drive down the return rate and reduce the return costs. For example, charging a delivery fee to compensate the transportation cost (Bernon et al., 2016); setting up time limits for returns or exchanges, such as the duration of the return period varied significantly from 14 days to 90 days (Bernon et al., 2016). The return hassle could provoke customers' showrooming behaviours to inspect the products in-store before purchasing online. However, product returns can be costly for consumers, deterring those who seek conveniences or purchase impulsively. For example, consumers may incur a travel cost for revisiting the store or pay shipping fees for shipping the product back to the retailer (Huang and Jin, 2020). Consumers must also wait for the reimbursement or exchanged products (Huang and Jin, 2020). Thus, online retailers need to balance the level of return hassles and customers purchase intentions and satisfaction.

Conversely, customers do not suffer from these drawbacks if they choose C&C, while they have to face the physical effort to collect an order in-store. Shoppers enjoy the convenience of adjusting their online orders by adding, returning, or replacing items upon pick-up (Gielens et al., 2020). According to a survey (Huang and Jin, 2020), 11% of online sales in the US were returned to stores in 2017. 38% of retailers found that BORS is increasing in 2018 (Federation, 2018). BORS may improve retailers' operational efficiency in managing product returns (Huang and Jin, 2020). Moreover, BORS can bring more store footprints and increase the chance of cross-sale, which could potentially exceed the cost of returns (Leberman, 2015). When customers return product in-store, staff can access customer feedback face-to-face, and potentially solve the problem straight away by offering substitute items, or even up-selling. Customers could leave the store with satisfaction. Furthermore, the introduction of physical showrooms shows positive influence in reducing return rate for online purchases and increasing overall demands (Bell et al., 2018), as customers could spend extra time, cost and hassle to ship the product back to the online retailer (Du et al., 2019). BORS may offer customers an economical and efficient return option. For example, consumers do not have to pay shipping fees for the returned products and may receive their refunds quicker than online returns (KPMG, 2016; Huang and Jin, 2020).

However, BORS also brings challenges. First, it requires high transparency of inventory across channels. The cost of excessing and integrating stock across channels in the supply chain is substantial (Banker, 2016). Second, under the SFS model, online orders are returned, unpacked, checked and re-sold in-store. Although it is an efficient way to handle returns and reduce the lost sales opportunities, the additional costs still incur. For example, uncertain in-store labour (e.g. unpacking, checking, fixing, re-packing, sorting, and re-selling) is involved due to uncertain conditions of returned products. Also, the returned items may not be popular SKUs in the local store. Third, under the STS model, returned orders will be sorted and shipped back to DC, which will have dual-labour costs (e.g. unpacking, checking, sorting and transportation) in-store and in DC. Most importantly, it will take longer to get return items back to the inventory, which could impact products with a short seasonal period or quick turnaround. Four, when online orders are returned in-store, stores will process the return and refund. Nevertheless, in a decentralised system where online and stores are operated separately, stores do not have incentives for cross-channel returns. They are not explicitly compensated when returned items cannot be sold at full prices.

Overall, implementing cross-channel returns may present retailers with both positive and negative outcomes. On the one hand, BORS can offer consumers a more convenient and zero-shipping-fee method to return unwanted products (Huang and Jin, 2020). On the other hand, the increasing conveniences could transfer more consumers from physical stores to online shops, potentially increasing the retailer's average return rate and costs. Moreover, when retailers implement C&C using third-party locations, e.g. CollectPlus in the UK. Retailers face the challenge of integrating with third-party delivery or inventory systems and failing to deliver the adjustment convenience and take cross-selling opportunities, as shoppers can only return other than amending the order upon pick-up. In practice, mixed strategies are observed by different retailers. For instance, retailers such as Gap and Zara offer the BORS policy, whereas retailers such as Clarks Outlet, H&M (China) and Uniqlo (China) do not (Huang and Jin, 2020). Therefore, these observations raise the curiosity of what factors influence retailers' decision to charge for handling returns (e.g. delivery fee) or subsidise the return-relevant additional costs; whether to offer BORS and generous return period. Retailers face the trade-off to balance return policies and customer demands in the omnichannel context to maximise overall profits. Furthermore, strategic decisions, such as where to offer returned and reprocessed goods, are important.

1.3 Research Focuses

Sales and operation decisions are more tightly intertwined in the omnichannel model, as fulfilments (e.g. delivery) and after-sales services (e.g. returns) that are vital components of the product offering became increasingly complicated (Agatz et al., 2008). This thesis will focus on shipment trade-offs in two stages, i.e. order fulfilment and returns.

Most studies discuss the shipment problems from an online retailer's perspective, and the research in an omnichannel setting is scarce. The first model is to deal with shipment trade-offs between customer demands and retailer's profits: 1) under what condition that C&C cause demand cannibalisation or generate additional demands; 2) profit will grow if C&C attracts new customers or converted demands generate cross-sales. However, C&C may convert initial demands to a less profitable channel, leading to a profit loss. It is vital to decide an optimal shipping policy for C&C to drive demand shift to profit growth. A stylised model is developed to capture the features of omnichannel retailing and look into three shipping options of C&C: free of charge, shipping discount and fixed shipping fees across channels. This study explores the possibility of turning a shipping charge as an opportunity to moderate demands to a more profitable channel and finally grow the total profit. This study also considers the effect of the retailer's operational factors (e.g. in-store unit selling costs and the convenience level of C&C) and customer heterogeneities on demands and total profitability. Thus, the following questions are studied in this model:

- How do operational factors affect retailers' shipping policies for C&C in the omnichannel setting?
- How do shipping policies for C&C affect the total demand and customers across channels?
- What is the optimal shipping policy for C&C maximising total profits in an omnichannel setting, and under what conditions?

There are few studies of return policies within an omnichannel context, yet return policy is critical as it will impact customer decisions in both pre-purchase stage (Blackwell et al., 2006; Bernon et al., 2016) and after-sales stage (Wood, 2001; Bernon et al., 2016). Within an omnichannel environment, online customers can cross-return their unwanted items. The convenience may boost their confidence in online purchases while potentially increase return rates and costs. Therefore, the second model is built to study the following questions:

- How do operational factors affect retailers' return policies in the omnichannel setting?
- How do omnichannel return policies affect customers demand across channels?
- What is the optimal return policy regarding total profits in an omnichannel setting, and under what conditions?
- Under what conditions should omnichannel retailers offer a generous return period?

1.4 Research Contributions

This study primarily contributes to the following areas.

First, model one endogenies customer channel choices and incorporates the shipping element in the model building. It captures the features of omnichannel operations that are relevant to the decision of shipping policies. Moreover, this model distinguishes online channels with physical stores in three ways: 1) from an operational view, both channels operate at different handling costs; 2) from a cost view, ordering through each channel may incur different shipping fees; 3) from a customer view, the perceived hassle cost may vary across channels. This study allows customers to be heterogeneous in two dimensions: product valuations and the hassle cost of visiting each channel. Three shipping policies are discussed reflecting the retailing practices: 1) charging the same shipping fee for both home delivery and C&C; 2) charging a discounted rate for C&C; 3) offering C&C free of charge. The benchmark is considered as the case when C&C is not available. By comparing three scenarios with the benchmark, this study could understand and analyse how the omnichannel function (i.e. C&C) and its pricing impact customer demand and retailer profitability. Furthermore, the impact of relevant factors on the decision of shipping policies and total profits will be examined, such as convenience level of C&C, shipping discount rate and store operational costs.

Second, theoretically, this study extends the application of utility theory in customer channel choices and decision theories in a retailer's shipping policy under the omnichannel setting. Practically, this study provides insights to help retail practitioners understand the effect of adding an omnichannel function on the retailer's store operations, existing shipping policies, and cross-channel customer behaviours. Most importantly, this study aims to help retailers understand the omnichannel trade-off and implement their omnichannel strategies effectively by determining two elements of shipping policy: whether to offer C&C and how to charge for this service. Besides, factors such as the convenience level of C&C, shipping discount rate and in-store operational costs are discussed regarding their influences on the shipping decision and customer channel choices. The study results reveal that the shipping policy of C&C has a positive effect on shifting demands across channels but does not always attract new customers as it depends on customer heterogeneities. Offering free omnichannel functions is not ways beneficial. The optimal shipping policy is identified with conditions: 1) charging C&C with a home delivery fee is not recommended; 2) charging omnichannel service at a discounted rate could help retailers allocate demands to a more profitable channel. Moreover, this study finds that the addition of C&C could affect the decision of home delivery fees. Thereby, a joint shipping policy is recommended for both C&C and home deliveries.

Third, model two provides insights into how elements in return policies affect customer demands across channels and retailer profitability under the omnichannel setting by building a stylised model. Previous studies primarily focus on the refund policies, such as full- or partial-refund, or embed the return costs into the selling price from an online firm's view. Distinctively, this study explores the possibility of turning return policies into a tool driving customers into stores to increase cross-selling opportunities. Optimal return policies are identified combining multiple return factors depending on the features of omnichannel operations. The relevant return factors include online return charges, length of the return period, the convenience of returning items in-store, and the product type. This study helps retailing practitioners with the operational decisions regarding return policies, such as under what condition should a retailer offer omnichannel returns, and identify the optimal online return fee maximising the overall profitability. Although offering omnichannel returns will give customers flexibility and a possible chance of cross-sales, it is not always beneficial if in-store handling cost is high. The result shows that free online returns are not recommended to be bundled with cross-channel returns. Also, the return fee may have a positive effect on migrating customers to a retailer's preferred channel and potentially grow the total profit depending on the operational factors, including salvage values, convenience level, cross-selling opportunities, and in-store operating costs. This can explain why some retailers choose to charge for returns (e.g. NEXT) while some choose to offer free services (e.g. John Lewis & Partners). Moreover, the product type influences the optimal return policy, e.g. online return fee, return period and whether to offer omnichannel returns, and return rate. For the product with a higher probability of mismatch, omnichannel returns should be offered, and online returns should be charged. This result helps explain why retailers choose not to offer omnichannel returns (e.g. Sainsbury's), while some offer a very generous return period (e.g. B & Q).

Last, this study incorporates the features of omnichannel operations, and the relevant elements of the shipping and return policies in the model building. Online channel and brick-and-mortar stores are distinguished through different hassle costs, operating costs and shipping or return charges.

The retailer's objective function is to divert customers to purchase and return through a more profitable channel to maximise the overall profit. Customers are heterogeneous in their perception of product values. Considering customer heterogeneity and homogeneity, this thesis discusses three shipping and four returning policies under the omnichannel setting.

The rest of the thesis is organised as follows: Chapter 2 provides a literature review about omnichannel operations, shipping policies and return policies. In Chapter 3, methodologies that are relevant to this study will be discussed. Stylised models will be developed to study omnichannel shipment policy in Chapter 4 and return policies in Chapter 5. In Chapter 6, the model robustness will be discussed, and the managerial insights are highlighted. Finally, this thesis ends with a summary of conclusions and limitations in Chapter 7. All proofs and relevant numerical studies are in the Appendix.

Chapter 2

Literature Review

Originated from the Latin word “omni”, omnichannel indicates the integration across physical and online channels. Rigby (2011) introduced the concept in the academic world. Then, it has been defined by researchers from different standpoints. *Omnichannel* is a synergetic method that manages numerous channels to deliver a seamless customer experience and optimise performance (Verhoef et al., 2015). Saghiri et al. (2017) study omnichannel as a complex adaptive system. Levy and Weitz (2013); Beck and Rygl (2015); Verhoef et al. (2015) conceptually differentiate omnichannel from multi- and cross-channel retailing depending on the degree of channel integration. Saghiri et al. (2017) structuralise the omnichannel system from three dimensions: channel stage, type, and agent.

Omnichannel has been conceptually studied, and many researchers are dealing with firms’ operational complexities when implementing omnichannel strategies. A retailer’s decision on cross-channel shipment involves various factors: product property (e.g. size and perishability), customer locations, customer requirement (e.g. nominated date and time), inventory, and retailer’s supply chain networks (Fairchild, 2014). How retailers deliver products closely affect customer channel choices. It thus becomes more complicated for retailers to decide how to optimally fulfil cross-channel shipment regarding profitability due to its influence on cost and revenue (Ansari et al., 2008). This chapter divides relevant literature into four areas: consumer channel choices, fulfilment, shipment policies, and returns policies under the omnichannel setting.

2.1 Cross-channel Behaviours

A stream of literature discusses what factors influence customer channel choices. Drivers of cross-channel behaviours, such as motivations and attitudes (Mishra et al., 2020; Kang, 2019; Schröder and Zaharia, 2008), customer journey (Barwitz and Maas, 2018), and channel-switching intentions (Gupta et al., 2004), have been reviewed. Some academics quantified factors and analysed how they affect customer channel choices: value uncertainty when purchasing online (Balakrishnan et al., 2014; Du et al., 2019), homogeneity and heterogeneity among customers (Chintagunta et al., 2012; Balakrishnan et al., 2014; Gao and Su, 2017; Kim and Chun, 2018; Du et al., 2019; Jin et al., 2020), cross-channel return policy strategies (Nageswaran et al., 2020; Jin et al., 2020); strategic customer behaviours using utility theory (Su, 2009; Gao and Su, 2017; Yang and Zhang, 2020), product availability using newsvendor model (Su, 2009; Gao and Su, 2017; Kusuda, 2019; Yang and Zhang, 2020), omnichannel implementations, such as BOPS (Chatterjee, 2010; Gallino and Moreno, 2014; Cao et al., 2016; Gao and Su, 2017; Jin et al., 2018; Kusuda, 2019; Saha and Bhattacharya, 2020); pricing strategies (Cao et al., 2016). Although the shipping fee is one main reason customers abandoned their online orders (Schindler et al., 2005), the above studies either ignore or consider shipments as part of services. Only very few focus on delivery charges in customer channel choices. This study contributes to this area by focusing on shipment charges, especially separating them from services.

Omnichannel shoppers tend to use multiple channels simultaneously. There is a growing body of literature studying how customers respond to omnichannel implementations and migrate across channels. Some studies show that omnichannel could amplify the channel competition, particularly customers converted from online channels to stores. Niu et al. (2019) examine the effect of Online to Offline (O2O) channel on demand and traffic congestions using utility theory. They find that O2O could ease traffic congestion by reducing online demands under conditions. Cao et al. (2016) develop an analytical model to study the impact of an Online to Store (O2S) channel on demand allocations using utility theory. The result shows that channel integration could cause cannibalisation to existing channels. Even so, some researchers argue that Omnichannel functionalities bring new customers and potentially increase total sales. Gallino and Moreno (2014) use a series of quasi-experiments to investigate the effect of BOPS on channel migration and cross-selling opportunities. They found that additional store sales are from converted online traffic, cross-selling effect and new customers. Adopting a similar method, Bell et al. (2018) study the effect of showrooming on demands generation and operational efficiency. They find that showrooming positively affects overall demands and online conversions. Their studies are empirical using customer data from retailers, whereas some researchers developed tractable stylised models to simulate the demand change. Through a stylised model, Gao and Su (2017) study the effect of BOPS on customer channel choices and store performances based on the utility theory and newsvendor model. They find that BOPS affects demands in two ways by shifting online customers to stores and helping stores reach new customers. Based on similar theories, Yang and Zhang (2020) analyse how SFS impact demand migration and a seller's profits. They find that the implementation of SFS broadens the customer base and switch store customers online. Studies above reveal that omnichannel operations can cannibalise existing channels while convert non-customers. Some of them (Cao et al., 2016; Gao and Su, 2017; Niu et al., 2019; Yang and Zhang, 2020) are similar to this study because I consider strategic customer behaviours using utility theory, yet this thesis focuses on distinctive operational matters that trigger the channel migration. Few of them shed light on how shipment charges of cross-channel impact demand in the omnichannel setting. This study will fill this gap by analysing omnichannel shipment and return policies.

2.2 Omnichannel Operations

While omnichannel may potentially increase cross-selling opportunities and generate new customers, cross-channel operations complicate order fulfilments and increase costs. Relevant fulfilment strategies under the omnichannel setting have been studied: systematic reviews (Berman and Thelen, 2004; Boyer and Hult, 2005), supply chain configuration(Metters and Walton, 2007), the conceptual framework for last-mile fulfilment (Hübner, Kuhn, Wollenburg, Towers and Kotzab, 2016), distributions (Hübner, Holzapfel and Kuhn, 2016; Arslan et al., 2020), design of in-store service area (Jin et al., 2018), evaluation of fulfilment options (Ishfaq and Raja, 2018; Witcher, 2020), delivery options (Piotrowicz and Cuthbertson, 2019)and formats of C&C (e.g. collecting in-store, near store or free-standing locations) (Gielens et al., 2020).

Despite the benefits, omnichannel fulfilment is not always suitable. There is a growing body of literature using theoretical models to identify conditions for the optimal fulfilment strategy. Mahar et al. (2012) use assignment models to examine whether retailers should offer BOPS in all stores.

They find that it is better off providing BOPS in the chosen stores when using store inventory because this can balance the trade-off between the cost of overstock (e.g. holding) and loss of understock (e.g. backorder and lost sales). Cao et al. (2016) develop an analytical model based on utility theory to study the trade-off between new demands generated by an O2S channel and associated growing costs and demand cannibalisation. Their results imply that not all products are suitable for the O2S channel, depending on the related operating costs (e.g. shipping, sourcing, and handling). Similar results also show in the study from Gao and Su (2017), who build a stylised model based on utility and game theories to examine what products are suitable for BOPS. It may be not profitable to implement BOPS on popular products in-store. Also, O2S migration may reduce profit if the online channel is more cost-effective than stores. Shi et al. (2018) find that the BOPS strategy with pre-orders is not always beneficial and identifies the condition for profitable strategy regarding the unit production cost and demand uncertainty. By segmenting customers into informed and uninformed groups, they find the proportion of informed consumers affecting profitability. For example, the more customers are informed, the more profitable a BOPS strategy is. Through a Difference in Difference (DID) empirical study, (Akturk et al., 2018) distinct the operational differences between BOPS and STS depending on where an order is shipped and whether the stock information in-store is provided. They show that online sales dropped while brick-and-mortar sales increased after STS was introduced, and the growth in-store surpassed the loss online. This switch occurred mainly for high-value purchases, and customers who remained or chose STS service bought low-value items. Furthermore, although STS increased cross returns from online channels to physical stores, these returns generated additional store sales. Kusuda (2019) extended the model (Gao and Su, 2017) by considering store inventory replenishment. Zhang et al. (2019) studied this matter under monopoly and competition scenarios, and found that omnichannel is suitable for high-value products and a low degree of online acceptance. The above studies focus on store choices, product types, and pricing, and few discuss the service charge for BOPS. This study contributes to this stream by examining whether retailers should offer BOPS or BORS for free and identifying the conditions for the optimal shipping policies in the pre-and post-purchase stages.

Some researchers focus on how omnichannel fulfilment is operated and optimised. The trade-off between simultaneously fulfilling online orders and serving walk-in customers in-store has been studied by MacCarthy et al. (2019). They use the Next Scheduled Deadline (NSD) metric to investigate when and how (e.g. once or multiple times per cycle) BOPS orders should be picked in-store. When BOPS is fulfilled through stores under different ownerships and with a revenue-sharing scheme, Saha and Bhattacharya (2020) investigate the optimal inventory policy in-store for walk-in and BOPS demands. Paul et al. (2019) minimise BOPS fulfilment costs by studying a flexible vehicle routing problem that utilises any spare capacity from the daily store inventory replenishment. Yang and Zhang (2020) use the newsvendor model and hyperbolic discounting to examine whether retailers should ship online orders from stores. Their results show that it is worse off offering SFS if customer-base expansion is not significant. Karp (2017) use algorithms to maximise revenue and deal with the trade-off between flexible policy for order cancellations and associated profits loss in the omnichannel setting. Bayram and Cesaret (2020) use a heuristic method to investigate dynamic cross-channel fulfilment decisions: from where an online order should dispatch (e.g. online fulfilment centre or stores) to maximise the retailer's profit. They incorporate the uncertainty in both demand and shipping costs in the model. This research adds to this area by dealing with the trade-off between profit compensation and positive channel migration thanks to shipping fees and associated negative effects on demands.

2.3 Shipping Policy

Previous studies have discussed online retailers' shipping issues from customer and operational views, and little study shipment charges considering cross-channel behaviours. As explored by Boyer et al. (2003), they examined the operational process for home delivery: order placement, picking and delivery. Last-mile delivery is the biggest challenge in the online shipping process(Boyer et al., 2009), such as the trade-off between customer satisfaction with good service and the retailer's higher operational costs of improving the service quality, i.e. speed, constrained period, transparency, availability, reliability and flexibility (Boyer et al., 2003; Rabinovich and Bailey, 2004).

2.3.1 Customer Shopping Behaviours

As a component of shipment policies, shipping fees affect customer shopping behaviours and the retailer's marketing performances. Some discuss shipping fees as part of a pricing strategy or promotion strategy. Schindler et al. (2005) used prospect theory to examine which marketing promotion is more effective: shipping charges are bundled into a selling price or separated from a base product price? Their research focuses on pricing and the effectiveness of promotions without consideration of omnichannel and retailers' operations. Yao and Zhang (2012) develop an analytical model to maximise profit and empirically analyses product base price and shipping prices of digital cameras and video games. They find that free shipping may increase the base prices, shipping prices are affected by the shipping mode (e.g. standard or expedited), shipping time and on-time probability. Kulkarni (2020) empirically compared the effectiveness of two shipping promotion forms, i.e. no shipping fees and free shipping. Their findings suggest that promotion effectiveness may be relevant to the temporal proximity and customer's elaboration degree. Some focus on how customers respond to Threshold-based Free Shipping (TFS) policy. TFS policy offers free delivery if order value or volume meets a set threshold. Thus, it may trigger customer padding behaviours to strategically add items to meet the order threshold for a free shipment. Cachon et al. (2018) empirically investigate how TFS policy impacts customer order-padding behaviour and subsequent adjustment in product return decisions and the firm's profitability. They find a threshold should be slightly above the average order value. Jin et al. (2019) consider channel differences and empirically study customer padding behaviours across PC and mobile channels under the TFS policy. Due to distinct searching costs between two channels, the padding behaviour is more likely to happen on the PC channel. Besides, how customers pad orders across two channels is different: mobile customers increase the quantify of the same item to increase basket size, whereas PC customers purchase higher-value substitutes.

Some investigate the elements in the TFS policy. Lewis (2006) use e-tailer's data to empirically study the effects of shipping policies and marketing activities on customer purchase behaviours (i.e. acquisition, retention, and average expenditures). They find that TFS policy is more effective than free shipping promotions and standard increasing fees structures. Lewis et al. (2006) consider customer heterogeneity and empirically investigate how shipping charges affect order incidence rates and order size. Koukova et al. (2012) also examine how different shipping fee structures, i.e. flat-rate and threshold-based free delivery, influence customers and profitability based on attribution and prospect theory. They find that the comparison between order size and threshold may affect customers evaluating promotion offers. Moreover, TFS may enhance customer perceptions of shipping fees as a profit generator and negatively impact customer offer evaluations. Huang and Cheng (2015) examine how consumers evaluate and respond to two forms of TFS, and they find that volume-based policy is more effective than value-based TFS. Huang et al. (2019) develop a conceptual model based on the dual entitlement principle to examine the effect of TFS policy (i.e. threshold level, shipping charge, and delivery time) on customer perceptions (i.e. fairness, willingness-to-pay for shipping charges, and perceived retailer's motives). The consumer's willingness-to-pay is primarily affected by the perception of shipping fees as a profit generator other than the perceived values and fairness.

Shipping charges influence consumers' online decision making, and allowing online orders fulfilled in-store makes the shipment policy more complicated. However, most of the above literature studies the single-channel shipment policy other than considering the cross-channel shipment. They use practice data to empirically understand online customers' purchase intention, retention, perception of fairness and padding behaviours. The role of shipping fees on customer channel choices is yet to discuss. This study fills this gap by concentrating on how shipping charges affect consumers' channel choice, especially channel-switching behaviour using mathematical models.

2.3.2 Online Shipping Operations

A stream of literature studies operational trade-offs regarding shipment as they influence business profitability. Some focus on the shipment charges: customers expect home delivery to be free, whereas the last-mile delivery cost constitutes a considerable portion of online order handling expenses. Leng and Becerril-Arreola (2010) study joint pricing and Contingent Free Shipping (CFS) decisions from an online retailer's view in both monopoly and duopoly structures. They find that the retailer can benefit more from a homogeneous market than from a heterogeneous one. They also find that the fixed shipping fees may have the most considerable impact on the retailer's profit. Also, the two retailers with the same fixed or variable shipping fees should decrease their profit margins under the competition but increase their CFS cut-off levels. Gümüş et al. (2013) develop a stylised model that captures the competition between (and within) these two formats (i.e. shipping fees are partitioned or non-partitioned in product prices). They use data from online retailers to empirically validate how shipping fees policies influence retailers' adjustment on prices. Shao (2017) investigates shipping policies' impact (i.e. calculated shipping policies and free shipping) on the multi-retailer competition and exclusive-retailer supply chains. They find that both the supplier and customers prefer a free shipping policy in the multi-retailer scenario. In the exclusive-retailer supply chain, they investigate two pricing models: geographical and uniform. They find that shipping charges make no difference under the geographical pricing approach. Under a uniform pricing approach, the shipping costs will impact a customer's preference in shipping policies. Some focus on how shipment decisions influence operational performances. Boyer et al. (2009) deal with the trade-off between customer convenience and delivery efficiency and empirically examine the effect of customer density and delivery window length on the delivery route efficiency. Hua et al. (2012) use an analytical model and numerical experiments to determine the retailer-supplier optimal order lot size for free shipping and the optimal retail price. They incorporate the supplier's quantity discount and transportation cost into the model. They find that free shipping between retailers and suppliers can also benefit end customers. This thesis focuses on the interaction between retailers and end customers instead of suppliers. Boone and Ganeshan (2013) analyse the trade-off between over-stock for free shipping promotion and additional inventory replenishment costs or lost sales opportunities if under-stock. These studies mainly focus on shipping fees or shipping promotions from the point of online retailers. None of them considers the operational differences between online and stores and discusses shipment under omnichannel setting, e.g. the BOPS shipment policy. This thesis will fill this gap.

Some focus on operational optimisations: minimise costs or maximise profits. Boyaci and Ray (2006) develop an analytical model to maximise profit by differentiating the shipment service elements: delivery time, length and prices. They segment customers based on their sensitivities to these factors and consider how these segments respond to different shipment strategies. Chintagunta et al. (2012) formulated the transaction costs for both online and store channels into the model of channel choices, such as time (e.g. travel and waiting), costs (e.g. transportation, searching in-store), and delivery charges. However, their studies consider both channels as silo operations, and the cross-channel effect is overlooked in their study. Hsu and Li (2006) use a Nonlinear Program (NLP) to examine delivery strategies (e.g. variable or uniform shipping cycles) for online retailers to maximise profits. Their demand is time-dependent (e.g. peak demand), and profit function is relevant to service cycles' number and duration. Results suggest that the variable service strategy is a better strategy for time-dependent demand. Acimovic and Graves (2015) use Linear Program (LP) to minimise online retailers' shipping costs by deciding where items should dispatch, and whether or how multiple-item orders will be broken up into multiple shipments. Jiang et al. (2013) use two Mixed Integer Nonlinear Program (MINLP) and numerical studies to optimise online retailers' shipping-fee charges and product selling prices for single and multiple product transactions. They take into account online channel costs and customer heterogeneity in reservation prices and delivery time requirements. Becerril-Arreola et al. (2013) consider a two-stage optimisation: they determine the profit margin for TFS and inventory level. Based on the model (Zhou et al., 2009; Kwon and Cheong, 2014) determine the optimal minimum threshold for free shipment and fixed shipping fee and consider inventory management based on the newsvendor model. Most of the above literature optimise either costs or profits by determining shipment operations, e.g. shipping cycle, shipping time, shipping locations, shipping fees, and threshold. Apart from shipping locations, little consider the operational integration between online channels and stores, especially the impact of the shipping-fee difference between BOPS and online channels on customers and profitability. This study develops analysed models using utility theory to understand customers' cross-channel behaviours triggered by shipping charges in pre-and post-purchase. Competition is not considered in the market. Besides, a critical feature in this research is incorporating the shipping fees in the demand and profit functions and considering the impact of cross-selling benefits. Unlike most model settings where the shipment is cost, the shipping fee is set as a profit generator.

2.4 Return Policy

The omnichannel implementation in the post-purchase stage allows customers to cross-return, buying from one channel and returning to the other. For example, place orders online and return in-store, or buy in-store and return via post. This section primarily focuses on three streams of return policy studies: 1) customer responses to return policies under a single-channel setting; 2) the effect of return operations on customer returning behaviours and retailer profitability under a single-channel or multichannel setting; 3) the cross-return operations under the omnichannel setting.

2.4.1 Customer Return Behaviours

Early studies explore how sellers' return policies affect customer behaviours: loyalty intentions (Mollenkopf et al., 2007; Ramanathan, 2011); re-purchase behaviours (Griffis et al., 2012); the exchange process (Petersen and Kumar, 2009, 2015); customer trust (Oghazi et al., 2018); return frauds (Speights and Hilinski, 2005; Ülkü et al., 2013). This thesis discusses how return policies affect customer channel choices for purchases and returns.

A body of studies discusses how customers respond to return policy leniency. Some suggest that a less restrictive return policy may signal positive customer perceptions, e.g. perceived good qualities in products and services (Bonifield et al., 2010). Return policy with Full Refund (FR) can effectively signal product quality (i.e. promised product attributes and service consistency) when transaction costs are not too high. Alternatively, FR could be a helpful supplement to a higher price (Moorthy and Srinivasan, 1995). Also, FR increases consumers' purchase intentions and willingness-to-pay (Suwelack et al., 2011), and the "no-questions-asked" FR policy ensures customers ex-post loss (Che, 1996). On the contrary, some find that return policies with fewer restrictions are not always favourable. A less restrictive policy face a trade-off: positive influences on re-purchases (Bower and Maxham III, 2012) and reducing customer risks, whereas negative effects on the probability of returns and retailer's costs based on the endowment and signalling effects (Wood, 2001). Apart from the refund amount, Zhang et al. (2017) find that the return window positively influences purchase intention. Conversely, the time window of returns does not signal service quality, while the return amount shows a moderating effect. The charges for return services can also affect customers' choices. Under an equity-based return shipping policy, retailers require a return fee if customers are at fault, (Bower and Maxham III, 2012) find that free returns increase customer re-purchases while charging return fees may decrease their re-purchases. Lantz and Hjort (2013) experimentally explore how free delivery and returns affect purchase intention and return behaviour. A lenient delivery or return policy may increase order frequency but increase the probability of returns and decrease the average value per order. Janakiraman et al. (2016) hold similar results that generous return policies may incite more customer returns. However, they find that a generous return policy could compensate for the loss of returns that positively impact purchase intention. Likewise, (Hjort and Lantz, 2016) find that free returns do not necessarily benefit the retailer's long-term profitability through an empirical study. Returners and repeat customers are more profitable than customers who enjoy free returns. A lenient return policy may increase value per order for repeat customers but decrease returners and customers who enjoy free returns. Distinctively, Bahn and Boyd (2014) empirically find that restrictive policies could reduce fraud returns and logistic costs if sufficient product information is provided, e.g. detailed product descriptions, opportunities for trial, and ex-post reviews. The above studies mainly discuss the restrictiveness of return policies in general, and most of them are empirical studies and based on behavioural theories (e.g. signalling theory). The discussion is lacking in how components of return policies affect customers' return channel choices. This thesis focuses on monetary leniency: return charges and non-monetary leniency: whether retailers allow customers to cross-return. Thus, this study will fill this gap by discussing how return policies impact customer channel choices based on utility theory.

Some studies spot various patterns in customer return behaviours. For example, customers face multi-stage decisions due to valuation uncertainties, and they determine whether to buy before the purchase and whether to return after receiving the item and finishing assessment (Davis et al., 1998; Wood, 2001; Chen and Bell, 2009; Su, 2009; Frambach et al., 2007; Ülkü et al., 2013; Mahar and Wright, 2017; Shi et al., 2018; Jin et al., 2020). This thesis will also consider customers' ex-ante and ex-post decisions. Foscht et al. (2013) empirically study return behaviours in the apparel industry and divide customers into four groups depending on their returning patterns: heavy returners, medium returners, light returners, and occasional returners. They find these groups differ significantly in their initial shopping motivations and spending patterns, and reasons for product returns. Nonetheless, it is unknown whether this segmentation works effectively in other industries with different returning patterns. A body of research segments customers based on valuation uncertainty. Yalabik et al. (2005) divide the market based on whether or not products match customer valuation. Liu and Xiao (2008) segment customers based on whether customers knew the value before or after purchasing. Su (2009) consider two types of customer: low valuations and high valuations. Similarly, Hsiao and Chen (2012) group customers based on their valuations and hassle costs. Thus, they have two consumer segments. They are homogeneous within each segment but heterogeneous in hassle costs, e.g. high-segment consumers obtain a high valuation and incur a higher hassle cost of returning a product. Li et al. (2013) segment customers based on their buying and returning behaviours. They discuss four scenarios where customer purchase intention is sensitive to pricing strategy or return policies, and customer returns are sensitive to pricing or return policies. Nageswaran et al. (2020) segment customers by channel preferences: the online type prefers to purchase the item online, and the store type visits the store to inspect the item before making a purchase. These studies consider customer behavioural differences and valuation uncertainty. This thesis is similar to theirs but considering multiple behavioural factors – segmenting customers according to channel preferences and valuation uncertainty.

2.4.2 Online Return Operations

Designing an effective return policy requires sellers to consider comprehensive factors: unit selling prices, inventory, return rates, operational costs, customer shopping and returning behaviours, market segments, and re-sell prices. Hence, return policymaking is crucial for retailers' efficiency and profitability.

A stream of studies looks into the return policy elements that influence customer behaviours and retailer profitability. Janakiraman et al. (2016) characterise the return leniency into five different dimensions: time, money, effort, scope, and exchange through meta-analysis. Davis et al. (1995) develop a stylised model and find that the FR policy's profitability is relevant to customer valuation of products, the salvaged values of returned products, the probabilities of products mismatching consumers' estimated values, and transaction costs of returns. This thesis considers similar influential factors but in an omnichannel setting. Some studies focus on a single element. Davis et al. (1998) study the hassle level of returns through an analytical model and find that a profitable low-hassle return policy is relevant to short product shelf life, cross-selling opportunity, and high salvaged values. Ertekin and Agrawal (2020) develop an analytical model to investigate a multichannel retailer's return period window's impact on sales, returns, and profitability. They find that shortening the return period decreases sales, return rates, and profits slightly, but this effect is insignificant. Some analyse multiple elements, such as time-depending, monetary, customer, and effort-related elements. Ülkü et al. (2013) developed a three-stage analytical model to study prices and the return period and their influences on consumers' valuations. They find that retailer profitability is relevant to customer sensitivity to return policies. Both profits and prices could be increased with customer sensitivity, even with fraudulent consumers' negative effect on sales. Yalabik et al. (2005) integrate three components: refund amount (i.e. full refund and non-full-refund), market segments (i.e. match and mismatch), and shipping and handling costs in their study. They find that the optimal refund amount is not unique for both match and mismatch segments. Also, retailers tend to over-invest in one component and under-invest in the other. Janakiraman and Ordóñez (2012) study two elements based on construal level theory, i.e. return deadlines and required effort for returns. They find that the deadline window's length and level of required effort negatively affect the return rate. Zhang et al. (2017) investigate how the return window (i.e. short return window verses long return window) and the refund amount (full refund verses partial refund) signal product quality and service quality. Xu et al. (2015) discuss how the refund amount and deadline window affect consumers valuations and identify the optimal refund amount and conditions. The determination of the return deadline window depends on the product lifecycle and the consumer return rate. The longer the return deadline, the better the consumer valuation. An indefinite return deadline works when the consumer return rate is low or the product lifecycle is short. Otherwise, the return deadline should depend on the product lifecycle. A retailer is best to refund the salvaged value of the product rather than a full-price unless the product value does not diminish. They suggest a policy that is contingent on return deadline when the product salvaged value is time-related. The above research primarily discusses how return-policy elements affect customers returns based on behavioural theories and retailer profitability using stylised models. None of them considers the cross-channel returns. This thesis contributes to this area by focusing on shipping fees and hassles under omnichannel returns, especially the difference between online and cross-channel returns. Furthermore, this study considers the strategic customer return behaviours: decide whether to keep the product to maximise the customer utilities.

A body of literature investigates different types of return policies and identify optimal policy and conditions. Stock et al. (2006) classify returns into two types (i.e. controllable and uncontrollable) depending on whether they can be avoided or eliminated. Hsiao and Chen (2012) classify return policies based on restrictions and customer perceived quality risks, e.g. the possibility of product misfit, defect, or unconformity. They develop a stylised model and two-segment market setting, where customers are heterogeneous in value valuations and hassle costs. Liu and Xiao (2008) investigate three return policies: 1) a single policy that serves one type of customers only; 2) a uniform policy that serves both types; 3) a rational policy that sells in the ex-ante stage at a high price and offers discounts in the ex-post stage with the risk of stockouts. They find that retailers are better off differentiating their return policies based on customer segments other than using a uniform policy. Hsiao and Chen (2014) compare the effect of two return policies on profitability, i.e. Money Back Guarantees (MBG)and hassle-free policies, considering customer heterogeneity in valuations and hassle costs. An MBG policy may discourage consumers with a high valuation or high hassle costs, and potentially leave those with low willingness-to-pay. Conversely, the hassle-free policy may induce customers with low willingness-to-pay. Focusing on re-selling returned products, Altug and Aydinliyim (2016) explores conditions for FR returns considering 1) consumers' discount-seeking purchase deferrals;2) clearance without a loss; 3) lenient returns stimulate aggregate demand; 4) consumers' transaction costs. They suggest returns should not be allowed for products with clearance prices below a threshold and work with a clearance partner with higher salvaging values. Shang et al. (2017) analyse products sold with different return policies by analysing data from eBay. Their results suggest that an FR policy's value may be overrated, and a non-refundable forward shipping charge quickly discredit the value of FR return policies. Walsh and Möhring (2017) investigates three instruments that prevent returns based on the risk theory: MBG, product reviews, and return labels/advice. Counterintuitively, MBG may increase returns while product reviews decrease returns, and offering free return labels makes no difference in customer return behaviour. These studies consider the optimal return strategy based on market segments and identify corresponding conditions, yet most are under a single channel (i.e. online) or multichannel setting. The effect of cross-returns is not discussed in these policy optimisations. This thesis will fill this gap.

Some identify the chance to transform return policies into opportunities. Che (1996) finds that the "no-questions-asked" FR policy allows retailers to charge more and is beneficial when consumers are highly sensitive to risks, or retail costs are high. Su (2009) studies the impact of FR and partial returns on supply chain performance with customer valuation uncertainty. They find that FR may not optimise the supply chain performance, and they identify the opportunity of utilising the refund amount as a moderating tool. Similarly, Chen and Bell (2012) investigate the effect of two return policies (i.e. FR policy with a high price and non-refund policy with low price) on pricing and inventory. They segment customers based on their sensitivity to prices and risks. They find that returns could be a profit generator if the right return policy is adopted for the right market segment. Akçay et al. (2013) study how an MBG policy influences retailer quantity, price, refund amount, and re-sell prices. They capture essential features of MBG sales in the model: valuation uncertainty, consumer returns, consumer choice between new and returned products, and the possibility of exchanges when restocking is considered. Offering an MBG without restocking fees increases the new product price. Re-selling returned products may help retailers create additional revenues and decrease the initial stocking levels. This thesis also considers restocking costs as return fees and explore the positive effect of return policies. Mainly, this study focuses on using returning fees as moderating tools in channel migrations.

2.4.3 Cross-channel Return Operations

In an omnichannel context, the cross-return operations become intricate as consumers can select various return channels (Bijmolt et al., 2019), while online-to-store returns may increase cross-selling opportunities in-store (Akturk et al., 2018). Bijmolt et al. (2019) develop a marketing-operation framework that characterises an omnichannel retailer's decisions and product flow from assortment choices, inventory planning, distribution, delivery, to returns. The omnichannel returns management has yet fully matured due to the challenges in network design and returns processes (Bernon et al., 2016).

Recent studies focus on helping omnichannel firms determine optimal store decisions in the return operation. For example, Mahar and Wright (2017) determine the optimal subset of stores and locations for in-store pickup and returns considering costs. They develop a mathematical model to analyse costs under stochastic channel demands in the multi-echelon setting. When customers cross-return orders to stores, retailers need to decide whether to add returned items into store stock. Thus, some studies look into the inventory issue. Radhi and Zhang (2019) determine optimal order quantities with resalable returned stock for four different return policies where both same- and cross-channel returns are offered. Choosing the right return policy may substantially increase the retailer's performance and profitability. He et al. (2020) extends the newsvendor model to study pricing and inventory when the returned products can be re-sold as refurbished products under the omnichannel setting based on game theory. They find offering BORS could lead to win-win results in that customers enjoy the convenience without additional costs, and retailers gain more profits than without BORS. The implementation of BORS does not change the optimal price of a new product while decreasing that for a returned product, increasing the optimal order quantity of the online channel but decreasing that of the store channel. Dijkstra et al. (2019) study dynamic policies for products returned from online to offline stores using a Markov decision process. When the product has a finite selling period, its value could be time decay. It becomes vital for the retailer to re-sell returned items profitably within a time window. Hence, the retailer needs to determine whether to re-sell the returned online orders in-store quickly yet face local demands or ship them back to the warehouse for centralised online demands but bear longer wait. They observe that dynamic policies are more effective than static ones in dealing with stock imbalances. This thesis will consider the channel cost differences between stores and online channels. In other words, the profitability is studied from a centralised view, because it is in line with the feature of channel integration under an omnichannel setting.

Some studies shed light on monetary decisions in omnichannel returns, such as pricing strategy, the refund amount, restocking fees, and salvaged values. Radhi and Zhang (2018) investigate how factors, such as same- and cross-channel returns, return rates, and customer preferences, influence the retailer's pricing strategy based on the game theory and identify the optimal pricing strategy. When considering market competitions, Jin et al. (2020) incorporate prices and online return fees and customers' heterogeneity into stylised models to investigate the cross-channel return policy based on game theory. They find that equilibrium exists if the retailers are sufficiently differentiated and stores have advantages in salvaged values of returned products. Neither retailer should offer the BORP option under an intense competition or when stores do not have advantages in salvaged values. Huang and Jin (2020) reveal that adopting BORS may hurt a retailer's profitability under situations in a monopolistic environment. However, in a competitive environment, both retailers prefer to offer BORS in nearly all conditions. Moreover, BORS profitability could be improved by increasing salvaged values of returned products and the proportion of returns handled by suppliers. Although the above studies discuss return policies under an omnichannel setting, they neglect the differences of channels, such as costs, processes, marketing, staffing, and how these differences affect return policies' decisions. Nageswaran et al. (2020) study the refund amount (i.e. FR or partial refund) and return policy decisions (i.e. whether to allow cross-return) under an omnichannel setting with customers valuation uncertainty. Customers' purchase and return decisions are endogenised in their model. They suggest that omnichannel firms offer FR when they have good salvage partners for online returns or sufficient store-based customers. Conversely, a partial-refund policy should apply if firms have a significant store network and better in-store salvage opportunities, so retailers can use refunds to swift online customers to return in-store. The return convenience and refund amount should be carefully decided as convenient store returns with partial refunds are not always profitable as one expected. This thesis is similar to theirs in the way we both consider cross-return and customer channel preferences. Their study the refund amount - a retailer's decision variable, while this study considers FR return policy uniformly across channels. This thesis primarily investigates the restocking fee, i.e. whether online orders should be charged when cross-channel returns are allowed. Also, the return fee is formulated into the profit function, whereas most relevant studies only incorporate it in demand.

2.5 Research Gaps

In summary, this study has identified gaps in four areas: cross-channel customer behaviours, omnichannel operations, shipping policy and return policy. Customer's channel choices impact cross-channel demands. Previous relevant studies have discussed potential motivations for driving customers to specific channels. Some of these motivations are customer-driven, e.g. valuation uncertainty, heterogeneity or homogeneity, strategic behaviours. Some are driven by retailers' strategies or operations, such as pricing, return, fulfilment, and product availability. As the primary driver that customers abandon online cart, delivery fees are either mentioned as part of shipping services or have not been thoroughly investigated in influencing customer channel choices, especially the positive effect. This thesis will fill the gap by separating it from services and exploring both negative and positive impacts on customer channel choices. Allowing customers to pick up online orders in-store can trigger channel cannibalisations. Simultaneously, some studies find that converting online to stores may bring new customers and increase cross-selling opportunities. Previous studies find that omnichannel functionalities are beneficial under conditions. Some studies consider strategic customer behaviours using the utility theory (Cao et al., 2016; Gao and Su, 2017; Niu et al., 2019; Yang and Zhang, 2020), whereas their research focuses are omnichannel implementations, such as BOPS, showrooming, O2O or O2S, and SFS. This thesis attempts to elucidate a different operational matter that triggers channel migration - omnichannel shipping and return policies. Most research that studies omnichannel fulfilment (e.g. BOPS, C&C, STS, and O2S) focus on operational decisions, like products, store choices and locations, pricing strategy, and inventory. However, very few discuss whether omnichannel services should be charged. This study contributes to this stream by exploring the service charge for omnichannel fulfilment and identifying the conditions for the ex-ante and ex-post's optimal shipping policies. A body of omnichannel studies fulfilment performance optimisations, e.g. maximising profitability, minimising costs, and optimising vehicle routes. Nevertheless, the trade-off has been neglected that charging for omnichannel services may put off customers. At the same time, it potentially migrates customers to a more profitable selling channel and compensates the shipping costs. This research aims to deal with this trade-off and optimise the retailer's profitability.

As the key driver that online customers do not complete their orders, shipping fees influence their final checkout decisions online. Cross-channel shipment makes the determination of shipping fees more complicated. Some retailers offer free BOPS in the business practice, whereas some charge for it or set threshold-based free services. Most relevant literature discusses online channel shipment policies, such as how much shipping fees should be for online orders, whether they should be included in online selling prices, or if they are an effective promotion tool. The shipment-operation studies optimise either costs or profits through adjusting shipping policies, e.g. shipping cycle, shipping time, shipping locations, shipping fees, and threshold. Little has been discussed how the shipping policy affects cross-channel behaviours, and the operational differences and integrations between online and stores under the omnichannel setting, e.g. the shipment policy for BOPS. This thesis endeavours to insert the "missing puzzle" into this research stream through stylised models and consider customers' strategic behaviours. This study develops analysed models based on strategic customer channel choices. The competition in the market and inventory issues are not considered. Unlike most model settings where the shipment is a cost, this study refers to business practices and previous works (Koukova et al., 2012) and formulate shipping fees as a profit generator. This setting allows us to understand the effects of shipping fees on customer demands and business profitability.

Return policies, especially online return policies, affect customer perceptions of the firm, such as product or service quality and branding. A stream of research discusses how customers respond to the return policy's restrictiveness. Some think a policy with fewer restrictive conditions may signal positive customer perceptions, while some point out adverse effects. Most of those studies are empirical and based on behavioural theories (e.g. signalling theory) from policy level rather than investigating how return policy components affect customers' return channel choices. This thesis focuses on monetary leniency - return charges, and non-monetary leniency: whether retailers allow customers to cross-return, and discussing how return-policy elements impact customer channel choices based on utility theory. Moreover, this thesis is similar to some studies that segment customers based on their return behavioural patterns and valuation uncertainty. From an operational side, a body of literature looks into return policy elements and discuss how they affect customers returns based on behavioural theories and retailer profitability using stylised models. Nevertheless, those are online return policies without considering cross-channel returns. This thesis contributes to this area by focusing on shipping fees and hassles under the omnichannel returns, considering the cost difference between online and stores. The recent studies regarding omnichannel return policies focus on store operational decisions or monetary decisions, such as pricing strategy, the refund amount, restocking fees, and salvaged values. This thesis is similar to Nageswaran et al. (2020) as we both consider cross-return and customer channel preferences using utility theories. However, they study the refund amount, a retailer's decision variable, while this study considers FR return policy across channels. This research investigates the restocking fee for omnichannel and focuses on using returning fees as moderating tools in channel migrations, i.e. whether omnichannel retailer should charge for cross-channel returns, and explore the positive effect of return policies. Also, return fees are formulated into the profit function, whereas most relevant studies only incorporate it in demand. This study considers the strategic customer return behaviours: decide whether to keep the product and choose which return channel to maximise the customer utilities. Furthermore, this study considers channel cost differences and studies profitability in a centralised view because that aligns with channel integration in an omnichannel setting. Generally, this thesis contributes to these streams in three ways. First, it concentrates on an element of the shipping and return policies, i.e. shipping fees and return fees. They are channel-related charges and influential unneglectable factors that affect customer purchase intentions, channel choices, and retailers' costs and profitability. However, they are unexplored in the omnichannel context. Second, this study fills the gap by considering shipping fees for C&C and return fees for BORS and investigating different shipping and return policies by differentiating channels in handling costs and hassle costs. Third, shipping fees and return fees are incorporated into both demand function and unit profit. In contrast, in most studies, neither shipping fees nor return fees are not discussed as profit generators. The contributions of the main references cited above are summarised and compared with this study in the following table 1 :

Table 1: Table of relevant literature compared with our work

Author(s)	**Utility Theory**	**Cross-channel Behaviours**	**Omnichannel Operations**	**Shipping Policy**	**Return Policy**
Our work	**v**	**v**	**v**	**v**	**v**
Moorthy and Srinivasan (1995)					v
Davis et al. (1998)	v				v
Wood (2001)	v				v
Schindler et al. (2005)				v	
Yalabik et al. (2005)	v				v
Lewis (2006)	v			v	
Lewis et al. (2006)				v	
Boyaci and Ray (2006)				v	
Schröder and Zaharia (2008)		v			
Liu and Xiao (2008)					v
Su (2009)	v	v	v		v
Chen and Bell (2009)					v
Chatterjee (2010)		v	v		
Leng and Becerril-Arreola (2010)	v			v	
Bonifield et al. (2010)					v
Suwelack et al. (2011)					v
Bower and Maxham III (2012)					v
Chen and Bell (2012)					v
Chintagunta et al. (2012)	v	v		v	
Hsiao and Chen (2012)	v				v
Yao and Zhang (2012)	v			v	
Hua et al. (2012)				v	
Mahar et al. (2012)		v	v		
Gümüş et al. (2013)				v	
Li et al. (2013)					v
Lantz and Hjort (2013)					v

Becerril-Arreola et al. (2013)				v	
Boone and Ganeshan (2013)				v	
Foscht et al. (2013)					v
Akçay et al. (2013)	v				v
Kwon and Cheong (2014)				v	
Bahn and Boyd (2014)					v
Balakrishnan et al. (2014)		v			
Gallino and Moreno (2014)		v	v		
Huang and Cheng (2015)				v	
Cao et al. (2016)	v	v	v		
Janakiraman et al. (2016)					v
Hjort and Lantz (2016)					v
Zhang et al. (2017)					v
Mahar and Wright (2017)		v	v		v
Gao and Su (2017)	v	v	v		
Shao (2017)				v	
Kim and Chun (2018)	v	v	v		
Jin et al. (2018)	v	v	v		
Shi et al. (2018)	v	v	v		v
Radhi and Zhang (2018)		v	v		v
Akturk et al. (2018)		v	v		v
Cachon et al. (2018)				v	
Du et al. (2019)		v	v		
Kusuda (2019)	v	v	v		
Radhi and Zhang (2019)		v	v		v
Huang et al. (2019)				v	
Niu et al. (2019)	v	v	v		
MacCarthy et al. (2019)			v		
Jin et al. (2019)				v	
Dijkstra et al. (2019)		v	v		v
Jin et al. (2020)	v	v	v		v
Saha and Bhattacharya (2020)		v	v		
Yang and Zhang (2020)		v	v		

Saha and Bhattacharya (2020)			v		
Kulkarni (2020)				v	
Nageswaran et al. (2020)	v	v	v		v
He et al. (2020)		v	v		v
Huang and Jin (2020)		v	v		v

2.6 Theoretical Background

The heart of this study is a retailer's operational decision with the consideration of strategic customer behaviours. Thus, the foundation of this research is rooted in the decision theory. This research adopts the relevant behavioural theory – utility theory to investigate how retailers' shipment policies affect customer behaviours and how these behaviours affect retailers' profitability.

2.6.1 Decision Theory

Decision theory is a rational framework helping decision-makers analyse and identify optimal options (Arrow, 1957) from a course of alternative actions (North, 1968) during uncertainty (Howard, 1968). It has been incorporated in many areas, such as management science (Vazsonyi, 1990), operations research, economics, and broad areas of statistics. A large of early studies have been reviewed: the history of decision theory (Tsoukiàs, 2008); the development of decision making (Vazsonyi, 1990; Buchanan and O Connell, 2006); how it evolved into a decision analysis methodology (Tsoukiàs, 2008). The decision theory has been discussed from a different perspective: North (1968) introduce the tutorial of decision theory from the lens of utility theory and probability theory; Edwards (1961) reviewed from behavioural perspective; (Liese and Miescke, 2007; Berger, 2013) discuss from a statistical perspective; Parmigiani and Inoue (2009) study from the views of rational axioms, statistics, and experimental design.

2.6.2 Utility Theory

As the machinery of decision making, utility theory is a branch of decision theory (Bell and Farquhar, 1986; North, 1968) and rooted in economics (Fishburn, 1968). Utility theory assumes that decision-makers will make choices consistently according to one's preferences to maximise one's utility (Fishburn, 1968; Keeney, 1982; Fishburn, 1990; Barberà et al., 2004) through formulating mathematical models to represent decision-makers' preferences and explain their behaviours under uncertainty in a simplified situation(Bell and Farquhar, 1986). It allows academics to study people's choices with preferability, e.g. worth, values, goodness and so on (Fishburn, 1968, 1970, 1990). Utility theory was firstly developed in the eighteenth century by Bernoulli (1738). Bernoulli initially proposed the concept of utility, discussing how much a rational man is willing to pay to enter a gamble (Starmer, 2000). The value of a game is subjected to each player's judgement depending on individual characteristics and circumstances. Bernoulli's theory was not widely developed until the 1940s, after Von Neumann and Morgenstern (1947) derived the expected utility hypothesis from a set of appealing axioms on preference. Then, utility theory was studied and developed (Neumann and Morgenstern, 1944; Friedman and Savage, 1952; Cramer, 1956; Luce, 1956, 1958; Luce and Raiffa, 1989; Fishburn, 1968, 1970; Savage, 1972; Fishburn, 1988). Since then, alternative axiomatisations have been developed as sound principles of rational choice that any reasonable person would make. Extended from the von Neumann-Morgenstern utility theory 1944; 1953, Multi-attribute Utility Theory (MAUT) consider preference functions with more than one attribute. Under conditions, these preferences with multiple attributes could be formulated into numerical functions and assigned values, calculated and compared. Integrating with psychological measurement models, MAUT provides an axiomatic foundation for choices involving multiple value-related criteria(Dyer, 2005). Hence, MAUT can be applied to examine these axioms, discuss rational behaviours' credibility, and evaluate these choices with multiple attributes (Von Winterfeldt and Fischer, 1975; Dyer, 2005). MAUT has been reviewed in many studies (Von Winterfeldt and Fischer, 1975; Dyer, 2005; Krabbe, 2017).

2.6.3 Revenue Management

Originated in the US airline industry in the 1970s, Revenue Management (RM) refers to the strategy and tactics to manage and allocate resources (e.g. capacity) over time through demand-based variables (Choi and Mattila, 2004; Cetin et al., 2016) in order to maximise revenue (Phillips, 2005), or other objectives such as profit (Strauss et al., 2018). The core of RM is to find the set of prices optimising total expected contribution, subject to a set of constraints (Phillips, 2005; Cetin et al., 2016). Pricing is a tool for balancing supply and demand and efficiently allocating goods(Talluri and Van Ryzin, 2004*c*). The price includes the product selling price and the service involved, such as delivery fees. RM has been broadly studied and reviewed: RM application (Smith et al., 1992; McGill and Van Ryzin, 1999; Chiang et al., 2007); the development of transportation RM covering forecasting, overbooking, seat inventory control, and pricing (McGill and Van Ryzin, 1999); choice-based RM in assortment optimisation and dynamic pricing Strauss et al. (2018).

2.6.4 Theoretical Implementation

According to Zhou et al. (2017), there are two dimensions of theoretical contributions: the originality and the practical application of the theory. This research extends the application of decision theory in the new operational setting - omnichannel fulfilment, particularly the operational decisions of shipping strategy in pre-purchase and return stages. This research reveals the effect of shipping practices on the retailer's profitability. The three factors examined are channel operational costs, shipping policy, and convenience, representing omnichannel operations characteristics. The omnichannel retail environment provides a unique experience for customers, impacting the factors that influence their perceived behavioural control. This study is the first to incorporate an omnichannel shipping policy in studying channel choices to the best of our knowledge. The results provide insights for omnichannel retailers to choose a profitable shipping policy based on operational characteristics and customer bases.

Also, this study further applies the utility theory in exploring customers' strategic cross-channel behaviours and discuss potential factors affecting customers' channel choices. This study considers multiple factors in shipping policies and omnichannel operations, which extends the application of MAUT on studying a customer's strategic behaviour in channel choices under the omnichannel setting. A customer will decide which channel to purchase and return a product to maximise utility in the pre-purchase and post-purchase stages. The utility will be impacted by multiple factors: the product valuation, unit selling price, hassle cost of visiting each channel, and the shipping fee. This study extends the application of decision theory on studying a retailer's shipping policy under an omnichannel setting, that is, considering a customer's cross-channel behaviours. In this thesis, a decision-maker is an omnichannel retailer that has both online and offline channels. In conventional bricks-and-mortar stores and online retailing, customers choose what and which channel to buy and return. However, an omnichannel retailer allows purchase and returns across channels. This thesis studies how the omnichannel service influences customer channel choices and their demands migrate across channels.

This thesis extends the RM by integrating the shipping fees into the profit function, which has been observed in business practice but scarcely studied in the academic world under the omnichannel setting. The prices of the products are fixed. The customers' demand is changeable depending on the retailer's shipping policy. Therefore, the retailer will actively use RM to optimise the profit by deciding the right shipping policy under the omnichannel setting. The constraints reflect the distinct costs of running multiple channels. Moreover, this study considers an omnichannel retailer that sells products to customers with heterogeneous preferences in the hassle cost and perceived product values. The scenario when customers are homogeneous is compared with that when they are heterogeneous.

Chapter 3

Methodology

In this chapter, the research methodology chosen will be outlined in the study. The research aim and the nature of research questions are explained in §3.1, and the research philosophy is discussed in §3.2. Then, §3.3 discuss how the research is designed, e.g. research plan, reasons for the chosen research method, methodological limitations, and the research ethics. Next, the research approach is introduced in §3.4, e.g. describing the research problem, defining decision-makers and relevant variables, formulating consumer utilities and assumptions, setting model stages, identifying trade-offs and defining objective functions, and introducing the modelling tools. The details of the modelling process are not discussed in this chapter, as both stylised models will be developed and demonstrated in Chapters 4 and 5. In §3.5, the research analysis will be discussed, including decision analysis, numerical methods, and research data. The method is introduced to validate the results and test the reliability of research outcomes in §3.6.

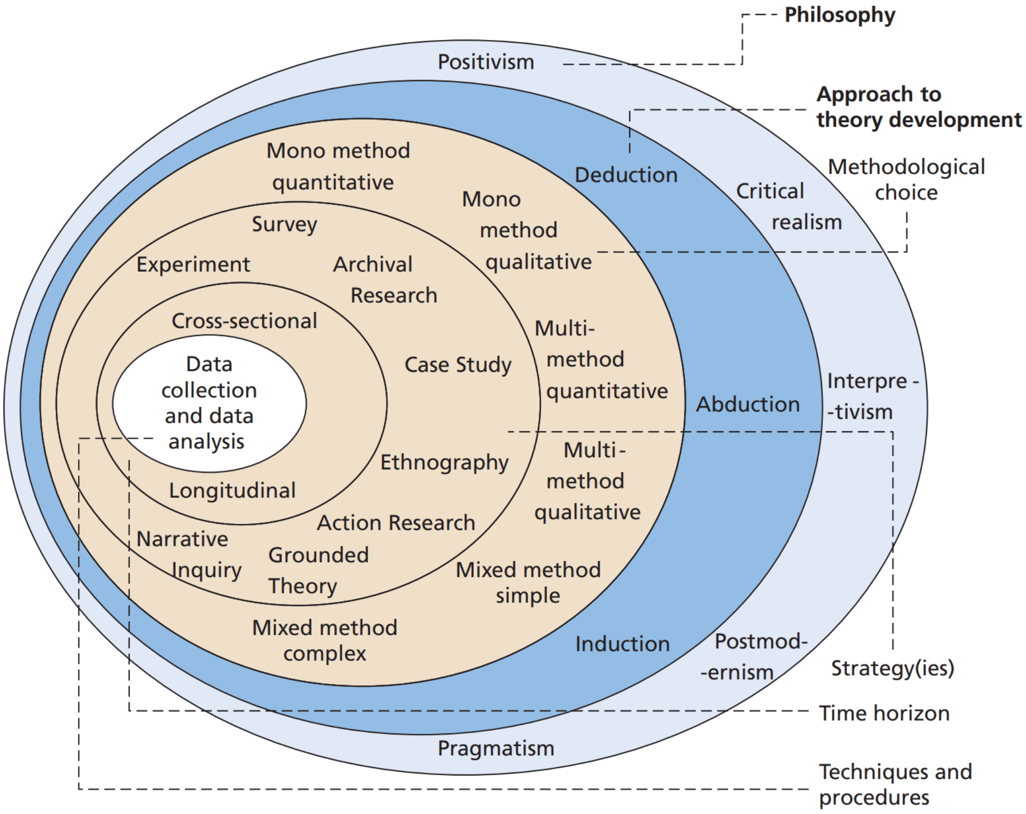
3.1 Research Overview

This research investigates how shipping policy affects customer demands across channels and the retailer's profitability in pre-purchase and post-purchase stages under an omnichannel setting. This study explores the opportunity to use the shipping and return policies to attract new customers, drive traffic into a more profitable channel, and eventually increase profitability. To distinguish from conventional multichannel, which is managed individually with silo effect, the primary setting in this study is the omnichannel operations that integrate online channels and stores. Thus, this research needs to characterise the omnichannel feature, allowing customers to order online and collect or return in-store, and identify the factors driving demands across channels.

The scope of this study is within the following settings. First, these models are limited to the theoretical framework that explores and analyses the effect of shipping and return policies without using primary data collected from businesses. Second, there are many implementations of omnichannel fulfilment in business practices, such as BOPS, ROPS, C&C, BORS, or collecting from or return to a third-party location. However, the omnichannel services discussed in this research are buying online and picking up or returning in-store. Third, as omnichannel orders are placed online, the process of online fulfilment varies across retailers and sectors. Some retailers use the STS model that centralises their supply chain, and any omnichannel order will be fulfilled directly from DCs to stores or third-party locations. Some adopt a decentralised SFS model that use store inventory to fulfil omnichannel orders. SFS fulfilment model is excluded in the discussion because the SFS model applies typically to retailers with a high level of transparency across the whole supply chain, such as Argos allows customers to choose stores with stock. Adopting SFS could be challenging for retailers with busy in-store traffic due to inaccurate store inventory. For example, customers may pick up an item and leave it anywhere in-store. Hence, it shows in stock, yet the shelf assistant cannot find it. This study will only focus on STS, the centralised supply chain that sends online orders from DC. Four, the interpretation of this study results is constrained by the assumptions, and the study with primary data and experiments could be further conducted. These stylised models are developed and analysed based on assumptions simplified from observed business practices. The solutions to the models will be measured and compared based on the problem assumption and within the research scope. The data used in the numerical analysis is chosen within the setting value range to represent different operational scenarios. Five, this study will divide the whole shopping journey into two. One is the stage before purchase, including product information searching and purchases. The other is after purchase, such as returns and refund. Six, I do not consider any geographic and cultural factors impacting the shipping policy in this model, as the central focus is the effect of shipping and return fees. At last, the audiences who may be interested in this study are retail and supply chain managers, and academics who study omnichannel operations, shipping or return policies, and channel migration behaviours.

3.2 Research Philosophy

Operational research enjoys a coherence of philosophies and methodologies developed upon a theoretical foundation from diverse disciplines, e.g. economics, marketing, psychology, applied sciences (Starbuck, 2003; Saunders et al., 2019; Morton et al., 2003). This study follows the research process outlined by Saunders et al. (2019) (shown in Figure 1) and begins with introducing the research philosophy. *Research philosophy* is defined as the underpinning belief (Guba et al., 1994; Saunders et al., 2019), the assumptions (Burrell and Morgan, 2017; Saunders et al., 2019), and research perspectives (Crossan, 2003) of knowledge development. Researchers understand the nature of their research problems through the lens of assumptions and decide what methods they employ and how they interpret the results based upon the assumptions (Crotty and Crotty, 1998; Saunders et al., 2019). Coherent studies are rooted in well-considered and logical assumptions because they are the backbone of credible research philosophy, underpinning research methods, approaches, and analysis (Saunders et al., 2019).



Source: Saunders et al. (2019)
Figure 1: Research Onion

There are various types of assumptions (Morton et al., 2003; Holden and Lynch, 2004; Burrell and Morgan, 2017; Saunders et al., 2019). Ontological assumptions shape research based upon the nature of reality (Morton et al., 2003), referring to how researchers see the phenomenon. On the other hand, Epistemological assumptions refer to the belief that knowledge can be acquired, tested, validated, accepted, discarded, and relative, representing how researchers communicate knowledge to others (Burrell and Morgan, 2017). Axiological assumptions refer to what degree the researcher's values and beliefs reflect on the research matter, showing one's value and how it influences the process of research. Furthermore, assumptions can be objective, believing that reality is external and independent of how researchers interpret and experience the social world (Burrell and Morgan, 2017; Saunders et al., 2019). They can also be subjective, arguing that reality is understood from researchers' perspectives and consequent actions (Saunders et al., 2019).

I choose the philosophical assumption in a multi-dimensional set: subjective epistemology (shaded with grey in Table 2). Subjective epistemology is value-laden, referring to the assumption that researchers understand knowledge through facts, opinions, and data ranging from numerical, lingual and visual (Saunders et al., 2019). In this study, the assumption is based on the belief that decision-makers are rational and consistent. They evaluate alternative options and subsequential outcomes, then make choices based on subjective criteria defined in this study. The formation of models reflects my understanding of omnichannel operations and how the retailer's policy influences customers. Choosing assumptions gives us as researchers interpret the nature of omnichannel retailing and customer channel choices, evaluate the possible outcome of each alternative action, and gain insights into the research questions.

Given the assumptions, the research philosophy can be discussed, which is served as the base for the research strategy. First of all, there are five major philosophies: positivism, critical realism, interpretivism, postmodernism and pragmatism. Positivism highlights the philosophical position of holding factual knowledge through an observable social entity (Saunders et al., 2019), based on strictly scientific empirical evidence supported by verified data without human bias. Critical realism focuses on explaining the structures underlying observable reality that is external and independent (Archer et al., 2013). Interpretivism argues that people interpret knowledge of the social reality differently according to their backgrounds or under different contexts (Saunders et al., 2019), aiming to create new and richer understandings of reality by collecting meaningful

Table 2: Philosophical assumptions two extremes

Assumption type	Two sets of extremes	
	Objectivism	**Subjectivism**
Ontology	Real,External,One true reality,(universalism),Granular (things), Order	Nominal/decided by convention,Socially constructed,Multiple realities (relativism), Flowing (processes), Chaos
Epistemology	Adopt assumptions of the natural scientist, Facts, Numbers ,Observable phenomena, Law-like generalisations	Adopt the assumptions of the arts and humanities, Opinions, Written, spoken and visual accounts, Attributed meanings, Individuals and contexts, specifics
Axiology	Value-free, Detachment	Value-bound, Integral and reflexive

Source: the table content is quoted from Saunders et al. (2019)

information. Postmodernism seeks alternative views of accepted knowledge by re-constructing realities through its language and classifications (Chia, 2003; Saunders et al., 2019). Pragmatism emphasises understanding reality from a practical view and contributes to a research problem that informs future practical uses and successes. (Kelemen and Rumens, 2008).

The chosen philosophical position is pragmatism under epistemological assumptions (shaded with blue in Table 3) because pragmatic researchers focus on practical and logical outcomes other than abstract principles. Unlike other management philosophies, pragmatism endeavours to harmonise opposites by converting theoretical concepts and research findings into practical consequences under contexts (Saunders et al., 2019). Pragmatist study is problem-centric and concentrates on the consequences of series of actions and (Creswell and Creswell, 2017). This research attempts to gain insights into dealing with the operational trade-off retailers face under the omnichannel context. Explanations are provided, possible factors essential to the omnichannel operations are discussed, and how customers make their channel choices in response to the alternative policies is predicted based on the assumptions. Eventually, the outcome of the alternatives is evaluated and produce practical insights into the research question.

3.3 Research Approach

After introducing the philosophical assumptions, the research approach needs to be decided in this section. There are three major approaches: deductive, inductive, and abductive approaches.

Table 3: Five research philosophical positions and three assumption type

Philosophy	**Assumptions**		
	Ontology	**Epistemology**	**Axiology**
Pragmatism	external 'reality' is the practical consequences of ideas, experiences and practices	practical meaning of knowledge in specific contexts, theories and knowledge that enable successful action, focus on problems, practices and relevance problem solving and informed future practice as contribution	value-driven research Research initiated and sustained by researcher's doubts and beliefs Researcher reflexive
Positivism	real, external, independent one true reality	scientific method observable and measurable facts, Law-like generalisations, causal explanation and prediction as contribution	value-free research Researcher is detached, neutral and independent of what is researched
Postmodernism	nominal, complex, rich, socially constructed through power relations, realities are dominated and silenced by others, experiences, practices	knowledge is decided by dominant ideologies, focus on absences, silences and oppressed/ repressed meanings, interpretations	value-constituted research, research embedded in power relations, research narratives are repressed and silenced at the expense of others
Interpretivism	complex, rich socially constructed through culture and language, multiple meanings, interpretations, experiences, practices	theories and concepts too simplistic, focus on narratives, stories, perceptions and interpretations, new understandings as contribution	value-bound research, researchers are part of what is researched, researcher interpretations
Critical realism	external, independent intransigent, objective structures	epistemological relativism, knowledge historically situated	value-laden research, researcher acknowledges bias by world views, cultural experience and upbringing, researcher tries to minimise bias

Source: the table content is quoted from Saunders et al. (2019)

Researchers tend to choose an approach according to their chosen philosophy,such as pragmatists are more likely to adopt an abductive approach (Saunders et al., 2019).

The deduction could conclude research based on logical premises, initialising research ideas from theories and testing them through reviewing the literature or measuring factual information (Ketokivi and Mantere, 2010; Saunders et al., 2019). It is counted as a positivistic method considering the scientific approach. Choosing research samples and sizes cautiously is necessary to generalise the problem using this approach. On the other hand, the inductive approach allows research to be concluded based on the observed premises (Ketokivi and Mantere, 2010; Saunders et al., 2019). For research involving data collection and phenomenon observation, an inductive method is suitable. Theory follows data rather than vice versa, as with deduction. As this method focuses on interpretation research from a subjective view, which can be categorised as interpretivistic philosophy.

Abduction begins with the conclusion rather than a premise. For example, possible premises are considered whether they are enough for explaining the conclusion (Ketokivi and Mantere, 2010; Saunders et al., 2019). It starts with observing facts that can happen at any study phase and figuring out how the factor happens based on a plausible theory (Van Maanen et al., 2007). The abductive approach does not follow an order and moves back and forth, e.g. data collection, theme categorisation, and pattern analysis (Suddaby, 2006; Saunders et al., 2019). Abduction combines deduction and induction. Thus, it is flexible to adapt to various research philosophies depending on the research purposes. However, the abductive approach is widely used under pragmatism or postmodernism or by critical realism.

Choosing an appropriate research approach is the backbone of a rigorous research configuration, involving what evidence should be gathered and where and how results are interpreted (Easterby-Smith et al., 2012; Saunders et al., 2019). I adopt an abductive approach (the approach comparison is shown in Table 4, and the chosen approach is shaded with blue). Firstly, pure deductive and inductive approaches are criticised due to their difficulty to achieve in practice. It is unclear how theories are selected and tested through hypothesis formulation in deductive reasoning. Likewise, theories developed via inductive reasoning may not be invalidated. Differently, existing theoretical frameworks can be developed and changed at any stage of the research process using an abductive approach. Many researchers choose abductive reasoning to address the downfalls by adopting a

Table 4: Comparing Three Research Approaches

	Deduction	Induction	Abduction
Logic	In a deductive inference, when the premises are true, the conclusion must also be true	In an inductive inference, known premises are used to generate untested conclusions	In an abductive inference, known premises are used to generate testable conclusions
Use of data	Data collection is used to evaluate propositions or hypotheses related to an existing theory	Data collection is used to explore a phenomenon, identify themes and patterns and create a conceptual framework	Data collection is used to explore a phenomenon, identify themes and patterns, locate these in a conceptual framework and test this through subsequent data collection and so forth
Theory	Theory falsification or verification	Theory generation and building	Theory generation or modification; incorporating existing theory where appropriate, to build new theory or modify existing theory

Source: the table content is quoted from Saunders et al. (2019)

pragmatist perspective (Saunders et al., 2019). I choose pragmatic philosophy, which underpins a well-developed abductive approach. My chosen philosophical assumptions are originated from mixed of theories and observed “realities”. The deductive approach is not suitable because it is valid only if all the setting premises are true. Neither is an inductive approach as I tend to extend the existing theories than developing a new one. This research uses an abductive approach to form an analytical mathematical framework regarding shipping policies. It leaves qualified remnants of uncertainties, which can be interpreted as “the best possible explanation”. The observed results will contribute to the existing decision and utility theories under the omnichannel setting.

3.4 Research Design

The nature of this study is applied research (Hedrick et al., 1993). It enhances the understanding of shipping policy in omnichannel operations, provides practical insights into the operational tradeoffs, and identifies policies maximising profits. This research aims to understand the impact of shipping and return policies on customer demand and retailer profitability under the omnichannel context and eventually maximise the retailer profitability. As a result, the insights gained from the research could potentially turn the shipping and return policies into opportunities to migrate customers into a more profitable selling channel and increase total profitability.

3.4.1 Research Questions

Therefore, the first research focuses on the trade-off between shipment policies and a retailer's profitability: a cheap omnichannel shipment could attract online traffic into stores. However, it may negatively impact profitability when stores are less profitable, and the costs of integrating online channels with stores outweigh the expected financial benefits. Thus, the first model will attempt to answer the following questions.

- How do operational factors affect retailers' shipping policies in the omnichannel setting?
- How do omnichannel shipping policies affect the total demand and customers across channels?
- What is the optimal shipping policy regarding total profits in an omnichannel setting, and under what conditions?

The second research concentrates on the trade-off between return policies and profitability within an omnichannel context: allowing cross-channel returns may boost customer confidence in the pre-purchase stage, however, potentially increase return rates and costs. Therefore, the second model will address the following research questions develop the second model to study the following questions:

- How do operational factors affect retailers' return policies in the omnichannel setting?
- How do omnichannel return policies affect customers demand across channels?
- What is the optimal return policy regarding total profits in an omnichannel setting, and under what conditions?
- Under what conditions should omnichannel retailers offer a generous return period?

3.4.2 Research Plan

Although many pragmatist researchers choose a mixed approach (Creswell and Creswell, 2017) that combines quantitative and qualitative methods to observe, explain, collect, and test, a quantitative approach is chosen to address the research questions aforementioned. Quantitative approach primarily develops knowledge or insights into specific variables and questions, quantify and measure the observed "realities", or test theories through observations (Creswell and Creswell, 2017). Moreover, the quantitative approach is mostly used to collect and analyse numerical or non-numerical data (Saunders et al., 2019). This research focuses on the impact of shipping and return policies on demands and profitability and aims to find the optimal policy under an omnichannel context. The quantitative approach helps test the research hypothesises and gain insights into research questions by developing mathematical models and analysing different scenarios with the time and cost restrictions. Qualitative research or a mixed method could be the extension of this study.

In the research design, two stages are considered: before and after purchase, representing two models in the study. I develop stylised models and conduct numerical tests to understand how shipping and return policies affect consumer channel choice, evaluate whether a retailer should charge its omnichannel service, and maximise its overall profit by deciding the optimal policy. Specifically, the first model explores the possibility of turning a shipping charge as an opportunity to migrate demands to a more profitable channel and finally grow the total profit. Thus, I identify the characteristics of omnichannel operations and choose the factors impacting the retailer's shipping policies. Next, how customers respond to different shipping policies will be analysed, and compare the profitability accordingly to find the optimal policy and its conditions. The second model studies the possibility of converting returns into opportunities for cross-selling and footfall attraction by choosing the right return policy. I need to distinct the omnichannel return operations from conventional retailing. It allows to understand features of omnichannel returns and identify the key factors impacting customers' channel choices and the retailer's return policies. I then discuss how customer demands change along with return policies and compare the results accordingly.

3.4.3 Research Theory

According to the research purpose, utility theory can characterise a rational customer's choices based on consistent criteria (Fishburn, 1968). Being rational customers means they will compare available products and choose the most preferred one based on their preferences, which may vary with the defined criteria. Hence, utility theory is useful in investigating how the customer's behaviour is affected. Prescriptive utility theory is chosen because it allows researchers to represent a customer's preferences in mathematical language and quantify how the behaviour is influenced based on the individual utilities (Fishburn, 1968). However, there are different interpretations of assumptions regarding preferences and choices. Similar to decision theory, utility theory can be predictive or prescriptive (Fishburn, 1968). The predictive approach focuses on the ability that predicts actual choice behaviour, while the prescriptive approach discusses how a person ought to make a decision. The utility assumptions are interpreted variably in disciplines. Many studies in management science are assumed to use the prescriptive approach (Fishburn, 1968) for three main reasons. Firstly, as already remarked, the theory serves as a normative guide in helping the decision-maker codify his preferences. Secondly, the theory aims to help a decision-maker "discover" or determine his preferences between complex alternatives. Utility theory helps transform preference data into corresponding numerical utility data, which can be manipulated to compute or derive utility comparisons between the actual alternatives. The compared results are then interpreted into derived preference statements. Lastly, the theory enables the decision-maker's preferences to be transformed into a numerical utility structure used in an optimisation algorithm. If the decision-maker's utility structure has desirable mathematical properties, it may be possible, using appropriate techniques, to determine the available alternative with the greatest utility.

Normative decision theory is chosen to study the retailer's decision-making in shipping and return policies, and utility theory is adopted to understand customer channel choices. Decision theory can be conducted descriptively or normatively (MacCrimmon, 1968; Vazsonyi, 1990). Descriptive decision theory emphasises how decision-makers actually choose without judgment of it. Therefore, it is suitable to explain and predict behaviours, which can be applied in empirical disciplines (Peterson, 2017). In contrast, normative decision theory aims to prescribe about what or how rational decision-makers should choose (Peterson, 2017). It is expected to help decision-makers select better alternatives, yet the criteria of "better" and rationality are debatable. Thus, researchers should have a reasonable definition of rationality and the criteria of better choice to avoid misinterpretation. Classified by Luce and Raiffa (1989); Fishburn (1990), decision-making is under three scenarios: certainty, risk and uncertainty. To be specific, certainty implies that the outcome of each choice is known to decision-makers beforehand without considering uncertainty. Risks represent that the unwanted choice could happen with a quantified probability. Uncertainty shows that the decision-maker is uncertain of the outcome once an alternative or course of action is chosen (Fishburn, 1968). The probability under uncertainty is hence either unknowable or non-assessable (Fishburn, 1990). The mathematical theory of probability is developed to describe uncertainty. However, probability can be objective, representing the characteristics of a phenomenon, or subjective, measuring the related knowledge or principles other than the phenomenon themselves (Howard, 1968). This research problem involves online shopping that has an uncertainty of product valuation. Thus, in the decision model, the subjective uncertainty will be represented as a probability, which describes the quantified chance of the assignment or states information (Howard, 1968).

Since this study aims to maximise the retailer profitability, RM is also considered. Originated from the airline industry, RM refers to the theory and practice of demand management by allocating available resources with constraints to maximise revenue (Phillips, 2005). It is not limited to revenue optimisation and is also utilised for maximising other objectives, such as profit (Strauss et al., 2018).

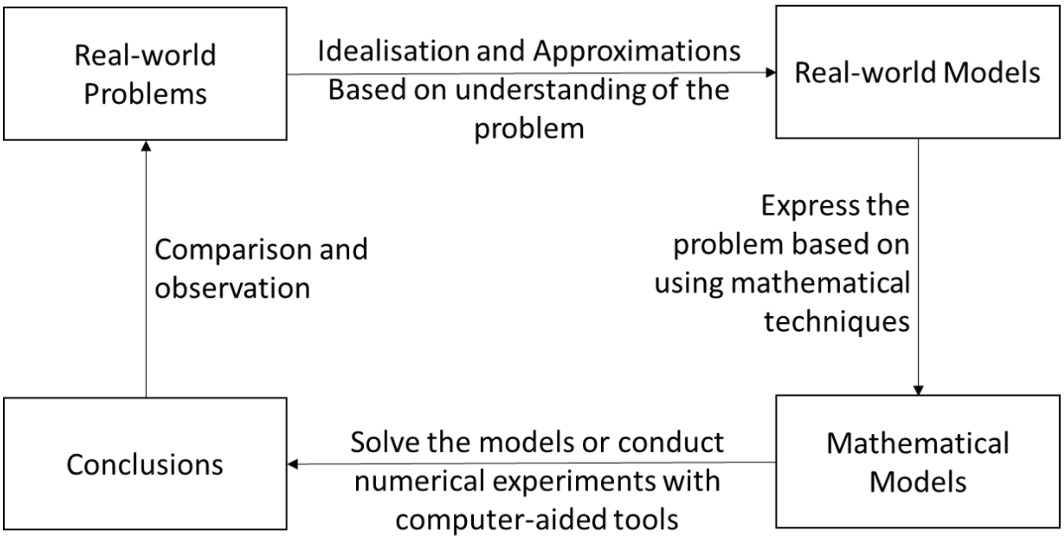
3.4.4 Research Method

Mathematical models are developed to gain insights into the research questions above. Mathematical modelling is an effective tool in studying, structuring, organising, analysing a real-world scenario's essential characteristics, and potentially getting crucial insights to predict possible outcomes and eventually solve the problem (Hritonenko and Yatsenko, 2003). Modelling is a process of formulating real-world problems into abstract mathematical concepts. For example, it describes key features of the phenomena by defining its variables, represents the relationships between features by forming equations and functions, manipulates models by changing the values or assumptions of variables, sets the purpose of the model by determining the decision-maker's point of view, and gains insights by interpreting model results (Edwards and Hamson, 2016).

Mathematical modelling can be classified in many ways (Kapur, 1988), such as linear or nonlinear based on equations, static or dynamic according to time-variation, deterministic or stochastic based on chance. Based on the method, modelling can be empirical and theoretical (Kapur, 1988). Empirical modelling explores, measures forecast correlations supported by empirical data sets. Theoretical modelling describes a system by focussing on the important and based on a set of assumptions (Achinstein, 1965; Kapur, 1988). Mathematical modelling can also be categorised following its purpose, e.g. system description, gaining insights, prediction, and optimisation. In this study, theoretical modelling is adopted for profit optimisation.

I choose mathematical modelling as it has been broadly adopted in operations and supply chain research (Geunes et al., 2002). Not all real-world problems can be described using mathematical concepts with generality and some models are too complex to be solved. However, modelling allows researchers to simplify or approximate a real-life problem, keep its essential features, and formulate them into abstract mathematical equations. In this study, modelling helps focus on the omnichannel features relevant to shipping policies (Kapur, 1988) and avoid distractive details, e.g. promotions, different order value thresholds for home delivery and C&C, various types of operations and shipping costs. For example, I define any operational cost of shipping a product from warehouse to customers as unit operational cost, which can vary depending on which channel customers choose; unit selling price and shipping charges are considered in both ex-ante and ex-post stages.

Second, mathematical modelling is an effective tool regarding time and costs to explore relationships between features. In the early research stage, it would be more cost-effective and time-effective to test hypotheses and stimulate decision-making processes by solving mathematical equations than collecting primary data through field tests and surveys (Keeney, 1982; Howard, 1988; Kapur, 1988). As Hritonenko and Yatsenko (2003) wrote, “instead of dealing with a tower or river”, modelling allows researchers to “deal with mathematical equations on paper.” Researchers can observe numerical experiments, predict behaviours, compare data and analyse the model results, and draw conclusions, which could be interpreted into insights that help understand and potentially solve the real-world problem (Kapur, 1988). Modelling helps researchers test and filter disinformation and focus on desirable and critical information. Thus, concentrating on decision modelling results in valuable insights into the research problem in the early research stage, and benefits researchers in time, effort, and costs. This study needs to discuss the retailer’s variance of operational costs, shipping fees and profitability per product, but collecting the information in real business could be challenging due to different accounting methods and sensitive financial data. It is an effective method to focus on the critical features of omnichannel operations, use decision variables to represent the retailer’s choice in shipping policies, make assumptions to predict a customer channel choice, and optimise the objective function to maximise the retailer’s total profit. Therefore, the model results can be analysed to gain managerial insights into the optimal shipping and return policy through solving the mathematical equations. Figure 2 shows the technique of modelling real-life problems into a mathematical model (Kapur, 1988).



Source: Kapur (1988)

Figure 2: Technique of mathematical modelling

Third, computer-aided tools, such as Wolfram Mathematica and Microsoft Excel, have significantly saved time and improved accuracy in calculating equations, solving mathematical models and conducting numerical experiments. With the aid of computer software, I can concentrate on the model purpose that decision-makers are investigating and test the effect of variable change on the final results. To simplify the calculation, sensible assumptions in the business practices are made, such as the value range of variables and constriction equations. When the model is not solvable, or the results are unsatisfactory, assumptions could be re-assessed and amended. Afterwards, the assumptions are relaxed to test the robustness of the model. If the model is robust, a slight alteration in the assumption or variable values should cause a modest change in the difference in results (Kapur, 1988).

Based on the modelling approach from Berry et al. (1995), the process is divided into four steps to formulate a real-life problem to a mathematical model (Berry et al., 1995). First, a problem's essential factors need to be identified and described, which is called problem description that also introduces the purpose of the model. Second, the problem is translated into simplified mathematical languages, such as equations to understand how the problem set and relationships developed among factors. The basic mathematical framework is constructed in this stage. Third, assumptions are made to reflect the belief of the problem and ease the complexity of solving equations. The solutions and different assumptions are compared and tested in this stage. At last, after solving and testing the solutions, results can be interpreted into managerial insights.

Structuring a decision problem involves the following steps (Arrow, 1957; Keeney, 1982; Howard, 1988). First, defining essential factors as variables and specifying alternatives that are available to the decision-makers. Decision analysis captures the dynamic processes by prescribing a decision strategy indicating what action should be chosen and subsequent events (Keeney, 1982; Howard, 1988). Second, identifying the consequences associate with alternatives. If one consequence is associated with each alternative, the consequence of each alternative can be quantified, and the criteria for evaluation can be defined. Decision-makers can choose the one with the best consequence. Unfortunately, the problem is usually not so simple because of uncertainties about the eventual consequences. Therefore, it is desirable to determine the set of possible consequences and the probability of each occurring for each possible alternative. There are several methods for quantifying probabilities. One method is to use a standard probability distribution function and assess parameters for that function. Third, denoting an objective function representing the decision-maker's desirable outcomes. Important decisions involve critical value trade-offs to indicate the relative desirability between the benefit of policy impact and operational costs (Keeney, 1982; Howard, 1988). In the decision analysis, the customer's objective function is referred to as a utility function. A rational customer would prefer alternatives with higher expected utilities over those with lower ones. Four, formulating the model representing relationships linking the objective function and alternatives or variables and imposing the assumptions with constraints. Last, evaluating model results based on assumptions, such as maximise the objective function with constraints.

Similarly, the utility theory approach also begins with a definition of the decision problem (Howard, 1988). To form a utility function, researchers should specify appropriate attributes indicating the information needed, then identify the possible alternatives to be learnt and discussed in the decision. Later, researchers should determine the criteria for how decision-makers compare alternatives by defining preferences. Then, researchers can formulate the objective function, also known as the utility function. Quantifying utilities allows researchers to compare and assess the consequences of alternatives and thus predict the decision-maker's choice. At last, researchers should check the consistency of their results based on the assumptions.

3.4.5 Research Ethics

Research ethics refer to the moral principles or behavioural standards of how research is formulated and clarified, designed, how research data is accessed, collected, processed and stored, and how research findings are interpreted morally and responsibly (Blumberg et al., 2014). There are two dominant philosophical standpoints in business research: deontology and teleology (Gass, 2009). Deontology emphasises the ethical process of research other than the consequences of the research. In contrast, teleology must consider whether the final cause of research justifies the research means. This thesis holds a deontological view for the research purpose. Teleology complicates the assessment of research findings. For instance, it is challenging to quantify and weigh the ethical benefits of modelling against the cost of acting unethically. This research procedure has followed the guidelines of Northumbria University's code of ethics or ethical guidelines from the proposal, research design, modelling, analysis, and result interpretation. This research develops mathematical models to stimulate and analyse retailing scenarios without actual participants, accessing, collecting, and using consumer and retailer transaction data. The information used in this research is accessible publicly on the retailer's official websites. Since this research do not involve any participants, it faces a low level of following ethical issues, such as privacy, consent, participants' emotional responses towards how the research is conducted, and researchers' behaviours.

Some researchers reviewed ethical concerns in Operational Research (Le Menestrel and Van Wassenhove, 2009; Gass, 2009; Kunsch et al., 2009; Kleijnen, 2011), but the ethics in Operations Retailing is not maturely discussed as other fields, e.g. social science and public health. Although the ethical risks of this research were assessed as a low level according to the Northumbria University ethical guideline, a few potential ethical concerns are discussed. Firstly, mathematical models are abstract frameworks representing real problems. A model itself has no ethics (Kleijnen, 2011). How researchers formulate the research problem into models can be subjective and reflect a researcher's understanding and perception of the problem. Therefore, the perception of the research problem can be influenced by factors such as culture, politics, and geographic locations. To reduce the influence of cultural factors, customers make their choice based on their preference in utilities. Customers are heterogeneous in their product valuation and the hassle of visiting the retailer that captures customer heterogeneity. From the retailer's view, essential factors are generalised to characterise the omnichannel operation with minimum bias, such as unit selling price, shipping fees, and unit handling cost, which are commonly considered in accounting without cultural influences.

Secondly, when there are various stakeholders in the model, researchers should be aware of the conflict of interests (Wenstøp and Koppang, 2009; Kleijnen, 2011) and consider the benefits and risks from all parties. There are two parties in this research, the decision-maker for the shipping and return policy is an omnichannel retailer, and the decision-maker for purchase is a customer. The retailer's interest is to maximise profit, while customers want to maximise their utilities. This study diminishes the conflicting interests between the retailer and customer by incorporating demands in utility and profit function. Thus, the retailer faces the trade-off, balancing the profitability and customer utilities. Although the model objective is to optimise the retailer's profitability, the retailer cannot achieve this goal without considering customers' utilities. Customer heterogeneity is considered, and they can leave the market if their utilities are not positive.Furthermore, to ensure customers with fair prices, a consistent unit selling price is set across different selling channels to avoid price discrimination. Additionally, modelling multiple selling channels face other concerns, like social justice underlying distribution and accessibility to a retailer's services (Le Menestrel and Van Wassenhove, 2009). For example, people with disabilities or little computer literacy face limited access to online channels. This model considers channel accessibility and distributive fairness by allowing all channels available, e.g. online channels, stores, and omnichannel.

Thirdly, modelling involves a high level of understanding of mathematical language and technical skills, restricting the diversity of relevant audiences. Thus, I will communicate model assumptions, constraints, and uncertainties to the research audiences using theoretical and practical examples in the modelling process. Moreover, the modelling results and research findings are interpreted into managerial implementations at the end of the thesis to consider audiences without expertise or knowledge in mathematical modelling.

At last, to test the robustness of these models and ensure the interpretation is credible and consistent, the numeric analysis uses generalised data other than collecting actual customer and retailer data, which reduces biases, such as racial, ethnic, and gender issues. The formulation process, assumptions, and calculations have been included in the thesis to ensure that the research design and conduct are reproducible.

3.5 Modelling

The nature of this research is applied research to improve understanding of the decision making of shipping and return policies under omnichannel context. The results will provide managerial insights into the operational decision for omnichannel retailers. Our findings are relevant to operational managers or retail managers for making shipment decisions.

3.5.1 Problem Description

According to the decision theory, the decision maker will choose from a course of alternative actions wherein the associated consequences of this choice are not completely predicted due to uncertain nature of the world (North, 1968; Parmigiani and Inoue, 2009; Peterson, 2017). When setting up a decision, the first thing is to define who the decision maker is. It can be a person, a business, an organisation or a government. A decision-maker is assumed to choose based on his belief, knowledge, information, or attitudes towards the choice, which are the decision-maker's preferences (Steele and Stefánsson, 2015). His objective is to make optimal choices under uncertainty, complexity, risks, and dynamics (Howard, 1968) when he only knows partial information (Peterson, 2017).

3.5.2 Define Variables

Therefore, the decision-maker in our model is a retailer that has both online and offline channels. The retailer faces three decisions from the following alternative actions: 1) whether to allow customers to buy online and collect in-store or return in-store; 2) whether to charge a fee for in-store collections or returns; 3) how much should the omnichannel shipment be charged? The decision-maker's objective is to maximise the overall profit. Hence, this study simplifies the omnichannel operations into essential factors.

I will start with defining independent variables. In the retailing business, the unit selling price is an essential factor impacting customer demand and is initially determined by the brand other than retailers. Thus, it makes sense to define a product's unit selling price as an independent variable, which will be the same across all selling channels. I also define the operational costs for selling a product in-store and online as independent variables. Pricing is a tool for balancing supply and demand and efficiently allocating goods (Talluri and Van Ryzin, 2004*c*). The price includes the product selling price and the service involved, such as delivery fees.

Then, the retailer will decide the policy factor to maximise their total profits, which are dependent variables in this study. As this study focuses on a retailer's choices in shipping strategy, the first decision variable is the home delivery fee when a consumer purchases a product online. This shipping fee represents the cost of transferring items from DC to the customer selected address. Depending on the retailer's supply chain networks and operations, the shipment costs can vary for each delivery (Chintagunta et al., 2012) and across different sectors. This shipping fee will impact customers' purchase intention online as it is vital in all stages of shopping channel choice (Chintagunta et al., 2012). The second decision variable is the shipping discount factor when a customer buys online and picks up in-store, which will impact the customer's decision to choose omnichannel service. Shipping fees are set as the key factor driving customers to choose a channel. Two scenarios are considered to capture the main features of omnichannel operations. One is when buying online and collecting in-store is unavailable, and the other is that omnichannel service is offered. By comparing between two scenarios, the impact of allowing omnichannel shipment could be learnt.

It is also vital to capture the essential relationship among these variables and precisely describe it (Howard, 1968). I will describe and structure the first model in detail in Chapter 4 and the second model in Chapter 5. The model structure is time-independent and linear in this study. The relevant variables are quantified to describe the retailer's preference, and I can evaluate and compare the retailer's outcome. According to the model purpose, values representing the retailer's profitability will be assigned to each outcome according to customer channel choices and our initial assumptions. Finally, the retailer can evaluate the outcome values in the decision analysis stage (Howard, 1968).

3.5.3 Define Utilities

In this study, utility theory is chosen to characterise customer channel choices. It assumes one's preferences in mathematical language, and the decision-maker will quantify the utilities of alternative actions and choose rationally under consistent conditions (Fishburn, 1968; Keeney, 1982; Barberà et al., 2004). The decision-makers in decision and utility theories are distinct.A retailer decides the shipping and return policies, and a consumer makes decisions in purchases and returns. A retailer's decision will be impacted by operational and financial factors, while a customer's choice is based on utilities. Utility theory can be useful in predicting a customer's choice behaviour or prescribing how a customer should choose (Fishburn, 1968). I choose prescriptive utility theory because a customer is assumed to consistently follow a logic-based assumption. When choose from a series of course, a decision-maker can face the uncertainty of what will happen after selecting an alternative action(Fishburn, 1968).

In the simplest utility form, the decision will be made according to only one attribute. For example, a customer chooses a product solely based on its monetary attribute and will prefer the product with a lower selling price to those with higher prices. In this study, multiple factors impact customer channel choices, and they are heterogeneous in their preferences. MAUT is also considered, which is extended from the theory developed by Neumann and Morgenstern (1944); Morgenstern and Von Neumann (1953) to characterise a customer's preference with multiple attributes. These attributes could be formulated into numerical functions and assigned values, calculated, and compared under setting assumptions. After setting up attributes, I can decide how to compare alternatives. Based on the theory of Neumann and Morgenstern (1944); Morgenstern and Von Neumann (1953), Expected Utility Theory (EUT) allows decision-makers to compare and choose between probabilistic alternatives under uncertainty through formulating preferences and quantifying the utility resulting from each action (Parmigiani and Inoue, 2009; Van De Kaa, 2010). Utilities refer to the extent a decision-maker prefers the alternative. Thus, the chance of each consequence can be quantified and compared. EUT preference functions follow certain axioms, such as order, continuity, and independence (de Moraes Ramos et al., 2011).

Customers will decide whether they purchase and return based on their utilities. Based on Neumann and Morgenstern (1944), a utility could be assigned to the consequence of each choice with the belief that a customer will choose the alternative with the highest expected utility to follow certain axioms. Hence, in my models, customers are assumed to be rational in choosing a selling channel to purchase or return, maximising their utilities. Thus, they face four choices 1) whether to buy a product, 2) which channel to buy a product, 3) whether to return the product if it does not match the customer's expectations and 4) which channel to return the product. Customers' purchase decisions are influenced by their product valuation, unit selling price, and sensitivities to risks or hassles of visiting a store and shipment costs. Specifically, in my analysis, customers are heterogeneous in the product valuation and hassle costs of visiting a channel. Similarly, in the post-purchase stage, the customer's return decision will be affected by product valuation, unit selling price, the chance of mismatching after receiving a product, hassle cost of returning through a channel, and shipment cost. He may face the valuation uncertainty whether a product's value matches their expectations, especially for online shopping. As a result, he could encounter the hassle and monetary risk of returning a product. Correspondingly, the uncertainty of a customer's product valuation and hassle costs will lead to various channel demands. As a result, the customer demand on each channel will vary along with their perceived utilities.

Choosing between online channels and stores, shipping fees and brand reputation are critical influences (Smith and Brynjolfsson, 2001; Chintagunta et al., 2012). Previous studies categorised transaction costs (Bell et al., 1998; Fox et al., 2004; Betancourt, 2005; Briesch et al., 2009; Chintagunta et al., 2012). For stores, there is the opportunity cost of time, including travelling to and from stores, searching, picking, packing and waiting time in-store, travel cost to and from stores, negative perceptions such as inconvenience, dissatisfaction, frustrations, and risk of OOS. There are delivery fees for online channels depending on time and selected locations, time of waiting for home delivery, potential risks of missing a delivery and receiving mismatched items, and potential hassle of returns. These hassle costs affect whether a customer channel choice. Two factors are used – hassle cost and shipping fees to distinguish our channels, as customers tend to search, compare, and then purchase products from a cheaper or more convenient selling channel (Fassnacht and Unterhuber, 2016; Xu and Jackson, 2019). Based on the utility theory, customers will compare the benefit of perceived product value and the costs, such as unit selling price, shipping fees, and hassle cost of visiting a channel. Hence, a positive utility of buying a product from a channel will increase purchase intention. Hence, the total price combining unit selling price and a shipping fee is critical for a customer's channel decision (Abad and Jaggi, 2003; Xu and Jackson, 2019).

In the post-purchase stage, if customers request a return, a hassle cost will incur if they choose to return in-store due to the extra time and potential transport costs involved (Hviid and Shaffer, 1999; Gino and Pisano, 2008). The hassle cost can vary depending on return policies and in-store operations, such as the requirement of order receipts, time length of processing refund, strictness of refunding products on promotion or paid by vouchers or gift cards, and the convenience of returning in-store. Return policies will influence their purchase intention and channel choices. The restriction of return policies varies across retailers and sectors. The return hassle depends on the length of product benefit, the chance of cross-selling, and salvage value of returned products (Davis et al., 1998). My research matter is the return shipment. I intentionally exclude the refund amount in this discussion, such as partial refund, and will focus on the return shipping and handling fee. The return hassle is separated into two elements to clarify the associated hassle cost. One is the hassle of returning to stores, and the other is returning fee. This setting allows us to quantify the negative customer perception associated with returns, especially under multiple return channels.

Due to the character of products, such as standardisation, intangibility, customer participation, and perishability, customers are heterogeneous in product valuation (Liu et al., 2019). Thus, I consider two types of customers. One is homogeneous in the product valuation but heterogeneous in the hassle cost of visiting a channel. The other is heterogeneous in both product valuation and hassle costs. The scenario when customers are homogeneous is compared with that when they are heterogeneous in model one. The prices of the products are fixed. The customer demand is changeable depending on the retailer's shipping policy.

3.5.4 Assumptions

Our primary theoretical assumption is that decision-makers are rational. In utility theory, customers are assumed to act rationally and maximise utility based on certain consistency conditions and within constraints (Barberà et al., 2004; Van De Kaa, 2010; Ramos et al., 2014). In the decision theory, retailers are rational in choosing alternative options to maximise their profitability.

In order to describe the uncertainty, the probability is used to characterise the chance of choosing an alternative action. The level of uncertainty can range from a deterministic scenario where all variables are available to an extremely probabilistic circumstance where few variables are known (Howard, 1968). The probability can be interpreted variably from representing the features of a scenario itself to measure the principles about the scenario (Howard, 1968). A subjective approach is used to quantify the probability of uncertainty (Howard, 1968).

I normalised the market size to 1 for the following reasons. First, normalisation helps convert the retailing market into a scalable standard range, giving variable values between a lower bound

0 and an upper bound 1. Second, some parameters are uniformly distributed within this fixed range between 0 and 1 to simplify the equation calculation, probability comparison, and numerical analysis. Third, normalisation provides researchers with a standard and consistent position to identify the minimum and maximum value with a limited impact of non-essential factors.

For the retailer, the unit selling price is the same across channels for this research focusing on shipping and return fees other than the selling price itself. Moreover, it limits the concerns of pricing discrimination based on distribution. In the ex-post stage, if customers request a return, retailers offer FR to exclude the impact of the refund amount on the purchase and return decisions. In terms of characterising omnichannel operations, costs vary across channels. For customers, they are rational and make their channel choice based on their perceived utility. The hassle cost of visiting a store in the pre-purchase stage is perceived the same as that in the post-purchase stage since similar time and travel costs will incur no matter the purpose of visiting a store.

The constraints reflect either business goals or limitations set by the organisation (Phillips, 2005), and I will discuss model constraints in detail in Chapters 4 and 5.

3.5.5 Model Stages

Models with multiple stages are developed to characterise the shopping journey(Kollmann et al., 2012). For example, a two-stage model is made of the pre-purchase stage and purchase intention during the transaction stage (Schröder and Zaharia, 2008; Kollmann et al., 2012). A three-stage model consists of pre-purchase, during-purchase, and post-purchase stages (Steinfield et al., 2002). A four-stage model separates pre-purchase stage into requirements determination and vendor selection (Choudhury and Karahanna, 2008).

Two stylised models are developed considering pre- and post-purchase stages. One focuses on the ex-ante stage only, and the other is consists of both stages. The shopping stage is not divided further, given that the centre of this study is how shipping and return policies impact customer channel choices and profitability. For the research matter, it makes more sense to discuss the pre-purchase stage as one other than splitting it into information gathering, the retailer's selection, and transaction. Hence, the first model only focuses on the ex-ante stage and how the omnichannel shipping policy impacts customer purchase decisions across channels and retailer profitability. The second model concentrates on the ex-post stage and how the omnichannel return policy affects customer return decisions, channels, and corresponding profitability. However, I will consider both ex-ante and ex-post stages in the second model because returns can only happen after purchases. Considering both stages allows me to discuss how omnichannel shipment policy affect different stages of the customer journey. The shipment cost occurs during home delivery, collection in-store, collection for online returns, and handling returns in-store. Sometimes, customers have to pay for home delivery and returns, whereas some retailers embed return cost into the home delivery fee. Hence, using two models helps look into how the shipping policy affect customer choice in the ex-ante and ex-post stages. Moreover, it eases the complexity of the model structuring and simplifies mathematical calculations.

3.5.6 Model Objectives

Normative decision theory is used according to Peterson (2017), prescribing what better choice a decision-maker should make with the assumption that they are rational (MacCrimmon, 1968; Howard, 1988; Vazsonyi, 1990; Peterson, 2017). As the definition can be significantly distinctive case by case, in this study, the criteria of a better choice are based on the retailer profitability. Instead of focusing on how customers actually make choices, changing over time or across cultures, the shipping and return policies are discussed on how the retailer should choose to maximise its profitability. Stylised models are proposed without time or cultural differences.

I also use revenue management (RM) theory to allocate selling resources (e.g. channels with various operating costs) through demand-based variables (Choi and Mattila, 2004; Cetin et al., 2016), maximising the retailer's profitability (Strauss et al., 2018) subject to a set of constraints, such as operational costs and shipment costs (Phillips, 2005; Cetin et al., 2016). It is important to charge the right service at the right price on the right channel to the right customer segment (Phillips, 2005). RM is usefully applied when customers are heterogeneous and demands change when circumstances vary. Understanding how demands and revenues respond to customer heterogeneity can help improve profitability (van Ryzin and Talluri, 2005). Customers will be segmented into groups during RM implementation based on characteristics, behaviours, and preferences (Talluri and Van Ryzin, 2004*d*). In this study, customers are segmented depending on their heterogeneity in product valuations and tolerance of hassle costs. This setting helps examine how customer demands are influenced by product types and the convenience of services. The optimal shipping and return policies are identified to maximise retailer profitability.

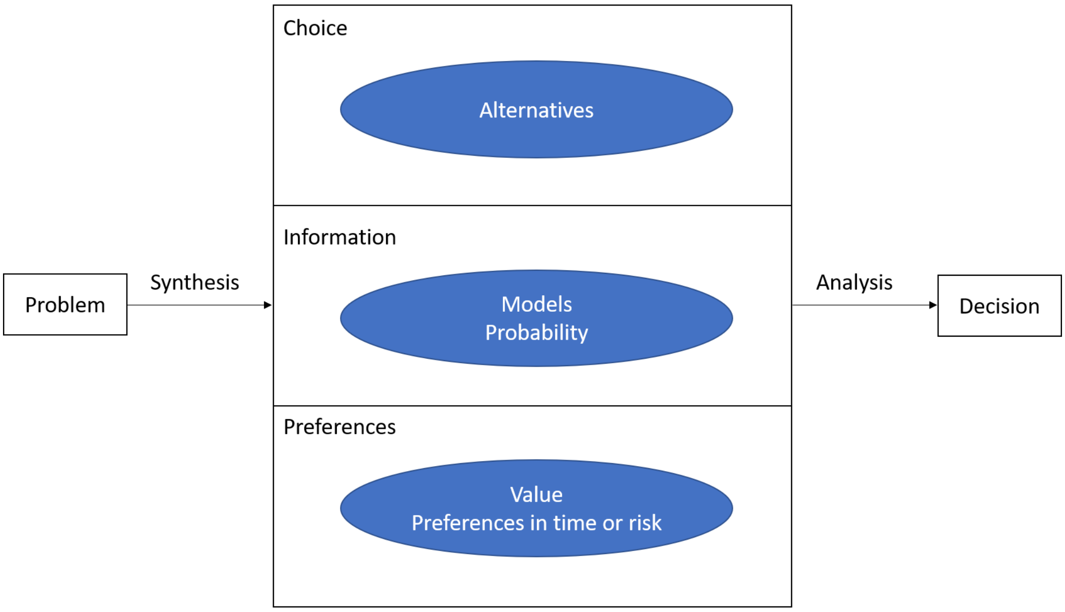
The trade-offs in my models are whether the benefit of customers migrated from one channel to another surpasses the costs of implementing omnichannel services. In the first model, operational costs vary across different channels. Moving online traffic into stores may bring new customers and potentially increase the chance of cross-selling in-store. However, the profit growth from new customers and potential cross-selling do not always cover the profit loss of channel migration and additional in-store operational costs of handling omnichannel orders. The profit loss of channel migration happens when selling a product online is more profitable than in-store. Hence, the first model will allow the retailer to explore the opportunity of using shipping fees to balance the channel migration and profitability. In the second mode, if a customer decides to return a product, the retailer will lose sales and incur extra costs for handling online returns. Thus, allowing customers to buy online and return in-store could potentially reduce the online return costs and increase cross-sales. However, the profit loss from selling a returned product at a salvage value in-store may be more than the benefit of allowing cross-channel returns. Therefore, the second model will allow the retailer to explore the opportunity of turning negative returns into a positive impact on profitability.

3.6 Research Analysis

The procedure of decision analysis (see Figure 3) involves , eliciting, evaluating, and appraising the decision problem (Howard, 1988). Thus, after models are formulated, this study can analyse the results, such as solving objective functions, comparing solutions, evaluating and interpreting results. The model objective is to maximise the retailer profitability and decide the optimal shipping and returning policy. Thus, I choose decision analysis, a quantitative application of analysing decisions under uncertain conditions (Siebert, 2003).

3.6.1 Decision Analysis

Decision analysis means that this study quantifies and compares the expected costs and outcomes of different scenarios considering probabilities. It provides a framework to unify traditional operations research and systems analysis techniques with computer-aided judgements to support decision-making. With decision analysis procedures, researchers use models and available data



Source: Howard (1988)
Figure 3: Decision Basis

information for tests to quantify the likelihoods of various consequences of alternatives in terms of probabilities. Decision analysis aims to produce insight to help decision-makers make better decisions other than solving decision models themselves (Howard, 1988). A good decision is an action that is logically consistent with the alternatives, the information, and the preferences (Howard, 1988).

The retailer offers customers three channels: online channel, physical stores, and omnichannel. In this model, these channels are distinguished based on operational costs and service charges from the retailer's perspective and hassle costs and shipping fees from a customer's view. Omnichannel shoppers are primarily driven by convenience (Xu and Jackson, 2019). The key drivers are formulated for consumer channel choices: 1) product valuation, 2) unit selling price, 3) shipping fees, and 4) hassle cost of visiting a channel. The perceived value can be homogeneous or heterogeneous. For channel transparency and price fairness, the unit selling price is consistent across channels. Shipping fees and hassle costs vary based on channels. Unlike Gao and Su (2017), inventory availability is not considered in this research. Both online and omnichannel have inventory because the risk of OOS is incorporated into the hassle of visiting a store. Customers will not buy directly from stores if they perceive the risk of out-of-stock is high. The retailer's shipping policy will impact shipping fees and hassle costs of visiting a channel. Customers face two decisions in the ex-ante stage, i.e. should they purchase a product? Which channel should they choose? Likewise, they also face two decisions in the ex-post stage, i.e. should they return the product? Which channel should they choose? As a result, customer demand will migrate across channels under the retailer's shipping policies. I endogenously determine customer demand function incorporating the channel choice drivers above.

Product price affects customer perception of product values and channel attributes (Iglesias and Guillén, 2004; Xu and Jackson, 2019). As the unit selling price is consistent, this study mainly discusses the service fees in this analysis. I segment customers based on their heterogeneity and discuss three scenarios depending on whether or not the retailer offers omnichannel services and how they are charged. Next, three scenarios are compared, and the optimal policies and corresponding conditions are identified. The scenarios are discussed in detail in Chapters 4 and 5. Customer segments are compared to examine whether the product valuation could impact the research results. Particularly, a customer's product valuation can vary based on the product categories. This setting will provide insights to help retailing practitioners understand the effectiveness of shipping policy in different product categories. Three scenarios are discussed since I can compare how different shipping policies impact the retailer profitability and how the optimal policies may change according to the parameters.

The second model focuses on return policies. Since it involves ex-ante and ex-post stages, the decision tree, a basic decision-analytic approach, visualises a decision process as the shape of a tree (Peterson, 2017), representing alternative options and the consequences of each option (Hunink et al., 2014). It is used for sequential decisions involving separate and multiple steps. There are two types of nodes: a choice node presents a decision-maker's decision to go up or down in the tree; a chance node represents the probability that an option may happen (Peterson, 2017). The decision tree illustrates branches after each alternative action. The number of branches depends on the number of possible options of each scenario. Decision tree is chosen because it is effective in analysing two-stage decisions with a fixed time horizon (Hunink et al., 2014). The first branch represents whether a customer purchases a product from the retailer, and the second branch represents whether the product matches the customer's expectations. The last branch is the return decision. In the model, the probability of mismatched products is for online purchases. This probability makes sense as customers pay online without receiving the actual order. Many reasons can cause the mismatch. For example, from customers' perspective, they may order the wrong sizes or change their minds without any reason. From a retailer's point of view, they may despatch the wrong item, or the online description does not match the actual product. The outcomes will show at the end of the tree by following the branches of alternative options. The decision tree can be quantified since the expected value of the consequence can be calculated, and the probability of each path can be weighted (Hunink et al., 2014).

3.6.2 Numerical Methods

Numerical analysis is a computer-aided numerical method that provides solutions to mathematical problems. It is widely utilised in solving mathematical problems originated from social sciences, engineering, medicine, business, and computer science (Atkinson, 1987). It was initially created by Newton–Raphson and developed during the 18th and 19th centuries (Atkinson, 1987). Numerical analysis is a helpful method for obtaining solutions to mathematical problems. Researchers can replace a mathematical problem that cannot be solved directly with a less complex approximation (Atkinson, 1987). The numerical analysis aims to yield an approximation other than striving exactness (Hildebrand, 1987). Additionally, it helps researchers extract valuable insights from available solutions (Hildebrand, 1987). Researchers can carry out numerical experiments by calculating models and observing how models respond to variables that vary over the setting value range (Bowman et al., 1993). A good numerical analysis is effective and robust(Lambers et al., 2019).

In this study, I conduct numerical analysis in Wolfram Mathematica 12 to study the scenario when customers are heterogeneous in product valuation and hassle cost. Retailers charge omnichannel service for a cheaper rate than home delivery. The equations for this scenario is the most complicated in comparison to the other two. The numerical analysis allows me to assign parameter values, i.e. unit selling price and operational cost variance across channels, shipping discount, and hassle cost. It is challenging to collect data representing actual retailing operations. Information, such as profit per product, delivery and handling costs per product, is often inaccessible or inaccurate, or retailers have different accounting methods. Thus, this study does not collect data from customers and retailers. Instead, data that is generalised value is chosen within the setting range, representing different operating features. I can then observe how the optimal shipping policy changes when variables change, conducted in Chapters 4 and 5.

3.7 Research Reliability

Reliability refers to the extent to which data collection techniques or analysis procedures will yield consistent findings (Saunders et al., 2019). I will assess the research reliability by testing whether research results still hold when parameters change within the setting range, according to Easterby-Smith et al. (2012); Saunders et al. (2019). The process of modelling and numerical experiments will be demonstrated in detail in Chapters 4 and 5, and the model calculation will be shown in the appendix to ensure the observation and model results are repeatable and traceable. As generalised data is used other than data collected, further explanation is needed on what the data represent when discussing the numerical experiments. A concern in the research design is the extent to which research results are generalisable, that is, whether research results may apply to other research settings (Robson, 2002; Saunders et al., 2019). Therefore, the robustness of research conclusions should be tested.

3.7.1 Sensitivity Analysis

Sensitivity analysis is a method to measure and assess the effect of research design, including modelling parameters, data collection, result interpretation, and assumptions, on the reliability and robustness of research outcomes. Sensitivity refers to how the solution to a research problem responds to small changes in the data or the problem's parameters (Atkinson, 1987). Sensitivity analysis is crucial in developing models and interpreting model outcomes since researchers can gain essential insights into its response to changes in the model inputs (Borgonovo and Plischke, 2016).

To test the robustness of the models and explore possible interaction effects, I conduct one-factor-at-a-time (OFAT) experiments. The factor levels are selected based on assumptions and constraints. Each factor is set at low and high levels reflecting a reasonable magnitude difference for the experiment. If the value is below 0.5, then the factor is low, and vice versa. I set 0.5 as the cut-off point because the factors range between 0 and 1, and 0.5 sits in the middle of the value range. The chosen factors play critical roles in moderating the optimal profit, and I can observe how the optimal profit changes along with the chosen parameters at low and high levels.

This model does not aim to verify the correlation between parameters. Hence, the sensitivity analysis aims to understand how the outcomes in each proposition respond to the variance of model parameters. Non-homogeneous demand and complex profit functions will be tested. The data intervention is equal and chosen to reflect certain operational features. The simulation and numerical analysis are conducted in Wolfram Mathematica 12. Parameter value changes from 10% to 80%, and find the rough turning point. Then the change of parameter values can be narrowed down and observed how the optimal profit changes. Later, graphs are developed to demonstrate the data obtained from the simulation. These graphs illustrate whether the relationships observed in the simulation are consistent with the model outcomes from analysing each proposition. Finally, managerial insights will be learnt from the sensitivity analysis.

3.8 Research Limitations

Research limitations are weaknesses or restrictions that are originated from the theory, methodology and assumptions researchers choose. Based on the epistemological assumptions, knowledge can be present in various formats, ranging from numerical to visual data and from facts to contextual opinions. Thus, it is crucial to understand potential restrictions to the choice of methodology and theories and subsequent research outcomes(Saunders et al., 2019). The research limitations may impact the interpretation of the research outcomes. In this section, the potential limitations are caused by the theories used and the model assumptions defined. In particular, it is highlighted how these limitations restrict the model results and applications. At last, I will go through the methods adopted to minimise the influence caused by these limitations.

The first limitation is originated from this theoretical assumption. Decision-makers are assumed to be rational, i.e. temporally stable, context-independent, have a preference order considering a choice criterion. Therefore, decision-makers are believed to make rational decisions to optimise their objective functions based on consistent conditions and constraints (Barberà et al., 2004; Van De Kaa, 2010; Ramos et al., 2014). However, human nature may pose an ultimate limitation (Howard, 1988; Van De Kaa, 2010). Utility theory is a useful tool in quantifying, understanding and predicting consumer behaviours, yet empirical studies dating from the early 1950s have commonly found that axioms in utility theories are inconsistent with decision-makers' actual choice behaviours (Bell and Farquhar, 1986; Starmer, 2000). Firstly, all relevant factors and dimensions influencing decision-makers' decisions or preferences may not be fully revealed or considered in the research. Unless all features are accounted for, it is difficult to reflect a decision-maker's decision process and choice preferences accurately (Bell and Farquhar, 1986). For instance, the actual channel choices are influenced by many factors, especially considering the market competition. Choosing the essential factors are natural procedures to process the information based on my understanding, as a result, cause biased judgements. In this mathematical modelling, distribution distance could be a relevant factor, but it is challenging to formulate all relevant factors in one equation. The level of accuracy, relevance and efficiency need to be balanced when addressing the research problems. Hence, this study concentrates on the elements essential to the research problems, allowing me to study the research matter in an effective and simplified format and achieve satisfied accuracy based on assumptions. This model is approximated to the research problem to a certain degree, and the research results will be interpreted based on this approximation. Secondly, the criteria of preference order are evidently not plausible as a real-life behavioural because each factor may weigh distinctively for different segments. For instance, customers who only shop online may value time over other factors and are willing to pay for delivery fees and accept the risk of returns. However, store customers may value the return hassle over other matters and are willing to visit a store to inspect the product and avoid returns. A preference assumption is generally guided by a logic-based criterion with consistency and coherence. However, if such an assumption does not follow common rules and is considered in a specific context, its credibility needs to be tested Fishburn (1968). The essential factors are prioritised based on their relevance to the research questions. Moreover, customers are heterogeneous in chosen factors. This setting allows flexibility reflecting customer variable choices and preferences.

The second limitation is that the purpose of decision analysis is decided by the researcher, limiting the applicability of research. Different from objective studies aiming to discover universal facts, subjective research focuses on different opinions and narratives. Therefore, subjective research hardly detaches the researcher's values and perceptions or even biases from their studies (Saunders et al., 2019). In order to describe the uncertain environment, a subjective approach that is value-laden is used. The retailer's objective function is defined to maximise total profitability. Profitability is chosen as the target because it is one of the most important indexes to measure a retailer's financial success. One shortcoming of normative decision analysis is that a decision with good intentions could negatively affect some stakeholders. The customer's utility functions are incorporated into the objective function as customer demand to avoid the scenario where the model results benefit one party only. Thus, the optimal outcome will consider both parties in the model.

The third limitation is from model settings. Some of the assumptions serve the purpose of calculation simplification, and they are not generalised to apply to all retailers. For example, the unit selling price is the same across channels, for this research focuses on shipping and return fees other than the selling price itself. However, the unit selling price could be different across channels as some stores can launch promotions locally. Moreover, the total cost of purchasing a product vary across channels in real life and this model. Second, Online channels differ from stores by defining cost variance. Omnichannel could be seen as an online operation because it is originated online and delivered from central DCs. This setting follows STS other than the SFS model. It is acknowledged that this setting restricts the generality of the omnichannel supply chain in this model. Hence, in the result interpretation, this assumption will be communicated. Third, the hassle cost in this model combines many influential factors, such as perception of OOS, travel cost, searching cost, time for queuing and payment. This setting limits the exploration in-depth on which factor plays the critical role in deterring purchase decisions. However, combining relevant hassle factors into one hassle cost makes sense, as it allows this study to focus on the hassle difference between channels other than hassles themselves. Four, in the second model, returns will not happen when customers buy in-store as they have inspected the product before purchases. This setting does not hold when customers are impulsive and show frequent return behaviours. Hence, customers are grouped by their channel choices. Last, accessing relevant data can be challenging as this study involves sensitive financial data, such as profit, unit handling cost, and unit delivery cost. The market size is normalised and assigned generalised values to the relevant parameters. Thus, this study can focus on the variance in demand across channels and total profitability other than the actual data.

At last, it is challenging to find prior research focusing on shipping and return fees and how they impact channel choices and profitability under the omnichannel setting. Although shipping policies are not contemporary, some studies focus on the order threshold of free delivery or study shipping policies for online retailers without considering the omnichannel effect. Not finding many recent and relevant academic papers may somewhat restrict the theoretical understanding for this matter under omnichannel retailing. However, shipment is broadly discussed in the retailing practice that can be observed and found supporting information for the model building and assumption setting. Compared to the works of experienced scholars, this study is also restricted by my experience in designing research, building models, calculating equations, analysing decisions and interpreting result outcomes. The scope and depth of shipping policies in omnichannel could be further explored and compromised in many levels, i.e. consider competitions between retailers, consider the effect of order threshold, and consider the availability of inventory.

Chapter 4

Model One - Omnichannel Shipping Policy

4.1 Model Background

High-street retailers are facing the pressure of rising operational costs (e.g. wages, leases, and utility bills), declining store footfall and fierce competition from other high-street stores, e-tailers, and manufacturers with direct channels (Thomas, 2018). The number of store closures has outstripped store openings in the UK for the past five years (PWC, 2019), and some of them were big names (Kollewe and Butler, 2020). Customers are attracted to alternative channels that are cheaper or more convenient. Thus, to capture extra footfall and shift online demands to stores, brick-and-mortar retailers adopt omnichannel strategies by leveraging their stores to cater to customers who are sensitive to prices and value shopping convenience. Click & Collect (C&C), where customers can place an order online and pick up or return in a selected store, has become a fast-growing implementation of omnichannel strategies. It made up 15% of UK online sales in 2014 (Mercer, 2014) and is expected to grow nearly 45% and reach around £10 billion by 2023 in the UK market, and has demonstrated a positive impact on the footfall and store cross-selling opportunities (Barclaycard, 2019). The top reasons customers choose C&C are guaranteed stock, quick order fulfilment, avoiding home delivery fees, reducing the risk of missing deliveries and product return (IMRG, 2018).

Table 5: Shipping Policies of Top UK Omnichannel Retailers for Non-members

Retailer	Shipment options	Order threshold	Shipping fees when meeting threshold	Shipping fees when below threshold
Asda	Home delivery	Yes	£1 - £7	Online orders must meet threshold otherwise the shipping service is not available
	Click & Collect	Yes	Free	Click & Collect orders must meet threshold otherwise the shipping service is not available
Tesco	Home delivery	Yes	£1 - £6.5	£5 - £11
	Click & Collect	Yes	Free	Up to £4
Sainsbury's	Home delivery	Yes	£0 - £9	Online orders must meet threshold otherwise the shipping service is not available
	Click & Collect	Yes	Free	Up to £4
M & S	Home delivery	Yes	Free	£3.5 - £5.99
	Click & Collect	No	-	Free
John Lewis & Partners	Home delivery	Yes	Free	£3.5 - £6.95
	Click & Collect	Yes	Free	Up to £2
Debenhams	Home delivery	Yes	Free	£3.49 - £9.99
	Click & Collect	Yes	Free	Up to £2
House of Fraser	Home delivery	No	-	£4.99 - £6.99
	Click & Collect	No	-	£4.99 and offer a £10 store voucher
Next	Home delivery	No	-	£3.99 - £5.99 for small items and £8 - £15 for large items
	Click & Collect	No	-	Free of charge
H & M	Home delivery	No	-	£3.99 - £5.99
	Click & Collect	Yes	Free	£ 3.99
ZARA	Home delivery	Yes	Free	£3.95 - £7.95
	Click & Collect	No	-	Free of charge
B & Q	Home delivery	Yes	Free	£5
	Click & Collect	No	-	Free of charge
Argos	Home delivery	No	-	£3.95
	Click & Collect	No	-	Free of charge

Note. Shipping policy obtained from the brand's official websites on 30th October 2019

However, shipping and handling online orders in-store can incur substantial costs. It requires additional investments and channel integration, e.g. upgrading IT systems, improving inventory transparency, and synergising assortments, promotions, and pricing (Gallino et al., 2014). Many retailers charge a shipping fee for online orders to compensate for the costs (Schindler et al., 2005; Jiang et al., 2013). This study selects 12 UK retailers with outstanding market share (Andrea, 2021) cross sectors and compares their shipping policies for non-members in Table 5. The information was collected before the global pandemic of coronavirus disease 2019 (COVID-19). Thereby, it may have been changed due to the pandemic. This study purposely excludes the impact of COVID-19, as many retailers, both e-commerce and physical stores, have adopted C&C during the pandemic due to the local or national lockdowns and restrictions. Although many retailers embrace omnichannel functions, they have implemented them differently. Some retailers adopt a strict approach. For example, ASDA and Sainsbury's offer home delivery only if an order value meets the threshold. Otherwise, it is available. Similarly, ASDA does not provide C&C if the order value is below the threshold, whereas Sainsbury's charges up to £4 for handling online orders in-store. In contrast, some retailers offer generous shipment policies, such as C&C is free of charge unconditionally or when an order value meets a threshold. In between the strict and generous policies, others charge C&C a shipping rate that is the same or cheaper than a home delivery fee when an order value is below a threshold. However, consumers are more sensitive to partitioned components' price that provide relatively low consumption benefits (e.g. delivery fees) than the product selling price (Brynjolfsson and Smith, 2001; Lewis et al., 2006; Hamilton and Srivastava, 2008). Therefore, this leads to two problems. First, customers expect C&C to be free or cheaper than home delivery because they complete the last mile, yet offering a free omnichannel service does not hold the promise of customer expansion. Moreover, it could dilute the retailer's profit by 1) converting demands to a less profitable channel; 2) conflicting with in-store priorities, thereby reducing in-store efficiency; 3) missing the best window for selling seasonal items if customers do not pick up their parcel and decide to return. However, charging C&C at a home delivery rate could deter customers from using the service and reduce the order conversion (Jiang et al., 2013). Especially, competitors are offering generous omnichannel services. Second, customers expect the process of C&C to be convenient, such as collect via drive-thru or at check-in counters or nearby third-party stores, so their searching and waiting time could be minimum during collection. However, making the process too convenient may lose cross-selling opportunities. Thereby it is unknown whether the growing sales from providing conveniences would surpass the corresponding rising costs. Most studies discuss the shipping-fee-related problems from an online retailer's perspective, and the research in an omnichannel setting is scarce. This research studies the following questions in this paper:

- How do operational factors affect retailers' shipping policies for C&C in the omnichannel setting?
- How do shipping policies for C&C affect the total demand and customers across channels?
- What is the optimal shipping policy for C&C maximising total profits in an omnichannel setting, and under what conditions?

To answer the questions above, this model develops a stylised model to capture essential operating characteristics of an omnichannel retailer and the consumer choice across channels. The retailer faces the three decisions: 1) whether to allow customers to collect their online orders in-store; 2) whether to charge for the omnichannel function; 3) decide the optimal shipping charge for collecting omnichannel orders. Customers face two decisions: 1) whether to purchase a product; and 2) determine which channel to purchase a product. Customers are heterogeneous in how they perceive the product value and hassle costs of visiting a channel. Thus, customers will make their channel choices for purchases based on their heterogeneous perceptions and the shipping policy, which vary depending on the retailer's strategy and features of omnichannel operations. From a single-channel view, most of the relevant omnichannel studies have been conducted from pricing, inventory or supply chain. However, this study concentrates on shipping policies under the omnichannel context, particularly, the online-to-store fulfilment and its service charge. The optimal omnichannel shipping policy will be identified, and the corresponding conditions will also be discussed. This study could help understand how elements of shipping policies (including whether to offer an omnichannel function and whether to charge a shipping fee for it) affect customer demands across channels and the retailer's overall profits.

The rest of this chapter is organised as follows. In §4.2, relevant literature will be reviewed regarding the decision of shipping policies and the trade-offs in omnichannel operations. In §4.3 the research questions will be transformed into a simplified problem setting, so that the base model can be formulated and developed based on homogenous customers in §4.4. §4.5 will analyse the effect of different shipping policies on customer demand and retailer profitability by comparing the shipping policy in each scenario with the benchmark. In §4.6, the model is extended by considering customer heterogeneities, and in §4.7, a series of numerical analyses will be conducted. This chapter ends with summarising the model results and briefly discuss the key managerial insights in §4.8. All proofs and relevant numerical studies are in Appendix A.

4.2 Relevant Literature

This model is predominantly relevant to two streams of research: one is the shipping policies of online businesses, the other is operational trade-offs during omnichannel implementations.

Existing works in the first stream discuss how elements of shipping policy impact customer demand and retailer profit. Boyaci and Ray (2006) develop an analytical framework based on capacity management to study the price-based, time-based, service-based elements in the shipping policy and how these factors impact the optimal shipping policy to maximise profit. They discuss three cases by exogenising these elements differently and understanding customer preferences in the shipping policy. This study also discusses the shipping pricing but under an omnichannel setting. (Hua et al., 2012) incorporate discount rate and transportation cost into an analytical model to study the optimal order size for free shipping from a supply chain's point of view. The trade-off is between increasing the order lot size from supplier to retailer may reduce the order frequency but lowering the threshold for free shipment may hurt the total profit. They find that larger order sizes may potentially reduce retail prices if suppliers offer free shipment. This study primarily focuses on retailers' shipping operations other than the supplier shipment decision. Some focus on two forms of shipping policies. One is fixed-rate shipping fees, where customers pay identical delivery fees when placing an order online regardless of the order size, weight or value. The other is a threshold-based shipping discount or free delivery. After comparing these two forms in an empirical study, Koukova et al. (2012) find that fixed-rate shipping fees are more favourable when the initial order value is below the threshold and vice versa. Lewis (2006) reveals that base delivery fees and order thresholds impact customers' choices and purchase retentions by analysing an online retailer's data. Leng and Becerril-Arreola (2010) study a retailer's joint decision of selling prices and order thresholds with the consideration of repeat purchase behaviours (Ehrenberg, 1988) and customer heterogeneities by developing a two-stage model. Jiang et al. (2013) explore the optimal shipping fees jointly with product selling prices for single and multiple product transactions through non-linear mixed-integer programming models. Cachon et al. (2018)

assess a retailer's profitability using an online retailer's data and identify conditions of profitable threshold-based policies. The order threshold is set slightly above the average order size, and the shipping fee accounts for a small portion of the total expenses. The studies above compare fixed-rate shipping with the threshold-based policy to examine how they influence customer purchase behaviours. They also explore the optimal shipping fees and thresholds, yet all from an online retailer's perspective and do not consider the complexity of omnichannel operations. This study filled the gap by characterising the operational features of omnichannel in the model building and focusing on the shipping policy of C&C, particularly how this shifts customers across channels. Moreover, this study identifies the optimal shipping policy for C&C and corresponding conditions in an omnichannel setting.

The other related stream of research considers operational challenges in omnichannel retailing businesses (Brynjolfsson et al., 2013; Bell et al., 2014; Shen et al., 2018; Verhoef et al., 2015; Cao and Li, 2018; Mou et al., 2018). The impact of implementing omnichannel functions (e.g. BOPS or C&C) on customer choices and profits have been studied. Some researchers choose empirical methods to look into how customers shift among channels: customers' migration between channels (Ansari et al., 2008); customers' choices between online and offline channels (Chintagunta et al., 2012); the impact of C&C on sales in-store and online (Gallino and Moreno, 2014). Akturk and Ketzenberg (2021) empirically study the effect of BOPS on cross-channel behaviours considering the market competition. They find that webrooming behaviours where customers research online and purchases in-store are enhanced and shifting online demand to the competitor's stores if free BOPS is offered. Similar to Gao and Su (2017), they find customers may not visit stores due to the information effect of BOPS. This study is similar to theirs as store demands increase due to shifted online traffic and cross-selling. In contrast, the study results show that the addition of C&C does not always positively affect the online-to-store conversion, total demands, and the retailer's profitability. It depends on the choice of shipping policies and customer heterogeneities. Furthermore, their works empirically examine how cross-channel functionalities affect retailers' performances and customers' channel choices, while this research theoretically explores the optimal shipping policy of cross-channel functionalities.

As omnichannel fulfilment can be implemented in various forms, some studies discuss the omnichannel fulfilment decision, including STS and SFS under an omnichannel setting. Fairchild

(2014) develop a framework to define and assess the Third Party Logistics (3PL) under the omnichannel setting from a logistical view. Gallino et al. (2017) the effects of ship-to-store on the overall sales contribution of different products and inventory. Akturk et al. (2018) empirically analyse retailers' transactional data to assess the performance of STS in pre- and post-purchase stages. They find that STS enhances cross-channel behaviours by shifting online customers to stores, especially for high-value purchases. However, Ship to Store (STS) affect revenues in ex-ante stage and returns in the ex-post stage differently. Yang and Zhang (2020) develop an analytical model to study the effect of implementing SFS on a firm's profit based on newsvendor and considering strategic customer behaviours. They investigate the trade-off: SFS positively improves delivery efficiency whereas shifting store customers online. When SFS does not significantly impact the expansion of the customer base, the store-to-online demand migration negatively affect the retailer's performance. Bayram and Cesaret (2020) use a heuristic method to investigate a dynamic decision of whether an online order should be fulfilled from DC or a nearby store to maximise profit under the STS setting. Their model allows online channels to differ from stores by having separate inventory levels. They identify the optimal threshold policy with cross-channel fulfilment and the condition when STS is profitable considering shipment cost, inventory, sales and customer satisfaction. This study is relevant to theirs as our studies aim to understand the trade-off during omnichannel implementations, and the effect of omnichannel functions on demands and profit considering distinctive operating costs when fulfilling through different channels. However, this study characterises the differences of omnichannel operations by defining varying a unit handling cost in the model setting with the consideration of customer heterogeneity through theoretical modelling other than analysing transaction data. Moreover, this study uses utility and decision theories to develop an analytical model and provide insights associated with omnichannel practices.

Besides, there are relevant theoretical studies in omnichannel operations. Gao and Su (2017) develop a stylised model to discuss the effect of Buy Online and Pick-up In-store (BOPS) on store operations (e.g. profits inventories). It helps reach new customers but may not be profitable for products sold well in stores. However, online demand is exogenous in their model, which is limited to explain how online demands allocate. This study endogenises customer channel choices and explores how both online and offline demands interact in response to the shipping policy. Also, They differentiate online channels with store operations by setting different hassle costs, while this model captures the channel variances in both hassle costs and operating costs. Kim and Chun (2018) study a monopolistic manufacturer's channel strategy by discussing channel conflicts (i.e. intra-cannibalisation and inter-competition) with its retailers using game theory. However, this study focuses on the channel interactions of an omnichannel retailer. Nageswaran et al. (2020) develop a stylised model to analyse two cross-channel return policies of an omnichannel retailer: full refund and partial-refund policies, and how they are related to in-store salvage values and retailer's profit. Although this study is similar to theirs in discussing how the cross-channel shipping costs impact customers and profits, this model concentrates on the pre-purchase, not the post-purchase stage. Moreover, in their model setting, customer channel preferences are exogenous. This model allows customers to be heterogeneous in the perception of product value and hassle cost of visiting a channel. An analytical model developed by (Cao et al., 2016) is very relevant. They study the effect of an online-to-store channel on the demand allocations and retailer's total profits under two scenarios: i) products are available online only; ii) products are available both online and in-store. They identify the optimal pricing strategy when unit selling prices are different across channels. In this model, selling prices are consistent, and I study how the shipping policy of C&C could shift the flow of customer migration to increase total profits. Overall, this study differs from the works above in the following ways. First, this model incorporates the shipping policy, especially the shipping fee, into the profit function, yet most research only focus on $p - c$. Second, this study endogenies customer channel choices depending on their sensitivity of risks and non-partitioned price and consider heterogeneities to further investigate how the shipping policy and customer segments impact customers choices. Third, besides discussing the selling price, this study sheds light on the service pricing and assumes the consistent unit price across channels. This study finds it necessary to review existing operations to implement an efficient omnichannel function, such as in-store operating costs, in-store assistant level, and online shipping policy, and understand how to adapt the omnichannel function to the existing operations.

This study discusses a retailer's decision to deal with shipping trade-offs to maximise profitability in the pre-purchases stage considering strategic customer behaviours. Therefore, this model of an omnichannel retailer's shipping-fee decision embeds in the decision theory, and customers' strategic choices in channels and their cross-channel behaviours are rooted in utility theories. In addition, as this model considers service pricing with the cost constraints, the profit optimisation is also under Revenue Management (RM) theory. These theories are widely adopted and discussed in operations management: history of decision theory (Tsoukiàs, 2008); development of decision making (Vazsonyi, 1990; Buchanan and O Connell, 2006); model formulation (North, 1968); utility theory (Bernoulli, 1896; Neumann and Morgenstern, 1944; Fishburn, 1968; Savage, 1972; Fishburn, 1988), the development of RM (McGill and Van Ryzin, 1999; Cetin et al., 2016), choice-based RM (Strauss et al., 2018; Talluri and Van Ryzin, 2004*a*), RM in retailing (Choi and Kimes, 2002; Netessine et al., 2006; Pauwels and Neslin, 2015). This research contributes theoretically by applying the utility and decision theories in dealing with shipping policies under the omnichannel setting and extending RM in determining the service pricing for an omnichannel function.

All in all, this study contributes to these two streams of research and understand the shipping policy of an omnichannel function (e.g. C&C) from an operating perspective. This study reflects retailing practices in the model building. First, one model assumption is that the unit selling price is identical across channels, so the different shipping fees impact customer channel choices. Second, this study determines the elements of shipping policies (e.g. whether to offer C&C and how to charge for this service) under an omnichannel setting, especially the effect of shipping fees on the cross-channel behaviours and retailer profitability. Third, this model does not consider the time-based element of shipping policy. Instead, it focuses on the pricing factor by separating the monetary cost from the hassle of visiting stores and incorporating the shipping fee into the demand and profit functions. Four, this model considers customer heterogeneity in product valuation reflecting the product categories with diverse perceptions and hassle cost of visiting stores, which can be caused by various factors while shipping in-store. Five, this model captures a retailer's operational factors, such as in-store selling costs, convenience level of C&C, and discount rate, and explores how these factors affect the shipping policy. Last, this study discusses three shipping policies and compare them with the benchmark when the omnichannel function is unavailable.

4.3 Problem Setting

This model describes an omnichannel retailer that sells a product via an online channel (shown as “o" in the model) and through a physical store (shown as “s" in the model). The retailer faces the choice of whether to leverage its stores for online fulfilment. This study will allow customers to buy online and pick up in a selected store (also known as C&C and shown as “b" in the model). Referring to Cao et al. (2016), the market size is normalised to 1 for the following reasons: 1) simplifying the model building and calculation; 2) generalising the market also ease the complexity of model comparison and profit maximisation.

Technologies have enabled customers to compare the prices of a product across channels and between retailers. Many high-street retailers offer a policy that guarantees to match competitors' unit selling prices, increasing consumer confidence in price competition (Hviid and Shaffer, 1999). Thus, this study will not differentiate selling prices. A product is sold at a unit selling price p that is consistent across channels (PWC, 2014). This setting is reasonable because it focuses on shipping charges other than unit price and represents the seamless and consistent shopping experience of omnichannel retailing expected by customers (Gallino et al., 2014). Moreover, different from many studies (Cao et al., 2016; Gao and Su, 2017; Li and Wang, 2019), this study exogenies p in the model because it helps focus on the decision of shipping policies other than product prices. The unit selling price is usually an average standard markup determined by the retailer over the unit cost suggested by manufacturers (Alexis, 2021). Next, this study denotes that an online shipping fee p_d could incur when consumers choose home delivery. The shipping fee p_d is not necessarily less than the unit selling price p, but their sum is $p + p_d < 1$ if customers purchase the product online. This setting is sensible because the unit selling price varies across sectors. Although the delivery fee is lower than the unit price in most cases, it could be the way around for grocery products, e.g. Tesco's shipping fee for online orders below a threshold is from £5 to £11 depending on the delivery slots, which may be higher than some grocery unit prices (see Table 5).

The retailer faces three decisions: 1) whether to offer an omnichannel function, e.g. C&C; 2) whether to charge for omnichannel function, as omnichannel orders are generated online, and online deliveries involve shipping fees; 3) if the retailer decides to charge for the service, what is the optimal shipping fee for C&C. A benchmark is set when the omnichannel function is not offered to understand further how the retailer makes these choices. Then three scenarios representing different shipping policies for the omnichannel function is available (i.e. C&C). The first scenario is when the retailer charges C&C service at the same rate as home delivery at p_d. C&C is free of charge unconditionally in the second scenario, and p_d is applied to home delivery only. In the third scenario, C&C will be charged less than home delivery at a shipping discount θ $(0 < \theta < 1)$, so consumers will pay p_d for home delivery and θp_d for C&C. This setting is sensible because Table 5 has demonstrated that retailers will decide the shipping service fee based on their operations, e.g. Tesco and Sainsbury's offer free C&C conditionally. Otherwise, they charge up to £4 for collecting online orders in-store if the order value is under the set threshold. Many factors could affect the discount factor θ: the efficiency of retailer's fulfilment (Verhoef et al., 2015); the cost of running a C&C in-store (Mou et al., 2018); the effect of cross-selling in-store (Gao and Su, 2017). For example, if the retailer can leverage their physical assets or third-party partners and integrate their processes cost-effectively, θ could be small, potentially driving online customers to stores through C&C. The setting range for θ is between 0 and 1, representing C&C is always less than the shipping fee for home delivery, as customers complete the last-mile delivery and charging a higher rate than home delivery will defer customers using this service.

Retailers are facing distinct operational costs across channels. Similar to Cao et al. (2016), this study assumes different operational costs between online and stores to reflect the trade-offs during omnichannel integration. Hence, a unit handling cost c_s will incur when a product is sold in-store. This study assumes the unit handling cost in-store is higher than that online $c_s > c_o$ due to high operational costs in-store (e.g. leases, utilities, labours, and depreciation). Moreover, one of the main handling costs for online orders has been captured as the home delivery fee. Nevertheless, unlike the cost setting for C&C refer to Cao et al. (2016), this study assumes the cost of selling through C&C is the same as c_o based on two reasons: i) consumers place C&C orders online, thereby omnichannel orders are searched, originated and paid through online channel, but fulfilled in a selected store; ii) although fulfilling C&C orders causes additional costs in-store, it could potentially increase the cross-selling opportunities (Barclaycard, 2019), which may partially compensate or even surpass the involved costs from local or central warehouses to stores (Gao and Su, 2017). This study sets $c_o = 0$ so that c_s indicates the unit cost variance between stores and online operations or C&C. This setting captures the operating difference other than the cost itself, which can vary across sectors. Also, it will ease the complexity of model calculation without the loss of generality. Considering the cost differences, this model assumes that selling a product through home delivery or C&C is more profitable than through a store because of the high in-store operational costs (Company, 2020). For example, online retailing can be operated in shifts other than store opening hours. It requires less rent as warehouses are normally located in suburban areas and less labour as the warehouse process can be highly automated (Miyatake et al., 2016).

Table 6: Table of Notation for Model One

Symbol	Description
v	the product value perceived by individual customer, where v is perceived homogeneously in the base model and in the extension, v is a random variable uniformly distributed within the range [0,1] ($v \in [0, 1]$);
h_s	the hassle cost of visiting a physical store perceived by individual customer, where h_s is perceived heterogeneously in both base model and extension as a random variable uniformly distributed within the range [0,1] ($h_s \in [0, 1]$);
h_b	the hassle cost of buying online and picking up in-store. Thus, $h_b = \beta h_s$, and $h_b < h_s \leq v$;
β	the factor of the inconvenience level of C&C service. It is assumed that the store hassle is more than using omnichannel function, thereby $\beta \in (0, 1)$;
p	unit selling price for a product. The price is fixed and consistent across channels. Thus it is assumed as a constant number between 0 and 1 in the model ($p \in [0, 1]$, and $p \leq v$);
p_d	the online delivery fee per product when consumers shop online, and it is the retailer's decision variable. The delivery fee can be either lower or higher than the unit selling price, but customers will consider a purchases only if the sum of unit price and delivery is less than the perceived product value, ($p_d \in [0, 1]$, and $p_d + p < v$);
θ	the discount rate for the shipping charge when consumer order the product through C&C ($\theta \in [0, 1]$). When $\theta = 1$, it represents scenario 1 where C&C is charged at the same rate as home delivery; when $\theta = 0$, it represents scenario 2 where C&C is free of charge; when $0 < \theta < 1$, it represents scenario 3 where C&C is charge at a discounted rate;
q_i	the consumer demand of each distribution channel for a product, and the subscript $i = s, o, b$, representing the consumer demand for stores, online channel and C&C, respectively;
Π_j	the total profit in each scenario, and subscript $j = 1, 2, 3$, representing scenario 1 to 3, respectively.
c_s	handling cost of selling a product in-store, as the handling cost of online channel c_o is assumed to be zero, thereby c_s also represents the cost variance between online and store operations.

All the notations are listed in Table 6. Refer to Cao et al. (2016), this study assumes that consumers are heterogeneous in product valuations. Thereby, they perceive the product value at v. In the base model, customers are first assumed to be homogeneous in perceived product values v, and then relaxed it in the extension by allowing v to be a random variable uniformly distributed between 0 and 1. This homogeneous customer valuation makes sense when products are highly standardised and offer similar benefits to customers, such as agricultural products, and the distinctive concepts between homogeneous and differentiated products can refer to (Rollo, 2014). This model sets h_i as consumer's perception on the hassle cost of visiting a channel, where the subscript $i = s, o, b$ represents stores, home delivery and C&C, respectively. The hassle cost of vising stores h_s is a random variable uniformly distributed between 0 and 1. The hassle cost h_s can vary due to many factors: travel distance (Bell et al., 2018), product properties (e.g. sizes and weights) and whether consumers are time-sensitive (Gao et al., 2018) or hassle-sensitive (Hviid and Shaffer, 1999). To further distinguish the inconvenience level across channels, this model assumes the hassle cost of shopping online as zero $h_o = 0$ for the following reasons. First of all, inconveniences of shopping online involve home delivery fees, waiting for delivery, risks of missing deliveries or hassle of returns, and home delivery fee is one of the main reasons customers abandon their shopping carts (Gümüş et al., 2013). In this model, a shipping fee is separated from online hassle costs, which would allow this research to focus on the main factor in the hassle costs and how shipping fees impact customer choices and retailers' profits. Secondly, although the online hassle is zero, this study allows p_d to be greater than h_s, which could deter customers that are delivery-fee-sensitive. Thus, the online channel is not dominant. Lastly, it simplifies the model calculation without loss of generality and allows the research to focus on the effect of differences in the inconvenience across channels other than the hassle cost on its own. One downfall of online shopping is product uncertainty. Although omnichannel orders are generated online, and customers have to go through the hassle of online ordering and visiting a store, using C&C service can avoid the risk of out-of-stock and the uncertainty of product and risks associated with home delivery (Gao and Su, 2017). Thus, refer to Cao et al. (2016), the hassle cost of using omnichannel h_b is assumed to be less than h_s, visiting a store directly. Thereby, a convenience factor $\beta \in (0, 1)$ is defined to reflect the convenience level of C&C, and its relationship with store hassle is $h_b = \beta h_s$. For instance, C&C is more convenient if the retailer could get the order ready for collection at any working time by the next or same day (Jasin et al., 2019), or allocate dedicated staff and spaces with clear signs in-store for C&C.

In the model extension, the assumption will be relaxed by allowing customers to be heterogeneous in two dimensions: product valuations and hassle cost of visiting each channel. The extended model assumes v as a random variable uniformly distributed: $v \in [0, 1]$, and h_i and v are independent of each other. Consumers will make their purchase and channel decisions to maximise their total utilities by considering the product valuation, unit selling price, the hassle cost of visiting a channel, and the shipping fee associated with the channel choice. Through comparing the base model with the extension, the results could help understand 1) the effect of customer heterogeneity on customer purchases, channel choices and retailer's total profit; 2) whether omnichannel function may work differently across product categories considering homogeneity and differentiations; the effect of customer heterogeneity on the retailer's shipping policies and omnichannel implementations.

4.4 Base Model - Homogeneous Customers

In the base model, q_i is denoted as the customer demand for a product on channel i, which is impacted by the unit selling price, delivery charges, perceived product values, and hassle costs of each channel. The subscript $i = s, o, b$ represents stores, home delivery and C&C, respectively. To understand how customer demand changes across channels, this model denotes that a consumer will gain a utility u_i after purchasing a product from a channel, and the subscript $i = s, o, b$, represents stores, home delivery and C&C, respectively. Customers make purchases and channel choices to maximise their utilities. Hence, the consumers' utilities for each channel are obtained as follows:

$$u_s = v - p - h_s \tag{4.1}$$

$$u_o = v - p - p_d \tag{4.2}$$

$$u_b = v - p - \theta p_d - \beta h_s \tag{4.3}$$

The customer will decide whether to purchase a product by comparing the product valuation v and unit selling price p, and when $v > p$, they will decide which channel to purchase from. If customers perceive the hassle cost of visiting a store higher than a home delivery fee ($h_s > p_d$), they will purchase the product online, and vice versa. The retailer will sell a product only from a profitable channel only. Therefore, the unit selling price is higher than the unit handling cost in-store ($p - c_s > 0$) to ensure selling through a store is profitable. In retailing practices, apart from product sales, delivery fees could be counted as a revenue component (ASOS, 2019), thereby the online shipping fee p_d is incorporated in the profit function for online channel and discounted shipping fee θp_d is embedded into omnichannel channel profit. Thus, the total profit function is obtained as below:

$$\Pi(p_d) \quad = \quad (p - c_s)q_s + (p + p_d)q_o + (p + \theta p_d)q_b \qquad (4.4)$$

where $p - c_s$ is the unit product profit sold in-store, thereby the term $(p - c_s)q_s$ represents total store profit. Similarly, the unit profit sold online is $p + p_d$ because of $c_o = 0$, the total online profit is $(p + p_d)q_o$. This model separates the shipping fee from online hassle costs and considers it as part of revenue. The unit profit sold through C&C is $p + \theta p_d$ due to the shipping discount factor θ, thereby the total omnichannel profits is $(p + \theta p_d)q_b$. When $0 \leq \theta < 1$, the unit profit via omnichannel is less than the unit profit online. Hence, the unit profit of selling a product differs across channels. For example, the unit profit online is higher than that in a physical store by $p_d + c_s$; similarly, the unit profit online is more than that through C&C by $(1 - \theta)p_d$; and the unit profit via C&C is more than that in-store by $\theta p_d + c_s$. This study denotes delivery fee p_d and the discount rate θ as decision variables. The value of discount rates, e.g. $\theta = 1$, $\theta = 0$ and $\theta \in (0, 1)$, will reflect the shipping policies from scenario 1 to 3, respectively (see the scenario summary in Table 7). The setting of p_d can be either smaller or larger than p, but online purchases can happen only when $p + p_d < 1$. This base model lays out the demand and profit functions based on different shipping policies when customers are homogeneous. Particularly, this study aims to understand how the shipping charge p_d for omnichannel function affects customer cross-channel behaviours and the retailer profitability.

Table 7: A Summary of Benchmark and Three Scenarios Discussed in Model One

Scenarios	C&C	Shipping fee for online orders	Shipping fee for omnichannel orders
Benchmark	Unavailable	p_d	-
Scenario 1	Available	p_d	p_d
Scenario 2	Available	p_d	Free of charge
Scenario 3	Available	p_d	θp_d

As customers are assumed to be homogeneous in the product valuation and their channel preferences are endogenous in the base model, the total demand for the product is determined by the unit selling price and perceived product value, which are identical in three scenarios. On the other hand, customer demands may vary across channels in response to the decision of p_d, β and θ. This study illustrates customer's channel choices for the benchmark and three scenarios in Figure 4. Benchmark and each scenario will be discussed in subsections §4.4.1, §4.4.2, §4.4.3 and §4.4.4, respectively regarding customer channel choices, demands and retailer profits. These demonstrate why omnichannel retailers adopt various shipping policies. In §4.4.5, the optimal shipping policy for omnichannel function and the corresponding conditions will be identified and analysed by comparing the benchmark with three scenarios Finally, this model explores the conditions for the optimal policies and how different parameters affect the results.

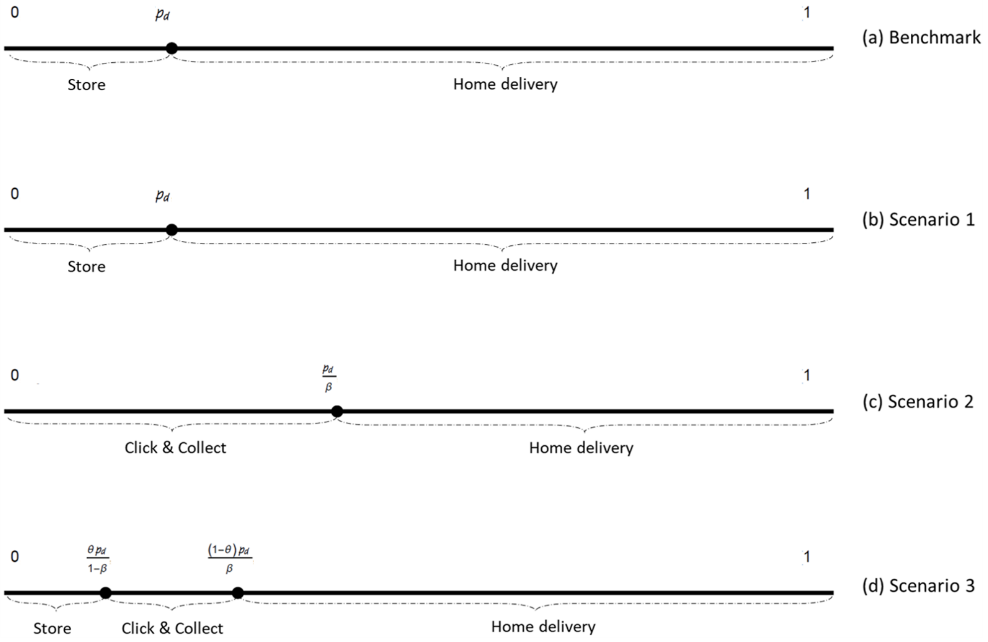


Figure 4: Consumer's Channel Choices in the Base Model in Model One

4.4.1 Benchmark - C&C is Unavailable

Figure 4(a) shows consumers' channel choices in the benchmark, where the retailer decides that omnichannel function (i.e. C&C) is not available. This case is set as the benchmark to understand why some retailers make C&C unavailable, and compare with three scenarios to understand how shipping policies of C&C could affect existing channels (e.g. cannibalise or expand) and retailer's total profit. In this case, customers will purchase in-store when $h < p_d$, or through online channel when $h > p_d$. Hence, the following functions are obtained including customer demands for stores q_s and online channels (home delivery) q_o and the retailer's total profit $\Pi(p_d)$:

$$\begin{aligned} q_s &= p_d && (4.5) \\ q_o &= 1 - p_d && (4.6) \\ \Pi(p_d) &= q_s(p - c_s) + q_o(p + p_d) \\ &= p - (1 - c_s)p_d - p_d^2 && (4.7) \end{aligned}$$

where q_s and q_o are obtained from (4.1) and (4.2), because a customer's channel preference is endogenous, thereby he will buy a product in-store if $u_s > u_o \geq 0$; otherwise, he will choose online channels if $u_o > u_s \geq 0$. Clearly, both online and store demands are influenced by p_d with opposite effects: store demands are increasing and online demands are decreasing in p_d. All proofs relevant to the base model are demonstrated in Appendix A. The total profit $\Pi(p_d)$ is obtained through substituting (4.5) and (4.6) in (4.4). The total profit is increasing in unit price p but decreasing in the unit handling cost in-store c_s. This can also be interpreted as that the larger cost variances between online and store operations, the more negative impact on the total profit. By maximising the total profit function with regards to the online delivery fee p_d, Lemma 1 is obtained as below:

Lemma 1. *When C&C is unavailable, the optimal online delivery fee is* $p_d^* = \frac{1-c_s}{2}$*; the maximum total profit is* $\Pi^* = (\frac{1-c_s}{2})^2 + p$.

This results is not difficult to understand, as the trade-off is cause by two things: 1) from the profit view, the online unit profit is higher than that in-store $p + p_d > p - c_s$, shifting online demand to stores means encouraging customers to purchase through a less-profitable channel; 2) from the demand view, the product valuation is assumed homogeneous in the base model, p_d plays an critical role influence customer channel choices, a higher p_d means less online demand but higher online profit. The total profit $\Pi(p_d)$ is concave in p_d, thereby get the optimal online delivery fee is $p_d^* = \frac{1-c_s}{2}$ in Lemma 1 when omnichannel function is not available. Moreover, the optimal home delivery fee is decreasing in c_s and independent with the unit selling price as p that is exogenous in the model. When the retailer faces a high operating cost in-store (i.e. higher c_s), he has higher motives to encourage customers to purchase the product online by reducing p_d. In contrast, if the retailer can operate the store in a cost-effective way (i.e. smaller c_s), the retailer should charge a higher delivery fee to nudge customers to visit stores. By substituting p_d^* in $\Pi(p_d)$, then get the optimal total profit $\Pi^* = (\frac{1-c_s}{2})^2 + p$ for the benchmark scenario.

4.4.2 Scenario 1 - C&C is Charged at a Home Delivery Rate

Figure 4(b) shows a consumer's channel choices in Scenario 1, where the retailer offers an omnichannel function (i.e. C&C) and charge this service as the same rate as home delivery. In the model assumption, hassle cost of shopping online involves the least hassle cost because shipping costs are separated. As the utility of using C&C is $u_b = v - p - \theta p_d - \beta h_s$, in this scenario, $\theta = 1$, thereby $u_b = v - p - p_d - \beta h_s$, which is always less than the utility of shopping online $u_o = v - p - p_d$. Therefore, shopping through online channel will dominate C&C due to $u_o > u_b$. This scenario shows the same results compared to these in the benchmark. It makes no difference in either customer demand allocation or profit growth as customers will choose home delivery over C&C. As a result, it is not recommended that charging an omnichannel function at a home delivery rate because this policy may make no differences to customer demand but potentially hurt the total profit due to the additional investment in delivering the omnichannel services. This result explains why most retailers do not charge C&C as the same rate as home delivery.

4.4.3 Scenario 2 - Free C&C

Figure 4(c) shows consumers' channel choices in Scenario 2, where the retailer offers a free C&C unconditionally. The customer utilities are obtained as: $u_b = v - p - \beta h_s$ where $\theta = 0$ and $0 < \beta < 1$, and $u_s = v - p - h_s$. Different from scenario 1 where customers prefer online channel over omnichannel, in scenario 2, C&C will dominate store channel because u_b is always smaller than u_s ($u_b < u_s$). This result shows that if customer channel choice is endogenous, store customers will be converted to omnichannel completely due to C&C. The customer demands for online channel q_{o_2} and C&C q_{b_2} under the condition: $\beta > p_d$, and retailer's profit as below:

$$
\begin{aligned}
q_{b_2} &= \frac{p_d}{\beta} && (4.8)\\
q_{o_2} &= 1 - \frac{p_d}{\beta} && (4.9)\\
\Pi_2(p_d) &= q_{b_2}(p) + q_{o_2}(p + p_d) \\
&= p + p_d - \frac{p_d^2}{\beta} && (4.10)
\end{aligned}
$$

where q_{o_2} and q_{b_2} are obtained from (4.2) and (4.3) because customers choose C&C if $u_b > u_o \geq 0$, alternatively, they will choose online channels if $u_o > u_b \geq 0$. It is worth noting that the shipping policy should also take into account the convenience level of omnichannel functions. As C&C is free of charge, if the collection process is highly convenient (i.e. $\beta \leq p_d$), C&C will dominate not only store but also online demands. In other words, this result indicates that if a retailer can operate C&C conveniently and cost-effectively, it is not recommended to offer free C&C, as it will dominate both channels. Therefore, a condition is set for the convenience level of C&C $\beta > p_d$ for offering free omnichannel services. In terms o the total profit, different from the store unit profit $p - c$, the retailer gain p through selling a product via free C&C for the following reasons. First, omnichannel orders are generated online, in the STS fulfilment, its handling cost is the same as $c_o = 0$. Second, the cost of handling omnichannel orders in-store differ from regular store products, e.g. C&C orders can be picked, packed and stored within a flexible time frame, but store shelves are re-filled regularly. Third, the potential cross-selling profit may compensate the cost of handling customers collection in-store. Hence, this model assume that the unit profit via omnichannel is higher than that in-store.

Similar to the benchmark, p_d and β affect demands with opposite effects: demands of C&C are increasing in p_d but decreasing in β; online demands are decreasing in p_d while increasing in β. The more convenient C&C is (i.e. smaller β), it will convert more customers who are sensitive to inconveniences of shopping in-store. Likewise, if the online delivery fee is higher, the more customers who are sensitive to delivery fees would use C&C and go to stores. Different from the benchmark, the total profit is increasing in unit price p and the inconvenience level of C&C β but independent from unit handling cost in-store c_s because all store demands have been converted. Through substituting (4.8) and (4.9) in (4.4) and maximising $\Pi_2(p_d)$ with regards to p_d, Lemma 2 is obtained as below:

Lemma 2. *When C&C is free and its inconvenience level is high enough* $\beta > p_d$*, the optimal online delivery fee is* $p^*_{d2} = \frac{\beta}{2}$ *and the maximum total profit is* $\Pi^*_2 = p + \frac{\beta}{4}$.

Lemma 2 shows that as the store demands are converted by omnichannel function totally when C&C is free, both the optimal home delivery fee and total profit are increasing in β and independent with c_s. It is sensible because customers place C&C orders online, and in-store the collection point could be separated from in-store shelves and normal checkout areas (Verhoef et al., 2015). The optimal delivery fee is p^*_{d2} is increasing in the inconvenience level of omnichannel function β. For example, if operating a convenient C&C service is not cost-effective, then the retailer can reduce the connivence level for omnichannel function, e.g. limited collection time windows or slow order fulfilment (Mou et al., 2018). Although it becomes less attractive to customers who are sensitive to hassle cost of store shopping, the retailer can raise its optimal delivery fee to make free C&C more attractive to customers who are sensitive to shipping costs. Consequently, it increases the optimal total profit Π^*_2.

4.4.4 Scenario 3 - C&C is Charged at a Discounted Rate

Figure 4(d) shows consumers' channel choices in Scenario 3, where the retailer offers C&C with a discounted shipping rate θp_d and $\theta \in (0, 1)$. Different from previous scenarios, as $0 < \theta < 1$, the customer utility of choosing omnichannel is $u_b = v - p - \theta p_d - \beta h_s$. Different from scenario 1 where customers prefer online channel over omnichannel or scenario 2 where customers prefer C&C over stores, there is no dominant channel in this case. Therefore, customers do not have channel preferences and choose a channel with maximum utility depending on the hassle cost of visiting stores h_s, shipping fee p_d, discount rate θ, and inconvenience factor β. The following functions are obtained, including customer demands for stores q_{s_3}, online channel q_{o_3} and C&C

q_{b_3}, and retailer's total profit:

$$
\begin{aligned}
q_{s_3} &= \frac{\theta p_d}{1-\beta} && (4.11)\\
q_{o_3} &= 1-\frac{(1-\theta)p_d}{\beta} && (4.12)\\
q_{b_3} &= \frac{(1-\beta-\theta)p_d}{(1-\beta)\beta} && (4.13)\\
\Pi_3(p_d) &= q_{s_3}(p-c_s)+q_{b_3}(p+\theta p_d)+q_{o_3}(p+p_d)\\
&= p+\frac{(1-\beta-\theta c_s)p_d}{(1-\beta)}-\frac{\left((1-\theta)^2-\beta(1-2\theta)\right)p_d^2}{(1-\beta)\beta} && (4.14)
\end{aligned}
$$

where q_{s_3} is obtained when customers choose store ($u_s > \max(u_o, u_b) \geq 0$); q_{o_3} is obtained when customers shop online ($u_o > \max(u_s, u_b) \geq 0$); and q_{b_3} is obtained when customers use C&C ($u_b > \max(u_s, u_o) \geq 0$). With the influence of shipping discount, C&C will not dominate either stores or online channels if the discount rate meet a condition: $\theta \in (1-\frac{\beta}{p_d}, 1-\beta)$. This condition is obtained from the channel choice (see Figure 4(d)), because $\frac{\theta p_d}{1-\beta} < \frac{(1-\theta)p_d}{\beta} < 1$. This condition reveals how the discount rate affect customer channel choices: 1) if the retailer offers C&C with a heavy discount ($\theta < 1-\frac{\beta}{p_d}$), online channel will be dominated by C&C; 2) if the retailer offers a reasonable discount within a range ($\theta \in (1-\frac{\beta}{p_d}, 1-\beta)$), then there is no dominant chananel; 3) if the discount is not attractive ($\theta > 1-\beta$), then customers will not choose omnichannel. This result can also be interpreted from operational view: 1) if a retailer can operate C&C conveniently and cost-effectively ($\beta \leq (1-\theta)p_d$), customers will prefer C&C over online channel; if C&C service is inconvenient ($(1-\theta)p_d$), customers will choose to visit store directly. Store demands are increasing in p_d, θ and β. It is sensible because high online delivery fee, or inconvenient C&C service will drive customers to shop in-store. Online demands are increasing in β and θ but decreasing in p_d, because high shipping fee will deter customers who are sensitive to non-partitioned prices. In contrast, the demands of C&C are decreasing in β and θ while increasing in p_d, e.g. high online shipping fee will drive customers to use C&C that is more convenient than stores and cheaper than home delivery. The total profit $\Pi_3(p_d)$ is gained by substituting (4.11), (4.12) and (4.13) in (4.4). The total profit is increasing in unit price p but decreasing in unit handling cost in-store c_s. The optimal delivery fee and discount rate are obtained in Lemma 3 by maximising the total profit:

Lemma 3. *When charging C&C with a discounted rate, and the shipping fee is within a range*

$0 < d < 1 - c_s$, *the optimal online delivery fee is* $p^*_{d3} = \frac{\beta(1-\beta-\theta^* c_s)}{2((1-\theta^*)^2-\beta(1-2\theta^*))}$, *and the maximum total profit is* $\Pi^*_3 = p + \frac{\beta(1-\beta-\theta^* c_s)^2}{4(1-\beta)((1-\theta^*)^2-\beta(1-2\theta^*))}$, *where* $\theta^* = \frac{1-c_s-\beta}{1-c_s}$ *and* $\theta \in (1 - \frac{\beta}{p_d}, 1-\beta)$.

Distinct from previous scenarios, e.g. p^*_d in the benchmark is relevant to handling cost in-store c_s, optimal shipping fee in both scenario 1 p^*_{d1} and scenario 2 p^*_{d2} are related to the inconvenience level of C&C β, the optimal delivery fee in Lemma 3 depends on three factors: c_s, β and discount rate θ. Both the optimal home delivery fee and total profit are increasing in unit price and decreasing in c_s, but concave in the discount rate θ when $0 < p_d < \frac{2-c_s}{2}$. Therefore, when a retailer has high operating cost in-stores, it is motivated to reduce the home delivery fee to convert customers to a more profitable channel. The total profit is concave in the discount rate θ, and the optimal discount is $\theta^* = \frac{1-c_s-\beta}{1-c_s}$, therefore the optimal delivery fee is $p^*_{d3} = \frac{\beta(1-\beta-\theta^* c_s)}{2((1-\theta^*)^2-\beta(1-2\theta^*))}$ when the shipping fee is small enough $0 < p_d < 1 - c_s$, and the corresponding total profit is $\Pi^*_3 = p + \frac{\beta(1-\beta-\theta^* c_s)^2}{4(1-\beta)((1-\theta^*)^2-\beta(1-2\theta^*))}$.

4.5 Analysing Base Model

This section will discuss the impact of different shipping policies on customer demands across channels and retailer profitability by comparing benchmark with three scenarios. In subsections §4.5.1, the demand and profit functions in scenario 2 will be contrasted with these in the benchmark to understand the impact of free C&C. Similarly, comparing scenario 3 with the benchmark will get the insight of C&C with discounted rate on demand and profit in §4.5.2. At last, to understand how a discount rate impacts the efficiency of omnichannel policy, scenario 3 will be compared and scenario 2 in each scenario will be discussed in §4.5.3. By comparing these scenarios, it helps understand the optimal shipping policy when omnichannel function is offered and understand the corresponding conditions and parameters.

4.5.1 The Impact of Free C&C

Due to the similar results between scenario 1 and the benchmark, there is no need to compare them because the C&C with home delivery fee does not convert consumers. Similarly, as this section will compare scenarios with the benchmark, I do not repeat the comparison between scenario 1 with others. Therefore, to start with the analysis, I subtract the results in the benchmark from those in Scenario 2, and the following proposition characterises the effect of free C&C.

Proposition 1. *When C&C is available and free, the demand, profit and delivery fee change as below:*

(i) C&C will convert all store customers and partial online demands by $(\frac{1-\beta}{\beta})p_d$ *if* $\beta > p_d$*;*

(ii) the retailer's total profit will increase if $p_d < \frac{\beta c_s}{1-\beta}$*;*

(iii) the optimal home delivery fee is smaller if $\beta < 1 - c_s$*; otherwise, it will increase.*

Proposition 1(i) shows a positive effect of free C&C on shifting customer demands across channels. In details, free C&C will convert all store customers online because u_b is always smaller than u_s in this scenario, as well as shift partial online traffic into stores by $(\frac{1-\beta}{\beta})p_d$ due to the convenience factor β and free shipping if C&C is not too convenient ($\beta > p_d$). Otherwise, C&C will dominate both store and online demands. The changed demand is increasing in online shipping fee p_d while decreasing in the inconvenience level of C&C β. Hence, this effect of migrating demands from online to store will be enhanced if the retailer has high transporting cost for online orders or if the omnichannel function is convenient. Specifically, Proposition 1(i) suggests that the retailer could use a higher p_d to convert online customers who are sensitive to delivery fees into stores. Reversely, the retailer can make C&C more convenient (i.e. smaller β), the hassle differences between online and C&C is smaller. Thus, customers who are sensitive to store hassles (e.g. out-of-stock, searching for shelves, and long checkout queues) will have more incentives to choose free C&C.

From a retailer's point of view, as the total demand does not change due to the base model setting where customer's channel choices are endogenous and homogenous in product valuation. The customer demand of C&C comes from two streams: 1) store channel with a less unit profit and 2) online channel with a higher unit profit. Therefore, the demand migration across channels will lead to a trade-off: an additional profit gain from store customers shifted online, whereas a profit loss from online demand converted to stores. As a result, the overall profit will rise when the profit gain surpasses profit loss. Proposition 1(ii) indicates that free C&C will grow a retailer's total profit based upon a condition: there is a cap for home delivery fees $p_d < \frac{\beta c_s}{1-\beta}$; otherwise, the retailer should not offer this free service. Thus, apart from demand, three parameters are relevant to the profit change: online shipping fee, incontinence level of C&C, and unit handling cost in-store. If omnichannel retailers could charge a low shipping fee by operating its home delivery in a cost-effective way, e.g. efficient warehouses and transportation networks or low-cost third-party logistics, they can benefit from offering a free C&C, because lowering the delivery fee will ease the effect of C&C on converting those who are sensitive to non-partitioned price. Also, the cap value of home delivery fee is increasing in β and c_s. When β is smaller, free C&C becomes more attractive to online customers who are sensitive to store hassles. Thus, p_d needs to be smaller to balance the online traffic shifted to stores. When c_s is higher, the retailer has more motives to encourage customers to purchase online by lowering the home delivery fee. If the online shipping fee p_d is too high ($p_d > \frac{\beta c_s}{1-\beta}$), C&C may cannibalise online demands completely and convert customers to a less profitable channel, and as a result, the profit loss from shifting online demands to store may outweigh the profit gain from converting store demands to C&C, and eventually hurt the total profit.

Free C&C affects not only the total profit but also the decision of a home delivery fee. Proposition 1(iii) indicates that the retailer should reduce its optimal home delivery fee if C&C is convenient enough $\beta < 1 - c_s$. Thus, when the hassle cost difference between home delivery and C&C is small, free C&C is attractive to online customers who are sensitive to the home delivery fee. To restrict the online-to-store demand migration, the retailer should reduce the optimal delivery fee to slow this demand flow, and ensure the profit loss will not surpass profit gain. The cap of β is decreasing in c_s. The higher handling cost in-store, the retailer is more likely motivated to nudge customers to shop through a more profitable channel by offering a convenient C&C.

4.5.2 The Impact of C&C with a Discounted Rate

After discussing free C&C, this subsection will compare the C&C with discounted shipping rate with the benchmark by subtracting the demand and profit functions in the benchmark from those in Scenario 3, the following proposition is obtained to demonstrate the effect of C&C with a discounted shipping rate.

Proposition 2. *When C&C is available and charged at a discounted rate, the demand, profit and delivery fee change as below:*

(i) C&C will convert store and online customers by $(\frac{1-\beta-\theta}{1-\beta})p_d$ *and* $(\frac{1-\beta-\theta}{\beta})p_d$*, respectively if* $\theta \in (1 - \frac{\beta}{p_d}, 1 - \beta)$*;*

(ii) the retailer's total profit will increase if $p_d < \frac{\beta c_s}{1-\beta-\theta}$ *and* $1 - \frac{\beta}{p_d} < \theta < 1 - \frac{\beta}{1-c_s}$*;*

(iii) the optimal delivery fee is smaller if $\beta < (1 - c_s)(1 - \theta)$.

Proposition 2(i) has demonstrated that the shipping fee of C&C has a positive influence in allocating store demands by $(\frac{1-\beta-\theta}{1-\beta})p_d$ and online demands by $(\frac{1-\beta-\theta}{\beta})p_d$ if the discount rate is within a range $\theta \in (1-\frac{\beta}{p_d}, 1-\beta)$. Distinct from Proposition 1(i) where C&C will cannibalise all store demands, this policy allows the omnichannel retailer to “manage" the flow of cross-channel demand migration and avoid channel domination, by adjusting the discount factor θ and home delivery fee p_d. The shifted demands are decreasing in θ and β, yet increasing in p_d. When the online shipping fee p_d is high, a retailer can offer an attractive discount for C&C to attract online customers who are sensitive to home delivery fees. Alternatively, it can make C&C more convenient to encourage customers who are sensitive to hassles in-store, e.g. out-of-stock and searching time. However, it is worth noting that the discount rate should be within a range $\theta \in (1 - \frac{\beta}{p_d}, 1 - \beta)$, because if the discount is too heavy ($\theta < 1 - \frac{\beta}{p_d}$), the shipping fee for C&C is significantly lower than home delivery fee, then C&C could potentially dominate online demands. In contrast, C&C becomes unappealing if the discount is small $\theta > 1 - \beta$. Proposition 2(i) explains why some retailers charge their C&C at a cheaper rate than home delivery, e.g. Tesco, H&M, and John Lewis & Partners.

From a retailer's view, Proposition 2(ii) shows that charging C&C at a discounted rate will grow the total profit under the condition: 1) $p_d < \frac{\beta c_s}{1-\beta-\theta}$ and 2) $1 - \frac{\beta}{p_d} < \theta < 1 - \frac{\beta}{1-c_s}$. This is because the total profit is concave in p_d and θ in Scenario 3. It indicates that charging for C&C at a discounted rate have positive effect on customer cross-channel behaviours and improve total profit. If the retailer can offer a small home delivery fee that meets the condition $p_d < \frac{\beta c_s}{1-\beta-\theta}$, and the discount rate for C&C is within a range $1 - \frac{\beta}{p_d} < \theta < 1 - \frac{\beta}{1-c_s}$ that is not significantly lower than home delivery fee or not attractive, then the omnichannel retailer can benefit from charging for C&C profitably. Otherwise, it is not advisable. Three factors impact the range of p_d. The first one is the inconvenience level of C&C. The more convenient omnichannel function is, such as same-day or next day collection, the more online customers who are sensitive to hassles could choose stores. As a result, the cap of p_d is lower to restrict this flow. The second factor is the discount rate. A heavier discount could attract online customers who are sensitive to p_d, so a smaller p_d can moderate the demand cannibalisation. The third one is the unit handling cost in-store. At a higher c_s, the retailer is motivated to divert store demands to online channels by lowering p_d.

Proposition 2(iii) indicates that the retailer should reduce the optimal home delivery fee if they adopt C&C with a discounted rate with the condition that C&C is convenient enough: $\beta < (1 - c_s)(1 - \theta)$. The range of β is decreasing in c_s and θ. It makes sense because when store operation is costly, the retailer is motivated to shift customers online and use store as fulfilment centre to reduce the total operating costs, e.g. Argos. When θ is small enough, C&C will be attractive to customers from both store and online channels. Hence, the retailer should reduce the optimal delivery fee to ease the effect of demand shifted to a less profitable channel.

4.5.3 Free C&C vs Charging a Discounted Rate

Previous comparisons are between benchmark where C&C is unavailable and scenarios with C&C. Finally, when C&C is available, between free policy and charging a discounted rate, this subsection will discuss which policy is better by subtracting the results in Scenario 2 from those in Scenario 3. The following proposition characterises the effect of C&C with a discounted shipping rate compared to free C&C.

Proposition 3. *Comparing with unconditional free policy, charging C&C at a discounted rate affects the demand, profit and delivery fee as below:*

(i) *the demands of C&C reduce by $\frac{\theta p_d}{(1-\beta)\beta}$, and store demands increase by $\frac{\theta p_d}{1-\beta}$ and online demands increase by $\frac{\theta p_d}{\beta}$, if $\theta \in (1 - \frac{\beta}{p_d}, 1 - \beta)$;*

(ii) *the retailer's total profit will grow if $p_d > \frac{\beta c_s}{2-2\beta-\theta}$;*

(iii) *the optimal delivery fee is smaller if $\beta < \frac{2-c_s-\theta}{2}$.*

Free C&C could provoke channel domination that initial store demands will be converted to omnichannel totally. In contrast, Proposition 3(i) shows that charging C&C at a discounted shipping fee can weaken this effect and avoid channel domination. In comparison to the total demand when C&C is free of charge, charging a discounted rate will reduce the demand for C&C by $\frac{\theta p_d}{(1-\beta)\beta}$. In particular, demands shifted from stores to C&C reduce by $\frac{\theta p_d}{1-\beta}$, and demands converted from online channels drop by $\frac{\theta p_d}{\beta}$. This change is because the dominant effect of free C&C is weakened by charging a discounted rate. Thus, store demands are not fully converted as some are sensitive to the delivery fee; likewise, less variance in shipping cost between online and omnichannel will restrict or slow the demand shifting from online to stores. After comparing the store with online demand changes, a demand conversion ratio is obtained: $\frac{\beta}{1-\beta}$. All changes in demands are increasing in the shipping fee of C&C θp_d. It is sensible that charging a higher θp_d, C&C becomes less attractive to customers who are sensitive to delivery fees, thereby fewer demands will be converted. Meanwhile, if the retailer can offer a convenient C&C: $\beta < \frac{1}{2}$, that is $\frac{\beta}{1-\beta} < 1$, the change in online demands will be more than that of store demands, and vice versa. It makes sense because convenient C&C can attract customers who are sensitive to store hassles, but θp_d could deter customers who are sensitive to delivery fee compare to free C&C.

Proposition 3(ii) shows that an omnichannel retailer is better off charging C&C at a discounted rate to grow the retailer's total profit based on one condition: $p_d > \frac{\beta c_s}{2-2\beta-\theta}$. Otherwise, offering free C&C is advisable. I compare conditions in Proposition 1(ii), Proposition 2(ii) and Proposition 3(ii), then get $\frac{\beta c_s}{2-2\beta-\theta} < \frac{\beta c_s}{1-\beta} < \frac{\beta c_s}{1-\beta-\theta}$. It implies that if the home delivery fee is small $p_d < \frac{\beta c_s}{2-2\beta-\theta}$, the optimal policy is to offer free C&C, because when shipping cost low enough, the variance between online and omnichannel is small, free C&C is more effective to attract both types of customers who are sensitive to delivery fee and store hassles. Thus, the profit gain from dominating stores will surpass the profit loss from shifted online customers. If p_d is medium $\frac{\beta c_s}{2-2\beta-\theta} < p_d < \frac{\beta c_s}{1-\beta-\theta}$, charging C&C at a discounted rate is a better policy. This policy can balance the demand migrated across channels to avoid channel domination, and will mainly attract customers who are sensitive to store hassles in this case. This result reveals an opportunity to use omnichannel shipping fee to nudge customers to a more profitable channel. When delivering online products is costly thereby p_d is large ($pd > \frac{\beta c_s}{1-\beta-\theta}$), the retailer is better off not offering C&C, because customers are willing to pay higher for delivery. For example, C&C service is not popular for large items with two-people lifting.

Compare to free C&C, Proposition 3(iii) indicates that the optimal home delivery fee is smaller when charging C&C at a discounted rate based on the condition: C&C is convenient $\beta < \frac{2-c_s-\theta}{2}$. Otherwise, the optimal home delivery fee will increase. It makes sense because convenient C&C will nudge online customers who are sensitive to the hassles of store shopping, therefore optimal delivery fee should be lower to moderate this demand migrated to a less profitable channel.

In summary, offering C&C will not impact the overall customer demand for a product due to the model assumption, but will cannibalise demands from both stores and online channels. The shipping discount for C&C could moderate the effect of channel domination caused by free C&C. The results indicate that a free C&C does not always benefit the retailer's overall profit due to the following trade-off: store customers shift to C&C will generate extra profit, yet a profit loss occurs when online customers choose C&C. Thus, conditions are identified to increase total profit by comparing three shipping policies:

- when operating online fulfilment is cost-effective (p_d is small), the retailer should offer free C&C;
- when the cost of operating online fulfilment is medium (p_d is medium), charging C&C with a discounted rate is a better policy;
- when operating online fulfilment is expensive (p_d is large), then the retailer is better off not offering C&C.

The model results show that the addition of C&C will impact the optimal home delivery fee. The retailer should reduce its home delivery fee if both the discount rate and convenient factor are low enough. Reviewing existing shipping policy is necessary before adding an omnichannel function. The model results are based on the assumption that customers are homogeneous in product values. This assumption will apply to products that are widely distributed, highly standardised with low unit values, and have basic benefits, such as some fast-moving consumer goods.

4.6 Extension - Heterogeneous Customers

In this section, the assumption that customers are homogeneous in product valuation is relaxed. In other words, customer heterogeneity is allowed in both product valuation and perceived hassle cost of visiting stores in the model extension, which characterises the product category beyond the basic consumption needs and involve differentiations. Customers perceive product values differently, such as fashion goods, designer furniture, customised products, or products enjoying powerful brand identifies. In the extension model setting, customers are heterogeneous in the product perception v and the hassle cost of visiting a channel h_i. As a result, the total demand for a product is determined by three factors: the unit selling price p, and random perception of product values v and hassle cost of visiting stores h_s, which will vary in the three scenarios. To simplify the demand calculation, as p is identical across channels, the model is transformed by defining a surplus of perceived product value $\lambda = v - p$. Accordingly, customer's channel choices in three scenarios (Figure 5) is demonstrated according to two dimensions: $\lambda \in [0, 1]$ and $h_s \in [0, 1]$. The benchmark and three scenarios will be discussed in §4.6.1, §4.6.2, §4.6.3 and §4.6.4, respectively. Then the optimal shipping policies for C&C will be compared between the benchmark with three scenarios in §4.7. Since customer heterogeneities will complex the profit function, numerical analysis will be conducted to observe the characterises of shipping policies and how c_s, β and θ influence results. All the relevant proofs are in Appendix A.

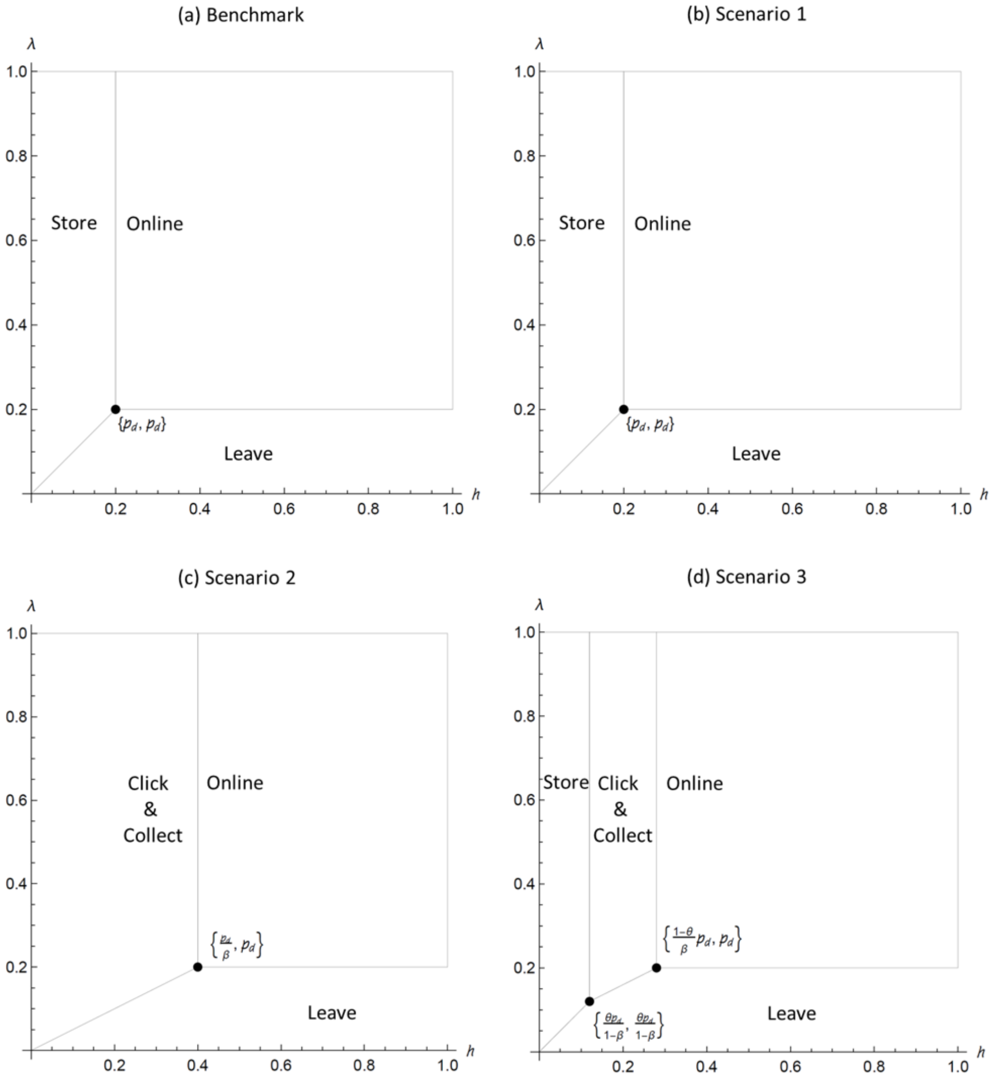


Figure 5: Consumer's Channel Choices in the Extension in Model One

4.6.1 Benchmark - C&C is Unavailable

Figure 5 (a) shows consumers' channel choices in the benchmark. The area labelled "leave" means both u_s and u_o are less than zero, so customers do not purchase the product. As h_s and λ are uniformly distributed in the range [0,1], customer demands for store $\tilde{q}_s$ and online channels $\tilde{q}_o$ are derived from customer utilities by channel, total demand Q and retailer's profit as follows:

$$
\begin{aligned}
\tilde{q}_s &= \frac{(2-p_d)p_d}{2} && (4.15)\\
\tilde{q}_o &= (1-p_d)^2 && (4.16)\\
Q &= \tilde{q}_s + \tilde{q}_o \\
&= \frac{2-2p_d+p_d^2}{2} && (4.17)\\
\tilde{\Pi}(p_d) &= \tilde{q}_s(p-c_s) + \tilde{q}_o(p+p_d) \\
&= p + (1-p-c_s)p_d - (\frac{4-p-c_s}{2})p_d^2 + p_d^3 && (4.18)
\end{aligned}
$$

where total demand Q is decreasing in p_d, as a high home delivery fee could deter customers who are sensitive to shipping fees, while it is not influenced by p_d in the base model due to the homogeneity. Similar to the base model, both channel demands have opposite effects in p_d: the store demand is increasing while the online demand is decreasing in p_d. A higher home delivery fee could drive online customers to stores. Hence, the effect of shipping fees on migrating demands across channels is similar between the base model and the extension. The total profit $\tilde{\Pi}(p_d)$ is obtained through substituting (4.15) and (4.16) in (4.4). Similar to the base model, $\tilde{\Pi}$ is increasing in unit selling price p and decreasing in the in-store unit handling cost c_s. Thus, by maximising the total profit, Lemma 4 is developed as below:

Lemma 4. *When C&C is not available and customers are heterogeneous, the optimal home delivery fee is* $\tilde{p}_d^* = \frac{1-p-c_s}{3}$ *and the maximum total profit is* $\tilde{\Pi}^* = \frac{1}{54}(8 + 39p + 6p^2 + p^3 + 3(p^2 + 4p - 5)c_s + 3(p+2)c_s^2)$.

Lemma 4 shows that the optimal home delivery fee is decreasing in c_s, which is similar to Lemma 1 in the base model, and decreasing in unit selling price p. It is sensible that when the running cost in-store is high, the retailer is motivated to drive store customers online. The optimal profit is non-monotonic in c_s. It is decreasing in c_s when $p < \frac{1}{2}$. When a retailer primarily sells products with low unit prices, the higher the handling cost in-store, the less total profit is. Although the retailer is motivated to offer a lower shipping fee when the unit handling cost in-store is high, when p is low ($p < \frac{1}{2}$), the ratio of the home delivery fee over the selling price $\frac{p_d}{p}$ is not small enough to attract customers who are sensitive to shipping fees. Hence, it weakens the effects on cross-channel demand migration and growing total profits. When p is high ($p \geq \frac{1}{2}$), the optimal profit is increasing in c_s, because at a higher handling cost in-store, the smaller the delivery fee is, thereby the ratio of $\frac{p_d}{p}$ becomes significantly smaller. As a result, it could attract store customers who are sensitive to delivery fees and the total profit increases.

4.6.2 Scenario 1 - C&C is Charged at a Home Delivery Rate

Figure 5(b) shows consumers' channel choices in Scenario 1 where C&C is charged at a home delivery fee. Similar to the base model, online channel will dominate C&C if they have the same shipping fee, because the utility of using online channel is always higher than choosing C&C. Therefore, when customers are heterogenous, charging omnichannel functions with a home delivery rate is still not an efficient option. The result is the same as the benchmark and the base model, and I do not compare it with other scenarios in the extension.

4.6.3 Scenario 2 - Free C&C

Figure 5(c) shows consumers' channel choices in Scenario 2, and similar to the base model, free C&C will provoke a channel domination by converting all store demands to omnichannel as u_b is always smaller than u_s, which is opposite to the results in scenario 1. This similarity between base model and extension suggests that the effect of channel dominance may be primarily relevant to the shipping fee other than customer heterogeneity. The customer demands for home delivery $\tilde{q}_{o_2}$ and C&C $\tilde{q}_{b_2}$ are derived from the utility functions. Thus, the total demand Q_2 and retailer's profit are obtained under the same condition $\beta > p_d$ as below:

$$
\begin{aligned}
\tilde{q}_{o_2} &= (1-p_d)(1-\frac{p_d}{\beta}) && (4.19)\\
\tilde{q}_{b_2} &= \frac{(2-p_d)p_d}{2\beta} && (4.20)\\
Q_2 &= \tilde{q}_{b_2} + \tilde{q}_{o_2}\\
&= 1-p_d+\frac{p_d^2}{2\beta} && (4.21)\\
\tilde{\Pi}_2(p_d) &= \tilde{q}_{b_2}(p)+\tilde{q}_{o_2}(p+p_d)\\
&= p+(1-p)p_d+(\frac{p-2-2\beta}{2\beta})p_d^2+\frac{p_d^3}{\beta} && (4.22)
\end{aligned}
$$

where the total demand Q_2 is decreasing in p_d, and a higher home delivery fee could deter more customers, but it is independent with p_d in the base model due to the customer homogeneity. This suggest that customers may be more sensitive to the home delivery fee for the sector with higher product differentiations. Between the base model and the extension, the condition of the inconvenience level of C&C is consistent: $\beta > p_d$, so are the effects of shipping fees on the cross-channel demand migration. This suggests that shipping price of C&C and the service convenience level need to be considered jointly, otherwise free C&C may not be an effective policy because it may trigger channel dominance. Similar to the base model, online demands are decreasing in p_d but increasing in β; in contrast, the demands of C&C are increasing in p_d and decreasing in β. The total profit $\tilde{\Pi}_2(p_d)$ is derived from substituting (4.19) and (4.20) in (4.4). By maximising $\tilde{\Pi}_2(p_d)$ with regard to p_d, the retailer's optimal home delivery fee and profit are obtained in Lemma 5 as below:

Lemma 5. *When C&C is free and $\beta > p_d$, and customers are heterogeneous, the optimal home delivery fee is $\tilde{p}_{d2}^* = \frac{1}{6}(\beta_1 - \sqrt{\beta_1^2 - 12\beta(1-p)})$; and the maximum total profit is $\tilde{\Pi}_2^* = \frac{1}{216\beta}(\beta_1 - \sqrt{\beta_1^2 - 12\beta(1-p)}) - 3(p-2(\beta+1))(\beta_1 - \sqrt{\beta_1^2 - 12\beta(1-p)})^2 + (\beta_1 - \sqrt{\beta_1^2 - 12\beta(1-p)})^3)$, where $\beta_1 = 2\beta + 2 - p$.*

Similar to Lemma 2, Lemma 5 shows that both the optimal delivery fee and total profit are increasing in β and independent with c_s. Store demands are completed converted by offering free C&C in both base model and extension. It reveals that with or without considering customer heterogeneity, offering a convenient C&C free of charge may not be as beneficial as expected.

4.6.4 Scenario 3 - C&C is Charged at a Discounted Rate

Figure 5(d) shows consumers' channel choices in Scenario 3. Similar to the base model, the discount rate $0 < \theta < 1$ weakens the effect of channel domination. Thus, customer demands for store $\tilde{q}_{s_3}$, home delivery $\tilde{q}_{o_3}$ and C&C $\tilde{q}_{b_3}$, total demand Q_3 are derived from utility function by channel, and retailer's profit is obtained as below under the same conditions $\theta \in (1 - \frac{\beta}{p_d}, 1 - \beta)$:

$$
\begin{aligned}
\tilde{q}_{s_3} &= \frac{\theta p_d}{2(1-\beta)}(2 - \frac{\theta p_d}{1-\beta}) && (4.23)\\
\tilde{q}_{o_3} &= (1 - p_d)(1 - \frac{1-\theta}{\beta} p_d) && (4.24)\\
\tilde{q}_{b_3} &= \frac{p_d}{2}(\frac{1-\theta}{\beta} - \frac{\theta}{1-\beta})(2 - p_d - \frac{\theta p_d}{1-\beta}) && (4.25)\\
Q_3 &= \tilde{q}_{s_3} + \tilde{q}_{b_3} + \tilde{q}_{o_3}\\
&= 1 - p_d - \frac{\beta - 2\beta\theta - (1-\theta)^2}{2\beta(1-\beta)} p_d^2 && (4.26)\\
\tilde{\Pi}_3(p_d) &= \tilde{q}_{s_3}(p - c_s) + \tilde{q}_{b_3}(p + \theta p_d) + \tilde{q}_{o_3}(p + p_d)\\
&= \frac{\theta p_d(p - c_s)}{2(1-\beta)}(2 - \frac{\theta p_d}{1-\beta}) + (p + p_d)(1 - p_d)(1 - \frac{1-\theta}{\beta} p_d)\\
&\quad + \frac{p_d(p + \theta p_d)}{2}(\frac{1-\theta}{\beta} - \frac{\theta}{1-\beta})(2 - p_d - \frac{\theta p_d}{1-\beta}) && (4.27)
\end{aligned}
$$

With the discount rate, C&C plays a role of "diverting" customer demands across channels. The total demand Q_3 is decreasing in β, θ and p_d, but it does not change in the base model due to assumption. It is sensible that the total demand may increase if shipping fee for online and omnichannel is low, or C&C is convenient. The effects of shipping fees of C&C on converting store and online demands are similar to the base model. This suggest that the channel migration effect is relevant to the service pricing with or without considering customer heterogeneity. To be specific, the store demand is increasing in inconvenience of C&C β, discount rate θ and home delivery fee p_d; and online demand is increasing in both β and θ while decreasing in p_d. Differently, the demand of C&C is decreasing in the discount factor θ, and concave in home delivery fee p_d, but is non-monotonic in β. The total profit $\tilde{\Pi}_3(p_d)$ is derived by substituting (4.23), (4.24), and (4.25) in (4.4). By maximising $\tilde{\Pi}_3(p_d)$, the retailer's optimal home delivery fee and profit are obtained in Lemma 6 as below:

Lemma 6. *When charging C&C at a discounted rate and* $\theta \in (1 - \frac{\beta}{p_d}, 1 - \beta)$, *and customers are* *heterogeneous, the optimal home delivery fee is* $\tilde{p}^*_{d_3} = \frac{1}{3\phi}(\mu + \omega)$ *and the maximum total profit is* $\tilde{\Pi}^*_3 = \frac{1}{54\beta\phi^3(1-\beta)^2}(3\beta\theta\phi(\omega+\mu)(p-c_s)(6\phi(1-\beta)-\theta(\omega+\mu))+(\omega+\mu)(1-\beta-\theta)(3\phi p+\theta(\omega+\mu))(6\phi(1-\beta)-(\omega+\mu(1-\beta+\theta)))+2(1-\beta)^2(3\phi-\omega-\mu(\omega+\mu+3p\phi)(3\beta\phi-\omega(1-\theta)-\mu(1-\theta))))$*, where* $\phi = (\beta(2-3\theta)(2-\beta)-(2+\theta)(1-\theta)^2)$, $\omega = (1-\beta)(2(\beta(\beta-2\theta)-(1-\theta)^2)-p(\beta(1-2\theta)-(1-\theta)^2))+\beta\theta^2 c_s$*, and* $\mu = \sqrt{6\phi\beta(1-\beta)((1-p)(1-\beta)-\theta c_s)+\omega^2}$.

Similar to Lemma 3 in the base model, Lemma 6 shows that both the optimal delivery fee and optimal profit are decreasing in c_s. Due to the complex form, I will discuss this further in the analysis by conducting a numerical analysis.

4.7 Analysing Model Extension

This section will analyse the impact of three shipping policies on customer demands across channels and retailer profitability when customers are heterogeneous. The impact of free C&C will be discussed in subsections §4.7.1 by contrasting results in scenario 2 with those in the benchmark. In §4.7.2, scenario 3 will be compared with the benchmark understand the impact of C&C with discounted rate on demand and profit. To understand how a discount rate impacts the implementation of omnichannel policy, the comparison between scenario 2 and 3 will be conducted in §4.7.3. Due to the complicate form in scenario 3, a series of numerical analysis will be conducted to demonstrate the change of total profit in response to the relevant parameters.

4.7.1 The Impact of Free C&C

Results above are compared to analyse the shipping policies for C&C with heterogeneous customers. I will highlight the similarities and differences of results between the base model and the extension to understand whether customer heterogeneities impact the final results. Similar to the base model, it is not necessary to compare Scenario 1 with other scenarios here. I first subtract the results in the benchmark from those in Scenario 2, and the following proposition characterises the effect of free C&C.

Proposition 4. *When C&C is free and customers are heterogeneous, the demand, profit and delivery fee change as below:*

(i) total demands will increase by $\frac{(1-\beta)p_d^2}{2\beta}$*; C&C will convert all store customers, and partial*

online demands by $\frac{(1-\beta)(1-p_d)p_d}{\beta}$*;*

(ii) the retailer's total profit will increase if $p_d < \frac{(\beta-1)(2-p)+\beta c_s-\sqrt{\xi}}{4(1-\beta)}$ *or* $p_d > \frac{(\beta-1)(2-p)+\beta c_s+\sqrt{\xi}}{4(1-\beta)}$, *and* $\beta \in (p_d, \frac{(p+6)c_s+(p-2)^2-4c_s\sqrt{p+2}}{\delta})$*, where* $\xi = 16\beta c_s(\beta-1) + (\beta c_s + (\beta-1)(p-2))^2$ *and* $\delta = 2(p+6)c_s + (p-2)^2 + c_s^2$*;*

(iii) the optimal home delivery fee is smaller if $\beta \in (\frac{1}{3}(1-p-c_s), \frac{(1+c_s)(1-p-c_s)}{1-p+2c_s})$*; otherwise, it will increase.*

Proposition 4(i) demonstrates that free C&C has a positive effect on increasing total customer demands as well as migrating customer demands across channels. In the base model, the total demand is consistent as v is perceived homogeneously, but in the extension, product values can be perceived differently between customers. Free C&C will increase the total demand by $\frac{(1-\beta)p_d^2}{2\beta}$, which is increasing in p_d but decreasing in β. For example, free C&C will attract new customers who are sensitive to non-partitioned prices if the home delivery fee is high, or those who are hassle-sensitive if C&C is more convenient compared to store shopping. Similar to the base model, free C&C will convert all store customers because the utility of shopping in-store is always smaller than that via free C&C ($u_b < u_s$), as well as shift online traffic to store by $\frac{(1-\beta)(1-p_d)p_d}{\beta}$ due to the convenience factor β and free delivery. Furthermore, the converted online demand is increasing in p_d and decreasing in β. The more convenient the free service is, more online customers who are sensitive to the hassle of shopping in-store will use C&C because it provides conveniences in guaranteed stock and flexibility in collection. For customers who are sensitive to the home delivery fee, at a higher delivery fee, free C&C is more attractive to online customers to avoid the shipping cost.

Different from the base model where omnichannel demands are converted from store and online channel only, when customers are heterogenous, C&C demand comes from three streams: a less profitable store channel, a more profitable online channel, and new customers. Therefore, profit growth is from both new customers and transferred store demands. Proposition 4(ii) indicates that the total profit would grow if: i) home delivery fee is either small $p_d < \frac{(\beta-1)(2-p)+\beta c_s-\sqrt{\xi}}{4(1-\beta)}$ or large $p_d > \frac{(\beta-1)(2-p)+\beta c_s+\sqrt{\xi}}{4(1-\beta)}$); ii) the inconvenience level is within the range $\beta \in (p_d, \frac{(p+6)c_s+(p-2)^2-4c_s\sqrt{p+2}}{\delta})$. This result implies that: 1) as free C&C dominates store customers, a low online delivery fee ($p_d < \frac{(\beta-1)(2-p)+\beta c_s-\sqrt{\xi}}{4(1-\beta)}$) could moderate the effect of demand cannibalisation shifting the online demand to a less profitable omnichannel; 2) if the online delivery fee is high ($p_d > \frac{(\beta-1)(2-p)+\beta c_s+\sqrt{\xi}}{4(1-\beta)}$)), free C&C will cannibalise more online customers as well as attract new customers who are sensitive to non-portioned prices ;3) if free C&C is too convenient $\beta < p_d$, then it will dominate all channels; 4) if it is not convenient, $\beta > \frac{c_s p+6c_s+p^2-4p+4-4c_s\sqrt{p+2}}{\delta}$, it becomes less attractive to new customers who are sensitive to the hassle of store shopping. Therefore, if omnichannel retailers could operate its home delivery cost-effectively or if the distribution costs are high, then it is advisable to offer a free C&C. Besides, it is not always financially beneficial for the retailers to invest in the convenience and effectiveness of C&C process.

Although C&C is free in this scenario, Proposition 4(iii) indicates that the retailer should reduce its optimal home delivery fee if the inconvenience level of C&C is within the range $\beta \in (\frac{1}{3}(1-p-c_s), \frac{(1+c_s)(1-p-c_s)}{1-p+2c_s})$. Otherwise, the optimal delivery fee is larger if $\beta > \frac{(1+c_s)(1-p-c_s)}{1-p+2c_s}$. Firstly, as $\beta > p_d$, the inconvenience factor is known $\beta > \frac{1}{3}(1-p-c_s)$; otherwise, C&C will become dominant. The disadvantage of dominating omnichannel is that the profit loss from online-to-store demand migration will exceed the profit gain from store demands and new customers. If free C&C is too convenient ($\beta < \frac{1}{3}(1-p-c_s)$), it will dominate both store and online channels, thereby home delivery fee should be lowered to avoid channel dominance. If the retailer can make the service convenient enough $\beta \in (\frac{1}{3}(1-p-c_s), \frac{(1+c_s)(1-p-c_s)}{1-p+2c_s})$, potentially free C&C could migrate more online demands. Thus, the retailer should reduce the optimal delivery fee to restrict this flow, and ensure the profit loss will not surpass the profit gain. However, if the retailer cannot make the service convenient, i.e. $\beta > \frac{(1+c_s)(1-p-c_s)}{1-p+2c_s}$, increasing the home delivery fee could also shift online demand who are sensitive to non-partitioned prices to store.

4.7.2 The Impact of C&C with Discounted Rate

This subsection will discuss the impact when C&C is charged at a discounted rate. Proposition 5 is obtained by comparing the demand, profit and optimal delivery fee in Scenario 3 with these in the benchmark as below:

Proposition 5. *When C&C is charged at a discounted rate and customers are heterogeneous, the demand, profit and delivery fee change as below:*

(i) total demands will increase by $\frac{(1-\beta-\theta)^2 p_d^2}{2\beta(1-\beta)}$*; C&C will convert store customers by* $\frac{p_d(1-\beta-\theta)(2(1-\beta)-p_d(1-\beta+\theta))}{2(1-\beta)^2}$ *and shift online demands by* $\frac{p_d(1-\beta-\theta)(1-p_d)}{\beta}$*, if the discount rate is within* $\theta \in (1-\frac{\beta}{p_d}, 1-\beta)$*;*

(ii) the retailer's total profit will increase if $p_d < \frac{\beta c_s(-\beta+\theta+1)+(\beta-1)(2-p)(\beta+\theta-1)-\sqrt{\varepsilon}}{4\beta^2+2\beta(\theta-4)-2(\theta^2+\theta-2)}$ *or* $p_d > \frac{\beta c_s(-\beta+\theta+1)+(\beta-1)(2-p)(\beta+\theta-1)+\sqrt{\varepsilon}}{4\beta^2+2\beta(\theta-4)-2(\theta^2+\theta-2)}$*; and* $\theta < \frac{(1-\beta)(-\beta^2 c_s^2+(\beta-1)^2(p-2)^2)+4c_s(\beta^2-\beta-\beta\sqrt{\vartheta})}{2\beta(1-\beta)(p+2)c_s+\beta^2 c_s^2+(\beta-1)^2(p-2)^2}$*; and* $\beta \in ((1-\theta)p_d, \frac{(p+6)c_s+(p-2)^2-4c_s\sqrt{p+2}}{\delta})$*, where* $\varepsilon = 8\beta c_s(\beta-1)(2\beta^2+\beta(\theta-4)-\theta^2-\theta+2)+(\beta c_s(\beta-\theta-1)+(\beta-1)(p-2)(\beta+\theta-1))^2$*, and* $\vartheta = (\beta-1)(\beta c_s-3(\beta-1)(p+1))$*;*

Proposition 5(i) shows that charging C&C at a discounted rate has positive effects on increasing total demand and migrating demands across channels. In the base model, the total demand does not change in this scenario due to customer homogeneity. The total demand increases by $\frac{(1-\beta-\theta)^2 p_d^2}{2\beta(1-\beta)}$, which is increasing in p_d but decreasing in β and θ. It implies that offering C&C with a discounted shipping rate can generate new customers. When the home delivery fee is high, offering C&C with a discounted shipping rate will convert customers who are sensitive to non-partitioned prices; if C&C is convenient enough, it will convert customers who are hassle-sensitive; the heavier discount C&C is charged, more new customers and online customers could be attracted. Thereby, when online delivery is high cost, the retailer should offer a convenient C&C with attractive discount, as it could convert customers who are either sensitive to the delivery fee or the hassle of shopping in-store.

Similar to the base model, by charging a discounted rate, C&C could sway the demand across channels and avoid channel domination, as it cannibalises partial store and online demands if the discount rate is within a certain range ($\theta \in (1-\frac{\beta}{p_d}, 1-\beta)$). C&C will cannibalise store demands by $\frac{p_d(1-\beta-\theta)(2(1-\beta)-p_d(1-\beta+\theta))}{2(1-\beta)^2}$, which is decreasing in θ and β, yet concave in p_d and reaching maximum when $p_d = \frac{1-\beta}{1-\beta+\theta}$. For example, a convenient C&C with a decent discount will convert more store demands to omnichannel. Likewise, online demand is converted to C&C by $\frac{p_d(1-\beta-\theta)(1-p_d)}{\beta}$, which is increasing in p_d but decreasing in θ and β, e.g. if the home delivery fee is high, customers who are sensitive to non-partitioned prices would choose C&C due to lower shipping fee. However, if the discount is heavy ($\theta < 1-\frac{\beta}{p_d}$), C&C may provoke channel dominance. If the discount is not attractive ($\theta > 1-\beta$), then the effect of C&C cross-channel migration will be weakened. Within a certain range ($\theta \in (1-\frac{\beta}{p_d}, 1-\beta)$), the heavier shipping discount (i.e. smaller θ) is, C&C is more attractive to customers who are sensitive to a home delivery fee. Likewise, the easier collection process is (i.e. smaller β), the more popular the C&C is to those who worry about hassle costs of shopping in-store (e.g. out-of-stock and searching and waiting time). It shows that charging C&C can avoid channel domination, and a shipping discount could help the retailer divert their demand flow to a more profitable channel. However, when the shipping fee is too high, it could deter customers who are sensitive to shipping cost, so home delivery and C&C become less attractive in comparison to stores.

In terms of profits, Proposition 5(ii) shows that the total profit will grow under the following conditions: 1) the delivery fee should be either small $p_d < \frac{\beta c_s(-\beta+\theta+1)+(\beta-1)(2-p)(\beta+\theta-1)-\sqrt{\varepsilon}}{4\beta^2+2\beta(\theta-4)-2(\theta^2+\theta-2)}$, or large $p_d > \frac{\beta c_s(-\beta+\theta+1)+(\beta-1)(2-p)(\beta+\theta-1)+\sqrt{\varepsilon}}{4\beta^2+2\beta(\theta-4)-2(\theta^2+\theta-2)}$; 2) the discount rate should be low enough $\theta < \frac{(1-\beta)(-\beta^2 c_s^2+(\beta-1)^2(p-2)^2)+4c_s(\beta^2-\beta-\beta\sqrt{\vartheta})}{2\beta(1-\beta)(p+2)c_s+\beta^2 c_s^2+(\beta-1)^2(p-2)^2}$; 3) the convenience level should be within the range $((1-\theta)p_d, \frac{(p+6)c_s+(p-2)^2-4c_s\sqrt{p+2}}{\delta})$. This proposition is different from the result in the base model. When the delivery fee is low, the convenience factor plays a key role in converting customers who are sensitive to the hassle of store shopping, which will increase profit. In contrast, when the delivery fee is high, discount rate shows the main effect on driving online customers that are sensitive by home delivery fee to stores. However, if C&C is too convenient $\beta < (1-\theta)p_d$, then C&C will dominate online channels. If it is not convenient enough, $\beta > \frac{(p+6)c_s+(p-2)^2-4c_s\sqrt{p+2}}{\delta}$, then it could weaken the attraction to customers who are sensitive to hassle costs of store shopping. It implies that the omnichannel retailer can benefit from charging for omnichannel function by adjusting the inconvenience factor β to grow the total profit if the online distribution cost is low or adjust the discount θ to a lower rate when p_d is high.

To understand how charging C&C at a discounted rate impacts the optimal home delivery fee, by subtracting the optimal shipping fee in Lemma 4 from that in Lemma 6, the difference $\frac{1}{3}(\frac{\mu+\omega}{\phi}-1+p+c_s)$ is obtained. Considering the complexity of the equation, a set of numerical experiments will be conducted to provide insights and evaluate the effect of shipping policies. Firstly, to observe the impact of unit handling cost in-store on the shipping options, the unit selling price is set from 0.1 to 0.7 with an interval of 0.2, which represents low prices when $p < \frac{1}{2}$ and high prices when $p \geq \frac{1}{2}$. Furthermore, the unit handling cost is denoted as 30% of the unit selling price p, which refers to the ratio of total UK operating costs over UK revenue (32%) from John Lewis (JohnLewis, 2019). This ratio in Marks & Spenser is similar, which is around 36 %(Mark and Spencer, 2019). The inconvenient factor β is set from 0.1 to 0.7 with an interval of 0.2, representing convenient C&C when $\beta < \frac{1}{2}$ and inconvenient when $\beta \geq \frac{1}{2}$, and I set the discount factor θ from 0.1 to 0.5 with an interval of 0.1 considering $\theta < 1-\beta$. By substitutung the above values in $\frac{1}{3}(\frac{\mu+\omega}{\phi}-1+p+c_s)$ and get Table 8 that summarises a set of numerical results of the difference in optimal shipping fees.

Table 8: Changes in Optimal Delivery Fees Between Benchmark and Scenario 3

p	0.1				0.3				0.5				0.7			
c_s	0.03				0.09				0.15				0.21			
β	0.1	0.3	0.5	0.7	0.1	0.3	0.5	0.7	0.1	0.3	0.5	0.7	0.1	0.3	0.5	0.7
θ	changes in p_d^*				changes in p_d^*				changes in p_d^*				changes in p_d^*			
0.1	-0.2339	-0.1370	-0.0643	-0.0167	-0.1560	-0.0798	-0.0279	0.0022	-0.0801	-0.0264	0.0062	0.0212	-0.0069	0.0232	0.0384	0.0404
0.2	-0.2200	-0.1066	-0.0351	-0.0024	-0.1453	-0.0599	-0.0124	0.0046	-0.0732	-0.0165	0.0101	0.0127	-0.0042	0.0240	0.0323	0.0215
0.3	-0.2008	-0.0730	-0.0137	0.0000	-0.1310	-0.0392	-0.0021	0.0000	-0.0643	0.0000	0.0105	0.0000	-0.0012	0.0232	0.0237	0.0000
0.4	-0.0407	-0.0410	-0.0024		-0.1116	-0.0206	0.0019		-0.0529	0.0041	0.0070		0.0021	0.0207	0.0128	
0.5	-0.1368	-0.0167	0.0000		-0.0861	-0.0069	0.0000		-0.0389	-0.0069	0.0000		0.0053	0.0159	0.0000	

Note. The negative values indicate that there is a decline in the optimal delivery fee, and positive ones (underlined) imply increases in the optimal delivery fees.

Observation 1.

(i) the optimal delivery fee in Scenario 3 is smaller when p and c_s are small. Otherwise, it will increase; the difference in optimal delivery fees will change from negative to positive when p or c_s grows;

(ii) the difference in optimal delivery fees is non-monotonic in β and θ and will grow when β and θ are small but will decrease when β and θ are large.

When p and c_s are small, reducing the home delivery fee could lower the ratio of $\frac{p_d}{p}$, which weakens the effect on deterring customers who are sensitive to a home delivery. If β and θ are small enough, C&C attract customers from both store and online channels. Hence, the retailer should reduce the optimal delivery fee to moderate effect of converting online demands to stores, and ensure the profit loss will not surpass the profit gain.

4.7.3 Free C&C vs Charging a Discounted Rate

Finally, to find out which policy is more effective regarding the total profit by subtracting the results in Scenario 2 from those in Scenario 3, and Proposition 6 is obtained to characterise the effect of C&C with discounted shipping rate compared to free C&C.

Proposition 6. *Comparing with unconditional free policy, charging C&Ct at a discounted rate affects the demand, profit and delivery fee as below:*

(i) *The total demands decrease by* $\frac{\theta(2-2\beta-\theta)p_d^2}{2(1-\beta)\beta}$. *Store demands increase by* $\frac{\theta p_d(-2\beta-\theta p_d+2)}{2(1-\beta)^2}$ *and online demands increase by* $\frac{\theta(1-p_d)p_d}{\beta}$, *in total, the demands of C&C decrease by* $\frac{\theta p_d(-2\beta-\theta p_d+2)}{2(1-\beta)^2\beta}$;

(ii) *the retailer's total profit will grow in Scenario 3 based on conditions:*

p_d *is within the range* $(\frac{\beta\theta c_s+(\beta-1)(2-p)(2\beta+\theta-2)-\sqrt{\eta}}{6\beta^2-12\beta-2\theta^2+6}, \frac{\beta\theta c_s+(\beta-1)(2-p)(2\beta+\theta-2)+\sqrt{\eta}}{6\beta^2-12\beta-2\theta^2+6})$, *when* $\beta \in ((1-\theta)p_d, \frac{(p+6)c_s+(p-2)^2-4c_s\sqrt{p+2}}{\delta})$ *and* $\theta \in (\frac{1}{2}(-2\beta-\beta c_s+\beta p-p+2-\sqrt{\kappa}), 1-\beta)$;

or p_d *is within the range* $p_d \in (\frac{\beta\theta c_s+(\beta-1)(2-p)(2\beta+\theta-2)-\sqrt{\eta}}{6\beta^2-12\beta-2\theta^2+6}, 1)$, *when* $\beta \in ((1-\theta)p_d, \frac{1-2p}{1-2p+2c_s})$ *and* $\theta < \frac{1}{2}(-2\beta - \beta c_s + \beta p - p + 2 - \sqrt{\kappa})$;

where $\eta = ((\beta-1)(p-2)(2\beta+\theta-2)-\beta\theta c_s)^2+8(\beta-1)\beta(3\beta^2-6\beta-\theta^2+3)c_s$, and $\kappa = -2\beta(\beta-1)(p+2)c_s+\beta^2c_s^2+(\beta-1)^2p(p+4)$. Proposition 6(i) shows that charging C&C at a discounted rate could restrict the expansion of total demand and cross-channel channel migration in comparison to free C&C. Distinct from the base model, the total demand decreases by $\frac{\theta(2-2\beta-\theta)p_d^2}{2(1-\beta)\beta}$, which is increasing in home delivery fee p_d and discount rate θ but decreasing in inconvenient factor of C&C β. Compared to free policy, if the retailer charges higher delivery fee for online channel, then C&C with a discount less appealing to customers who are sensitive to non-partitioned prices. Likewise, if C&C is less convenient, then less customers who are hassle-sensitive will be attracted by the discounted omnichannel service. Thus, charging C&C at a discounted rate could weaken the effect of attracting new customers compare to free C&C. Similar to the base model, by charging a discounted rate, C&C could avoid channel domination and "manage" the flow of migrating demands across channels. In particular, it weakens the effect of shifting store demands to C&C by $\frac{\theta p_d(-2\beta-\theta p_d+2)}{2(1-\beta)^2}$, which is increasing in p_d, β and θ. When a retailer has a high online shipping fee, or the shipping discount is not attractive enough, or less convenient collection, C&C with a shipping discount becomes less attractive to store demands. When $\frac{p_d}{p}$ is high, it will weaken the moderating effect of shipping discount and free C&C becomes more popular than the discounted policy. Shifted online demands decline by $\frac{\theta(1-p_d)p_d}{\beta}$, which is decreasing in β but increasing in θ, and concave in p_d and reaching maximum when $p_d = \frac{1}{2}$. When C&C is inconvenient or does not offer attractive discount, it will weaken the effect of converting online traffic to stores. Thus the total demand for C&C decrease by $\frac{\theta p_d(-2\beta-\theta p_d+2)}{2(1-\beta)^2\beta}$, which is increasing in p_d, β and θ.

Although the total demand reduces in Scenario 3, Proposition 6(ii) shows that the total profit could grow if p_d is within $(\frac{\beta\theta c_s+(\beta-1)(2-p)(2\beta+\theta-2)-\sqrt{\eta}}{6\beta^2-12\beta-2\theta^2+6}, \frac{\beta\theta c_s+(\beta-1)(2-p)(2\beta+\theta-2)+\sqrt{\eta}}{6\beta^2-12\beta-2\theta^2+6})$. I then discuss two cases. First, when $\frac{\beta\theta c_s+(\beta-1)(2-p)(2\beta+\theta-2)+\sqrt{\eta}}{6\beta^2-12\beta-2\theta^2+6} < 1$, it is known that the convenient level of C&C is within $((1-\theta)p_d, \frac{(p+6)c_s+(p-2)^2-4c_s\sqrt{p+2}}{\delta})$, and the discount rate is within $(\frac{1}{2}(-2\beta-\beta c_s+\beta p-p+2-\sqrt{\kappa}), 1-\beta)$. Second, if $\frac{\beta\theta c_s+(\beta-1)(2-p)(2\beta+\theta-2)+\sqrt{\eta}}{6\beta^2-12\beta-2\theta^2+6} > 1$, the range of convenient level of C&C is narrower $\beta \in ((1-\theta)p_d, \frac{1-2p}{1-2p+2c_s})$, and the discount rate is smaller $\theta < \frac{1}{2}(-2\beta-\beta c_s+\beta p-p+2-\sqrt{\kappa})$, then the home delivery fee is within the range $p_d \in (\frac{\beta\theta c_s+(\beta-1)(2-p)(2\beta+\theta-2)-\sqrt{\eta}}{6\beta^2-12\beta-2\theta^2+6}, 1)$. Considering the complex form, I will compare the conditions in Proposition 4(ii), Proposition 5(ii) and Proposition 6(ii) through conducting a series of numerical experiments (see Table 9).

Table 9: Numerical Results of Comparing Conditions in Proposition 4(ii), 5(ii) and 6(ii)

	$\beta = 0.1$															
p	0.1				0.2				0.3				0.4			
c_s	0.03				0.06				0.09				0.12			
θ	0.1	0.2	0.3	0.4	0.1	0.2	0.3	0.4	0.1	0.2	0.3	0.4	0.1	0.2	0.3	0.4
Prop4(ii)-min	0.0035	0.0035	0.0035	0.0035	0.0074	0.0074	0.0074	0.0074	0.0119	0.0119	0.0119	0.0119	0.0169	0.0169	0.0169	0.0169
Prop5(ii)-min	0.0040	0.0045	0.0053	0.0063	0.0084	0.0096	0.0112	0.0134	0.0134	0.0153	0.0179	0.0215	0.0190	0.0218	0.0255	0.0308
Prop6(ii)-min	0.0019	0.0020	0.0021	0.0023	0.0039	0.0042	0.0045	0.0048	0.0063	0.0067	0.0071	0.0076	0.0089	0.0095	0.0101	0.0108
Prop4(ii)-max	0.9482	0.9482	0.9482	0.9482	0.8959	0.8959	0.8959	0.8959	0.8431	0.8431	0.8431	0.8431	0.7898	0.7898	0.7898	0.7898
Prop5(ii)-max	0.8980	0.8528	0.8119	0.7745	0.8482	0.8051	0.7660	0.7300	0.7978	0.7568	0.7193	0.6846	0.7468	0.7076	0.6716	0.6379
Prop6(ii)-max	$\underline{1.1995}$	$\underline{1.1430}$	$\underline{1.0944}$	$\underline{1.0529}$	$\underline{1.1343}$	$\underline{1.0808}$	$\underline{1.0348}$	0.9954	$\underline{1.0689}$	$\underline{1.0184}$	0.9748	0.9376	$\underline{1.0032}$	0.9556	0.9145	0.8794

	$\beta = 0.2$															
p	0.1				0.2				0.3				0.4			
c_s	0.03				0.06				0.09				0.12			
θ	0.1	0.2	0.3	0.4	0.1	0.2	0.3	0.4	0.1	0.2	0.3	0.4	0.1	0.2	0.3	0.4
Prop4(ii)-min	0.0079	0.0079	0.0079	0.0079	0.0168	0.0168	0.0168	0.0168	0.0270	0.0270	0.0270	0.0270	0.0386	0.0386	0.0386	0.0386
Prop5(ii)-min	0.0091	0.0106	0.0127	0.0159	0.0193	0.0225	0.0271	0.0341	0.0309	0.0362	0.0438	0.0552	0.0444	0.0522	0.0633	0.0806
Prop6(ii)-min	0.0042	0.0045	0.0049	0.0053	0.0090	0.0096	0.0103	0.0112	0.0143	0.0153	0.0165	0.0179	0.0204	0.0219	0.0236	0.0256
Prop4(ii)-max	0.9458	0.9458	0.9458	0.9458	0.8907	0.8907	0.8907	0.8907	0.8343	0.8343	0.8343	0.8343	0.7764	0.7764	0.7764	0.7764
Prop5(ii)-max	0.8896	0.8394	0.7942	0.7531	0.8369	0.7886	0.7446	0.7039	0.7827	0.7360	0.6929	0.6518	0.7267	0.6811	0.6381	0.5954
Prop6(ii)-max	$\underline{1.1898}$	$\underline{1.1280}$	$\underline{1.0759}$	$\underline{1.0324}$	$\underline{1.1226}$	$\underline{1.0640}$	$\underline{1.0146}$	0.9733	$\underline{1.0547}$	0.9994	0.9525	0.9135	0.9861	0.9339	0.8896	0.8526

	$\beta = 0.3$															
p	0.1				0.2				0.3				0.4			
c_s	0.03				0.06				0.09				0.12			
θ	0.1	0.2	0.3	0.4	0.1	0.2	0.3	0.4	0.1	0.2	0.3	0.4	0.1	0.2	0.3	0.4
Prop4(ii)-min	0.0136	0.0136	0.0136	0.0136	0.0291	0.0291	0.0291	0.0291	0.0469	0.0469	0.0469	0.0469	0.0679	0.0679	0.0679	0.0679
Prop5(ii)-min	0.0159	0.0192	0.0240	0.0322	0.0341	0.0411	0.0518	0.0700	0.0551	0.0668	0.0849	0.1168	0.0802	0.0981	0.1267	0.1816
Prop6(ii)-min	0.0073	0.0079	0.0087	0.0095	0.0156	0.0169	0.0184	0.0203	0.0250	0.0271	0.0296	0.0326	0.0358	0.0389	0.0426	0.0470
Prop4(ii)-max	0.9428	0.9428	0.9428	0.9428	0.8838	0.8838	0.8838	0.8838	0.8224	0.8224	0.8224	0.8224	0.7579	0.7579	0.7579	0.7579
Prop5(ii)-max	0.8787	0.8222	0.7716	0.7250	0.8219	0.7667	0.7159	0.6667	0.7622	0.7073	0.6548	0.5993	0.6985	0.6424	0.5851	0.5140
Prop6(ii)-max	$\underline{1.1775}$	$\underline{1.1094}$	$\underline{1.0534}$	$\underline{1.0085}$	$\underline{1.1076}$	$\underline{1.0430}$	0.9898	0.9470	$\underline{1.0365}$	0.9753	0.9248	0.8840	0.9639	0.9060	0.8580	0.8190

	$\beta = 0.4$															
p	0.1				0.2				0.3				0.4			
c_s	0.03				0.06				0.09				0.12			
θ	0.1	0.2	0.3	0.4	0.1	0.2	0.3	0.4	0.1	0.2	0.3	0.4	0.1	0.2	0.3	0.4
Prop4(ii)-min	0.0213	0.0213	0.0213	0.0213	0.0458	0.0458	0.0458	0.0458	0.0745	0.0745	0.0745	0.0745	0.1095	0.1095	0.1095	0.1095
Prop5(ii)-min	0.0256	0.0322	0.0432	0.0658	0.0553	0.0699	0.0951	0.1500	0.0907	0.1162	0.1630	0.3000	0.1353	0.1787	0.2818	-
Prop6(ii)-min	0.0116	0.0128	0.0142	0.0160	0.0247	0.0273	0.0303	0.0342	0.0399	0.0440	0.0491	0.0554	0.0577	0.0638	0.0713	0.0808
Prop4(ii)-max	0.9387	0.9387	0.9387	0.9387	0.8742	0.8742	0.8742	0.8742	0.8055	0.8055	0.8055	0.8055	0.7305	0.0638	0.7305	0.7305
Prop5(ii)-max	0.8642	0.7993	0.7408	0.6842	0.8013	0.7358	0.6729	0.6000	0.7327	0.6638	0.5890	0.4500	0.6548	0.5756	0.4542	-
Prop6(ii)-max	$\underline{1.1615}$	$\underline{1.0857}$	$\underline{1.0258}$	0.9806	$\underline{1.0878}$	$\underline{1.0158}$	0.9587	0.9154	$\underline{1.0121}$	0.9437	0.8891	0.8472	0.9338	0.8685	0.8160	0.7749

Note. The values (underlined) of $\frac{\beta\theta c_s+(\beta-1)(2-p)(2\beta+\theta-2)+\sqrt{\eta}}{6\beta^2-12\beta-2\theta^2+6}$ are above 1 because $\beta \in ((1-\theta)p_d, \frac{1-2p}{1-2p+2c_s})$ and $\theta < \frac{1}{2}(-2\beta-\beta c_s+\beta p-p+2-\sqrt{\kappa})$.

Table 10: Numerical Results of Comparing Conditions in Proposition 4(ii), 5(ii) and 6(ii) after Applying Constraints

	$\beta = 0.1$															
p	0.1				0.2				0.3				0.4			
c_s	0.03				0.06				0.09				0.12			
θ	0.1	0.2	0.3	0.4	0.1	0.2	0.3	0.4	0.1	0.2	0.3	0.4	0.1	0.2	0.3	0.4
Prop4(ii)-min	0.0035	0.0035	0.0035	0.0035	0.0074	0.0074	0.0074	0.0074	0.0119	0.0119	0.0119	0.0119	0.0169	0.0169	0.0169	0.0169
Prop5(ii)-min	0.0040	0.0045	0.0053	0.0063	0.0084	0.0096	0.0112	0.0134	0.0134	0.0153	0.0179	0.0215	0.0190	0.0218	0.0255	0.0308
Prop6(ii)-min	0.0019	0.0020	0.0021	0.0023	0.0039	0.0042	0.0045	0.0048	0.0063	0.0067	0.0071	0.0076	0.0089	0.0095	0.0101	0.0108
Prop4(ii)-max	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Prop5(ii)-max	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Prop6(ii)-max	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	$\beta = 0.2$															
p	0.1				0.2				0.3				0.4			
c_s	0.03				0.06				0.09				0.12			
θ	0.1	0.2	0.3	0.4	0.1	0.2	0.3	0.4	0.1	0.2	0.3	0.4	0.1	0.2	0.3	0.4
Prop4(ii)-min	0.0079	0.0079	0.0079	0.0079	0.0168	0.0168	0.0168	0.0168	0.0270	0.0270	0.0270	0.0270	0.0386	0.0386	0.0386	0.0386
Prop5(ii)-min	0.0091	0.0106	0.0127	0.0159	0.0193	0.0225	0.0271	0.0341	0.0309	0.0362	0.0438	0.0552	0.0444	0.0522	0.0633	0.0806
Prop6(ii)-min	0.0042	0.0045	0.0049	0.0053	0.0090	0.0096	0.0103	0.0112	0.0143	0.0153	0.0165	0.0179	0.0204	0.0219	0.0236	0.0256
Prop4(ii)-max	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Prop5(ii)-max	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Prop6(ii)-max	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	$\beta = 0.3$															
p	0.1				0.2				0.3				0.4			
c_s	0.03				0.06				0.09				0.12			
θ	0.1	0.2	0.3	0.4	0.1	0.2	0.3	0.4	0.1	0.2	0.3	0.4	0.1	0.2	0.3	0.4
Prop4(ii)-min	0.0136	0.0136	0.0136	0.0136	0.0291	0.0291	0.0291	0.0291	0.0469	0.0469	0.0469	0.0469	0.0679	0.0679	0.0679	0.0679
Prop5(ii)-min	0.0159	0.0192	0.0240	0.0322	0.0341	0.0411	0.0518	0.0700	0.0551	0.0668	0.0849	0.1168	0.0802	0.0981	0.1267	0.1816
Prop6(ii)-min	0.0073	0.0079	0.0087	0.0095	0.0156	0.0169	0.0184	0.0203	0.0250	0.0271	0.0296	0.0326	0.0358	0.0389	0.0426	0.0470
Prop4(ii)-max	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Prop5(ii)-max	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Prop6(ii)-max	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	$\beta = 0.4$															
p	0.1				0.2				0.3				0.4			
c_s	0.03				0.06				0.09				0.12			
θ	0.1	0.2	0.3	0.4	0.1	0.2	0.3	0.4	0.1	0.2	0.3	0.4	0.1	0.2	0.3	0.4
Prop4(ii)-min	0.0213	0.0213	0.0213	0.0213	0.0458	0.0458	0.0458	0.0458	0.0745	0.0745	0.0745	0.0745	0.1095	0.1095	0.1095	0.1095
Prop5(ii)-min	0.0256	0.0322	0.0432	0.0658	0.0553	0.0699	0.0951	0.1500	0.0907	0.1162	0.1630	0.3000	0.1353	0.1787	0.2818	-
Prop6(ii)-min	0.0116	0.0128	0.0142	0.0160	0.0247	0.0273	0.0303	0.0342	0.0399	0.0440	0.0491	0.0554	0.0577	0.0638	0.0713	0.0808
Prop4(ii)-max	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Prop5(ii)-max	-	-	-	-	-	-	-	0.6000	-	-	-	0.4500	-	-	0.4542	-
Prop6(ii)-max	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Note. - means values are invalid after applying constraints

The following conditions are observed:

- $\frac{\beta\theta c_s+(\beta-1)(2-p)(2\beta+\theta-2)-\sqrt{\eta}}{6\beta^2-12\beta-2\theta^2+6} < \frac{(\beta-1)(2-p)+\beta c_s-\sqrt{\xi}}{4(1-\beta)} < \frac{\beta c_s(-\beta+\theta+1)+(\beta-1)(2-p)(\beta+\theta-1)-\sqrt{\varepsilon}}{4\beta^2+2\beta(\theta-4)-2(\theta^2+\theta-2)}$;
- $\frac{\beta c_s(-\beta+\theta+1)+(\beta-1)(2-p)(\beta+\theta-1)+\sqrt{\varepsilon}}{4\beta^2+2\beta(\theta-4)-2(\theta^2+\theta-2)} < \frac{(\beta-1)(2-p)+\beta c_s+\sqrt{\xi}}{4(1-\beta)} < (\frac{\beta\theta c_s+(\beta-1)(2-p)(2\beta+\theta-2)+\sqrt{\eta}}{6\beta^2-12\beta-2\theta^2+6})$,

However, the values are invalid after applying constraints in the later conditions ((see Table 10)). Therefore, the optimal shipping policies are identified when customers are heterogeneous as follow:

- If p_d is small ($p_d < \frac{\beta\theta c_s+(\beta-1)(2-p)(2\beta+\theta-2)-\sqrt{\eta}}{6\beta^2-12\beta-2\theta^2+6}$), offering free C&C is better;
- if p_d is medium ($p_d \in (\frac{\beta\theta c_s+(\beta-1)(2-p)(2\beta+\theta-2)-\sqrt{\eta}}{6\beta^2-12\beta-2\theta^2+6}, \frac{\beta c_s(-\beta+\theta+1)+(\beta-1)(2-p)(\beta+\theta-1)-\sqrt{\varepsilon}}{4\beta^2+2\beta(\theta-4)-2(\theta^2+\theta-2)})$), charging C&C at a discounted rate is a better;
- if p_d is large ($p_d \in (\frac{\beta c_s(-\beta+\theta+1)+(\beta-1)(2-p)(\beta+\theta-1)-\sqrt{\varepsilon}}{4\beta^2+2\beta(\theta-4)-2(\theta^2+\theta-2)}, \frac{\beta c_s(-\beta+\theta+1)+(\beta-1)(2-p)(\beta+\theta-1)+\sqrt{\varepsilon}}{4\beta^2+2\beta(\theta-4)-2(\theta^2+\theta-2)})$), the retailer is better off not offering C&C.

To understand how shipping discount of C&C impacts the optimal home delivery fee, I subtract the optimal shipping fee in Lemma 5 from that in Lemma 6, and get the difference $\frac{1}{3\phi}(\mu+\omega) - \frac{1}{6}(2\beta-p+2-\sqrt{4\beta^2-4\beta+p^2+8\beta p-4p+4})$. Similarly, a numerical analysis is conducted to evaluate the effect of shipping policies and get Table 11 that summarises results of the difference in optimal shipping fees.

Table 11: Changes in Optimal Delivery Fees Between Scenario 3 and Scenario 2

p	0.1				0.3				0.5				0.7			
c_s	0.03				0.09				0.15				0.21			
β	0.1	0.3	0.5	0.7	0.1	0.3	0.5	0.7	0.1	0.3	0.5	0.7	0.1	0.3	0.5	0.7
θ	changes in p_d^*				changes in p_d^*				changes in p_d^*				changes in p_d^*			
0.1	$\underline{0.0103}$	$\underline{0.0255}$	$\underline{0.0315}$	$\underline{0.0274}$	$\underline{0.0080}$	$\underline{0.0176}$	$\underline{0.0184}$	$\underline{0.0107}$	$\underline{0.0054}$	$\underline{0.0096}$	$\underline{0.0066}$	-0.0035	$\underline{0.0023}$	$\underline{0.0017}$	-0.0036	-0.0156
0.2	$\underline{0.0241}$	$\underline{0.0559}$	$\underline{0.0607}$	$\underline{0.0418}$	$\underline{0.0187}$	$\underline{0.0375}$	$\underline{0.0339}$	$\underline{0.0132}$	$\underline{0.0123}$	$\underline{0.0194}$	$\underline{0.0105}$	-0.0120	$\underline{0.0049}$	$\underline{0.0024}$	-0.0097	-0.0345
0.3	$\underline{0.0433}$	$\underline{0.0894}$	$\underline{0.0822}$	$\underline{0.0441}$	$\underline{0.0331}$	$\underline{0.0581}$	$\underline{0.0442}$	$\underline{0.0086}$	$\underline{0.0212}$	$\underline{0.0286}$	$\underline{0.0109}$	-0.0247	$\underline{0.0079}$	$\underline{0.0017}$	-0.0182	-0.0560
0.4	$\underline{0.0702}$	$\underline{0.1215}$	$\underline{0.0935}$		$\underline{0.0525}$	$\underline{0.0768}$	$\underline{0.0482}$		$\underline{0.0326}$	$\underline{0.0359}$	$\underline{0.0075}$		$\underline{0.0112}$	-0.0009	-0.0291	
0.5	$\underline{0.1074}$	$\underline{0.1458}$	$\underline{0.0000}$		$\underline{0.0780}$	$\underline{0.0905}$	$\underline{0.0463}$		$\underline{0.0467}$	$\underline{0.0400}$	$\underline{0.0005}$		$\underline{0.0144}$	-0.0057	-0.0420	

Note. The negative values indicate that the retailer should reduce the optimal delivery fee, and positive ones (underlined) imply increases in the optimal delivery fees.

Observation 2.

(i) the retailer should increase the optimal delivery fee in Scenario 3 when p *and* c_s *are small; the difference in optimal delivery fees between Scenario 3 and 2 will change from positive to negative when* p *or* c_s *grows;*

(ii) the difference in optimal delivery fees is non-monotonic in β *and* θ *and will grow when* β *and* θ *are small but will decrease when* β *and* θ *are large.*

Observation 2(i) indicates that the retailer should raise the optimal home delivery fee if C&C is charged at a discounted rate in comparison to free C&C when the unit selling price and unit handling costs are small. For example, when the retailer sells products with low price, the optimal home delivery should be lower to restrict the effect of free C&C on migrating online demands; however, when C&C is charged at a discounted fee, the retailer can use discount rate to moderate the cross-channel effect, thereby it is unnecessary to lower optimal home delivery fee. This result is similar to that in the base model. When the unit selling price and selling costs are high, the differences in optimal home delivery fees between the two scenarios will change from positive to negative. It implies that the retailer should reduce the optimal home delivery fee when the unit selling price and selling costs are high. The potential reason is that when the in-store handling cost is high, the retailer has more motivation to drive traffic online, thereby reduce the optimal home delivery fee to enhance the cross-channel effect. However, Observation 2(ii) shows the change in optimal delivery fee is non-monotonic with β and θ. If β and θ are small enough, C&C attract customers from both store and online channels. Thus, the retailer should reduce the optimal delivery fee to moderate the demand migration from online to stores, and ensure the profit loss will not surpass profit gain.

Overall, the addition of C&C shows a positive effect on generating new customers when customers are heterogeneous, which is distinct from the results in the base model where the total demand is consistent due to customer's homogeneity in a product. It implies customer's heterogeneity could positively change the effect of the shipping policy on increasing the total demand for a product. However, the impacts of C&C on migrating customer demand across channels and optimal home delivery fees are similar between the base model and the extension. In the extension, the ratio is gained to represent the cross-channel effect $\frac{\beta(-2\beta+(\beta-\theta-1)p_d+2)}{2(1-\beta)^2(1-p_d}$ by comparing shifted store over online demands in Scenario 3. When the ratio is above 1, then there are more store customers shifted; otherwise, more online customers are converted if the ratio is below 1. The ratio is increasing in p_d but decreasing in θ and non-monotonic in β.

4.8 Summary

In summary, this study aims to understand the relevant elements affecting a retailer's omnichannel shipping policy and provide insights that help retailing practitioners make efficient shipping policy when they implement omnichannel functions, i.e. Click & Collect (C&C).

I develop a stylised model considering customer homogeneity and heterogeneity to understand how the shipping policy of an omnichannel function impacts the cross-channel behaviours and a retailer's total profit. To capture omnichannel operations, I consider the differences between online channels and stores in operating costs, inconvenience level and perceived hassle costs. In the base model, customers are homogeneous in product valuations but heterogeneous in the perceived hassle cost of visiting a store. In the model extension, customers are heterogeneous in both product valuations and the hassle cost of visiting stores. Comparing the base model and extension helps understand how customer heterogeneity affects omnichannel implementation. In each model, a benchmark where C&C is unavailable and three scenarios representing different omnichannel shipping policies are discussed, e.g. charging C&C with a home delivery fee, free C&C, charging C&C at a discounted rate. By comparing the benchmark with three scenarios, this study identifies the optimal shipping policy and the corresponding conditions.

As a result, this study has found the following insights. First, if a retailer decides to offer C&C, this service should be either free or charged lower than the home delivery. Otherwise, adding an omnichannel function may not impact customer demand but may hurt total profit due to the investment in channel integration. Second, whether customers are homogeneous or heterogeneous, C&C shows a positive effect on cross-channel demand migration when charged at a discounted rate or free of charge. Third, the discount rate of C&C shows a positive effect on moderating demand converted to a less profitable channel. Four, when customers are heterogeneous in both product valuations and hassle cost of visiting a store, C&C positively impacts expanding total demand. Five, when the online operation is cost-effective, the retailer should offer free C&C, and if the cost of delivering online orders is not low or too high, the retailer can charge C&C at a discounted rate.

Chapter 5

Model Two - Omnichannel Return Policy

5.1 Model Background

Internet shopping breaks barriers of conventional brick-and-mortar stores in geographic locations and normal operational hours and allows customers to shop anytime and anywhere. Online-only grocery has reached over 25% of the UK total grocery market by 2018 (Mintel, 2020*b*). Despite the conveniences online channels offer, online shopping faces a significantly higher return rate than in-store shopping. The return rate for customers purchasing online could be doubled compared to shopping in a brick-and-mortar store (Orendorff, 2019). Moreover, the rate can also vary across product categories, such as footwear and garments (IMRG, 2020). UPS did a survey and identified top reasons for returning online orders: wrong items or damaged during delivery, items that do not meet a customer's expectations, including different from the product description and poor quality, and issues with deliveries (UPS, 2019). Therefore, to moderate the drawbacks of online shopping, some retailers adopt an omnichannel strategy that allows customers to purchase online and collect or return in a selected store.

The benefits of offering omnichannel returns are multi-fold. First, returning online items to a store could increase in-store footfall and boost cross-selling opportunities (IMRG, 2020). Second, nudging customers to complete returns themselves could reduce the retailer's shipment and operational costs, such as arranging home collections and liaising with third-party partners and the delivery cost from collected location to DC or suppliers. Third, a low-hassle or hassle-free return process could mitigate the risks of online shopping and thus alleviate the rate of shopping cart abandonment and enhance customer satisfaction, e.g. more than 50% of online customers review return policies before purchase (UPS, 2019). Omnichannel returns provide conventional retailers with unique advantages compared to e-commerce by leveraging their existing store networks. An omnichannel return policy gives customers flexibility and could be a chance to turn a negative return experience into a bespoke customer service in-store, therefore building customer relationships and enhancing customer loyalty (Deloitte, 2019).

Table 12: Return Policies of Top UK omnichannel Retailers for Non-members

Retailer	Return Period	Online Return Fee	Omnichannel Return	Return at Third-party
George (Asda)	30-day return policy and 100-day retrun guarantee for selected products	Free	Yes, but except for certain products and omnichannel exchange is not allowed	Collect Plus
Tesco	30-day return policy except for health or hygiene products, and some products have different return time limits; 100-Day Quality Guarantee for certain products	Free	Yes, except for Express stores and certain products	Tesco Express
Sainbury's	30-day return policy but some items cannot be returned unless faulty	Do not accept grocery returns by post	Yes, return to any of sainsbury's stores except for certain products	Argos
Marks & Spenser	Standard returns policy is 35 days for both online and in-store items, except in case of sale items where you have 14 days to return.	Free depending on the size of items	Yes for online items; Products purhcased in-store must be returned to stores.	Carrier partners: Hermes & Royal Mail & Collect Plus
John Lewis & Partners	Return unwanted items up to 35 days after purchase except for certain products.	Free depending on the size of items	Yes for certain products	Waitrose or carrier partners: Hermes & Royal Mail & Collect Plus; or retailing partners: Shell, Booths, and Coop.
Next	Must tell us within 14 days (beginning on the day after the day you receive the goods), and you then have 14 days to return the items.	£2.00 returns charge will be applied for each collection made by courier, regardless of the number of items collected.	Yes	Couriers: local Hermes ParcelShop, local Hermes Locker, Royal Mail
H&M	Refund within 28 days for any unsuitable items, but return policy may differ for certain products.	Free depending on the size of items	Yes for online items; Items purchased in store must be returned to store.	Couriers: Hermes Parcel Shop Drop off points, Hermes courier collection, Royal Mail
ZARA	30 days from the order shipping day to return the purchase.	Free	Yes, but HOME items can be returned as well to ZARA HOME stores.	Drop-off points
B&Q	Return the purchase in its original condition within 135 days	the fee will depend on the products returned, but will not exceed £50	Yes, but iems purchased in store must be returned to store.	Collection Service

Note. Return policies obtained from the brand's official websites are standard policies without extension due to Covid-19. Accessed 6th August 2020.

Although many retailers benefit from omnichannel return policies, they face great pressure to balance the operating costs and deliver a satisfying and efficient return policy. Fundamentally, handling returns is costly using third-party partners or retailers' own logistics. When customers purchase online, no matter how many items from an order are returned, the return operating costs are incurred (IMRG, 2020). For example, the shipping cost of average clothing order is over £3, and the return cost could be doubled or trebled (Ram, 2016). The sales loss is over 1.5 billion US dollars annually because of online returns (Li et al., 2013). Omnichannel returns potentially reduce the shipping cost from the customer's home to stores. However, the extra labour cost of sorting out returned items is still incurred, such as inspecting whether the item is damaged, unpacking and cleaning the item, repackaging it, re-store them either in-store or shipping it back to the central warehouse. Additionally, if the returned items are seasonal or perishable products, the re-sellable values could be discounted (Ram, 2016). Moreover, where and how retailers sell their returned items could impact their salvage values. For example, if retailers have a limited network of stores or third-party sellers, the margin could be diluted in return handling, or sales opportunities are lost compared to selling it at a full unit selling price. At last, to deliver a seamless omnichannel service including shipment and returns, retailers need to invest in the technological infrastructure to capture orders across channels and platforms, check accurate inventory availability, allocate order collection, tracking shipment and returns (Deloitte, 2017). Therefore, offering a return policy with a high level of generosity and convenience return means a considerable investment in technology and operating costs in the supply chain.

Nine UK retailers are selected with outstanding market share cross sectors and list their return policies for non-members in Table 12. It demonstrates that retailers decide relevant elements in the return policy differently. For example, the first element is the return period that starts from receiving and returning vary from 14 days to 135 days across sectors. Some offer a generous return period, like B & Q, as their products generally are not perishable. Nevertheless, the fashion and homeware retailer NEXT requires customers to request the return within the first 14 days and then have 14 days to return or post the item. The second element is the return charge for returning items through the post, known as online returns. Some offer free online returns, while some charge the return delivery at a standard rate or based on the products, such as the size and weight of items. Sainsbury's does not even offer grocery returns via post. The third element is whether retailers allow cross-channel returns. Most of the selected retailers embraced omnichannel returns allowing customers to buy online and return to stores except for certain products, such as hygiene products, or exchange in-store due to inventory problems. However, some retailers do not allow items bought in-store returned via post. The last element is whether retailers choose third-party to process returns. For example, most of them partner with courier services, such as arranging home collection while delivery, or allow customers to drop the parcel at a third-party location, e.g. Collection Plus, Lockers, and Post offices. From a customer's view, these factors influence purchase intention and channel choice depending on their sensitivity to the risks and hassles (IMRG, 2020). To decide an effective return policy, retailers have to determine these elements considering their operating costs and the impact on customer demand.

As a result, retailers face operational trade-offs when deciding the return policy to balance the benefits and costs of offering omnichannel returns. Offering omnichannel returns gives customers flexibility and confidence when shopping online and attracts online traffic in-store, potentially increasing cross-selling opportunities. However, omnichannel returns also mean extra handling cost in-store, loss of sales opportunity when returned products are re-sold at a discounted price. Thus, the first trade-off weighs between the profit gain from cross-sales in-store and profit loss from re-selling the returned product and in-store handling cost. Although omnichannel returns are convenient, customers who prefer to shop online and return online, or customers who prefer visiting a store than paying a return shipping fee, may choose to return online via post. Hence, the second trade-off is that offering a free online return will encourage a certain type of online customers to return online. Therefore, retailers lose the cross-selling opportunity, while charging a shipping fee for returning items via post could increase the perceived risk of online shopping and cart abandonment. As a consequence, this study attempts to gain insights to answer the following research questions:

- How do operational factors affect retailers' return policies in the omnichannel setting?
- How do omnichannel return policies affect customers demand across channels?
- What is the optimal return policy regarding total profits in an omnichannel setting, and under what conditions?
- Under what conditions should omnichannel retailers offer a generous return period?

To address the questions above, this model captures omnichannel operations' features and develops a stylised model considering a retailer with both online channels and brick-and-mortar stores. The retailer faces the following decisions: 1) whether to offer omnichannel returns; 2) whether to charge for online returns; 3) the optimal return charges when returning via post. The unit selling price is consistent across channels referring to retailing practices, and the omnichannel return is free of charge. Moreover, the effect of refund is excluded in this model by assuming all returns will be full-refund. Customers are heterogeneous in product valuations and homogeneous in the hassle cost of returning items to stores. Customers who buy the product in-store are assumed not to return it because they have inspected it before purchase. Customers who shop online face the uncertainty of receiving the product mismatching their expectations. There is a probability that customers find the product received does not match as expected, and it varies across product categories. Hence, customers face the following choices: 1) whether and where to buy a product; 2) whether to return the product; 3) where to return. Customers will choose to purchase and return based on their valuations and hassle costs, depending on the retailer's characteristics of omnichannel operations and supply chain networks, including the number of stores and third-party networks. Existing research on return policies has mostly focused on e-commerce. I study the return policy, especially how much the return charge should be in an omnichannel setting and discuss how relevant factors influence the optimal return policies.

The rest of this chapter is organised as follows. In §5.2, relevant literature is reviewed about return policies and omnichannel operations, especially how this study differs from existing research. In §5.3, the research problem setting is described, and the base model is formulated in §5.4. Then, I analyse how different scenarios of return policies impact customer demands and retailer profitability in §5.5 by comparing among scenarios to understand the impact of omnichannel return policies. Later, the model is extended by studying the longer return period and conducting a series of numerical analyses in §5.6. Finally, this chapter ends with a summary of results in §5.7. All proofs and relevant numerical studies are in Appendix B.

5.2 Relevant Literature

Three streams of research are the most relevant to this study: first is the return policy of single-channel retailers; second is the return policy of omnichannel retailers; the last is the operational trade-offs during omnichannel fulfilment.

The first research stream related to return policies primarily focuses on determining the elements in the return policy and studying their effects on customer behaviours and the retailer's costs and profits. Janakiraman et al. (2016) summarised five elements in a return policy: time, money, effort, scope, and exchange, through a meta-analysis. They find that the positive effect of lenient return policies on purchase decisions outweighs the negative impact on encouraging customer returns. In particular, elements such as monetary and effort positively increase customers' purchase intentions. Therefore, early studies discuss the impact of monetary elements. Davis et al. (1995) developed a stylised model to study the condition of a profitable full-refund policy by considering salvage values of returned items, the chance of a product mismatching customer expectations, and the shipping cost of returns. Moorthy and Srinivasan (1995) study how full-refund impacts customer perception on product quality using signal theory. Hess et al. (1996) use empirical methods and find that shipping and handling charges depending on the order values could positively impact profitability and reduce customer returns. Su (2009) develops a stylised model to study returns policies from the supply chain perspective, including full-refund and partial-refund considering salvage values using the newsvendor model to capture homogeneous and heterogeneous customer demands. They find the optimal refund should be in line with the salvage value of returned items when customers are homogeneous, while higher than the salvage value if customers are heterogeneous in the product valuations. Shulman et al. (2010) developed an analytical model to examine how the return charge is impacted by the channel member (e.g. manufacture and retailer) re-selling the returned products using game theory. They find that the return charge could be higher when the channel member for more salvage values. Shulman et al. (2011) developed a stylised model to investigate the pricing and return charge decisions in a competitive game. Consumers will try the product before purchase as they are heterogeneous in product tastes. They find that return charges can be higher when consumers have less information regarding how well the product matches their preferences. Bower and Maxham III (2012) empirically study the return shipping policy that customers pay for returns when at fault through filed studies using equity theory. They find that free product returns do not always bring positive business outcomes as they may result in less spending after returns. It depends on a customer's perception of fairness. Some studies discuss the element of effort. Davis et al. (1998) develop an analytical model to understand the hassle level in a retailer's return policy. They identify that retailers are more likely to offer return policies with low hassle depending on product duration, cross-selling opportunities and salvage values of returned items. Janakiraman and Ordóñez (2012) study the effort and time of return policy and their impacts on consumer returns using construal level theory. They find that a shorter return period cannot reduce the return rate under certain conditions, while a return policy with less hassle could moderate the return rate. Ertekin and Agrawal (2020) developed an analytical model to understand the impact of restricting return policy (e.g. shorten the return period, restrict return windows) on sales, returns, and profitability for a multichannel retailer. The empirical test finds that restricting the time element in return policy does not significantly reduce returns. Instead, it negatively impacts sales since it accelerates customer return behaviours. However, it may be more profitable if stores face high sales and return volumes. Although these studies discuss the elements involved in the decision of return policies, their research primarily concentrates on single-channel retailers such as online-only retailers and catalogue-only retailers. They exclude customers' cross-channel behaviours and corresponding retailers' operational complexities in their discussion. Therefore, their studies provide limited insights on cross-channel return policies. This research will fill this gap by capturing the characteristics of a retailer's omnichannel operations and cross-channel behaviours. This study primarily discusses return charges in the return policy under the omnichannel context.

The second stream involves more recent works focusing on the policy under the omnichannel setting. Ofek et al. (2011) use game theory to study how adding a new online channel to conventional stores impact the choice of product categories, the likelihood of customer returns, pricing and retailer profitability. They find that the omnichannel model can reduce the chance of returns when competition is intense, and the product category involves in-store inspection, yet may not increase profit due to extra investment in-store assistance. Gao et al. (2021) investigate the effect of return rate on how omnichannel function is carried out (e.g. showroom, cross-channel return, and BOPS) and the choice of store number and sizes. Jin et al. (2020) develop a multi-stage model based on game theory to study cross-channel returns during competition. They investigate pricing and return charges considering customers' heterogeneity. Customers are heterogeneous in brand preference and return costs. The model describes three stages. The first stage is when the retailers decide whether to adopt a cross-channel return policy. Then the retailers decide the retail prices accordingly. In the final stage, customers choose which retailer to purchase and which channel to return. In their model, the decision of cross-channel return is relevant to four customer segments, return efficiency by channel, and competitor differentiation. They find that allowing cross-channel returns can be sustained when retailers are adequately distinguished and salvage values of returned items in-store is more profitable than the online channel. This research is relevant but different in many ways. First, their customers are segmented into four groups depending on brand preferences and shipping and return costs. The customer setting is heterogeneous in product valuations and the hassle cost of returning to a store. Second, this study does not take into account competition. Yan et al. (2020) develop stylised models to identify the optimal decision in pricing and return policies (e.g. return through the same channel and cross-channel returns). They find it beneficial for the policy with a low return service charge and cross-channel return when cross-selling profit is high. However, adopting a cross-channel return policy may not be profitable if the cross-selling profits are low or the hassle cost of shopping online is low enough, as it always increases the return quantity instead of customer demand. This research is similar to theirs in identifying the condition of the profitable omnichannel return policy as well as these model assumptions. For example, customers are heterogeneous in product valuations, and salvage values are the same across channels. However, this study is different from theirs in the research focuses, and therefore certain model settings. First, the customer setting in this model is homogeneous in the hassle cost of returning to a store. Second, this study does not exclude the free online returns, widely adopted by many online and omnichannel retailers. Third, the operating cost difference is captured between online channels and stores. Fourth, the unit selling price and return charges are separated, and I set the selling price consistent across channels to exclude its impact on the results. Nageswaran et al. (2020) capture omnichannel operations in their stylised model and study the retailer's decision in pricing and return policy considering the salvage values of returned items and customer heterogeneity. They find that return policy is relevant to salvage values, store networks, and products. Unlike Su (2009) where they find that refund should be identical to salvage value, Nageswaran et al. (2020) reveal that partial-refund policy is beneficial when the salvage value of returned items are high, or the retailer has significant store networks for cross-channel returns, while FR policy will benefit retailers if their products are likely to be inspected in-store. Combining a convenient return process with a partial-refund policy can negatively affect retailer profitability. This study is similar to theirs in the following ways. In the model assumption, cross-channel returns are allowed, unit selling price is assumed identical across channels, and customer demand is exogenous. Nevertheless, purchases and return channels are affected by the return policy in the based model. However, this study differentiates from theirs in research focuses and model settings. First, the return charge in this model is defined as a decision variable other than being embedded into the refund decision as the variance between the unit selling price and refund amount. Second, the difference between stores and online channels is described by capturing their variances in operating costs other than salvage values. Third, the return shipping fee is incorporated into the profit function. Fourth, the assumption of exogenous customer demand will be loosed in the model extension and further discussed. Although these studies discuss cross-channel return policy and relevant factors, their research focuses on the relationship between refund amount and salvage values, the condition of adopting profitable cross-channel return policy or combining return charges with pricing strategy. They limit the insight into how return shipping fees as an important factor affecting customer channel choices in the pre- and post-purchase stages. This research will fill this gap by focusing on the return charge and embedding it in the profit function and the differences in operating costs across channels.

The third research stream focuses on operational trade-offs during omnichannel fulfilment, especially the impact of adding an online channel to the physical stores on store operations, customer demand, and retailer profitability. Bell et al. (2018) empirically study the impact of omnichannel implementation (i.e. showroom) on online and sampling channels. They find that showrooming shifts the demand that prefers to inspect in-store to the online channel, generating new demands overall, increasing revenue, and reducing returns on sampling channels. Chen, Liu and Wan (2016) use game theory to formulate the decision-making process of inventory, pricing and revenue share across channels under BOPS model. They incorporate the loss of both under-stocking and overstocking into the online profit function and gain from cross-sales into the store profit function. They find that stores and online channels are influenced by BOPS distinctively. The impact of implementing BOPS on revenue and cross-channel behaviours is also empirically studied by (Gallino and Moreno, 2014; Gallino et al., 2017). Gallino and Moreno (2014) empirically examine how BOPS affect online and store sales. They find that BOPS generates new customers, shifts some online traffic to stores, and enhances the cross-sales effect. Gallino et al. (2017) empirically study the effects of STS on inventory management, e.g. sales dispersion that is the revenue contribution of different products, assuming that store orders enjoy higher priority than STS orders. They find that STS does not increase total revenue yet increase sales dispersion as customers can access products in-store without considering substitutes or low-stock or out-of-stock. Gao and Su (2017) developed a stylised model based on game theory and newsvendor model to investigate the impact of the BOPS on cross-channel behaviours and store operations, including inventory, product category, revenue sharing across channels. In their model assumption, customers will switch to online channels or leave the market if they are out-of-stock in-store. They also exogenies the proportion of online and stores customers to understand the demand migration across channels. They find that BOPS is not applicable for all products, especially the popular items in-store, because revealing inventory availability in-store may deter customers from visiting stores. Although BOPS can attract new customers in-store, it is not profitable if customers are converted from the channel with a higher profit margin. This study is relevant to theirs in the following ways. This study attempts to understand and deal with trade-offs between the benefit of implementing an omnichannel strategy and the related costs or potential loss from inventory or cross-channel behaviours. The features of omnichannel operations are characterised in our model setting, considering customer heterogeneity. Online channels differ from store operations, such as different hassle costs Gao and Su (2017) and variance unit costs Chen, Liu and Wan (2016) between online and stores. Like Gao and Su (2017), this study allows customers to be heterogeneous in product valuations and endogenises customers channel choices in purchases and returns in the extension. Utility theories are adopted to understand customers' choices and maximise the overall profit function as model objectives Gao and Su (2017); Chen, Liu and Wan (2016). However, this study differs from theirs in the research focuses. Most of these studies focus on the impact of an omnichannel strategy on the pre-purchase stage. However, this research concentrates on the effect of cross-returns on online return shipment, the customer channel choice and profitability in the post-purchase stage. Moreover, instead of embedding service prices into unit selling prices, the unit selling price is consistent across channels. Online return charge is separated from the unit selling price and incorporated into our profit function and differentiate online and store operations by allowing variance handling costs and perceived hassle costs of visiting stores. Most of these studies focus on one stage only. This research will fill this gap by capturing how the return charge impacts channel choices in ex-ante and ex-post stages. In addition, omnichannel retailers need to be cautious in implementing cross-channel returns and free online returns.

This model considers strategic customer channel decisions in the post-purchase stage. Therefore, the decision of service charge in the return policy is rooted in the decision theory, and customer cross-channel behaviour and choices are motivated by utility theory. Both theories have been developed (North, 1968; Tsoukiàs, 2008; Vazsonyi, 1990; Buchanan and O Connell, 2006; Bernoulli, 1896; Neumann and Morgenstern, 1944; Fishburn, 1968; Savage, 1972; Fishburn, 1988)and broadly applied in the operations management and omnichannel research are widely adopted and discussed in operations management(Davis et al., 1995, 1998; Su, 2009; Chen, Liu and Wan, 2016; Gao and Su, 2017; Jin et al., 2020; Yan et al., 2020; Nageswaran et al., 2020). This research contributes theoretically by extending utility theory in understanding cross-channel behaviours and channel choices in the ex-post stage. This study also extends the application of decision theory in determining the optimal return charges under the omnichannel setting.

Overall, this study marries these three streams of research to understand the return policy from an omnichannel retailer's perspective. The discussion reflects four retailing practices. First, identical unit selling prices are set, and online returns are charged for a post fee. Second, customers are heterogeneous in the product valuations. Our hassle cost does not include the monetary travel cost because customers are assumed not to return in-store if the travel cost is more than the online return fee. Thus, the hassle cost in this model represents the inconvenience of the return process, including finding the counter in-store, keeping the receipt, waiting for the refund etc. Last, the extension considers the time element in the return policy and discusses how these factors impact the decision of return charges.

5.3 Problem Setting

This model considers a customer to buy a product from an omnichannel retailer with both online channels such as its own website or digital APPs (shown as "o" in the model) and physical stores (shown as "s" in the model). If the product is purchased through an online platform, the customer faces the uncertainty of whether it matches his expectations. If the product does not match, it will be returned in the same condition as customers received it, and the customer will receive an FR regardless of which channel customers purchased it from. However, if customers choose to return it online via a standard delivery, the omnichannel retailer will need to make the following decision. First, should the retailer allow customers to return online free of charge (known as free return)?

The benefit of free return will reduce customers' uncertainty before purchase, but what should the retailer charge for online returns if free delivery is not profitable? The online return charge is an important decision because it may defer customers sensitive to non-partitioned prices while potentially nudge them to return in-store. Second, should the retailer allow customers to return across channels, e.g. an online order in a selected store? However, this scenario is not considered in which customers buy in-store and return online because they have already inspected the product in-store and eliminated the product uncertainty before purchase. Although consumers may change their minds about products brought in-store without any reason or due to poor product quality, our model will concentrate on the main driver of returns primarily caused by the mismatch between product valuation and customer expectations (UPS, 2019), such as non-fit fashion products. Third, should the retailer offer a convenient return process, e.g. a generous return window? In business practices, most retailers offer a full refund if the product is kept in its initial condition and returning online items to a selected store is generally free of charge (Nageswaran et al., 2020). Hence, in this study, cross-channel returns from online channels to stores are free.

The retailer sells a product at a unit selling price p which is identical across channels. This setting is reasonable because a product's price has become transparent since online search engines, such as GOOGLE, allow customers to compare prices across channels and sellers anywhere and anytime, especially for a branded product with broad distributions. Different from many studies (Li et al., 2013; Jin et al., 2020; Nageswaran et al., 2020), price is set to be exogenous and fixed because the product's retail price is generally suggested by manufacturers other than retailers (Alexis, 2021). This setting allows me to focus on the impact of service pricing for return policies other than the product selling price itself. The retailer faces a unit handling cost c if the product is sold in-store, the same as model one. c is set as in-store handling cost other than production cost (Nageswaran et al., 2020) or procumbent cost (Jin et al., 2020) that is related to how business is conducted as I differentiate the cost of running online channel from in-stores operations other than treating the production costs as a whole. The unit handling cost sold online as zero to simplify the calculation, thereby c represents the cost variance between online and store, which is assumed to be smaller than p ($c < p$), otherwise it is not profitable to sell the product in-store. The value of c represents two things. One is the efficiency of store operations, such as reasonable store layouts with clear signs, counters for checking in, collecting and returning online orders, and sufficient and welltrained staff to offer satisfactory store assistance. The more efficient the in-store operations are, the more advantages stores have in handling cross-channel orders. The other is the cost difference of selling a product in a store and through an online channel. Thus, the less c is, the in-store operation is more cost-efficient, and the retailer would have motives to drive online orders to return in a store.

If a product is returned, it will be re-sold at a salvage value s. Thus, if the returned item is sold online, then its salvage value is s, and if it is returned to a physical store and re-sold in-store, the salvage value is $s - c$ due to the cost difference between stores and online channels. The salvage value is set differently from Jin et al. (2020); Nageswaran et al. (2020) in the two ways. First, they set salvage values for online and stores independently. Instead, the salvage value is the same across channels, but in-store handling cost c is to differentiate them as selling a product regardless of whether it is returned will generate a handling cost. This setting reflects the salvage differences between online channels and stores due to high in-store operating costs. Second, their salvage value is restricted by the marginal cost of production. s is smaller or equal to the unit selling price p: $0 < s \leq p$, because a returned product with initial conditions could be potentially sold at a full price either online or in-store (Jasmine, 2019). The value of s shows the capability of re-selling returned products profitably through its own channels. In this study, the retailer's inventory always meets customer demand. Thus, the out-of-stock is not considered. This assumption helps focus on the return charge problem (Nageswaran et al., 2020). Table 13 summarises notations in our models.

Table 13: Table of Notation for Model Two

Symbol	Description
p	the unit selling price for a product $0 < p < 1$, and it to be an identical constant across channels;
c	the unit handling cost for a product sold through a physical store and $c < p$;
s	salvage value of re-selling a returned product online and $0 < s \leq p$; thus, salvage value of re-selling a returned product in-store is $s - c$;
d	the shipping fee charged for the online return and $0 < d < 1$;
v	perceived product value, where v is a random variable uniformly distributed $v \sim U[0, 1]$;
h	the hassle cost of visiting a physical store, where $0 < h < 1$ in the base model when customers are homogeneous in the inconvenience of visiting a store;
β	probability that a product matches customer expectations, where β is a rate within the range $\frac{1}{2} < \beta < 1$; thus, the probability that a product dis-matches customer expectations is $1 - \beta$, and it reflects various return rates for different customer segments or product categories;
α	the additional profit $0 < \alpha < 1$ generated by customers who cross-return online orders in-store;
λ	fraction of online customers when customers are exogenous, thus $1 - \lambda$ characterises the fraction of store customers;
δ	additional demand motivated from offering free online return $\delta > 1$;
q_i	the demand for a product on a channel i,and subscript $i = s, o$ represents stores and online respectively;
Q_j	the total demand in each scenario, and subscript $j = s_1, s_2, s_3$ and s_4 represents scenario 1 to 4 respectively;
π_i	the profit of selling a product through a channel i is defined as π_i, and subscript $i = s, o$ represents stores and online respectively;
Π_j	the total profit in each scenario, and subscript $j = s_1, s_2, s_3$ and s_4 represents scenario 1 to 4 respectively.

5.4 Base Model

In the base model, the market size is normalised to 1 because it helps simplify the model calculation and analysis, thereby finding the maximum results. In the model assumption, customers are assumed to be exogenously segmented by channel Nageswaran et al. (2020). This setting represents the proportion of each customer group varies across sectors. For example, the fashion industry may attract more online customers (e.g. H&M) than hardware products (e.g. Screwfix). Also, it allows analysing the cross-channel behaviours. Therefore, a fraction λ is defined to characterise customers that prefer to purchase online. They purchase online but inspect the item in-store or collect product information (e.g. descriptions, images, and reviews) through digital platforms (e.g. retailer's website, social media, search engines, and review websites). As the inspection happens before purchase, customers face uncertainty. A variable v is devoted to representing their valuations for a product before purchasing, where v is a random variable distributed uniformly ranging from 0 to 1 ($[0, 1]$). Unlike buying in-store, customers face uncertainty about whether an online order matches their expectations. This setting is similar to many studies (Cao et al., 2016; Nageswaran et al., 2020) considering product uncertainty. To describe the product may not match a customer's expectation, a probability β is defined when the product matches customer valuation, thereby the customer will keep it. Accordingly, the chance of the item mismatching the customer valuation is $1 - \beta$. Then the customer will return it and need to decide where to return it: return it online by post or cross-channel return by dropping the item to a selected store. This customer decision will depend on 1) whether the retailer allows customers to return online orders in-store (cross-channel return); 2) whether the retailer charges a shipping fee for online returns; 3) the hassle or inconvenience of returning items in a selected store, such as parking, searching for the service desk for returning, waiting for a long queue, and keeping the receipt. Although online returns are not hassle-free (e.g. shipping fees, drop-in a post office or third-party collection point, waiting for home collection, printing labels), it is assumed to be zero compared to travelling to stores for the following reasons. First, this model characterises returning shipping charge that is the main hassle cost for online returns, as a decision variable (UPS, 2019). Second, returning online offers flexibility, allowing customers to arrange collections at a convenient time and location or drop in a nearby location other than travelling to the retailer's stores. Customers can avoid the cost of travelling to a store. Third, it captures the hassle variance between online and stores yet simplifies the model calculation and analysis. Thus, this model characterises operating differentiations between online channels and physical stores from a retailer's view and considers the variance of perceived hassle cost from the customer's perspective.

To further describe customers' preferences, in response to the online customers, the fraction $1 - \lambda$

is defined to represent customers who prefer to purchase a product in-store (Nageswaran et al., 2020). Similarly, they inspect the item in-store (e.g. touch, smell, try the sample on and check if it fits) or review it online (i.e. webrooming). They finalise the purchase in a brick-and-motor store to ensure the product bought is what they expected. Hence, to simplify the model calculation and analysis, since they have evaluated the product and know v, the study assumes that store customers do not return their purchased products (Nageswaran et al., 2020). However, they have to deal with the hassle cost h of visiting a physical store (e.g. travelling, waiting and searching time), where customers homogeneously perceive h in the base model. This assumption makes sense because, for a customer, the travelling cost or time from his home to a high-street location could be similar each time for the homogeneous setting. Some researchers have a different setting (Nageswaran et al., 2020; Jin et al., 2020). They differentiate the hassle costs of buying and returning in-store because they believe that customers perceive returns occur more hassle than purchases. However, this model assumes h as the hassle of visiting a store regardless of which stage it happens, either in the purchase or return stage, because the distance of travelling remains the same no matter the customer visits a shop to purchase or return. This study does not consider the psychological differences between visiting a store for purchases and returns.

The parameter λ is assumed to be exogenous because it captures a customer's channel preference across sectors. For example, according to the global survey and statistics from (Stephanie, 2017), customers preferences of shopping online or stores vary across product categories, e.g. customers prefer shopping in-store (70%) in the grocery sector while preferring to buy books, music, films and video games online (60%). This setting represents this business practice and focuses on how the decision variables impact across-channel behaviours and profits. The value of λ can be interpreted in various ways. Firstly, customers' channel preferences may vary due to retailers' distinct business focuses. For instance, when $\lambda = 1$, the retailer does not sell products offline and specialises in online trading, such as Amazon and ASOS. When $0 < \lambda < 1$, the retailer offers both online and offline channels, but customers have their shopping channel preferences due to many factors, such as customers over 65 purchased least the least amount through online channels in comparison to the age group between 16 to 24 (Daniela, 2020). Secondly, shopping behaviours could differ because of product categories. For example, over 50% of customers prefer to inspect, compare and purchase household products in-store (e.g. appliances, DIY tools, and homeware), and nearly 60 % of customers prefer to purchase online for books and music. I will discuss the case when customers do not have channel preferences in the model extension.

Therefore, considering this product uncertainty, online customers are facing three sequential decisions: 1) in the pre-purchase stage, they choose whether to buy a product based on the valuation of the product v; 2) in the post-purchase stage, after receiving and examining the product, they decide to keep or return the order depending on whether the product meets the customer's expectation; 3) in the return stage, the customer needs to choose a return channel based on three factors to maximise his overall utilities: whether the cross-channel return is offered, the shipping fee for online returns, and the hassle cost of returning items to stores. This study focuses on online return shipping fees on the purchase and returns decision. Thus, I denote a shipping fee d, which only incurs in the return stage instead of the pre-purchase stage, such as NEXT offers free standard home delivery but charges £2 for online returns. The setting on the probability β in this study is different from previous studies (Nageswaran et al., 2020), where dis-match is endogenous based on v. This model exogenies the chance of returns for the following reasons. First, it allows the research to explore the effect of return rate on the analysis results. Second, the model focus is not on whether to return or why customers return. Instead, this study looks into how an online return shipping fee impacts a customer's channel choice in ex-ante and ex-post stages. Third, this setting reflects returning operations in business practices, such as return rate could vary across product categories or customer demographics due to increasing diverse needs(Lobaugh et al., 2019). Four, assigning certain values to β allows this study to conduct numerical experiments to analyse complex scenarios in the extension. Furthermore, the value of β can be interpreted in different ways. For example, the return rate β could be customer-based due to different return behaviours. Profitable customers show less chance and frequency to return a product. In contrast, non-profitable customers have a pattern of frequent returns or even abuse the return policies loss (Speights and Hilinski, 2005), therefore could lead to a financial (Katie, 2018). In addition, the return rate β can be product-based as return rates vary across product categories, such as fashion products facing higher return rates than groceries (UPS, 2019). Moreover, β can vary based on return policies, such as a restricted return policy (e.g. short return period or inflexible return windows) may provoke more returns thereby β is higher (Janakiraman and Ordóñez, 2012; Ertekin and Agrawal, 2020), or $\beta = 0$ means a strict non-refundable policy, e.g. non-refundable due to hygiene and safety. Most businesses balance the generosity of the return policy and related costs with the belief that generous policies could drive conversion rates, reduce return rates and improve customer satisfaction IMRG 2020. A threshold is denoted for the probability $\frac{1}{2} < \beta < 1$, since e-commerce average return rate is between 20% to 30%, even the category with high return rate, like footwear, face return rate under 50% (Orendorff, 2019). Businesses would not be profitable or offer generous return policies if the return rate is excessive IMRG 2020. Instead, they may restrict their return policies to drive the return rate down.

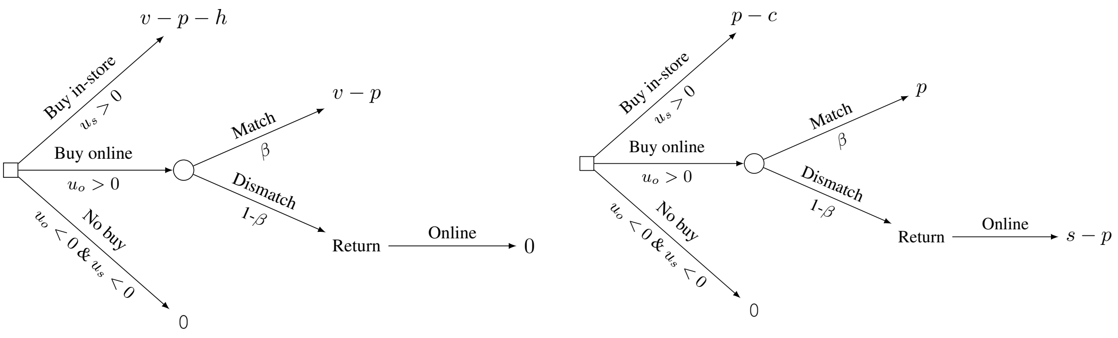
This study discusses four scenarios in our base model to understand the decision of service charge in return policies under the omnichannel setting. Before the cross-channel return is offered, online customers can only return the product by post if they find it does not meet their expectations. In scenario 1 (shown as "s_1"), return online is free of charge, whilst in scenario 2 (shown as "s_2"), a shipping fee d is incurred when the product is returned online by post. After offering cross-channel returns, customers are allowed to buy online and return orders in a selected store. In scenario 3 (shown as "s_3"), online return is free of charge, while a shipping fee d is charged for online returns by post in scenario 4 (shown as "s_4"). A summary of four scenarios is shown in Table 14. This study denotes d as a decision variable, and it does not have to be smaller than the unit selling price p, as a shipping fee could be higher than the unit selling price in practice, such as groceries. In early studies (Chen, Liu and Wan, 2016; Nageswaran et al., 2020), a unit price p and refund amount are the decision variables and independent, the shipping fee for online returns could be seen as the difference between the unit price and refund amount. However, in this study, full-refund is offered regardless of which channel customers return the product. Thereby, the return fee is an independent variable. This model studies how the return shipping fee d influences cross-channel customer behaviours and the total profitability in an omnichannel context. Each scenario will be discussed in subsections §5.4.1, §5.4.2, §5.4.3 and §5.4.4 respectively, regarding customer channel choices, demands and retailer profits. Thus, this model could help understand what factors impact an omnichannel retailer's decisions in return policies. Next, by comparing these scenarios, the optimal return policy will be identified and analysed in §5.4.5. In addition, the priority of relevant elements in the return policy will be discussed based on their positive effects on the overall profits. Lastly, this study will disclose the related conditions for the optimal return policies and how they are affected by relevant factors.

Table 14: A Summary of Four Scenarios Discussed in Model Two

Scenarios	**Symbol in the model**	**Cross-channel Return**	**Shipping fee for online returns**
Scenario 1	s_1	No	Free of charge
Scenario 2	s_2	No	d
Scenario 3	s_3	Yes	Free of charge
Scenario 4	s_4	Yes	d

5.4.1 Scenario 1 - Free Online Return and No Cross-channel Return

In scenario 1, the retailer offers free online returns, thereby $d = 0$ and only allow online orders to be returned by post. Customers will strategically maximise their utilities. Offering a free online return could enhance customers' confidence in purchasing online (IMRG, 2020), potentially inducing additional demands as it reduces the inconveniences of returning misfit items. Thus, $\delta > 1$ is denoted as the additional proportion of demands evoked due to the free return policy. Decision trees are used (figure 6) to illustrate sequential customer decisions for the following reasons. First, decision tree is a straightforward, logical and tangible way for readers to understand all the actions for a customer in multiple stages, and demonstrate the path of each action to the corresponding outcome. Second, it allows researchers to trace the decision-maker's choice and thereby calculate the probability of outcome accordingly. Specifically, figure 6 demonstrates two decision trees in scenario 1. One represents customer choices and his utilities, see figure 6(a), and the other demonstrates the retailer's profits, see figure 6(b). The chance node is shown by a circle representing the probability of whether a product meets an online customer's expectation. The decision node demonstrated by a square shows the decision to be made by the decision-maker.



(a) Customer's Utility

(b) Retailer's Profit

○ = Chance node □ = Decision node

Figure 6: The sequence of customer decisions and associated utilities and retailer profits in scenario 1

In figure 6(a), for store customers, if they perceive the product value v exceeds the unit price p and the hassle cost of travelling to the store h, that is $v - p - h > 0$, then they will purchase it and gain a positive utility $v - p - h$ (shown as "Buy in-store" in the decision tree), otherwise, they will not buy it (shown as "No buy"). As they know v after inspecting and purchasing the product in-store, there will be no returns. Thus, the utility for the store customer in scenario 1 is obtained as below:

$$u_s = Emax\{v - p - h, 0\} \tag{5.1}$$

where the possibility of purchasing in-store can be worked out as $1 - h - p$, which decreases in the hassle cost of visiting a store h and unit selling price p. Hence, it can get a constraint for store customers in scenario 1: $0 < h < 1 - p$, representing store customers will buy a product only if they perceive the hassle cost of visiting a store is less than the unit selling price. This study defines the demand for a product on channel i as q_i, and subscript $i = s, o$ represents stores and online, respectively. A portion of customers $1 - \lambda$ prefers to shop in-store, and the associated profit is the difference between the unit selling price and unit handling cost in-store, $p - c$ in figure 6(b). The profit of selling a product through channel i is defined as π_i, and subscript $i = s, o$ represents stores and online respectively. Thus, the store demand and profit of a product are obtained as below:

$$\begin{aligned} q_s &= (1-\lambda)(1-h-p) && (5.2) \\ \pi_s &= q_s(p-c) = (1-\lambda)(1-h-p)(p-c) && (5.3) \end{aligned}$$

The term $p - c$ is the unit profit when a product is sold in-store. As this study assumes the retailer is self-interested, it will not sell a product if it is unprofitable. A product is sold in-store only if $p - c > 0$. The store demand of a product decreases in the hassle cost of visiting a store h and its unit selling price p. The unit profit is decreasing in the unit handling cost in-store.

In figure 6(a), there are two cases for online customers. One is when the item meets their expectations at the probability β (shown as “Match” in the decision tree), they will keep it and gain a utility $v - p$. The other, however, is when it does not match their expectations at the probability $1 - \beta$ (shown as “Dismatch”), they will return it online by post free of charge and receive a full refund, thereby they face a zero utility (shown as “Online”). Thus, the utility for an online customer in scenario 1 is as below:

$$u_{o_{s_1}} = Emax\{\beta(v-p), 0\} \tag{5.4}$$

where the term $\beta(v-p)$ characterises the utility when online customers are satisfied with the product and keep it. Online customers buy a product only if $u_{o_{s_1}} > 0$. The possibility of purchasing online is calculated as $1-p$, decreasing in the unit selling price p only. After a product is returned online by post, the retailer will re-sell it online at a salvage value s ranging between 0 and unit selling price p ($0 < s \leq p$) and face a loss $s - p$ due to an opportunity cost. As there is a portion of customers λ who prefer to shop online, the online demand and profit of a product sold online are obtained in scenario 1 as below:

$$\begin{aligned} q_{o_{s_1}} &= \lambda(1-p) && (5.5) \\ \pi_{o_{s_1}} &= q_{o_{s_1}}\big(\beta p + (1-\beta)(s-p)\big) \\ &= \lambda(1-p)\big(\beta p + (1-\beta)(s-p)\big) && (5.6) \end{aligned}$$

where the term βp in (5.6) describe the unit profit when the product matches a customer’s expectation, and $(1-\beta)(s-p)$ shows the unit profit loss when the product does not match the expectation. Each scenario's total demand and profit are defined as Q_j and Π_j, and subscript $j = s_1, s_2, s_3$ and s_4 represents scenario 1 to 4, respectively. Since this study assumes the free return policy could generate additional demand $\delta > 1$, the total demand Q_{s_1} and the total profit of a product Π_{s_1} in scenario 1 are obtained as below:

$$\begin{aligned} Q_{s_1} &= \delta(q_s + q_{o_{s_1}}) = \delta\big((1-\lambda)(1-h-p) + \lambda(1-p)\big) && (5.7) \\ \Pi_{s_1} &= \delta(\pi_s + \pi_{o_{s_1}}) \\ &= \delta\Big((1-\lambda)(1-h-p)(p-c) + \lambda(1-p)\big(\beta p + (1-\beta)(s-p)\big)\Big) && (5.8) \end{aligned}$$

where the total demand decreases in the hassle cost of travelling to a store h and the unit selling price p whereas increasing in the effect of free online returns δ and the proportion of online customers λ. The factor δ may increase if the retailing business predominately sells products through online channels or in the sector with high return rates. Thus, Lemma 7 regarding the total profit Π_{s_1} is gained (see proof in Appendix B) as below:

Lemma 7. *When cross-channel return is unavailable and online return is free, the total profit is*

(i) decreasing in c and h;

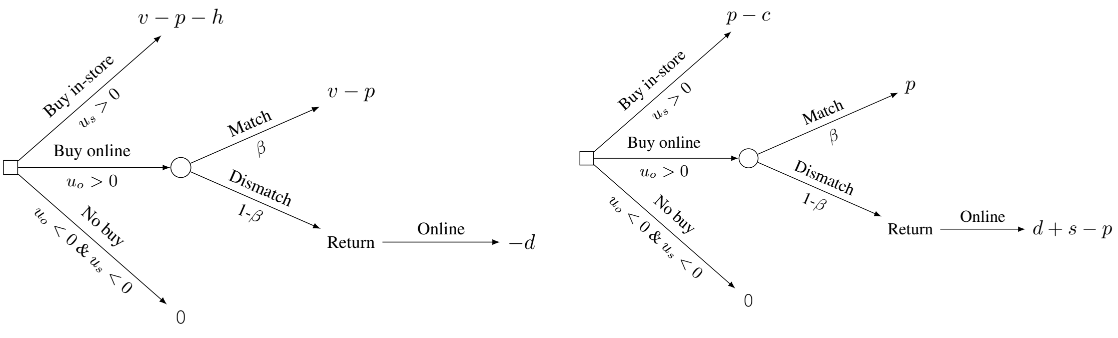
(ii) increasing in s, δ, and β;

(iii) increasing in λ if $c < c_1 \& h_1 < h < 1-p$ or $c > c_1 \& 0 < h < 1-p$; otherwise, decreasing in λ if $c < c_1 \& 0 < h < h_1$.

where $c_1 = (1-\beta)(2p-s)$ and $h_1 = \frac{(1-p)((1-\beta)(2p-s)-c)}{p-c}$ in Lemma 7. From a store operational view, the total profit is smaller if the unit handling cost c is getting higher in-store. From a channel point of view, if the cost difference between online channels and physical stores is getting larger, the overall profit is smaller. The potential reason could be that the retailer does not allow customers to cross-return, thereby store customer demands are not shifted to online channels, which are more cost-effective. For store customers, if visiting a store to purchase a product takes more hassle, they will leave the market and not buy from the retailer, thereby reducing the total profit. If the retailer can re-sell the returned products at a higher salvage value, it has a positive impact on the total profits. For instance, if the product is returned timely within the season, it could be sold at high salvage value or even unit selling price. Thus, the profit will increase. For online customers who are sensitive to non-partitioned pricing, i.e. shipping fees, offering free online returns could reduce their perceived risks of paying for returns and increase their confidence in online purchases. Hence, the effect of free returns could be enhanced, i.e. δ is growing, and the total profit increases. When the matching rate β in which an online product matches customer expectation is higher, fewer online items would be returned. Thereby, the total profit could be increased. To increase the matching rate, the retailer could provide more product information online, including product images, videos, descriptions, customer reviews, or showroom and Virtual Reality (VR) to help them assess the product (Bell et al., 2014). Regarding customer segments, when the in-store handling cost is low but visiting a store is perceived inconvenient, or if unit handling cost in-store is high, the retailer may be profitable if he has a larger portion of online customers. However, if visiting a store becomes convenient, in-store handling costs are low. A larger portion of store customers could positively impact the retailer's total profits.

5.4.2 Scenario 2 - Online Return is Charged and No Cross-channel Return

In scenario 2, as the retailer does not offer cross-channel returns, online customers can return a product only by post. The retailer will charge a standard delivery fee d for online returns. The decision trees (figure 7) below demonstrates sequential customer decisions in scenario 2, and figure 7(a) shows customer choices and his utilities, and figure 7(b) represents the retailer's profits.



(a) Utility

(b) Profit

○ = Chance node □ = Decision node

Figure 7: The sequence of customer decisions and associated utilities and retailer profits in scenario 2

Before discussing the decision tree, some similarities are observed for store customers across four scenarios. For instance, utilities for store customers and the corresponding in-store unit profit stay consistent across all scenarios. This similarity is caused by the model assumption that store customers will not return products. Thereby, their utilities are only affected by product valuation, unit selling price, and the hassle of visiting a store, which the online return policy will not impact. On the other hand, although the utilities for store customers are the same, it does not mean the store demands are the same due to the effect of free returns. Thus, in scenario 1, the total store demand is $\delta(1-\lambda)(1-h-p)$, whereas, in scenario 2, the store demand is $(1-\lambda)(1-h-p)$ as online returns are not free. This setting is sensible because this research focuses on the effect of cross-return on demand shifting from online to stores. Also, products bought in-store are most likely returned to stores due to return policies, such as H&M and B&Q. Likewise, the utility of online customers whose orders meet their expectations at the probability β, and the corresponding profit sold online are consistent across all scenarios, because it is primarily affected by product valuation, unit selling price, and the probability, thereby also not impacted by the online return policy. Because of these similarities, there is no need to repeat the discussion. This study will focus on when an online order does not meet customer expectations at the probability $1-\beta$. Online customers will return online by post, and pay a shipping fee d, and face a negative utility

$-d$. Thus, the utility for an online customer in scenario 2 is obtained below:

$$u_{o_{s_2}} = Emax\{\beta(v-p) - d(1-\beta), 0\} \tag{5.9}$$

where the term $\beta(v-p)$ characterises the utility when an online item matches customer expectations. The term $-d(1-\beta)$ represents the utility when customers are unsatisfied with the item and will return it by post and pay a shipping fee d. Customers will purchase a product online only if $u_{o_{s_2}} > 0$, and the possibility that a customer decides to purchase a product online is obtained as $1 + d - p - \frac{d}{\beta}$ in scenario 2. Thus, the constraint for scenario 2 is gained: $0 < d < \frac{\beta(1-p)}{1-\beta} < 1$, representing the shipping charge for returning online by post is capped. In terms of retailer's profit, unlike scenario 1 where the unit profit for returned item is $s - p$, as the return shipping fee d is charged in scenario 2, this model incorporates the shipping fee into the profit function. Thus, the retailer will get a unit profit $d + s - p$, which could be a profit or loss depending on the shipping charge and the retailer's capability to re-sell returned products, such as NEXT charges £2 for online returns. In retailing practices, apart from product sales, delivery fees could be counted as a revenue component (ASOS, 2019). As there are a portion of customers λ who prefer to shop online, the online demand and retailer profit are obtained in scenario 2 as below:

$$\begin{aligned} q_{o_{s_2}} &= \lambda(1 + d - p - \frac{d}{\beta}) && (5.10) \\ \pi_{o_{s_2}}(d) &= q_{o_{s_2}}\big(\beta p + (1-\beta)(d + s - p)\big) \\ &= \lambda(1 + d - p - \frac{d}{\beta})\big(\beta p + (1-\beta)(d + s - p)\big) && (5.11) \end{aligned}$$

where the term βp is the unit profit when the product matches expectation, and the term $(1-\beta)(d + s - p)$ describes the unit profit when the product dis-matches customer's expectation. The customer pays a shipping fee d to return it by post. Thereby, the total demand Q_{s_2} and total profit $\Pi_{s_2}(d)$ are obtained in scenario 2 as below:

$$\begin{aligned} Q_{s_2} &= q_s + q_{o_{s_2}} = (1-\lambda)(1-h-p) + \lambda(1 + d - p - \frac{d}{\beta}) && (5.12) \\ \Pi_{s_2}(d) &= \pi_s + \pi_{o_{s_2}}(d) \\ &= (1-\lambda)(1-h-p)(p-c) \\ &\quad +\lambda(1 + d - p - \frac{d}{\beta})\big(\beta p + (1-\beta)(d + s - p)\big) && (5.13) \end{aligned}$$

where the total demand Q_{s_2} decreases in the shipping fee d, hassle cost of visiting a store h, and unit selling price p, whereas increases in the probability β that the product matches the expectation thereby the customer keeps it. Unlike scenario 1 in which additional proportion of demands δ is generated due to free online returns, as online returns are not free, no additional demands are created in scenario 2. When the hassle cost of visiting a store is high $\frac{d-\beta d}{\beta} < h < 1$, the retailer would grow its total demands if its proportion of online customers is larger (i.e. higher λ); when the hassle cost is low $0 < h < \frac{d-\beta d}{\beta}$, the total demand would grow if the retailer has more store customers base (i.e. smaller λ). That is because, in the base model, hassle cost is homogeneously perceived by customers. If the retailer struggles to reduce the hassle of in-store shopping, then increasing the online customer base could be considered. Conversely, if the retailer specialises in offering an in-store experience with convenience, driving customers to stores would increase total demand. Therefore, Lemma 8 regarding the total profit $\Pi_{s_2}(d)$ is calculated below:

Lemma 8. *When cross-channel return is unavailable and online return is charged at* d*, the total profit* $\Pi_{s_2}(d)$ *is*

(i) concave in d, and the optimal shipping fee is ${d_{s_2}}^* = \frac{\beta-3\beta p+p-(1-\beta)s}{2-2\beta}$*;*

(ii) decreasing in c *and* h*;*

(iii) increasing in s*;*

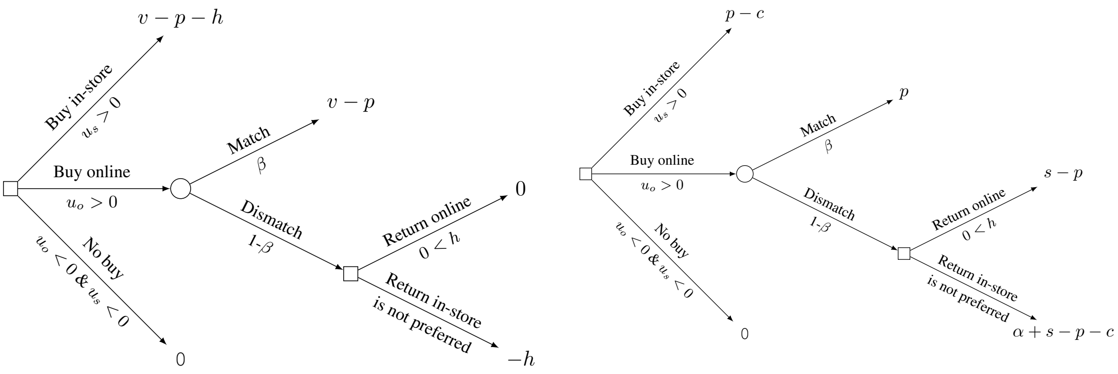
(iv) increasing in λ *if* $c_2 < c < p$*; otherwise, decreasing in* λ *if* $0 < c < c_2$*;*

(v) increasing in β *if* $0 < d - p + s < p$ *or decreasing in* β *if* $d - p + s < 0$.

where $c_2 = p - \frac{(1+d-p-\frac{d}{\beta})((1-\beta)(d-p+s)+\beta p)}{1-h-p}$. Although charging a shipping fee d for online returns could reduce the online customer demand, shipping fee d could potentially compensate the loss $s - p$ from re-selling the returned item. Therefore, the total profit is concave in the online shipping charge d, and the optimal shipping fee ${d_{s_2}}^*$ is found in scenario 2. This result shows that charging online returns at a certain rate could benefit the retailer's total profits. The optimal shipping fee ${d_{s_2}}^*$ is decreasing in p and s. Thus, the optimal shipping fee should be reduced when the unit selling price is high, or the retailer can sell the returned item at a high salvage value. If the unit price is small ($0 < p < \frac{1}{2}$), the higher probability that a customer will keep the product (i.e. higher β is), the retailer should increase ${d_{s_2}}^*$. For example, for grocery products with low unit selling prices and low return rates, the retailer should raise the optimal online return fees to reduce the unprofitable return behaviours. Adversely, when the unit price is high ($\frac{1}{2} < p < 1$), the higher chance that the product is kept (i.e. higher β), the smaller the optimal return charge ${d_{s_2}}^*$ should be. That implies that when the retailer mainly sells high-profit products, the return shipping fee could be smaller to reduce customer's risks and attract more online demands. In contrast, when products have low unit profit, the retailer should charge a higher shipping fee to raise customers' awareness before purchasing and discourage returns. Similar to Lemma 7, the total profit decreases in the unit handling cost in-store and the hassle cost of visiting a store whilst increasing in salvage value. When the in-store handling cost is high $c_2 < c < p$, the retailer has motives to drive more online demands, thereby a retailer with a larger portion of online customers could show a positive impact on its total profits; or else when the unit handling cost is low $0 < c < c_2$, the retailer would benefit profitably from a larger base of store customers. Moreover, the total profit is increasing in product keeping rate β if the delivery fee could cover the loss of re-selling a returned item. The profit of re-selling is less than the unit selling price $0 < d + s - p < p$, it may decrease in β if $d + s - p < 0$. That implies that depending on whether the return delivery fee can cover the loss of a re-sold item, the total profit does not always grow even if the keeping rate is high. For example, for perishable food, if the return fee cannot cover the loss of re-sale, even this category has a low return rate, it may hurt total profit.

5.4.3 Scenario 3 - Free Online Return and Cross-channel Return is Available

In scenario 3, the retailer allows online customers to return products by post free of charge, and allows them to buy online and return in-store. The decision trees (figure 8) below show sequential customer decisions in scenario 3, and figure 8(a) illustrates customer choices and his utilities, and figure 8(b) reveals the retailer's profits accordingly.



(a) Utility

(b) Profit

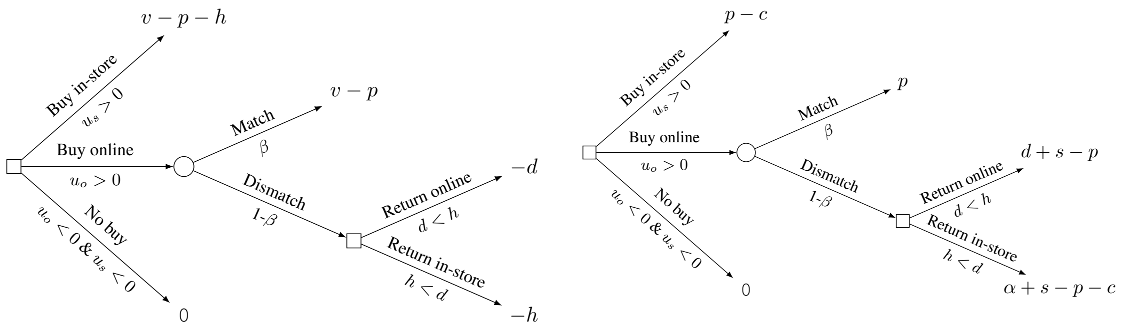
○ = Chance node □ = Decision node

Figure 8: The sequence of customer decisions and associated utilities and retailer profits in scenario 3

Differences must be highlighted between the decision trees in scenario 3 and previous scenarios. First of all, as the cross-channel return is offered, an additional decision node is added, representing customer choices between buying online and returning by post (shown as “Return online” in the decision tree) and ordering online and returning in a selected store (shown as “Return in-store” in the decision tree). Second, cross-return is not attractive to online customers in this scenario. Free online return means that customers gain zero utility if they return online. In contrast, they have to face a negative utility $-h < 0$ (shown) if they return in-store due to the hassle of travelling to a store. Although the return utility in scenario 2 is also negative, online customers have to choose it due to no alternative options for returning online orders. It indicates that when online return is free of charge, with or without cross-return, online customers will always prefer to return by post than bring it back to the store. Hence, the return policy allowing customers to return online orders by post free of charge and cross-return to a selected store is not necessarily beneficial. The elements, free online returns and cross-channel returns, do not collaborate as well as expected. As customers always prefer free online returns in this scenario, thus customer choices are the same between scenarios 3 and 1, so there is no need to repeat the discussion.

5.4.4 Scenario 4 - Online Return is Charged and Cross-channel Return is Available

In scenario 4, the retailer will charge a standard shipping fee d for returning by post and allow customers to return online orders to a selected store. This study assumes that if online customers return in-store, a cross-selling opportunity $0 < \alpha < 1$ could be provoked (Nageswaran et al., 2020). The value of α is influenced by many factors, such as the broadness of product assortments, the efficiency of store operations, and the marketing influences (Jin et al., 2018; Jack et al., 2019). Sequential customer decisions are demonstrated in the following decision trees (figure 9), and figure 9(a) and figure 7(b) show customer utilities and the retailer's profits in scenario 4.



(a) Utility

(b) Profit

○ = Chance node □ = Decision node

Figure 9: The sequence of customer decisions and associated utilities and retailer profits in scenario 4

Different from scenario 3, returning online by post is charged a shipping fee d in this scenario, thereby customers do not have a preference in return channels when the online item does not match their expectations. They will face the choice between 1) paying a shipping fee for returning the item by post and 2) dealing with the inconvenience of returning it directly to a selected store. If online customers are sensitive to the hassle of visiting a store, they may find that the shipping fee is less than the perceived inconvenience of visiting a store $d < h$, then they will choose to return online and face a negative utility $-d$. In contrast, if online customers are sensitive to non-partitioned prices, they will return the online item in-store because they think the hassle of visiting a store is less than the shipping fee $h < d$, thereby facing a negative utility $-h$. The retailer could reduce h by wisely selecting store locations, determining the number of stores, and making the store operations more efficient, such as reasonable store layouts to reduce searching time and short waiting time for checkout (Jin et al., 2018). As a result, the utility for an online customer in scenario 4 is obtained as below:

$$u_{o_{s_4}} = Emax\{\beta(v-p)+(1-\beta)\big(-d(1-d)-hd\big),0\} \tag{5.14}$$

where the term $(1-\beta)\big(-d(1-d)-hd\big)$ characterises online customers returning the mismatched item. Specifically, $-d(1-d)$ represents those who return online by post, and $1-d$ shows the associated probability; the term $-hd$ reflects those who choose to return online items in-store, and d is the associated chance. The smaller d is, the more likely online customers will return via post, and vice versa. As online customers make a purchase only if $u_{o_{s_4}} > 0$, the possibilities of purchasing a product online in scenario 4 is calculated as $1-p+\frac{(1-\beta)(d^2-dh-d)}{\beta}$, which is increasing in β but decreasing in p, and convex in d. When online customers choose to return by post ($0 < d < h$), the corresponding retailer profit is $d+s-p$ that could be a gain or a loss depending on whether d covers the loss from re-selling the returned item. Alternatively, customers will return online orders in a store ($h < d < 1$), but re-selling through a store will involve a handling cost c. At the same time, potentially create a cross-selling profit $\alpha > 0$, thereby the retailer gets a profit $\alpha+s-p-c$ that could be a gain or a loss depending on whether the cross-sell profit will cover the re-selling loss and the in-store handling cost. Thus, the online demand $q_{o_{s_4}}$ and associated profits $\pi_{o_{s_4}}(d)$ in scenario 4 are obtained as below:

$$\begin{aligned} q_{o_{s_4}} &= \lambda\big(1-p+\frac{(1-\beta)(d^2-dh-d)}{\beta}\big) &(5.15)\\ \pi_{o_{s_4}}(d) &= q_{o_{s_4}}\Big(\beta p+(1-\beta)\big((1-d)(d+s-p)+d(\alpha+s-p-c)\big)\Big)\\ &= \lambda\big(1-p+\frac{(1-\beta)(d^2-dh-d)}{\beta}\big)\Big(\beta p+(1-\beta)\big((1-d)(d+s-p)\\ &\quad +d(\alpha+s-p-c)\big)\Big) &(5.16)\end{aligned}$$

where the term $(1-\beta)\big((1-d)(d+s-p)+d(\alpha+s-p-c)\big)$ describes the profit when the product dis-matches customer's expectation. Specifically, the term $(1-d)(d+s-p)$ shows the profit when returning online by post, and the term $d(\alpha+s-p-c)$ represents the profit when online customers return in-store. Thus, the total demand Q_{s_4} and the retailer profit $\Pi_{s_4}(d)$ in scenario 4 are obtained as below:

$$\begin{aligned}
Q_{s_4} &= q_s + q_{o_{s_4}} = (1-\lambda)(1-h-p) + \lambda\big(1-p+\frac{(1-\beta)(d^2-dh-d)}{\beta}\big) \quad (5.17)\\
\Pi_{s_4}(d) &= (1-\lambda)(1-h-p)(p-c) + \lambda\big(1-p+\frac{(1-\beta)(d^2-dh-d)}{\beta}\big)\Big(\beta p\\
&\quad +(1-\beta)\big((1-d)(d+s-p)+d(\alpha+s-p-c)\big)\Big) \quad (5.18)
\end{aligned}$$

where the total demand Q_{s_4} decreases in hassle cost of visiting a store h and the unit selling price p whereas increasing in the probability β that a product matches customer expectations. Similar to scenario 2, without the effect of free returns, no extra proportion of demands δ is generated. If the hassle cost of visiting a store is high $\frac{(1-\beta)(1-d)d}{\beta-(1-\beta)d} < h < 1$, then the retailer may grow the total demand if he has a large proportion of online customers (i.e. higher λ). If the hassle cost is low $0 < h < \frac{(1-\beta)(1-d)d}{\beta-(1-\beta)d}$, the retailer may grow the total demand if his store customer base is larger (i.e. smaller λ). In comparison to scenario 2 (see figure 10), as $\frac{(1-\beta)(1-d)d}{\beta-(1-\beta)d} < \frac{d-\beta d}{\beta}$, whether the retailer should make cross-channel returns available depends on its store operations and the structure of the retailer's customer base. That implies that if a retailer contemplates offering cross-channel returns, he needs to understand the primary customer base, assess its in-store operations and ensure the hassle of visiting a store is low enough to drive customers into stores.

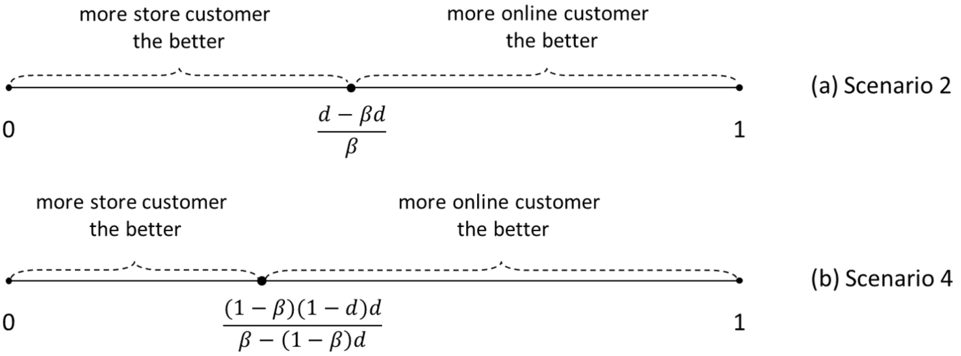


Figure 10: The impact of hassle cost of visiting stores and proportion of online customers on the total demand

Different from scenario 2 where total demand decreases in d when cross-channel is not available, the total demand Q_{s_4} is convex in d in this case as online customers have an alternative return option. When visiting a store is inconvenient $2d-1 < h < 1-p$, online customers would choose to pay for returning online by post. The higher the shipping fee is, returning through either channel would reduce customer's utilities. As a result, it may put off online customers and total demand would be less. When visiting a store is convenient $0 < h < 2d - 1$, the higher the shipping fee is, the more online customers will choose to return in-store. Thus, total demand could increase. Since the cross-channel return is offered, charging d for online return could potentially nudge online customers to return in-store. As cross-channel returns potentially transform the negative effect of misfit products into an opportunity to drive online traffic into stores and increase cross-sales. Thus, Lemma 9 regarding the total profit is obtained as below:

Lemma 9. *When cross-channel return is available and online return is charged at* d*, the total profit is*

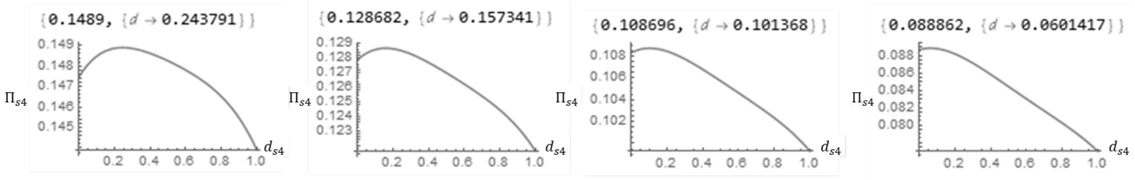
- *(i) concave in* d *if the condition is met; and the optimal shipping fee is* ${d_{s_4}}^* = \phi + \sqrt[3]{\gamma - \sqrt{\gamma^2 + \varsigma^3}} + \sqrt[3]{\gamma + \sqrt{\gamma^2 + \varsigma^3}}$*;*
- *(ii) decreasing in* c*;*
- *(iii) decreasing in* h *if* $0 < c < c_3$*;*
- *(iv) increasing in* s *and* α*;*
- *(v) increasing in* λ *if* $s_1 < s \leq p$*; otherwise, decreasing in* λ *if* $c < s < s_1$*;*

where $\gamma = \frac{(h-\alpha+c)(4\beta+(\beta-1)((c-\alpha)(\alpha-c+2)+h(h+2)+4(p-s)))}{64(\beta-1)}$, $\varsigma = \frac{1+p-3\beta p+(\beta-1)(-\alpha+h(-\alpha+c-1))}{6(1-\beta)} - \phi^2$, and $\phi = \frac{1}{4}(2+\alpha-c+h)$ in Lemma 9 (i); and $c_3 = \frac{p\left(\beta-2\beta^2 d\lambda+\beta(3d-1)\lambda-d\lambda\right)-(\beta-1)^2 d\lambda\left(d^2-(\alpha+1)d-s\right)}{\beta^2 d^2\lambda-\beta(2d^2\lambda+\lambda-1)+d^2\lambda}$ in Lemma 9 (iii). The condition in Lemma 9 (i) is in Appendix B. Allowing cross-channel returns could provoke a more complex variation in online demands compared to other scenarios, yet some trends are similar. Firstly, the total profit is concave in the shipping charge d. Hence, the optimal shipping fee is ${d_{s_4}}^*$ in scenario 4. In scenario 2, online customers choose not to buy if they think d is too high. The retailer uses shipping fees to balance satisfying online customers and reduce unprofitable return behaviours. In this scenario, online customers can alternatively return online orders to stores. Therefore, the value of d will nudge those who are more sensitive to non-partitioned price than hassles to visit stores. Similar to Lemma 7 and Lemma 8, It is sensible that the total profit is decreasing in the unit handling cost in-store and the hassle cost of visiting stores. If the in-store unit handling cost is small enough, the retailer will have more motivation to drive customers into stores. In contrast, it is understandable that the total profit increases in the salvage value or returned items and the cross-selling profit. Also, if the salvage value is high

$s_1 < s \leq p$, where $s_1 = d^2 - d(1+\alpha-c) + \frac{(1-2\beta)p}{1-\beta} + \frac{\beta(p-c)(-h-p+1)}{(1-\beta)^2 d(d-h-1)+\beta(1-\beta)(1-p)}$, the profit loss from re-selling returned online products reduces. Therefore, the retailer will benefit from having a larger online customer base. Otherwise, if the retailer can only sell the returned products at a low price, the larger store customer base is better. As the function of optimal delivery in this scenario is complex, to visually demonstrate how different factors impact ${d_{s_4}}^*$, values will be assigned to the function to observe the changes (see table 15). Firstly, as c and s were discussed early, this numerical study focused on how p, β and α impact the optimal delivery fee. Values are assigned based as follow and will not change during this simulation: $h = 0.1$ and $c = 0.3p$, representing the unit handling cost as 30% of the unit selling price and $s = 0.75p$, showing the returned product will be sold 25% off (Alexis, 2021), and 30% of customers are online thereby $\lambda = 0.3$. To observe the change, firstly, the unit selling price is assigned values under $\frac{1}{2}$ ($p < \frac{1}{2}$) from 0.1 to 0.5 with interval (0.1) because when $p > \frac{1}{2}$, the optimal delivery fee is outside of the value range. Similarly, the probability of a product matching customer expectations is from 0.7 to 0.9 with an interval (0.05). Besides, the cross-selling profit is assigned value regarding the in-store hassle cost and unit handling cost. The results show that when cross-selling profit α is small, ${d_{s_4}}^*$ gently increases with the probability that customer keeping the product β, whereas significantly decreases in the unit selling price p. That implies that when the surplus between cross-sales and handling cost in-store $\alpha - c$ is lower than the hassle cost of visiting a store h, that is $\alpha - c < h$, if product unit price is low, the retailer should charge higher return fee ${d_{s_4}}^*$, e.g. groceries. In contrast, when cross-selling profit α is high, ${d_{s_4}}^*$ gently decreases with the matching rate β, but considerably increases in the unit selling price p. Thus, when the surplus between cross-sales and handling cost in-store $\alpha - c$ is higher than the hassle cost, that is $\alpha - c > h$, if product unit price is high, the retailer should charge the higher return fee ${d_{s_4}}^*$ to drive customer return in-store to create cross-sales. Figure 11 shows how total profit changes with a return shipping fee. Both $\Pi_{s_4}(d)$ and ${d_{s_4}}^*$ become smaller when visiting a store becomes more inconvenient (higher h). When the hassle cost is high, such as the retailer is located in areas that are hard to reach, the return shipping fee should be small to attract customer demands online, also high visiting hassle cost could reduce the store demands. Thus, the retailer could provide a broader range of portfolios to increase in-store cross-selling.

Table 15: Numerical Results of Assigning Values in Optimal Delivery Fee in Scenario 4

h=0.1, c=0.3p, s=0.75p, λ=0.3	α=0.1<h+c					α=0.3>h+c				
${d_{s_4}}^*$	β					β				
p	0.7	0.75	0.8	0.85	0.9	0.7	0.75	0.8	0.85	0.9
0.1	0.5293	0.5304	0.5312	0.5319	0.5324	0.6780	0.6682	0.6611	0.6558	0.6516
0.2	0.4966	0.5008	0.5037	0.5059	0.5076	0.6907	0.6752	0.6646	0.6570	0.6513
0.3	0.4221	0.4391	0.4502	0.4579	0.4636	0.7406	0.7063	0.6842	0.6696	0.6594
0.4	0.2123	0.2438	0.2770	0.3080	0.3340	0.9029	0.8527	0.7953	0.7446	0.7090
0.5	0.0341	0.0164	0.0003	0.0001	0.0001	1.0000	1.0000	0.9999	0.9999	0.9999



(i) h=0.1 (ii) h=0.2 (iii) h=0.3 (iv) h=0.4

($p = 0.4$, $\beta = 0.75$,$\alpha = 0.3$, and $\lambda = 0.3$)

Figure 11: The Total Profit Change with Return Shipping Fee in Scenario 4

5.5 Analysing Base Model

This section will analyse the impact of different return policies on customer channel choices and retailer profitability when customers are homogeneous in the hassle cost of visiting stores. The impact of return shipping fee when cross-channel return is unavailable will be discussed in §5.5.1 by contrasting results between scenarios 1 and 2. In §5.5.2, the impact of return shipping fee when cross-channel return is available will be discussed by comparing results in scenario 4 with scenario 2. Due to the complex form in scenario 4, numerical analyses will be conducted to gain insights and observe how the total profit changes according to relevant parameters.

5.5.1 The Impact of Return Shipping Fee When Cross-channel is Unavailable

After discussing each scenario in the base model, this section will analyse the results discussed above and how the elements in return policies (i.e. whether to charge shipping fees and offer cross-channel returns) affect customer demands across channels and the retailer's profit under an omnichannel setting.

This subsection will discuss the variations in demands, especially the demand shifting from online to stores, and retailer profits by comparing total demand, total profit and optimal delivery fee in each scenario. The similar results between scenarios 1 and 3 indicate that free online returns will limit the effect of cross-channel returns on the demand migration and profits, because online customers will prefer a free online return by post than going through the hassle of returning it to a store in person, based on the utility theory. This result implies 1) the elements of online return policy must be reviewed before a retailer offers an omnichannel return function; 2) the implementation of omnichannel returns are not simply aggregated to the existing services without considering the potential effect of added function on existing channels. This conclusion is drawn based on the model assumptions that a customer's channel preferences are exogenous. Although cross-channel return may encourage cross-sales, it does not stimulate additional total demands like free online return shipping. Thus, the comparison between scenario 3 and others will not be discussed further in this section.

Firstly, this subsection will analyse the effect of return shipping fees when cross-channel returns are unavailable. This comparison helps study a single element of return policy – shipping fee, without the impact of cross-channel behaviours. By comparing scenario 1 with free returns and scenario 2 with return shipment fees, the following proposition is obtained to characterise the effect of the return policy with a shipping fee on customer demands and retailer profits. I subtract the demand and profit functions in scenario 1 from these in scenario 2, and get proposition 7 below.

Proposition 7. *When customer channel preferences are exogenous and their perception on hassle cost of visiting a store is homogeneous, the return policy with a shipping fee will:*

(i) reduce the total demand by $(\delta-1)(1-\lambda)(1-h-p)+(\frac{d(1-\beta)}{\beta}+(\delta-1)(1-p))\lambda$*; specifically, the store demand will decrease by* $(\delta-1)(1-\lambda)(1-h-p)$ *and the online demand will decrease by* $(\frac{d(1-\beta)}{\beta}+(\delta-1)(1-p))\lambda$*;*

(ii) the total profit is concave in d, and will increase by $-\beta\lambda(\hat{\beta}d)^2+\sigma\lambda\hat{\beta}d+\kappa(\delta-1)$ *when* $1-\frac{\hat{\beta}\lambda(\beta-1+\sigma)}{\kappa}<\delta<1-\frac{\lambda\sigma^2}{4\beta\kappa}$ *and* $d_1<d<d_2$*; or* $1<\delta<1-\frac{\hat{\beta}\lambda(\beta-1+\sigma)}{\kappa}$ *and* $d_1<d<1$ *; otherwise, the total profit will decrease when* $\delta>1-\frac{\lambda\sigma^2}{4\beta\kappa}$*;*

(iii) the optimal shipping fee is $\hat{d}^*_{s_2}=\frac{\sigma}{2(1-\beta)}$.

where $\hat{\beta}=\frac{1-\beta}{\beta}$, $\sigma=\beta-3\beta p+p-(1-\beta)s$ and $\kappa=c(1-\lambda)(-h-p+1)+h(1-\lambda)p+p^2+(1-\beta)\lambda(1-p)(2p-s)-p$, $d_1=\frac{\sigma\lambda-\sqrt{\lambda(\lambda\sigma^2+4\beta\kappa(\delta-1))}}{2(1-\beta)\lambda}$ and $d_2=\frac{\sigma\lambda+\sqrt{\lambda(\lambda\sigma^2+4\beta\kappa(\delta-1))}}{2(1-\beta)\lambda}$.

From a customer's view, proposition 7(i) shows a negative influence of return shipping fees on customer demand both online and in-store. Charging online return fees decreases the total demand. This negative effect on total demand decreases in β, h and p, but increases in d and δ. Overall, a higher return fee will put off both store and online customers demands. Although charging a return fee may negatively affect overall demand, retailers that sell products with high unit prices and low return rates may be affected less than those whose products are low prices with high return rates. In detail, the store demand is negatively affected by $(\delta - 1)(1 - \lambda)(1 - h - p)$, primarily because the effect of additional demand stimulated by free returns is weakened if a shipping fee is charged. In the model assumption, the extra demand is from customers who perceive free returns signal good product quality or fewer risks, varying across product categories (Zhang et al., 2017). The reduced store demand increases in the δ whereas decreasing in λ, h, and p. The value of δ indicates the influence of generating additional demands as a free return policy could enhance the purchase with confidence (Moorthy and Srinivasan, 1995; Bonifield et al., 2010). Although the return shipping fee is assumed for online customers only, it is sensible that charging a shipping fee may negatively affect store customers who associate free returns with positive product perception. Similarly, charging return shipping fee decreases online demands by $(\frac{d(1-\beta)}{\beta} + (\delta - 1)(1 - p))\lambda$. This negative effect of return fees on online demand increases in δ, d and λ, yet decreases in β and p. That implies that the retailer with a large online customer base or a product category with a high signal effect of free returns may need to be cautious when charging a return fee. Also, charging shipping fees for online customers who are sensitive to return shipping fees or the risk of returns will negatively impact more online customers. However, if the retailer sells products with a low return rate or high unit price, the negative effect of charging a return fee is mild.

From the retailer's perspective, although the total demand decreased after introducing the online return shipping fee, it does not always hurt its total profit. Although charging a return shipping fee does not impact the return behaviour of store customers due to our model setting, it causes store profit loss due to the deduction of store customer demand. Despite the similar decrease in online demand, the return fee affects the online profit differently. On the one hand, the return fee may have positive effects. It may defer customers who show a frequent return pattern or abuse the free return policy (Speights and Hilinski, 2005). Also, charging a return fee allows some retailers to cover their return fulfilment cost, reducing the profit loss for returned products. On the other hand, charging a return fee may drive online demands away, especially those sensitive to non-partitioned prices and associate free returns with good services or product quality, thereby causing the online profit loss. Hence, the trade-off is extra profit gain from preventing unprofitable return behaviour, whereas a profit loss is from deterring customers from purchases. Proposition 7(ii) shows that the total profit is concave in d, and it is primarily relevant to the simulation effect δ. When the effect is weak ($1 < \delta < 1 - \frac{\hat{\beta}\lambda(\beta-1+\sigma)}{\kappa}$), the retailer may benefit from charging a return fee. When the effect is medium ($1 - \frac{\hat{\beta}\lambda(\beta-1+\sigma)}{\kappa} < \delta < 1 - \frac{\lambda\sigma^2}{4\beta\kappa}$), the retailer may also benefit from charging a return fee as long as it is below a cap d_2. However, charging a return fee is not recommended when the simulation effect is significant. For example, hassle-free returns are important for fashion garments, and free returns will ease perceived risks (IMRG, 2020). Charging a return fee may increase the chance of shopping cart abandonment online (Kukar-Kinney and Close, 2010; Barwitz and Maas, 2018).

The optimal return fee is $\hat{d}^*_{s_2} = \frac{\sigma}{2(1-\beta)}$, due to its complex format, in order to analyse the change of optimal return fee with regards to the relevant factors. Values will be assigned to the function to illustrate the variances.

5.5.2 The Impact of Return Shipping Fee When Cross-channel is Available

This section will discuss the impact of return shipping fees when cross-channel is available. I compare scenarios 2 with 4 to understand whether the effect of the return policy may change when cross-channel returns are allowed. Choosing scenarios 2 and 4 is because customers are charged for online return shipment in both scenarios, while only scenario 4 offers cross-channel returns. Hence, this comparison will help understand how effective cross-channel return is when a shipping fee is charged, and how jointly decide shipping fees when cross-channel returns are available. I subtract the demand and profit functions in scenario 2 from these in scenario 4, and get proposition 8 below.

Proposition 8. *When customer channel preferences are exogenous and their perception on hassle cost of visiting a store is homogeneous, the return policy with a shipping fee and allows cross-channel return will:*

(i) increase the total demand by $\frac{d(d-h)(1-\beta)\lambda}{\beta}$ if $h < d$; otherwise, decrease the total demand if $d < h$;

(ii) total profit change by $-\frac{\lambda\big((\beta-1)d^2-(\beta-1)d(h+1)+\beta(p-1)\big)\big((\beta-1)d(-\alpha+c-1)+(\beta-1)d^2+(2\beta-1)p-\beta s+s\big)}{\beta}-\left(-\frac{d}{\beta}+d-p+1\right)((\beta-1)\lambda(-d+p-s)+\beta\lambda p)$*;*

From the customer point of view, proposition 8(i) shows how a combined return policy with both shipping fees and cross-channel returns affects customer demands. Interestingly, adding cross-channel returns makes no difference for customers who prefer stores and will not impact their choices because no additional demands are simulated in both scenarios. Cross-channel returns will not impact store customer returns decisions as they have already inspected the product in-store before purchase according to the model assumption. Hence, only online demands are impacted by the cross-channel return policy. Firstly, the changing demand is decreasing in the hassle cost of visiting a store h, e.g. if visiting a store or the store operation is not convenient, the cross-channel return may not be appealing. Secondly, this effect of cross-channel behaviour can be positive or negative depending on whether customers perceive the hassle cost of visiting a store compared to the shipping fee. Specifically, when the perceived hassle of visiting a store is less than paying a shipping fee for online returns ($h < d < 1$), the omnichannel return function will drive online demand who are sensitive to the non-partitioned prices into stores. Thereby, the total demand increases $\frac{d(d-h)(1-\beta)\lambda}{\beta}$. For example, NEXT charges £2 for partnered couriers to collect online orders from home. However, customers who can easily access NEXT stores may find that returning orders to a store is more convenient than paying the charge and waiting at home for the collection. When visiting a store becomes more inconvenient than paying for online returns ($h > d$), online customers would find cross-channel returns less attractive. Customers who are sensitive to the inconvenience of store visiting, e.g. living in a rural area, or retailer stores are not based in a convenient location, then offering cross-channel returns may not convert online demands to stores. Thirdly, the probability of matching rate β and the proportion of online customers λ have opposite effects on the changing demand: when $d > h$, the total demand may increase when cross-channel return is offered, and the shifted demand is decreasing in β but increasing in λ; when $d < h$, the total demand may decrease, and the changing demand is decreasing in Δ yet increasing in λ. For example, when the return fee is higher than the perceived hassle, cross-channel returns positively affect converting online return traffic to stores and increasing total demand for the retailer with a larger online customer base or higher return rate. In contrast, when the perceived hassle is more than the return fee, cross-channel returns are not as appealing as returning online by post. When customers' channel preferences are exogenous, and the perception of hassle cost is homogeneous, proposition 8(i) has demonstrated that the retailer needs to review its store operation efficiency and online return fee before they offer cross-channel returns, because the omnichannel function may not affect cross-channel demand migration as expected.

From the retailer's view, when the retailer charges for online returns, making cross-channel returns available will positively or negatively impact the total profit. The profit change increases in the salvage value s if $d > h$, or decreases in s if $d < h$. Moreover, the cross-sales factor α and the in-store handling cost c have the opposite effect on the profit change: it is increasing in α, e.g. if the retailer has more cross-selling opportunities, such as a wide range of product portfolio, the more profit will change, and potentially cross-channel returns may increase the total profit; whereas it is decreasing in c, e.g. if the in-store handling cost is high, less profit may change and handing online returns in-store may incur high operating costs, thereby cross-channel returns may hurt the overall profits.

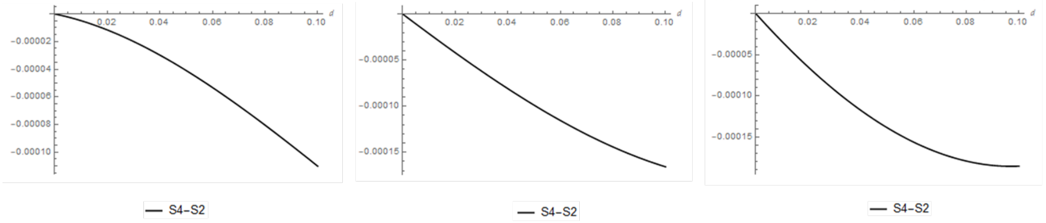
As the profit function in scenario 4 is in a complex form. To illustrate how the total profit is changed in response to relevant parameters. A series of numerical analyses have been conducted. I denote Δ_{S4-S2} as the variance by subtracting the total profit in scenario 4 from scenario 2, where Δ_{S4-S2} can be positive or negative. Firstly, values will be assigned in Δ_{S4-S2} when $h < d$, that is, the perceived hassle cost is lower than the online return shipping fee. As it is known how α, c and s impact the changed total profit, I will assign a value to these parameters and focus on the remaining factors. The hassle cost h is assigned from 0.1 to 0.3 with an interval at 0.1, which is sensible because $h < 1-p$, and hassle cost is assumed to be lower than the unit price, or customers will not purchase it. The probability of product matching β is from 0.7 to 0.85 with an interval at 0.05. That setting represents the return rate from high to low. The unit price p is set from 0.45 to 0.65 with an interval at 0.1, representing low to high price. The cross-sales factor ranges from 0.1 to 0.3 with an interval at 0.1, representing the opportunity for cross-selling from low to high. Similar to Model 1, I assume $c = 0.3p$ and $s = 0.75p$. The numerical results are presented with scientific notation in Table 16 (Appendix B) because some results are too small. Secondly, the same values will be assigned to Δ_{S4-S2} when $h < d$, the numerical results are shown in Table 17 (Appendix B).

Observation 3.

- *(i) if a retailer charges for online returns, and when $h < d$, offering cross-channel returns could increase its total profit. The profit change increases in p and α, decreasing in h and β. h<d*
- *(ii) if a retailer charges for online returns, and when $h > d$, offering cross-channel returns could decrease its total profit. The profit change is increasing in p, α, in h and β;*

Overall, the changed profit increases in the unit selling price and cross-sales. A retailer with a broader range of portfolios or higher unit selling prices may consider offering omnichannel return because the profit from a potential cross-selling opportunity may compensate for the associated rising costs of handing return items in-store. When the return fee is perceived higher than the hassle of returning to a store ($h < d$), offering a convenient omnichannel return could benefit the overall profit, however, interestingly, if the return rate is low, it is not beneficial to offer cross-channel returns, as the potential footfall is limited. In contrast, if visiting a store is not convenient and is perceived as more hassle than paying a return fee ($h > d$), offering omnichannel returns is unnecessary as it could hurt the overall profit.

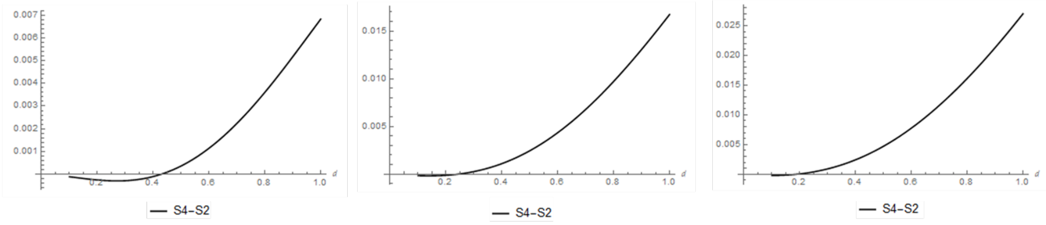
To further observe and discuss how the total profit change depending on d and h when parameters change. According to the numerical results, figure 12 illustrates how cross-channel returns affect the total profit when the hassle cost changes. Figures on the top of Figure 12 demonstrates the profit variance Δ_{S4-S2} changes with d when $d < h$ when $p = 0.45$ (a), $p = 0.55$ (b), and $p = 0.65$ (c). In contrast, the figures on the bottom demonstrate Δ_{S4-S2} when $d > h$. The results show that the profit change will turn from negative to positive depending on whether the hassle of visiting stores is perceived higher than the return fee. When $d > h$, the higher the unit price, the more profit will be increased after offering cross-channel returns.



(a) d<h, p=0.45
$\Delta^* = -2.05742 \times 10^{-7}$
$d^* = 5.25346 \times 10^{-4}$

(b) d<h, p=0.55
$\Delta^* = -1.03026 \times 10^{-7}$
$d^* = 4.7949 \times 10^{-5}$

(c) d<h, p=0.65
$\Delta^* = -9.28225 \times 10^{-8}$
$d^* = 2.61407 \times 10^{-5}$



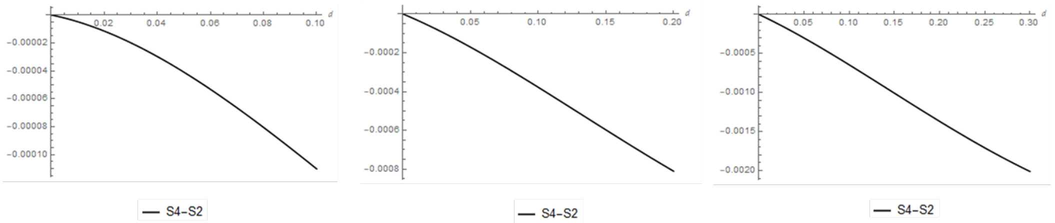
(a) d>h, p=0.45
$\Delta^* = 0.00682866$
$d^* = 0.999994$

(b) d>h, p=0.55
$\Delta^* = 0.0167362$
$d^* = 0.999998$

(c) d>h, p=0.65
$\Delta^* = 0.0270037$
$d^* = 0.999998$

($h = 0.1$, $\beta = 0.8$, $\alpha = 0.2$, and $\lambda = 0.3$)
Figure 12: The Variance in the Total Profit between Scenario 4 and 2 change with p

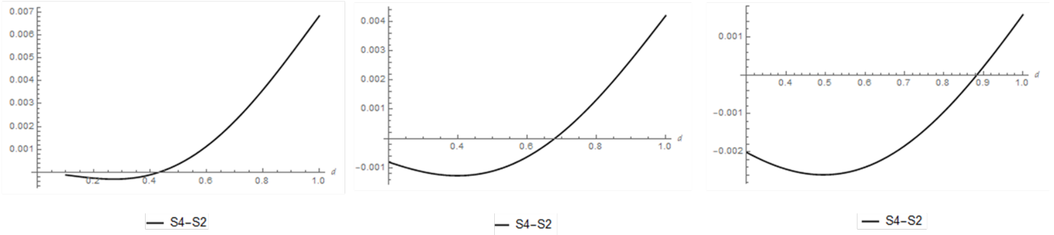
Similarly, figure 13 outlines how the total profit is affected by the cross-channel returns when the hassle cost changes. Figures on the top of Figure 13 demonstrates the profit variance Δ_{S4-S2} changes with d when $d < h$ when $h = 0.1$ (a), $p = 0.2$ (b), and $p = 0.3$ (c). It shows a similar trend that the profit variance will turn negative to positive if $d > h$. However, the less convenient the service is, the less effective the cross-channel return policy would grow total profit.



(a) d<h, h=0.1
$\Delta^* = -2.05742 \times 10^{-7}$
$d^* = 5.25346 \times 10^{-4}$

(b) d<h, h=0.2
$\Delta^* = -9.55913 \times 10^{-8}$
$d^* = 3.27605 \times 10^{-5}$

(c) d<h, h=0.3
$\Delta^* = -9.26548 \times 10^{-8}$
$d^* = 1.70041 \times 10^{-5}$



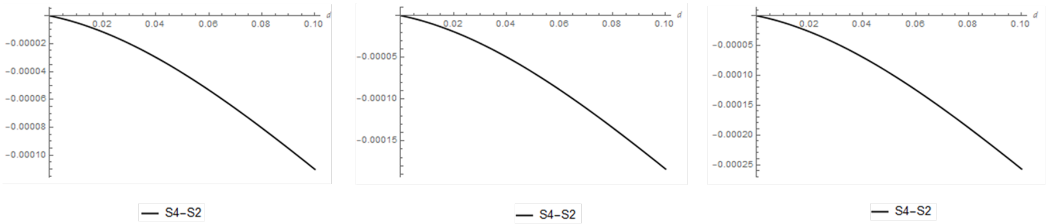
(a) d>h, h=0.1
$\Delta^* = 0.00682866$
$d^* = 0.999994$

(b) d>h, h=0.2
$\Delta^* = 0.00419991$
$d^* = 0.999994$

(c) d>h, h=0.3
$\Delta^* = 0.00157116$
$d^* = 0.999994$

($p = 0.45$, $\beta = 0.8$, $\alpha = 0.2$, and $\lambda = 0.3$)
Figure 13: The Variance in the Total Profit between Scenario 4 and 2 change with h

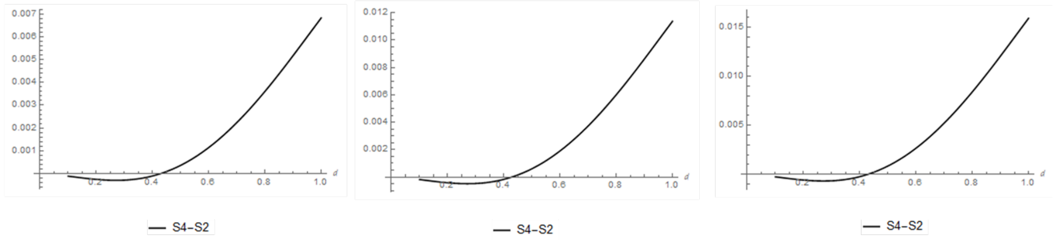
Figure 14 shows how the total profit is affected by the cross-channel returns when the proportion of online customers changes. Figures on the top of Figure 14demonstrates the profit variance Δ_{S4-S2} changes with d when $d < h$ when $\lambda = 0.3$ (a), $\lambda = 0.5$ (b), and $\lambda = 0.7$ (c). Cross-channel return is beneficial if the retailer has a larger online customer base.



(a) d<h, λ=0.3
Δ*= -2.05742 x 10^{-7}
d*= 5.25346 x 10^{-4}

(b) d<h, λ=0.5
Δ*= -1.00262 x 10^{-7}
d*= 1.55108 x 10^{-4}

(c) d<h, λ=0.7
Δ*= -2.9108 x 10^{-8}
d*= 3.20253 x 10^{-4}



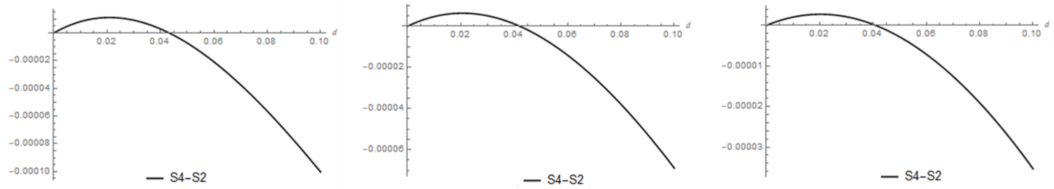
(a) d>h, λ=0.3
Δ*= 0.00682866
d*= 0.999994

(b) d>h, λ=0.5
Δ*= 0.0113811
d*= 0.999996

(c) d>h, λ=0.7
Δ*= 0.0159337
d*= 0.999998

($p = 0.45$, $\beta = 0.8$, $\alpha = 0.2$, and $h = 0.1$)
Figure 14: The Variance in the Total Profit between Scenario 4 and 2 change with λ

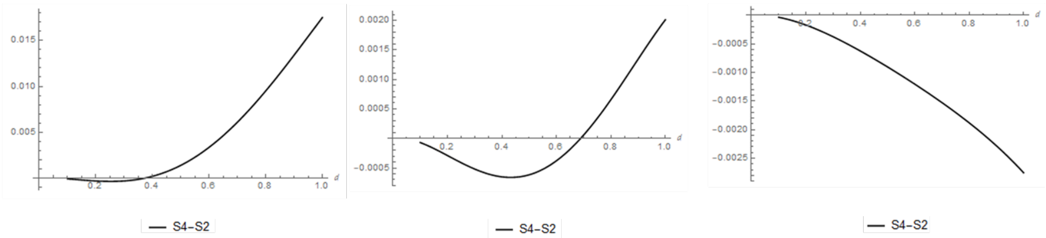
Figure 15 shows how the total profit is affected by the cross-channel returns when the probability of product matching expectations changes. Figures on the top of Figure 15 demonstrates the profit variance Δ_{S4-S2} changes with d when $d < h$ when $\beta = 0.7$ (a), $p = 0.8$ (b), and $p = 0.9$ (c). The profit variance turns from concave to convex in d when $d > h$. Interestingly, when the return rate is low, it is not recommended to offer omnichannel returns.



(a) d<h, β=0.7
Δ*= 1.11536 x 10^{-5}
d*= 0.0210775

(b) d<h, β=0.8
Δ*= 6.33491 x 10^{-6}
d*= 0.0207798

(c) d<h, β=0.9
Δ*= 2.73914 x 10^{-6}
d*= 0.0207683



(a) d>h, β=0.7
Δ*= 0.0175113
d*= 0.999998

(b) d>h, β=0.8
Δ*= 0.0020099
d*= 0.999983

(c) d>h, β=0.9
Δ*= 3.57302 x 10^{-5}
d*= 0.100433

($p = 0.4$, $\lambda = 0.3$, $\alpha = 0.2$, and $h = 0.1$)
Figure 15: The Variance in the Total Profit between Scenario 4 and 2 change with β

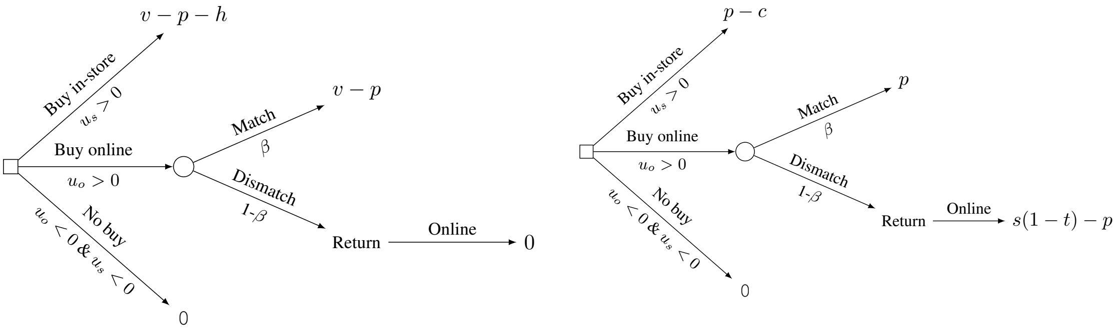
Finally, when online return is free in scenarios 1 and 3, with or without cross-channel returns, online customers will always prefer to return online by post as it is free. Therefore, the impact of cross-channel returns when online return is free is not discussed.

5.6 Extension- Extend Return Period

This section will discuss a generous return policy by extending the return period. Therefore, a new factor t is introduced within the range between 0 and 1, representing the length of a return period. Introducing t in the base model extends the discussion on how a return period impacts the results. Regarding the free return policy, as discussed in the base model, there is no need to repeat the discussion on scenario 3. Therefore, I will extend scenario 1 and analyse its difference between the base model and extension in §5.6.1. Similarly, the extension of scenario 2 and its contrast with the base model will be discussed in §5.6.2; Last, scenario 4 will be extended and compared in §5.6.3 in this section. All the relevant proofs are in Appendix B.

5.6.1 Extend Return Period in Scenario 1

In the extension, the return policy with a longer return period is assumed to positively affect the demand generation due to the signal effect (Oghazi et al., 2018), whereas a negative impact on salvage value (Janakiraman et al., 2016). For example, some products may depreciate their values heavily over a certain period, such as fashion garments or smart devices. Figure 16 demonstrates the decision trees in scenario 1 extension.



(a) Customer's Utility

(b) Retailer's Profit

○ = Chance node □ = Decision node

Figure 16: The sequence of customer decisions and associated utilities and retailer profits in scenario 1 extension

In scenario 1 where online returns are free and cross-channel returns are unavailable, offering a longer return period does not change the hassle of visiting a store or unit selling price. Also, it does not change the unit profit for store customers due to the model assumption. However, it negatively affects the salvage value for the returned product and varies the unit profit from $s-p$ in the base model to $s(1-t)-p$ in the extension. The term $1-t$ represents the extent that a product depreciates over time, e.g. the larger t is, the more depreciation will be. Therefore, I do not repeat the customer utility discussion here. Instead, I will primarily focus on the demand and profit as below:

$$\begin{aligned}
\hat{\pi}_{o_{s_1}} &= q_{o_{s_1}}\big(\beta p + (1-\beta)(s(1-t)-p)\big) \\
&= \lambda(1-p)\big(\beta p + (1-\beta)\big(s(1-t)-p\big)\big) && (5.19) \\
\hat{Q}_{s_1} &= \delta(1+t)(q_s + q_{o_{s_1}}) = \delta(1+t)\big((1-\lambda)(1-h-p) + \lambda(1-p)\big) && (5.20) \\
\hat{\Pi}_{s_1} &= \delta(1+t)(\pi_s + \hat{\pi}_{o_{s_1}}) \\
&= \delta(1+t)\Big((1-\lambda)(1-h-p)(p-c) + \lambda(1-p)\big(\beta p + (1-\beta)(s(1-t)-p)\big)\Big) && (5.21)
\end{aligned}$$

Where the term $\delta(1+t)$ represents the signal effect of extending the return period. With free online returns and an extended return period, the total demand will be stimulated by $\delta(1+t)$. Extending the return period will provoke a trade-off: a long return period may signal positive product perceptions, thereby encouraging more demand, whereas a long return period could reduce the salvage value of the returned product and increase the profit loss. By calculating $\hat{\Pi}_{s_1}$ with regards to relevant parameters, Lemma 10 is gained as below:

Lemma 10. *When cross-channel return is unavailable and online return is free, after extending return period, the total profit* $\hat{\Pi}_{s_1}$*:*

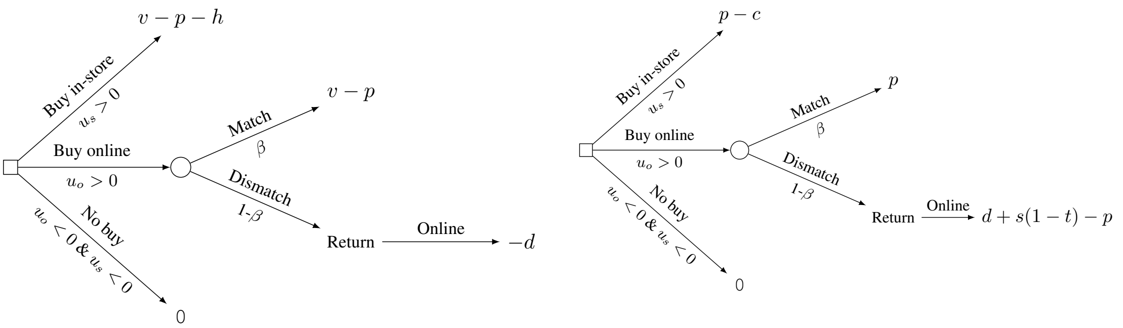
(i) increasing in s*,* δ*, and* β*;*

(ii) decreasing in c *and* h*.*

By comparing Lemma 10 with Lemma 7, it is found that offering a generous return policy by extending the return period does not change how the total profit is affected by s, δ, β, c and h. However, extending the return period could provoke a trade-off between stimulated total demand due to the signal effect and the product value depreciation over time. A retailer with high operating costs in-store would motivate customers to purchase online by offering a generous return policy. It may be beneficial when the retailer can re-sell the returned item at a satisfactory value, yet the salvage value depreciates with the return period.

5.6.2 Extend Return Period in Scenario 2

When extending scenario 2, where cross-channel is unavailable, the retailer will charge online customers if they return a product by post. The decision trees (figure 17) below demonstrates sequential customer decisions in scenario 2 after extending the return period.



(b) Profit

(a) Utility

○ = Chance node □ = Decision node

Figure 17: The sequence of customer decisions and associated utilities and retailer profits in scenario 2 extention

Similarly, in scenario 2, offering a longer return period does not change the hassle of visiting a store or unit selling price. Thereby, customer utilities remain the same. However, it impacts the salvage value for the returned product. The unit profit is changed from $d+s-p$ in the base model to $d+s(1-t)-p$ in the extension. Therefore, the customer demand and profit are obtained as below:

$$\begin{aligned}
\hat{\pi}_{o_{s_2}}(d) &= q_{o_{s_2}}\big(\beta p+(1-\beta)(d+s(1-t)-p)\big)\\
&= \lambda(1+d-p-\frac{d}{\beta})\big(\beta p+(1-\beta)(d+s(1-t)-p)\big) && (5.22)\\
\hat{Q}_{s_2} &= (1+t)(q_s+q_{o_{s_2}})\\
&= (1+t)\big((1-\lambda)(1-h-p)+\lambda(1+d-p-\frac{d}{\beta})\big) && (5.23)\\
\hat{\Pi}_{s_2}(d) &= (1+t)(\pi_s+\pi_{o_{s_2}}(d))\\
&= (1+t)\Big((1-\lambda)(1-h-p)(p-c)\\
&\quad +\lambda(1+d-p-\frac{d}{\beta})\big(\beta p+(1-\beta)(d+s(1-t)-p)\big)\Big)\\
& && (5.24)
\end{aligned}$$

Where the term $1+t$ shows the demand stimulated by the generous return policy. However, as the online return is charged, δ is not considered in this scenario. When cross-channel return is unavailable and online return is charged at d, after extending return period, Lemma 11 is gained as below:

Lemma 11. *When cross-channel return is unavailable and online return is charged at* d*, after extending return period, the total profit* $\hat{\Pi}_{s_2}$*:*

(i) concave in d*, and the optimal shipping fee is* $\hat{d}^*_{s_2} = \frac{\beta-3\beta p+p+s(\beta-\beta t+t-1)}{2-2\beta}$*;*

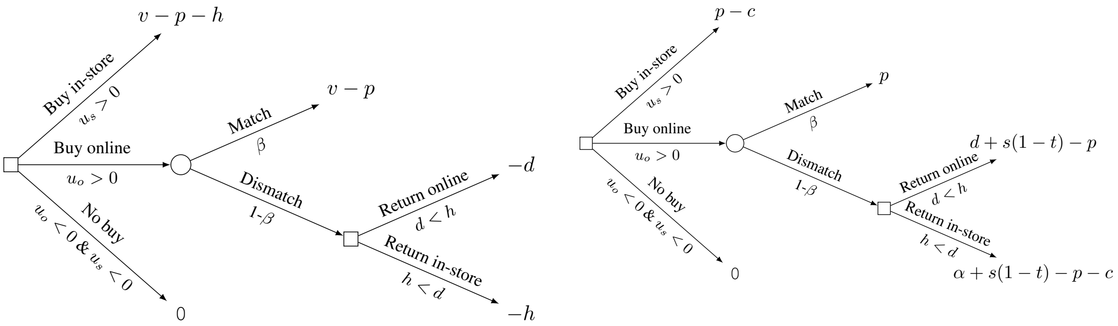
(ii) increasing in s*;*

(iii) decreasing in c *and* h*;*

By comparing Lemma 11 with Lemma 8, it is found that offering a generous return policy by extending the return period does not change how the total profit is affected by s, c and h. However, extending the return period could impact the optimal return fee $\hat{d}^*_{s_2}$, increasing in t. It suggests that the longer the return period is offered, the retailer could potentially charge higher return fees.

5.6.3 Extend Return Period in Scenario 4

Extending scenario 4 is more complex than previous scenarios, where cross-channel is available, and the retailer will charge for online returns, as customers have alternative return channels. The decision trees (figure 18) below demonstrates sequential customer decisions in scenario 4 after extending the return period.



(b) Profit

(a) Utility

○ = Chance node □ = Decision node

Figure 18: The sequence of customer decisions and associated utilities and retailer profits in scenario 4 extension

A product can be returned both online or in-store, so extending a return period affects the salvage value. It changes the unit profit for the returned product from $\alpha + s - p - c$ in the based model to $\alpha + s(1-t) - p - c$ in the extension when customers return to store, and from $d + s - p$ to $d + s(1-t) - p$ when customers return online and pay for the return fee. Therefore, the customer demand and profit are obtained as below:

$$\begin{aligned}
\hat{\pi}_{o_{s_4}}(d) &= q_{o_{s_4}}\Big(\beta p + (1-\beta)\big((1-d)(d+s(1-t)-p) + d(\alpha + s(1-t) - p - c)\big)\Big) \\
&= \lambda\big(1 - p + \frac{(1-\beta)(d^2 - dh - d)}{\beta}\big)\Big(\beta p + (1-\beta)\big((1-d)(d+s(1-t)-p) \\
&\quad + d(\alpha + s(1-t) - p - c)\big)\Big) \qquad (5.25) \\
\hat{Q}_{s4} &= (1+t)(q_s + q_{o_{s_4}}) \\
&= (1+t)\Big((1-\lambda)(1-h-p) + \lambda\big(1 - p + \frac{(1-\beta)(d^2 - dh - d)}{\beta}\big)\Big) \\
&\qquad (5.26) \\
\hat{\Pi}_{s4}(d) &= (1+t)\Big((1-\lambda)(1-h-p)(p-c) + \lambda\big(1 - p + \frac{(1-\beta)(d^2 - dh - d)}{\beta}\big)\big(\beta p \\
&\quad + (1-\beta)\big((1-d)(d+s(1-t)-p) + d(\alpha + s(1-t) - p - c)\big)\big)\Big) \qquad (5.27)
\end{aligned}$$

Where the term $1 + t$ shows the demand stimulated by the generous return policy policy, similar to scenario 2. When the cross-channel return is available, and online return is charged at d, after extending the return period, Lemma 12 is gained as below:

Lemma 12. *When cross-channel return is available and online return is charged at* d*, after extending return period, the total profit* $\hat{\Pi}_{s_4}$*:*

- *(i) concave in* d *if the condition is met; and the optimal shipping fee is* $\mathrm{d}_{s_4}{}^{*} = \phi + \sqrt[3]{\hat{\gamma} - \sqrt{\hat{\gamma}^2 + \varsigma^3}} + \sqrt[3]{\hat{\gamma} + \sqrt{\hat{\gamma}^2 + \varsigma^3}}$*;*
- *(ii) increasing in* s *and* α*;*
- *(iii) decreasing in* c*;*

where $\hat{\gamma} = \frac{(h-\alpha+c)(4\beta+(\beta-1)((c-\alpha)(\alpha-c+2)+h(h+2)+4(p-s(1-t))))}{64(\beta-1)}$. By comparing Lemma 12 with Lemma 9, it is found that offering a generous return policy by extending the return period does not change how the total profit is affected by s, c and α. However, extending the return period could impact the optimal return fee $\hat{d}^{*}_{s_4}$, due to the complex form, I assign values to observe how the optimal return fee change with t.

5.7 Analysing Extension- Extend Return Period

This section will analyse the impact of offering a generous return policy on customer channel choices and retailer profitability when customers are homogenous in the hassle cost of visiting stores. The effect of extending a return period in scenario 1 will be discussed in subsection §5.7.1 by contrasting results between scenario 1 and its extension. In §5.7.2, the impact of extending a return period on scenario 2 will be discussed by comparing outcomes in scenario 2 with its extension. Then, I discuss the impact on scenario 4 in §5.7.3. Due to the complex form in scenario 4, a series of numerical analyses will be conducted to gain insights and observe how the total profit change according to relevant parameters.

5.7.1 The Impact of Extending Return Period on Scenario 1

This subsection will primarily discuss how the generous return policy impacts the channel choice and total profit compared to the base model. This comparison helps study a single element of return policy – return period, without the impact of cross-channel behaviours. I subtract the demand and profit functions in scenario 1 from these in its extension, and get proposition 9 below.

Proposition 9. *Extending the return period in scenario 1 will:*

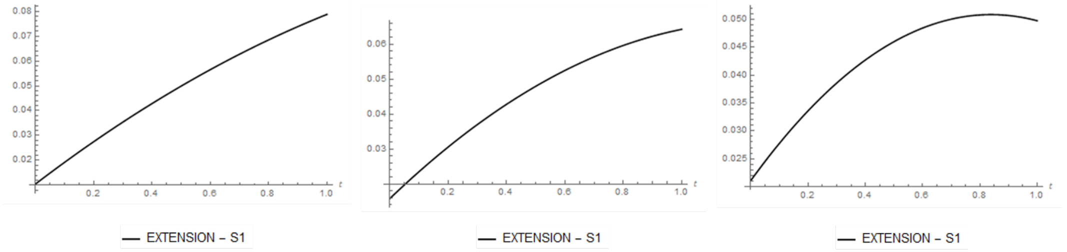
(i) *increase the total demand by* $t\delta(1-h-p+h\lambda)$*; specifically, the store demand will increase by* $t\delta(1-h-p)(1-\lambda)$ *and the online demand will increase by* $t\delta\lambda(1-p)$*;*

(ii) *the total profit will change by* $\Delta_{\hat{s_1}-s1} = \delta(-c(\lambda-1)t(h+p-1)+p^2(-(-\beta\lambda+(\beta-2)\lambda t+t))+(\beta-1)\lambda st^2)+pt(h(\lambda-1)-(\beta-1)\lambda(st-2)+1)$*;*

(iii) $\Delta_{\hat{s_1}-s1}$ *may concave in* t*, and* $t^* = -\frac{(\lambda-1)(c-p)(h+p-1)+(\beta-1)\lambda(p-1)p-\beta\lambda p}{2(\beta-1)\lambda(p-1)s}$ *when the condition is met:* $c_4 < c < p$ *and* $s_2 < s \leq p$*; or increase in* t *when the condition is met:* $0 < c < c_s$ *and* $c_4 < s < s_2$*; where* $s_2 = -\frac{c(\lambda-1)(h+p-1)+p(-2\beta\lambda+h(-\lambda)+h+2\lambda+\beta\lambda p-2\lambda p+p-1)}{2(\beta-1)\lambda(p-1)}$ *and* $c_4 = \frac{p(h(\lambda-1)+2\lambda(\beta-\beta s+s-1)+1)+p^2(-((\beta-2)\lambda+1))+2(\beta-1)\lambda s}{(\lambda-1)(h+p-1)}$*;*

On the one hand, a generous policy could positively affect the total demand. Therefore, the total demand will increase, including store and online channels. As introducing t provokes a trade-off, and the salvage value depreciates with the return period, the total profit may concave in t. When a retailer can run the store cost-effectively yet cannot re-sell the product at decent salvage value, offering a generous return policy may benefit more from stimulating more demands into the stores than the loss from the product depreciations.

To further discuss how the proportion of online customers affects a generous return policy on total profit. I will use assign values in the $\Delta_{\hat{s_1}-s1} = \hat{\Pi}_{s_1} - \Pi_{s_1}$. I assign the λ from 0.4 to 0.8 with an interval at 0.2, representing the online customer base from small to large. I also assign the keeping rate $\beta = 0.6$ (Figure 19) and $\beta = 0.8$ (Figure 20), showing high return and low return rates. The rest of the parameters are set as follow: $p = 0.2$, similar to previous numerical analysis, I assume $c = 0.3p$, and $s = 0.75p$, $\delta = 1.1$.



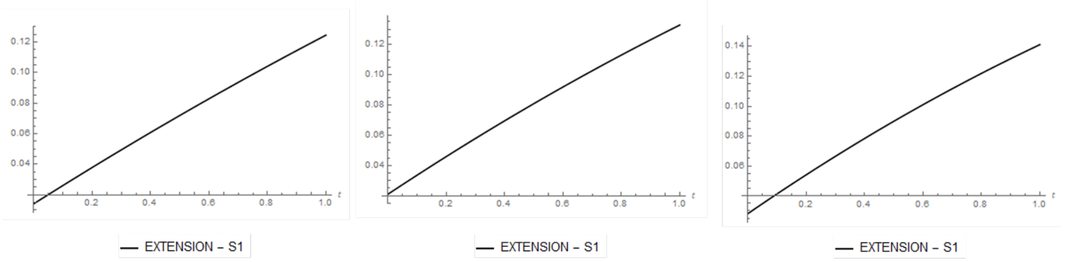
(a) λ=0.4, Δ is increasing in t
s_2= 0.317187
c_4= 0.161905

(b) λ=0.6, Δ is increasing in t
s_2= 0.189583
c_4= 0.114286

(c) λ=0.8, Δ is concave in t
s_2= 0.125781
c_4= -0.0285714

($p = 0.2$, $\beta = 0.6$, $\delta = 1.1$, and $h = 0.1$)

Figure 19: The Variance in the Total Profit between Scenario 1 and its extension change with t and $\beta = 0.6$



(a) λ=0.4, Δ is increasing in t
s_2= 0.859375
c_4= 0.27619

(b) λ=0.6, Δ is increasing in t
s_2= 0.604167
c_4= 0.371429

(c) λ=0.8, Δ is increasing in t
s_2= 0.476563
c_4= 0.657143

($p = 0.2$, $\beta = 0.8$, $\delta = 1.1$, and $h = 0.1$)

Figure 20: The Variance in the Total Profit between Scenario 1 and its extension change with t and $\beta = 0.8$

Figures 19 and 20 demonstrates how the total profit changes with t, and when the parameters meet the condition in Lemma 10, it is concave or increases in t. This result implies that the retailer may not benefit from extending a longer return period for products that may depreciate heavily over time. The potential reason is that a generous policy may decrease the salvage value over time. The larger the online customer, the more returned items, therefore the profit loss from product depreciation may outweigh the demand stimulated by the generous return policy. Furthermore, when the return rate is low (i.e. higher β), the retailer may benefit from a generous policy because the gain from demand stimulation could exceed the loss from product depreciation, especially when the return rate is low.

5.7.2 The Impact of Extending Return Period on Scenario 2

I subtract the demand and profit functions in scenario 2 from their extension and get proposition 10 below.

Proposition 10. *Extending the return period in scenario 2 will:*

(i) *increase the total demand by* $t(-\frac{d\lambda}{\beta}+d\lambda+h(\lambda-1)-p+1)$*; specifically, the store demand will increase by* $t(\lambda-1)(h+p-1)$ *and the online demand will increase by* $\frac{\lambda t(\beta+(\beta-1)d-\beta p)}{\beta}$*;*

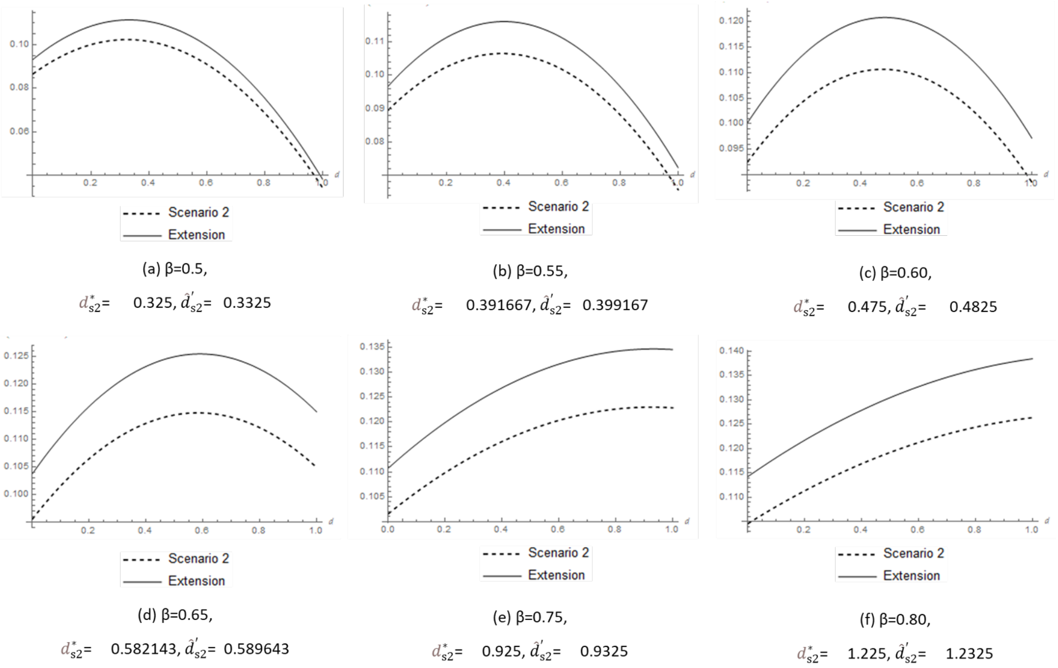
(ii) *the total profit will change by* $\Delta_{\hat{s_2}-s2}=-\frac{t}{\beta}(\beta c(\lambda-1)(h+p-1)-p(\beta+d\lambda+\beta^2\lambda(3d-st+2)+\beta\lambda(-4d+st-2)+\beta h(\lambda-1))+(\beta-1)\lambda(\beta+(\beta-1)d)(d-st)+\beta p^2(2(\beta-1)\lambda+1))$*;*

(iii) $\Delta_{\hat{s_2}-s2}$ *may concave in t, and* ${t^*}_{s2}=\frac{1}{2(\beta-1)\lambda s(\beta+(\beta-1)d-\beta p)}(\beta c(\lambda-1)(h+p-1)+(\beta-1)d\lambda(\beta+(\beta-1)d)-p(\beta^2(3d+2)\lambda+\beta(-4d\lambda+h(\lambda-1)-2\lambda+1)+d\lambda)+\beta p^2(2(\beta-1)\lambda+1))$ *when the condition is met:* $0<{t^*}_{s2}<\frac{1}{2}$*; otherwise,* $\Delta_{\hat{s_2}-s2}$ *is increasing in t, if* ${t^*}_{s2}>\frac{1}{2}$*;*

(iv) *may concave in d, and the optimal shipping fee is* $\hat{d'}_{s2}=\frac{\beta-3\beta p+p-\beta st+st}{2-2\beta}$*;*

(v) $\hat{d'}_{s2}$ *is increasing in t but decreasing in p, and decreasing in* β *if* $p>\frac{1}{2}$ *or increasing in* β *if* $p<\frac{1}{2}$.

From a customer point of view, as a generous return policy stimulates extra demands, the total demand will increase, including both store and online channels. The total profit may concave in t when ${t^*}_{s2}<\frac{1}{2}$. The retailer faces the trade-off of whether the demand stimulation will surpass the loss from product depreciation. This result implies that for products that may depreciate heavily over time, the retailer may not benefit from extending a longer return period. However, for products that return period will stimulate significant demand, then the longer return period, the better. Extending the return period would not change the concavity of the initial total profit, but the optimal delivery fee is increasing in t. To demonstrate the effect of the generous return policy on how the total profit change with d in proposition 10. A comparison between $\hat{\Pi}_{s_2}(d)$ and $\Pi_{s_2}(d)$ change with d will be conducted in Figure 21. The optimal delivery fee is only relevant to p, s, t and β. As s and t have been discussed previously, the observation will focus on the change of β. I assign the β from 0.5 to 0.8 with an interval at 0.05, representing the return rate from high to low. I do not assign two values to p, as when $p > \frac{1}{2}$, the total profit is not concave within $d \in [0, 1]$ because $\hat{d}'_{s2}$ decreases in β when $p > \frac{1}{2}$. The rest of the parameters are set as follow: $h = 0.1$ $\lambda = 0.3$, and $p = 0.2$, similar to previous numerical analysis, I assume $c = 0.3p$, and $s = 0.75p$, $t = 0.1$.



(a) β=0.5,
d^*_{s2}= 0.325, $\hat{d}'_{s2}$= 0.3325

(b) β=0.55,
d^*_{s2}= 0.391667, $\hat{d}'_{s2}$= 0.399167

(c) β=0.60,
d^*_{s2}= 0.475, $\hat{d}'_{s2}$= 0.4825

(d) β=0.65,
d^*_{s2}= 0.582143, $\hat{d}'_{s2}$= 0.589643

(e) β=0.75,
d^*_{s2}= 0.925, $\hat{d}'_{s2}$= 0.9325

(f) β=0.80,
d^*_{s2}= 1.225, $\hat{d}'_{s2}$= 1.2325

($p = 0.2$, $\lambda = 0.3$, $t = 0.1$, and $h = 0.1$)
Figure 21: The Variance in the Total Profit between Scenario 2 and its extension change with d

Figure 21 demonstrates that extending a return policy could increase the total profit due to the demand stimulation. However, the profit variance will slowly increase with the keeping rate β. The retailer may benefit from offering a generous return rate under scenario 2 if the product return rate is low.

5.7.3 The Impact of Extending Return Period on Scenario 4

The optimal delivery fee is in a complex form compared to other scenarios. The demand change will be calculated, and a numerical analysis will be conducted to understand the profit change with different parameters. I subtract the demand and profit functions in scenario 4 from their extension and get proposition 11 below.

Proposition 11. *Extending the return period in scenario 2 will:*

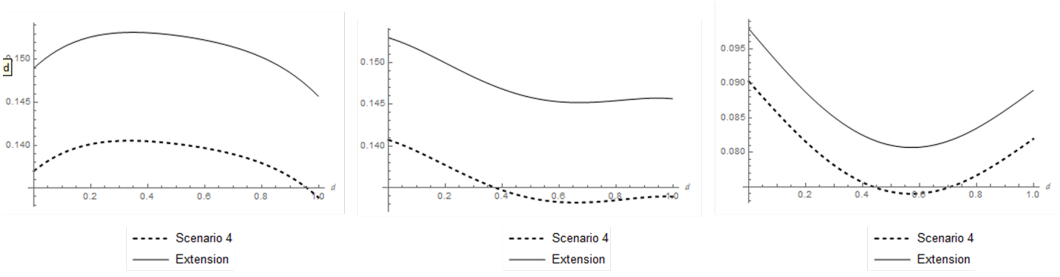
(i) increase the total demand by $t(d^2(-\lambda)+\frac{d\lambda(d-h-1)}{\beta}+h(d\lambda+\lambda-1)+d\lambda-p+1)$*; specifically, the store demand will increase by* $t(\lambda-1)(h+p-1)$ *and the online demand will increase by* $-\frac{\lambda t}{\beta}(\beta-1)d^2-(\beta-1)d(h+1)+\beta(p-1)$*;*

(ii) the total profit will change by $\Delta_{\hat{s_4}-s4}=\lambda(-\beta+(\beta-1)d(d-h-1)+\beta p)((\beta-1)(d(-\alpha+c-1)+d^2+p-s)+\beta p)-(t+1)(\lambda(-\beta+(\beta-1)d(d-h-1)+\beta p)((\beta-1)(d(-\alpha+c-1)+d^2+p+s(t-1))+\beta p)+\beta(\lambda-1)(c-p)(h+p-1))+\beta(\lambda-1)(c-p)(h+p-1)$*;*

(iii) $\Delta_{\hat{s_2}-s2}$ *may concave in t, and* ${t^*}_{s4}=-\frac{d(-\alpha+c-1)+\frac{\beta(\lambda-1)(c-p)(h+p-1)}{(\beta-1)\lambda(-\beta+(\beta-1)d(d-h-1)+\beta p)}+d^2+\frac{\beta p}{\beta-1}+p}{2s}$ *when the condition is met:* $0<{t^*}_{s4}<\frac{1}{2}$*; otherwise,* $\Delta_{\hat{s_4}-s4}$ *is increasing in t, if* ${t^*}_{s4}>\frac{1}{2}$*;*

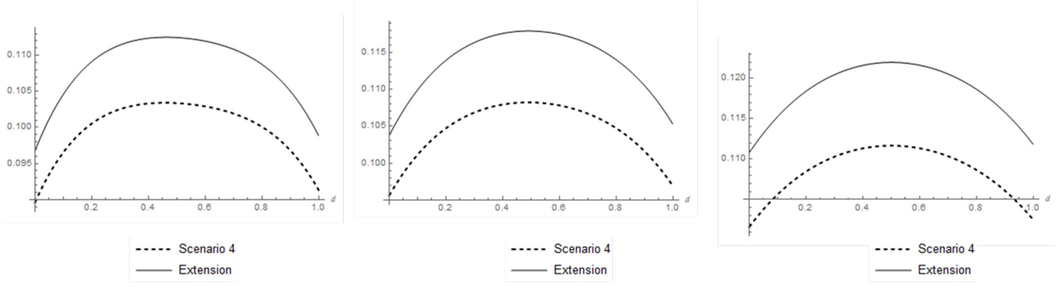
Due to the demand stimulation, the total customer demand will increase for both stores and online channels. Similar to scenario 2, the total profit may concave in t when ${t^*}_{s4}<\frac{1}{2}$. If the retailer charges for online returns, with or without cross-channel, extending the return policy faces the same trade-off whether the demand stimulation will surpass the loss from product depreciation. The only difference is that scenario 4 may have slightly higher unit profit for the returned product as returning to stores may increase cross-sales.

To demonstrate the effect of a generous return policy on how the total profit change with d in proposition 11. A series of numerical studies will be conducted. Based on the constraints in scenario 4: $1-h-p>0$ and $\frac{\beta-(\beta-1)d^2+(\beta-1)d(h+1)-\beta p}{\beta}>0$, I will compare $\hat{\Pi}_{s_4}(d)$ with $\Pi_{s_4}(d)$ and understand how the total profit change with p, β, h and λ. The total profit is increasing in s and α. Thereby, I do not discuss them in the analysis. Figure 22 demonstrates the total profit changes with delivery fee and unit price for scenario 4 and its extension. The unit selling price ranges from $p=0.35$ to $p=0.75$ with an interval at 0.2, representing low to high values. Figure 23 demonstrates the total profit changes with delivery fee and keeping rate for scenario 4 and its extension. The keeping rate ranges from 0.55 to 0.75 with an interval at 0.1, representing a high to low return rate. Figure 24 demonstrates the total profit changes with delivery fees and online customer base for scenario 4 and its extension. The online proportion ranges from 0.4 to 0.8, with an interval at 0.2. I assume $c = 0.3p$, $s = 0.75p$, and the remaining parameters are $t = 0.1$, $\alpha = 0.1$, $\lambda = 0.3$, $\beta = 0.7$, and $h = 0.1$.



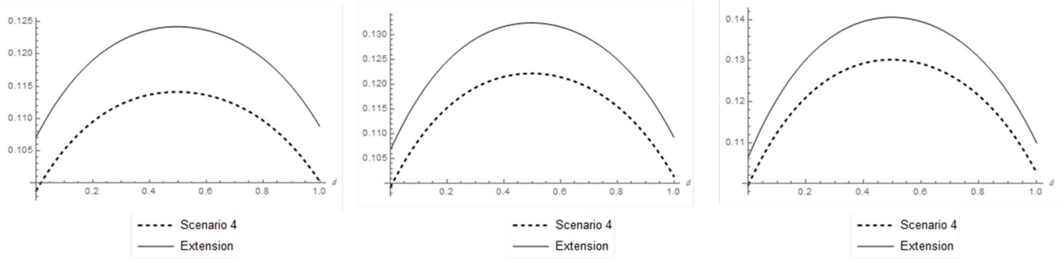
(a) p=0.35 (b) p=0.55 (c) p=0.75

($t = 0.1$, $\lambda = 0.3$, $t = 0.1$, $\alpha = 0.1$, $\beta = 0.7$ and $h = 0.1$)
Figure 22: The Total Profit in the Scenario 4 and its extension change with d and p



(a) β=0.55 (b) β =0.65 (c) β =0.75

($t = 0.1$, $\lambda = 0.3$, $t = 0.1$, $\alpha = 0.1$, $p = 0.2$ and $h = 0.1$)
Figure 23: The Total Profit in the Scenario 4 and its extension change with d and β



(a) λ=0.4 (b) λ=0.6 (c) λ=0.8

($t = 0.1$, $p = 0.2$, $t = 0.1$, $\alpha = 0.1$, $\beta = 0.7$ and $h = 0.1$)
Figure 24: The Total Profit in the Scenario 4 and its extension change with d and λ

The figures above show that the total profit is non-monotonic in d and partially depends on the unit selling price. The higher the unit selling price, the less profit variance between the base model and the extension. The return rate could impact the effect of return period extension gently. However, the proportion of online customers may expand the profit gap between the base model and extension. That suggests that if a retailer has a larger online customer base, they may benefit from offering a longer return period.

5.8 Summary

This study aims to understand the relevant elements affecting a retailer's omnichannel return policy and provide helpful insights into dealing with operational trade-offs in omnichannel returns. I developed a stylised model considering customer homogeneity to understand how an omnichannel function in the post-purchase stage impacts the customer cross-channel behaviours and total profit. I consider the differences between online channels and stores in operating costs, hassle costs and return fees. Customer channel preferences are exogenous in the model assumption. Thereby, store and online customers are segmented in the model. I assume that online customers face product uncertainty, whereas store customers do not return their purchases. This study considers four scenarios representing different shipping policies. Also, the potential signal effect of free returns or generous return policy on customer demand is considered. In the base model, customers are heterogeneous in the perceived product values but homogeneous in the hassle cost of visiting a store. In the model extension, a generous return policy is considered by extending the model considering the time-related factor. Comparing the base model and extension helps understand the relevant elements in return policies under an omnichannel setting.

As a result, this study has found the following insights. Firstly, retailers do not always benefit from offering omnichannel returns. As an alternative return channel, customers will make their channel choices based on the inconvenience level of visiting a store and online return shipment fees. When cross-channel is not available, although a return shipping fee negatively affects both store and online demands, it may increase the total profit when: 1) the signal effect is insignificant, a high return fee primarily defers online customers who show frequent return patterns or abuse the free return policy; 2) the signal effect is medium, and the return fee is within an affordable range. When the signal effect is significant, it is not recommended to charge for online returns. Secondly, when cross-channel is available, if the online return is free, the customer will always prefer free return by post other than returning it to a store based on the model assumption, thereby a return policy with both cross-returns and free online returns may not affect demands or profit as expected. For a retailer who considers offering omnichannel returns and also charging for post returns, the critical factors are 1) whether the inconvenience of in-store returns is perceived in comparison to the online return fee; 2) salvage values; 3) cross-sales. If the retailer can provide a convenient cross-return, factors including salvage values, cross-sales, product matching rate, and the proportion of online customers will positively impact the total profit. Hence, offering omnichannel returns may increase the total profit. Last, offering a generous return window could amplify the signal effect based on the model assumption and show a similar impact on the total profit with or without cross-channel returns.

Chapter 6

Discussion

6.1 Model Robustness

For model one, the base model is based on homogeneous customers. The main results still hold when this assumption is relaxed in the extension by allowing product valuation to be heterogeneous in both perceived product values and the hassle cost of visiting stores. Moreover, a sensitivity analysis has been conducted, discussing how conditions change affect the optimal profits in scenarios 1 and 2. The results still hold when conditions are met.

I choose to vary two parameters β , the C&C convenience factor, and c_s, unit holding cost in-store, to test their impacts on the optimal profit difference between scenarios 2 and 1. I set $\beta = 0.1$ and $c_s = 0.1$ separately, which follows the assumption of Proposition 1. It is shown in Figure 25, and c_s is presented as c in the sensitivity analysis. β and c_s are chosen because p_d^* is relevant to them in both scenarios, and β affects the customer's channel choice, and c affects the retailer's profitability. The change of optimal profits $\Delta\Pi$ is observed between both scenarios is relatively stable when β increases. At the same time, it is unstable when c_s increases more than 40%. The optimal profit and c_s in scenario 1 are non-linear, and scenario 2's optimal profit and β are linear. I also choose the parameter θ, delivery fee discount factor, when comparing the optimal profit difference between scenarios 3 and 1, because θ will impact both demands and profitability. It is shown in Figure 26. $\beta = 0.1$, $c_s = 0.1$ and $\theta = 0.3$ are set separately, which follows the assumption of Proposition 3. It is observed that the change of optimal profits $\Delta\Pi$ between both scenarios is relatively stable when θ increases, while it is unstable when c_s increases more than

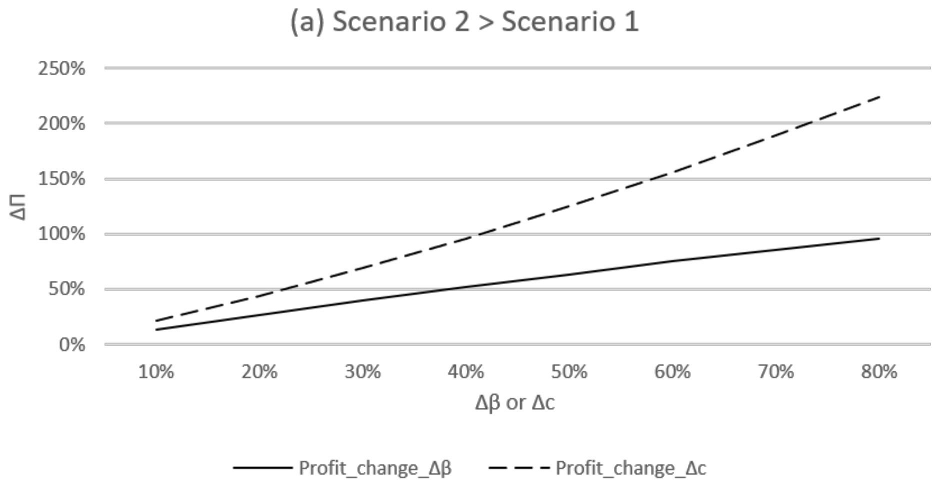


Figure 25: Sensitivity Analysis of Profit between Scenario 2 and Scenario 1

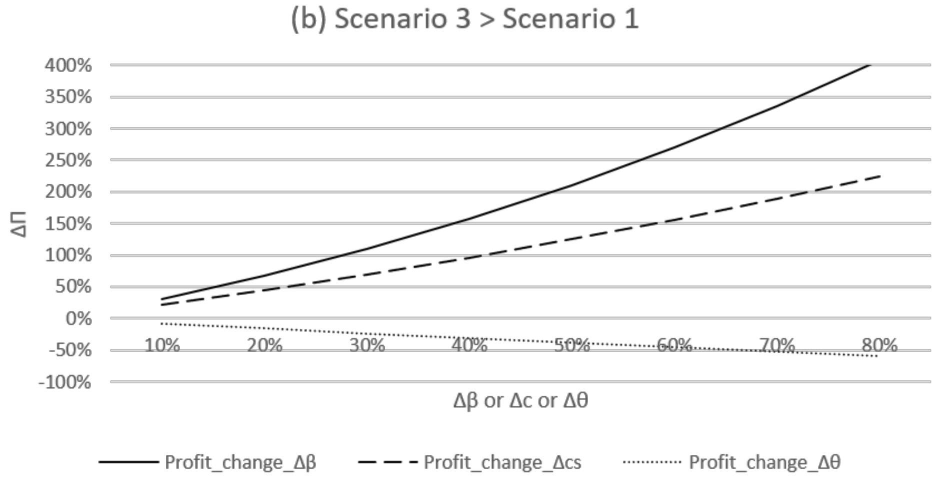


Figure 26: Sensitivity Analysis of Profit between Scenario 3 and Scenario 1

40% or when β increases over 20%. The optimal profit is negatively relevant to θ and c_s and β in scenario 3 is non-linear with optimal profit.

When comparing scenario 3 with 2, I primarily discuss two cases: one is when profit in scenario 2 is optimal, which is shown in Figure 27, and the other is when profit in scenario 3 is optimal, shown in Figure 28. In the first case, the change of optimal profits $\Delta\Pi$ between both scenarios is relatively stable when θ or β increases, while it is unstable when c_s increases more than 40%. In the second case, $\Delta\Pi$ is stable when θ increases and relatively stable when β grows, while it is unstable when c_s increases more than 40%. It is because scenario 2's optimal profit and β are linear

For model two, the assumptions in the base model are that customer channel choices are exogenous

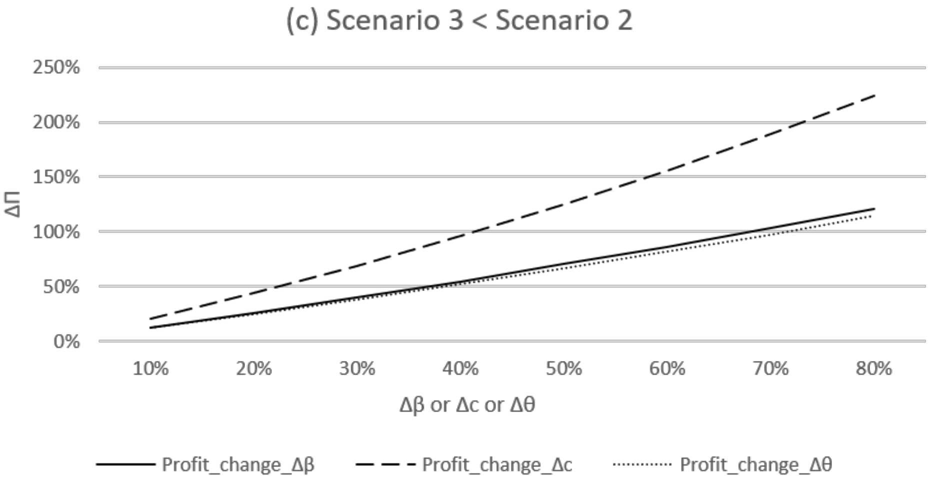


Figure 27: Sensitivity Analysis when Profit in Scenario 2 is higher than in Scenario 3

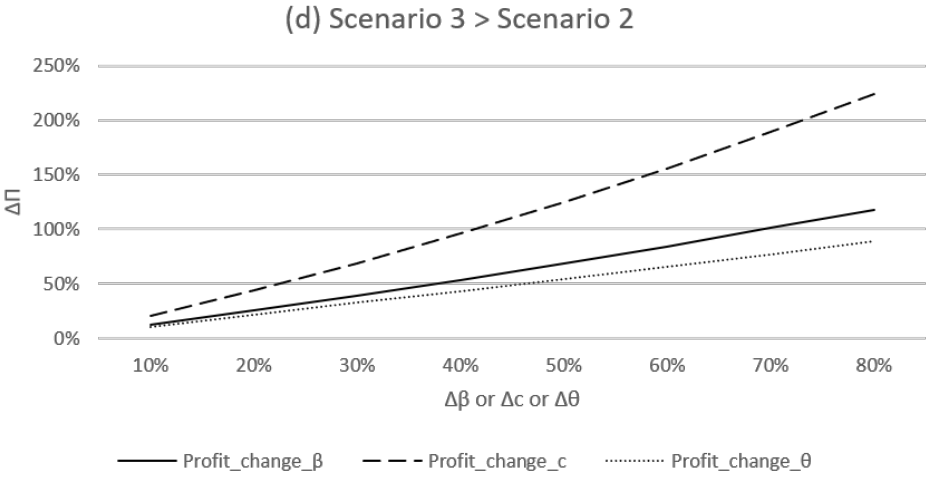


Figure 28: Sensitivity Analysis when Profit in Scenario 3 is higher than in Scenario 2

and customers are heterogeneous in product valuations but homogeneous in the hassle cost of visiting stores when this assumption is relaxed in the extension in Appendix C, where the customer channel choices are endogenous. The main results still hold.

6.2 Managerial Insights

Omnichannel integrates online channels with stores. Thereby, it needs to consider the impact of implementing omnichannel functions on the existing policies. This study provides useful insights when deciding a shipping policy in both ex-ante and ex-post stages. Firstly, the service fee for omnichannel functions, either buying online and collecting or returning in-store, should be lower than the online delivery. Otherwise, it is not attractive to customer demands. This result explains why some retailers offer free C&C or free in-store returns. Secondly, if the online orders are free of charge for either delivery or returns, the retailer should review its store operation efficiency, supply chain networks, category return rate and in-store cross-selling opportunities before they offer omnichannel functions. For example, the retailer can choose which stores or product categories are most efficient for omnichannel returns. Thirdly, charging for a shipment fee either in the pre-purchase or post-purchase stage will positively impact the cross-channel behaviours, especially nudge customers to the retailer's preferred selling channel. For instance, NEXT charges £2 for online returns but is free for in-store returns. Determining the affordable and justifiable shipping fee will increase total profit potentially and help retailers divert their demands across channels. Therefore, the discount rate that may signal the significant differences between online and omnichannel shipment costs may work effectively on cross-channel demand migration. Last, the product category may impact the efficiency of omnichannel implementation. Charging a higher shipping fee in both stages is recommended for products with standard or low unit prices.

Chapter 7

Conclusions

7.1 Conclusions

Traditional high-street retailers are seeking opportunities to capture extra footfall and shift online demands to physical stores. Hence, the omnichannel strategy is popular in retailing businesses, as customers can order online and pick up or return in-store. Retailers can convert the online clicks to in-store footfall. However, retailers face a dilemma whether to charge for the omnichannel service and therefore decide the shipping policy. Firstly, the related shipping costs and operational costs are increasing, yet charging shipping fees could deter customers sensitive to home delivery fees. Store customers shifting to Click & Collect (C&C) will generate extra profit, yet a financial loss occurs when online customers choose C&C in the pre-purchase phase. Secondly, customers face product uncertainty when shopping online post purchase. Hence, buying online and returning in-store may reduce the shipping cost for product returns and potentially increase footfall and cross-sales opportunities in-store. However, handling returned products in-store means extra labour costs to process the returned product and potentially a financial loss via re-selling the returned item. Hence, this thesis develops two models representing shipping policy for C&C in the ex-ante phase and return policy for cross-channel returns in the ex-post stage.

Model one incorporates the features of omnichannel operations in the pre-purchase stage. Customers expect C&C to be free or at lower rates than home delivery. With the more significant differences in shipping fees between C&C and home delivery, C&C could convert more demands from existing stores and online channels. Thus, the retailer deals with a trade-off: a profit gain from shifting store demands to C&C and attracting new customers, and a profit loss from converting online demand to stores. It is vital to decide an optimal shipping policy for C&C to drive profit growth. Model one captures the features of omnichannel retailing and examines three shipping options of C&C: free of charge, shipping discount, and fixed shipping fees across channels. It explores the possibility of turning a shipping charge into an opportunity to help an omnichannel retailer allocate its demands to a more profitable channel and grow the total profit. Model two incorporate the features of omnichannel operations in the post-purchase stage. It allows customers to be heterogeneous in the product valuations but homogenous in the hassle of returning to a store. In the model assumption, customers are segmented by their shopping channel, and their channel preferences are exogenous. Store customers will inspect a product in-store, and they will not return it once purchased. However, online customers will face the uncertainty that a product may not match their expectations, thereby facing a return decision. Model two captures omnichannel returns' features and studies how shipping policies impact customer channel choices and the retailer's profitability in the ex-post stage. Model two aims to provide insights helping retailing practitioners understand the omnichannel return policy and identify the optimal policy and its conditions. For both models, the effect of the retailer's operational efficiency (e.g. in-store unit selling costs and the convenience level of C&C or returns) and customer demand and total profitability. The unit selling price is identical across channels in both models.

In both models, omnichannel functions positively migrate customers across channels. However, total customer demands are not always expanded with omnichannel implementations. Customers will prefer to purchase a product online in the ex-ante stage, charging C&C at a home delivery rate. Thereby, retailers have no financial benefit from charging C&C with a home delivery fee. Alternatively, charging C&C at a cheaper rate positively migrates demands across channels. A free omnichannel function may trigger channel domination, and charging C&C at a discounted rate can avoid channel domination in the pre-purchase stage. Moreover, C&C could attract new customers and increase total demands if the product is perceived heterogeneously (e.g. fashion garments and personalised items). Otherwise, the total demand is consistent if customers perceive the product homogeneously (e.g. low-price and highly-standardised groceries). As demands of C&C come from stores, online channels, and new customers, the profit streams are two-fold: a financial gain from shifted store demands and attracting new customers while a financial loss from converted online demands. Thus, charging C&C at the right rate could help direct demands to a more profitable channel and ease the financial loss. Depending on the retailer's efficiency and distribution costs, this research reveals that if the home delivery cost is small enough, then the optimal shipping policy is to offer free C&C, because it would attract both types of customers who are sensitive to delivery fees and store hassles. The profit gain from dominating the store channel could surpass the loss from shifted online customers. If the home shipping cost is medium, then charging C&C at a lower rate is better since this policy can avoid channel domination and restrict the flow from online. If the home delivery cost is high, neither free C&C nor shipping discount is advisable. The retailer is better off making C&C unavailable. When the fulfilment cost is high, or customers are willing to pay higher for delivery, for example, large items where two people are required for delivery, C&C service is not popular. Model one also indicates that the retailer should make a joint decision on the home delivery fee and C&C discount rate. The more convenient C&C is, the more attractive it is for existing and new customers who are sensitive to the hassles of shopping in-store. However, when C&C is free, it is not beneficial to make C&C too convenient as it could cause channel domination. Finally, the addition of C&C could affect the optimal home delivery fee, which could be smaller if C&C is free or charged at an attractive rate.

Model two finds that the omnichannel return should be considered jointly with the online return. As free returns signal a positive product perception and increase customer confidence, charging for online returns faces a trade-off: potential cross-selling opportunities and additional demands simulated by an omnichannel return policy, whereas the retailer faces extra handling costs and loss from selling returned items. The results in model two imply that although return fees negatively affect total demand, it may increase the overall profit by deferring customers who show a frequent return pattern or abuse free return policy. When the signal effect of free return is not significant, charging an online return fee could be beneficial. Otherwise, a free return should be offered. With a larger customer base and the capability of re-selling returned items at reasonable prices, the retailer may benefit from cross-channel returns. Otherwise, retailers with a wide store network may benefit from omnichannel returns. Other factors also impact the efficiency of implementing cross-channel returns, including the convenience level of cross-returns, increased salvage values, or offering a broader range of product portfolios for cross-sales and return rates. Last, offering a generous return window could amplify the signal effect based on the model assumption. However, it does not change how the total profit is affected with or without cross-channel returns.

Overall, offering omnichannel functions and making their processes convenient is not always beneficial and should be jointly reviewed with existing policies. Charged at a fee for omnichannel service may negatively affect demands but positively provoke cross-channel behaviours and avoid channel dominance.

7.2 Limitations and Future Research

This study has some limitations. Thus, there are a few directions for future studies of omnichannel shipping and return policy. First, both models do not consider competition, but customers could switch to a competitor at a low cost. The extension could be conducted to discuss shipping and return policies using game theories. Second, it would be worth investigating the impacts of convenience level, shipping fees and thresholds of C&C on retailer's profitability through empirical studies. Also, how is the threshold changed when omnichannel is offered? Third, this study has built analytical models to capture the decisions of shipping and return policies and how they affect channel cannibalisation under an omnichannel setting. The more convenient the omnichannel shopping is, it may trigger more cross-channel returns and potentially erodes retailers' profits. Hence, it is worth further investigating jointly designing shipping and returning policies through a multi-stage model. Four, this study does not consider the change of the operating costs depending on how online orders are fulfilled, e.g. STS model sending from the central or regional warehouse or SFS model sending from a nearby store. For example, how this fulfilment difference impacts the shipping and return fees? Four, will the threshold value be changed when omnichannel is offered. Last, it is worth further investigating how customer heterogeneity impacts return policies and profits.

Appendix A

Proof of Model One

Proof of Base Model - Homogeneous Customers

Proof of Lemma 1. The total profit $\Pi(p_d)$ is concave in p_d, we thus can get p_d^* through solving its first-order-condition (FOC) $\frac{\partial \Pi(p_d)}{\partial p_d} = 1 - c_s - 2p_d = 0$ as well as examining the result is interior solution $p_d^* \in [0, 1]$. We then get Π^* by substituting p_d^* in (7). ☐

Proof of Lemma 2. We restrict $\beta > p_d$ to avoid channel domination, otherwise, u_b becomes smallest and C&C will shift customers from stores and online channels completely; the total profit $\Pi_2(p_d)$ is concave in p_d, we thus can get p_{d2}^* through solving its FOC $\frac{\partial \Pi_2(p_d)}{\partial p_d} 1 - \frac{2p_d}{\beta} = 0$ as well as examining the result is interior solution $p_{d2}^* \in [0, 1]$. We then get Π_2^* by substituting p_{d2}^* in (10). ☐

Proof of Lemma 3. As in Scenario 3, consumers choose C&C only if $u_b > max(u_s, u_o)$, we then get $h_s \in (\frac{\theta p_d}{1-\beta}, \frac{(1-\theta)p_d}{\beta})$, and checking $\frac{\theta p_d}{1-\beta} < \frac{(1-\theta)p_d}{\beta}$ we get a condition $\theta < 1 - \beta$. To avoid channel dominance in this case, we restrict $\frac{(1-\theta)p_d}{\beta} < 1$ and get $\beta > (1 - \theta)p_d$. The total profit $\Pi_3(p_d)$ is concave in p_d, we thus can get p_{d2}^* through solving its FOC $\frac{\partial \Pi_3(p_d)}{\partial p_d} = \frac{\beta + c_s\theta - 1}{\beta - 1} + \frac{2p_d\left(\beta(2\theta-1)+(\theta-1)^2\right)}{(\beta-1)\beta} = 0$ as well as examining the result is interior solution $p_{d3}^* \in [0, 1]$. We then get Π_3^* by substituting p_{d3}^* in (14). Similarly, I thus can get $\theta = 1 - \frac{\beta(c_s + 2p_d)}{2p_d}$ through solving its FOC $\frac{\partial \Pi_3(p_d)}{\partial \theta} = \frac{p_d(\beta c_s + 2p_d(\beta+\theta-1))}{(\beta-1)\beta} = 0$ as well as examining the result is interior solution $\theta^* \in [0, 1]$ and get the range $0 < d < \frac{2-c_s}{2}$, then substituting θ into p_{d2}^* and get $\theta^* = \frac{1-c_s-\beta}{1-c_s}$, and examine its interior and get $0 < d < 1 - c_s$, thereby substituting θ^* in p_{d2}^* will get Lemma 3. ☐

Proof of Proposition 1. Since $\frac{p_d}{\beta} > p_d$, we know that C&C has converted all store customers in the benchmark. The cannibalisation of online demands reflects in Proposition 1(i), which is obtained through subtracting (6) from (9). It is easy to know that Proposition 1(i) is increasing in p_d and decreasing in β.

We then subtract (7) from (10) and get $\frac{p_d(\beta c_s+(\beta-1)p_d)}{\beta}$, the difference of total profit between the benchmark and Scenario 2. To examine its concavity, we find the only solution $p_d = \frac{\beta c_s}{2(1-\beta)}$ from solving the FOC $\frac{\partial \frac{p_d(\beta c_s+(\beta-1)p_d)}{\beta}}{\partial p_d} = \frac{\beta c+(\beta-1)p}{\beta} + \frac{(\beta-1)p}{\beta} = 0$; and find the second derivative $\frac{\partial^2 \frac{p_d(\beta c_s+(\beta-1)p_d)}{\beta}}{\partial^2 p_d} = \frac{2(\beta-1)}{\beta} < 0$ because $\beta \in (0,1)$. We then know the difference in total profit is concave in p_d and Proposition 1(ii) is obtained by solving $\frac{p_d(\beta c_s+(\beta-1)p_d)}{\beta} > 0$.

To understand how the addition of C&C impacts the optimal home delivery fee, we subtract the optimal shipping fee in Lemma 1 from that in Lemma 2, and get $\frac{1}{2}(\beta+c_s-1)$, which is increasing in β. We thus get the condition in Proposition 1(iii) by solving $\frac{1}{2}(\beta+c_s-1) < 0$. ☐

Proof of Proposition 2. Through subtracting (5) from (11), we get $-\frac{p_d(1-\beta-\theta)}{1-\beta} < 0$, thus store demand in Proposition 2(i) is shifted to C&C by $\frac{p_d(1-\beta-\theta)}{1-\beta}$, which is decreasing in β and θ but increasing in p_d, because $\frac{\partial \frac{p_d(1-\beta-\theta)}{1-\beta}}{\partial p_d} = \frac{\beta+\theta-1}{\beta-1} > 0$, $\frac{\partial \frac{p_d(1-\beta-\theta)}{1-\beta}}{\partial \beta} = -\frac{\theta p_d}{(\beta-1)^2} < 0$ and $\frac{\partial \frac{p_d(1-\beta-\theta)}{1-\beta}}{\partial \theta} = \frac{p_d}{\beta-1} < 0$. Similarly, we get $\frac{p_d(\beta+\theta-1)}{\beta} < 0$ by subtracting (6) from (12), thus online demand in Proposition 2(i) is converted by $\frac{p_d(1-\beta-\theta)}{\beta}$, which is decreasing in β and θ but increasing in p_d, because $\frac{\partial \frac{p_d(1-\beta-\theta)}{\beta}}{\partial p_d} = \frac{1-\beta-\theta}{\beta} > 0$, $\frac{\partial \frac{p_d(1-\beta-\theta)}{\beta}}{\partial \beta} = \frac{(\theta-1)p_d}{\beta^2} < 0$ and $\frac{\partial \frac{p_d(1-\beta-\theta)}{\beta}}{\partial \theta} = -\frac{p_d}{\beta} < 0$.

We then subtract (7) from (14) and get $\frac{p_d(\beta+\theta-1)(\beta c_s+p_d(\beta+\theta-1))}{(\beta-1)\beta}$, the difference of total profit between the benchmark and Scenario 3. To examine its concavity, we find the only solution $p_d = \frac{\beta c_s}{2(1-\beta-\theta)}$ from solving the FOC $\frac{\partial \frac{p_d(\beta+\theta-1)(\beta c_s+p_d(\beta+\theta-1))}{(\beta-1)\beta}}{\partial p_d} = \frac{(\beta+\theta-1)(\beta c_s+2p_d(\beta+\theta-1))}{(\beta-1)\beta} = 0$; and find the second derivative $\frac{\partial^2 \frac{p_d(\beta+\theta-1)(\beta c_s+p_d(\beta+\theta-1))}{(\beta-1)\beta}}{\partial^2 p_d} = \frac{2(\beta+\theta-1)^2}{(\beta-1)\beta} < 0$ because $\beta \in (0,1)$. We then know the difference in total profit is concave in p_d and Proposition 2(ii) is obtained by solving $\frac{p_d(\beta+\theta-1)(\beta c_s+p_d(\beta+\theta-1))}{(\beta-1)\beta} > 0$.

To understand how charging C&C at a discounted rate impacts the optimal home delivery fee, we subtract the optimal shipping fee in Lemma 1 from that in Lemma 3, and get $-\frac{(\beta+\theta-1)(\beta-c_s(\theta-1)+\theta-1)}{2(\beta(2\theta-1)+(\theta-1)^2)}$. To examine its concavity, we find the first derivative $\frac{(\theta-1)(\beta+\theta-1)}{2(\beta(2\theta-1)+(\theta-1)^2)} > 0$ because $\beta \in (0,1)$ and $\theta < 1-\beta$; and the only solution to FOC is $c_s = \frac{\beta+\theta-1}{\theta-1}$; we thus know that the change of optimal shipping fees is increasing in c_s. We thus get $c_s < \frac{\beta+\theta-1}{\theta-1}$ by solving $-\frac{(\beta+\theta-1)(\beta-c_s(\theta-1)+\theta-1)}{2(\beta(2\theta-1)+(\theta-1)^2)} < 0$, the condition in Proposition 2(iii) can be obtained by reforming the result. ☐

Proof of Proposition 3. Through subtracting (9) from (12), we get $\frac{\theta p_d}{\beta} > 0$, thus online demands in Scenario 3 is more than that in Scenario 2, it shows that shifted online demand drops by $\frac{\theta p_d}{\beta}$ in Proposition 3(i), which is decreasing in β but increasing in the shipping fee of C&C θp_d. Similarly, as store demands are shifted completed in Scenario 2, we subtract zero from (11) to get $\frac{\theta p_d}{1-\beta} > 0$, thus converted store demand in Proposition 3(i) declines by $\frac{\theta p_d}{1-\beta} > 0$, which increasing in β and θp_d. We compare the demands of C&C between both scenarios by subtract (8) from (13), and get $-\frac{\theta p_d}{(1-\beta)\beta} < 0$, we thus know that the demands reduce by $\frac{\theta p_d}{(1-\beta)\beta}$.

We then subtract (10) from (14) and get $\frac{\theta p_d(\beta c_s+p_d(2\beta+\theta-2))}{(\beta-1)\beta}$, the difference of total profit between the Scenario 2 and 3. To examine its concavity, we find the only solution $p_d = \frac{\beta c_s}{4-4\beta-2\theta}$ from solving the FOC $\frac{\partial \frac{\theta p_d(\beta c_s+p_d(2\beta+\theta-2))}{(\beta-1)\beta}}{\partial p_d} = \frac{\theta(\beta c_s+2p_d(2\beta+\theta-2))}{(\beta-1)\beta} = 0$; and find the second derivative $\frac{\partial^2 \frac{\theta p_d(\beta c_s+p_d(2\beta+\theta-2))}{(\beta-1)\beta}}{\partial^2 p_d} = \frac{2\theta(2-2\beta-\theta)}{(1-\beta)\beta} > 0$ because $\beta \in (0,1)$ and $\theta < 1-\beta$. We then know the difference in total profit is convex in p_d and Proposition 3(ii) is obtained by solving $\frac{p_d(\beta+\theta-1)(\beta c_s+p_d(\beta+\theta-1))}{(\beta-1)\beta} > 0$.

To understand how the optimal home delivery fee is impacted, we subtract the optimal shipping fee in Lemma 2 from that in Lemma 3, and get $-\frac{\beta\theta(2\beta+c+\theta-2)}{2(\beta(2\theta-1)+(\theta-1)^2)}$. To examine its concavity, we find the first derivative $\frac{\partial(-\frac{\beta\theta(2\beta+c+\theta-2)}{2(\beta(2\theta-1)+(\theta-1)^2)})}{\partial c_s} = -\frac{\beta\theta}{2(\beta(2\theta-1)+(\theta-1)^2)} < 0$ because $\beta \in (0,1)$ and $\theta < 1-\beta$; and the only solution to $-\frac{\beta\theta(2\beta+c+\theta-2)}{2(\beta(2\theta-1)+(\theta-1)^2)} = 0$ is $c_s = 2-2\beta-\theta$; we thus know that the change of optimal shipping fees is decreasing in c_s. Then we get $c_s > 2-2\beta-\theta$ by solving $-\frac{\beta\theta(2\beta+c+\theta-2)}{2(\beta(2\theta-1)+(\theta-1)^2)} < 0$, the condition in Proposition 3(iii) can be obtained by reforming the result. ☐

Proof of Extension - Heterogeneous Customers

Proof of Lemma 4. Solving the total profit's FOC $\frac{\partial\tilde{\Pi}(p_d)}{\partial p_d} = 1-c-p+p_d(c_s+p-4)+3p_d^2 = 0$, we get two results: $p_{d_1} = 1$ and $p_{d_2} = \frac{1}{3}(1-p-c_s)$. Later, we substitute p_{d_1} and p_{d_2} in second derivative $\frac{\partial^2\tilde{\Pi}(p_d)}{\partial^2 p_d} = p+c_s+6p_d-1$, and get $p+c_s+6p_{d_2}-1 = -2-p-c_s < 0$, thus we get $\tilde{p_d}^* = \frac{1}{3}(1-p-c_s)$. To examine if $\tilde{p_d}^*$ is within [0,1], we then get $p+c_s \leq 1$. We then get $\tilde{\Pi}(p_d)^*$ by substituting $\tilde{p_d}^*$ in (18). ☐

Proof of Lemma 5. We restrict $\beta > p_d$ to avoid channel domination, otherwise, u_b becomes smallest and C&C will shift customers from stores and online channels completely. Through solving the total profit's FOC $\frac{\partial \tilde{\Pi}_2(p_d)}{\partial p_d} = \frac{\beta-\beta p+p_d(p-2(\beta+1))+3p_d^2}{\beta} = 0$, we get $p_{d_1} = \frac{1}{6}(2\beta - p + 2 - \sqrt{4\beta^2 - 4\beta + p^2 + 8\beta p - 4p + 4})$ and $p_{d_2} = \frac{1}{6}(2\beta - p + 2 + \sqrt{4\beta^2 - 4\beta + p^2 + 8\beta p - 4p + 4})$. Later, we substitute p_{d_1} and p_{d_2} in second derivative $\frac{\partial^2 \tilde{\Pi}_2(p_d)}{\partial^2 p_d} = \frac{p+6p_d-2(1+\beta)}{\beta}$, and get $\frac{1}{\beta}(p + 6p_{d_1} - 2(1+\beta)) < 0$, thus we get $\tilde{p}_{d2}^* = \frac{1}{6}(2\beta - p + 2 - \sqrt{4\beta^2 - 4\beta + p^2 + 8\beta p - 4p + 4})$ as well as examine the result is interior solution $\tilde{p_d}^* \in [0,1]$. We then get $\tilde{\Pi}_2(p_d)$ by substituting $\tilde{p}_{d2}^*$ in (22). □

Proof of Lemma 6. As in Scenario 3, consumers choose C&C only if $u_b > max(u_s, u_o)$, we then get a condition $\theta < 1 - \beta$. To avoid channel dominance in this case, we restrict $\frac{(1-\theta)p_d}{\beta} < 1$ and get $\beta > (1-\theta)p_d$. Through solving the total profit's FOC $\frac{\partial \tilde{\Pi}_3(p_d)}{\partial p_d} = \frac{1}{2(\beta-1)^2\beta}(2\beta c_s\theta(\beta + p_d\theta - 1) + 3p_d^2(\beta^2(2-3\theta) + \beta(6\theta-4) + \theta^3 - 3\theta + 2) - 2(\beta-1)p_d(2(\beta^2 - 2\beta\theta - (\theta-1)^2) + p(\beta(2\theta - 1) + (\theta-1)^2)) - 2(\beta-1)^2\beta(p-1)) = 0$, we get $p_{d_1} = \frac{1}{3\phi}(\mu + \omega)$ and $p_{d_2} = \frac{1}{3\phi}(-\mu + \omega)$, where $\phi = (\beta(2-3\theta)(2-\beta) - (2+\theta)(1-\theta)^2)$, $\omega = (1-\beta)(2(\beta(\beta-2\theta) - (1-\theta)^2) - p(\beta(1-2\theta) - (1-\theta)^2)) + \beta\theta^2 c_s$, and $\mu = \sqrt{6\phi\beta(1-\beta)((1-p)(1-\beta) - \theta c_s) + \omega^2}$. Later, we substitute p_{d_1} and p_{d_2} in the second derivative $\frac{\partial^2 \tilde{\Pi}_3(p_d)}{\partial^2 p_d} = \frac{1}{(\beta-1)^2\beta}(\beta c_s\theta^2 + 3p_d(\beta^2(2-3\theta) + \beta(6\theta-4) + \theta^3 - 3\theta + 2) + (1-\beta)(2(\beta^2 - 2\beta\theta - (\theta-1)^2) + p(\beta(2\theta-1) + (\theta-1)^2)))$, and get $\frac{\partial^2 \tilde{\Pi}_3(p_d)}{\partial^2 p_d} < 0$, thus we get $\tilde{p}_{d3}^* = \frac{1}{3\phi}(\mu + \omega)$ and the condition $p + c_s < 1$ by examining the result is interior solution $\tilde{p}_{d3}^* \in [0,1]$. We then get $\tilde{\Pi}_3(p_d)$ by substituting $\tilde{p}_{d3}^*$ in (27). □

Proof of Proposition 4. By subtracting (17) from (21), we get the difference of total demand between the benchmark and Scenario 2 $\frac{(1-\beta)p_d^2}{2\beta} > 0$, thus the total demand increases. Since $\frac{p_d}{\beta} > p_d$, we know that C&C has converted all store customers in the benchmark. The cannibalisation of online demands reflects in Proposition 4(i), which is obtained through subtracting (16) from (19), which is increasing in p_d as the first derivative is $\frac{(1-\beta)(1-p_d)}{\beta} > 0$.

We then subtract (18) from (22) and get $-\frac{p_d(\beta c_s(p_d-2)+p_d(\beta-1)(2p_d+p-2))}{2\beta}$, the difference of total profit between the benchmark and Scenario 2. As $\frac{p_d}{2\beta} > 0$, to simplify the calculation, we will examine the concavity on $-\beta c_s(p_d - 2) - (\beta-1)p_d(2p_d + p - 2)$ only, so the only solution $p_d = -\frac{\beta c_s+(\beta-1)(p-2)}{4(\beta-1)}$ from solving the FOC $\frac{\partial -\beta c_s(p_d-2)-(\beta-1)p_d(2p_d+p-2)}{\partial p_d} = -\beta c_s - (\beta-1)(4p_d + p - 2) = 0$; and find the second derivative $\frac{\partial^2 -\beta c_s(p_d-2)-(\beta-1)p_d(2p_d+p-2)}{\partial^2 p_d} = 4(1-\beta) > 0$ because $\beta \in$

$(0,1)$. We then know the difference of total profit is convex in p_d and Proposition 4(ii) is obtained by solving $-(\beta c_s(p_d-2)+p_d(\beta-1)(2p_d+p-2))>0$, we then get $p_d<\frac{(\beta-1)(2-p)+\beta c_s-\sqrt{\xi}}{4(1-\beta)}$ or $p_d>\frac{(\beta-1)(2-p)+\beta c_s+\sqrt{\xi}}{4(1-\beta)}$), and after checking the results are interior solution $p_d^*\in[0,1]$ and after applying the constraints: $\beta\in(p_d,\frac{(p+6)c_s+(p-2)^2-4c_s\sqrt{p+2}}{\delta})$ and $p+p_d\leq 1$ (see details in Appendix C), we get $p_d<\frac{(\beta-1)(2-p)+\beta c_s-\sqrt{\xi}}{4(1-\beta)}$ and $\beta\in(p_d,\frac{(p+6)c_s+(p-2)^2-4c_s\sqrt{p+2}}{\delta})$, where $\xi=16\beta c_s(\beta-1)+(\beta c_s+(\beta-1)(p-2))^2$ and $\delta=2(p+6)c_s+(p-2)^2+c_s^2$.

To understand how the addition of C&C impacts the optimal home delivery fee, we subtract the optimal shipping fee in Lemma 4 from that in Lemma 5, and get $\frac{1}{6}(2\beta+2c_s-\sqrt{4\beta^2-4\beta+p^2+8\beta p-4p+4}+p)$, which is increasing in c_s. We thus get the condition in Proposition 4(iii) by solving $\frac{1}{6}(2\beta+2c_s-\sqrt{4\beta^2-4\beta+p^2+8\beta p-4p+4}+p)<0$ as well as considering $\beta>p_d$, we then get $\frac{1}{3}(1-p-c_s)<\beta<\frac{(c_s+1)(c_s+p-1)}{-2c_s+p-1}$. □

Proof of Proposition 5. We find the difference of total demand between Scenario 3 and the benchmark $\frac{p_d^2(\beta+\theta-1)^2}{2(1-\beta)\beta}>0$ by subtracting (17) from (26), which is increasing in p_d but decreasing in β and θ. As it is larger than zero, we know the total demand increases. Through subtracting (15) from (23), we get $\frac{p_d(\beta+\theta-1)(-2\beta+p_d(\beta-\theta-1)+2)}{2(\beta-1)^2}<0$, thus store demands in Proposition 5(i) are shifted to C&C by $\frac{p_d(1-\beta-\theta)(-2\beta+p_d(\beta-\theta-1)+2)}{2(\beta-1)^2}$, which is decreasing in β and θ but concave in p_d, because there is the only solution to its FOC $\frac{\partial\frac{p_d(1-\beta-\theta)(-2\beta+p_d(\beta-\theta-1)+2)}{2(\beta-1)^2}}{\partial p_d}=\frac{(1-\beta-\theta)(1-\beta+p_d(\beta-\theta-1))}{(\beta-1)^2}=0$, and its second derivative $\frac{\partial^2\frac{p_d(1-\beta-\theta)(-2\beta+p_d(\beta-\theta-1)+2)}{2(\beta-1)^2}}{\partial^2 p_d}=\frac{(1-\beta+\theta)}{(\beta-1)^2}(\beta+\theta-1)<0$ due to $\theta<1-\beta$. Similarly, we get $-\frac{(p_d-1)p_d(\beta+\theta-1)}{\beta}<0$ by subtracting (16) from (24), thus online demands in Proposition 5(i) are converted by $\frac{(p_d-1)p_d(\beta+\theta-1)}{\beta}$, which is decreasing in β and θ but increasing in p_d.

We subtract (18) from (27) and get $\frac{p_d}{2(\beta-1)^2\beta}((1-\beta-\theta)(\beta c_s(-2\beta+p_d(\beta-\theta-1)+2)+p_d(\beta+\theta-1)(p_d(2\beta-\theta-2)+(\beta-1)(p-2))))$, the difference of total profit between the benchmark and Scenario 3. As $\frac{p_d(1-\beta-\theta)}{2(\beta-1)^2\beta}>0$, to simplify the calculation, we will examine the concavity on $\beta c_s(-2\beta+p_d(\beta-\theta-1)+2)+p_d(\beta+\theta-1)(p_d(2\beta-\theta-2)+(\beta-1)(p-2))$ only, we find the only solution $p_d=\frac{\beta c_s(-\beta+\theta+1)+(\beta-1)(2-p)(\beta+\theta-1)}{(\beta+\theta-1)(4\beta-2(\theta+2))}$ from solving the FOC $\frac{\partial\beta c_s(-2\beta+p_d(\beta-\theta-1)+2)+p_d(\beta+\theta-1)(p_d(2\beta-\theta-2)+(\beta-1)(p-2))}{\partial p_d}=\beta c_s(\beta-\theta-1)+(\beta+\theta-1)(p_d(4\beta-2(\theta+2))+(\beta-1)(p-2))=0$; the second derivative $\frac{\partial^2\beta c_s}{\partial^2 p_d}(-2\beta+p_d(\beta-\theta-1)+2)+p_d(\beta+\theta-1)(p_d(2\beta-\theta-2)+(\beta-1)(p-2))=\beta(\beta+\theta-1)(4\beta-2(\theta+2))>0$ because $\theta\in(0,1-\beta)$.

We then know the difference of total profit is convex in p_d and Proposition 5(ii) is obtained by solving $\beta c_s(-2\beta + p_d(\beta - \theta - 1) + 2) + p_d(\beta + \theta - 1)(p_d(2\beta - \theta - 2) + (\beta - 1)(p - 2)) > 0$ as well as checking its interior solutions within [0,1] and after applying the constraints: $\beta \in ((1 - \theta)p_d, \frac{(p+6)c_s+(p-2)^2-4c_s\sqrt{p+2}}{\delta})$; and $\theta < -4\sqrt{-\frac{(\beta-1)^3\beta^2c_s^2(\beta c_s-3(\beta-1)(p+1))}{\vartheta^2}} - \frac{(\beta-1)}{\vartheta}(-\beta^2c_s^2 + 4\beta(\beta-1)c_s + (\beta-1)^2(p-2)^2)$ and $p + p_d \leq 1$ (see details in Appendix C), thus we get $0 < p_d < \frac{\beta c_s(-\beta+\theta+1)+(\beta-1)(2-p)(\beta+\theta-1)-\sqrt{\varepsilon}}{4\beta^2+2\beta(\theta-4)-2(\theta^2+\theta-2)}$, $\theta < -4\sqrt{-\frac{(\beta-1)^3\beta^2c_s^2(\beta c_s-3(\beta-1)(p+1))}{\vartheta^2}} - \frac{(\beta-1)}{\vartheta}(-\beta^2c_s^2 + 4\beta(\beta - 1)c_s + (\beta - 1)^2(p - 2)^2)$; and $\beta \in ((1 - \theta)p_d, \frac{(p+6)c_s+(p-2)^2-4c_s\sqrt{p+2}}{\delta})$.

□

Proof of Proposition 6. We find $-\frac{\theta(-2\beta-\theta+2)p_d^2}{2(1-\beta)\beta} < 0$, the difference of total demand between Scenario 3 and 2 by subtracting (21) from (26), thus the total demand decreases by $\frac{\theta(-2\beta-\theta+2)p_d^2}{2(1-\beta)\beta}$, which is increasing in p_d and θ but decreasing in β. As it is smaller than zero, we know the total demand decreases. Since in Scenario 2, the store demand is zero, through subtracting zero from (23), we get $\frac{\theta p_d(-2\beta-\theta p_d+2)}{2(\beta-1)^2} > 0$, thus Proposition 6(i) shows that store demands in Scenario 3 increase in by $\frac{\theta p_d(-2\beta-\theta p_d+2)}{2(\beta-1)^2}$, which is increasing in p_d, β and θ. We get $\frac{\theta(1-p_d)p_d}{\beta} > 0$ vis subtracting (19) from (24), thus online demands in Scenario 3 is more than that in Scenario 2 in Proposition 3(i), which is decreasing in β but increasing in θ, and concave in p_d because there is the only solution to its FOC $\frac{\partial \frac{\theta(1-p_d)p_d}{\beta}}{\partial p_d} = \frac{\theta-2\theta p_d}{\beta} = 0$, and its second derivative $\frac{\partial^2 \frac{\theta(1-p_d)p_d}{\beta}}{\partial^2 p_d} = -\frac{2\theta}{\beta} < 0$. We compare the demands of C&C between both scenarios by subtract (20) from (25), and get $\frac{\theta p_d(-2\beta-\theta p_d+2)}{2(1-\beta)^2\beta} < 0$, we thus know that the demands reduce by $\frac{\theta p_d(-2\beta-\theta p_d+2)}{2(1-\beta)^2\beta}$, which is increasing in θ and p_d.

We then subtract (22) from (27) and get the difference in total profit between the Scenario 2 and 3 in the extension: $\frac{\theta p_d(\beta c_s(2\beta+\theta p_d-2)+p_d((-3\beta^2+6\beta+\theta^2-3)p_d+(\beta-1)(2-p)(2\beta+\theta-2)))}{2(\beta-1)^2\beta}$, to simplify the calculation, we will examine the concavity on $\beta c_s(2\beta + \theta p_d - 2) + p_d((-3\beta^2 + 6\beta + \theta^2 - 3)p_d + (\beta - 1)(2 - p)(2\beta + \theta - 2))$ only, from solving the FOC $\beta\theta c_s + 2\left(-3\beta^2 + 6\beta + \theta^2 - 3\right)p_d + (\beta - 1)(p - 2)(2\beta + \theta - 2) = 0$, we find the only solution: $p_d = \frac{\beta\theta c_s+(\beta-1)(2-p)(2\beta+\theta-2)}{6\beta^2-12\beta-2\theta^2+6}$; the second derivative $2(-3\beta^2 + 6\beta + \theta^2 - 3) < 0$ because $\theta \in (0, 1 - \beta)$. We then know the difference in total profit is concave in p_d and Proposition 6(ii) is obtained by solving $\beta c_s(2\beta + \theta p_d - 2) + p_d((-3\beta^2 + 6\beta + \theta^2 - 3)p_d + (\beta - 1)(2 - p)(2\beta + \theta - 2)) > 0$ as well as checking its interior solutions within [0,1] and applying constraints: $\beta \in ((1 - \theta)p_d, \frac{(p+6)c_s+(p-2)^2-4c_s\sqrt{p+2}}{\delta})$ and

$\theta \in (\frac{1}{2}(-2\beta-\beta c_s+\beta p-p+2-\sqrt{\kappa}), 1-\beta)$, and $p+p_d \leq 1$ (see details in Appendix C), thus we get $p_d \in (\frac{\beta\theta c_s+(\beta-1)(2-p)(2\beta+\theta-2)-\sqrt{\eta}}{6\beta^2-12\beta-2\theta^2+6}, \frac{\beta\theta c_s+(\beta-1)(2-p)(2\beta+\theta-2)+\sqrt{\eta}}{6\beta^2-12\beta-2\theta^2+6})$, when $\beta \in (p_d, \frac{1-2p}{1-2p+2c_s})$ and $\theta < \frac{1}{2}(-2\beta-\beta c_s+\beta p-p+2-\sqrt{\kappa})$, and $\frac{\beta\theta c_s+(\beta-1)(2-p)(2\beta+\theta-2)+\sqrt{\eta}}{6\beta^2-12\beta-2\theta^2+6} > 1$ in the assumption.

□

Numerical Results of Comparing Conditions of Profit Growth in Extension

Considering the complexity of the equation, we have conducted a set of numerical experiments to compare conditions of delivery fee setting in Proposition 4 (ii), Proposition 5 (ii) and Proposition 5 (ii). As $\varepsilon \geq 0$, we set the unit selling price from 0.1 to 0.4 with an interval of 0.1 and the unit selling cost is 30% of p, and because $\beta \in (p_d, \frac{1-2p}{1-2p+2c_s})$ and $\theta < \frac{1}{2}(-2\beta - \beta c_s + \beta p - p + 2 - \sqrt{\kappa})$ in Proposition 6 (ii), we set the convenient factor β and discount factor from 0.1 to 0.4 with an internal of 0.1. We substitute above in the conditions in the corresponding propositions and get Table 9 that summarises a set of numerical results of conditions of increasing profits. In the table, Proposition 4 (ii) - Min is $\frac{(\beta-1)(2-p)+\beta c_s-\sqrt{\xi}}{4(1-\beta)}$, and Proposition 4 (ii) - Max is $\frac{(\beta-1)(2-p)+\beta c_s+\sqrt{\xi}}{4(1-\beta)}$); Proposition 5 (ii) - Min is $\frac{\beta c_s(-\beta+\theta+1)+(\beta-1)(2-p)(\beta+\theta-1)-\sqrt{\varepsilon}}{4\beta^2+2\beta(\theta-4)-2(\theta^2+\theta-2)}$, and Proposition 5 (ii) - Max is $\frac{\beta c_s(-\beta+\theta+1)+(\beta-1)(2-p)(\beta+\theta-1)+\sqrt{\varepsilon}}{4\beta^2+2\beta(\theta-4)-2(\theta^2+\theta-2)}$; Proposition 6 (ii) - Min is $\frac{\beta\theta c_s+(\beta-1)(2-p)(2\beta+\theta-2)-\sqrt{\eta}}{6\beta^2-12\beta-2\theta^2+6}$, and Proposition 6 (ii) - Max is $\frac{\beta\theta c_s+(\beta-1)(2-p)(2\beta+\theta-2)+\sqrt{\eta}}{6\beta^2-12\beta-2\theta^2+6}$. After applying the following constraints:

- apply $\beta \in (p_d, \frac{(p+6)c_s+(p-2)^2-4c_s\sqrt{p+2}}{\delta})$ and $p + p_d \leq 1$ in Proposition 4 (ii) - Max;
- apply $\beta \in ((1-\theta)p_d, \frac{(p+6)c_s+(p-2)^2-4c_s\sqrt{p+2}}{\delta})$ and $\theta < -4\sqrt{-\frac{(\beta-1)^3\beta^2c_s^2(\beta c_s-3(\beta-1)(p+1))}{\vartheta^2}} - \frac{(\beta-1)}{\vartheta}(-\beta^2c_s^2+4\beta(\beta-1)c_s+(\beta-1)^2(p-2)^2)$ and $p+p_d \leq 1$ in Proposition 5 (ii) - Max;
- apply $\beta \in ((1-\theta)p_d, \frac{(p+6)c_s+(p-2)^2-4c_s\sqrt{p+2}}{\delta})$ and $\theta \in (\frac{1}{2}(-2\beta - \beta c_s + \beta p - p + 2 - \sqrt{\kappa}), 1 - \beta)$, and $\frac{\beta\theta c_s+(\beta-1)(2-p)(2\beta+\theta-2)+\sqrt{\eta}}{6\beta^2-12\beta-2\theta^2+6} \leq 1$, and $p + p_d \leq 1$ in Proposition 6 (ii) - Max;

Then, we get the final results in Table 10. We observe that: firstly, results in Proposition 4 (ii) - Max and Proposition 6 (ii) - Max are invalid; secondly, even we find a few results in Proposition 5 (ii) - Max are valid, we get $p_d > p$. We do not constraint the setting of delivery fee below the unit selling price, but in reality, customers could be deterred by the high delivery fee if $\frac{p_d}{p} > 1$ and abandon the shopping cart online (Lewis et al., 2006), or customers will pad orders to match minimum order to avoid the delivery fee. Thus we will mainly focus on discussing the case that home delivery fee is low. Thus we will compare the results when p_d is low only, we then observe that Proposition 6 (ii) - Min is the smallest, and Proposition 5 (ii) - Min is the largest, but overall, $p_d < p$.

Observation 4. *We thus observe the following results:*

(i) $\frac{\beta\theta c_s+(\beta-1)(2-p)(2\beta+\theta-2)-\sqrt{\eta}}{6\beta^2-12\beta-2\theta^2+6} < \frac{(\beta-1)(2-p)+\beta c_s-\sqrt{\xi}}{4(1-\beta)} < \frac{\beta c_s(-\beta+\theta+1)+(\beta-1)(2-p)(\beta+\theta-1)-\sqrt{\varepsilon}}{4\beta^2+2\beta(\theta-4)-2(\theta^2+\theta-2)}$;

(ii) Although $\frac{\beta c_s(-\beta+\theta+1)+(\beta-1)(2-p)(\beta+\theta-1)+\sqrt{\varepsilon}}{4\beta^2+2\beta(\theta-4)-2(\theta^2+\theta-2)} < \frac{(\beta-1)(2-p)+\beta c_s+\sqrt{\xi}}{4(1-\beta)} < \frac{\beta\theta c_s+(\beta-1)(2-p)(2\beta+\theta-2)+\sqrt{\eta}}{6\beta^2-12\beta-2\theta^2+6}$, *their values are invalid after applying constraints.*

Appendix B

Proof of Model Two

Proof of Base Model - Homogeneous Customers

Proof of Lemma 7. The total profit $\Pi_{s_1} = \delta((\lambda-1)(p-c)(h+p-1)-\lambda(p-1)((2\beta-1)p-\beta s+s))$ is decreasing in c and h, but increasing in s, δ and β. Calculating the derivative of Π_{s_1} wrt λ and get $\frac{\partial \Pi_{s_1}}{\partial \lambda} = \delta((p-c)(h+p-1)-(p-1)((2\beta-1)p-\beta s+s))$. With the constraints: $c < p$, $h < 1-p$, $s < p$, and $\frac{1}{2} < \beta < 1$, when $\frac{\partial \Pi_{s_1}}{\partial \lambda} > 0$ then get $c < c_1 \& h_1 < h < 1-p$ or $c > c_1 \& 0 < h < 1-p$; when $\frac{\partial \Pi_{s_1}}{\partial \lambda} < 0$ then $c < c_1 \& 0 < h < h_1$ is gained. $\square$

Proof of Lemma 8. The total profit $\Pi_{s_2} = (1-\lambda)(p-c)(-h-p+1)+\lambda(-\frac{d}{\beta}+d-p+1)((1-\beta)(d-p+s)+\beta p)$, which is decreasing in c and h but increasing in s. Calculating the derivative of Π_{s_2} wrt d and get $\frac{\partial \Pi_{s_2}}{\partial d} = \frac{(1-\beta)\lambda(\beta-2(1-\beta)d-3\beta p+p+\beta s-s)}{\beta}$. To examine its concavity , the only solution is found ${d_{s_2}}^* = \frac{\beta-3\beta p+p-(1-\beta)s}{2-2\beta}$ from solving the FOC $\frac{\partial \Pi_{s_2}}{\partial d} = 0$. Then, the second derivative is found $\frac{\partial^2 \Pi_{s_2}}{\partial^2 d} = -\frac{2(\beta-1)^2\lambda}{\beta} < 0$, as well as examining the result is interior solution ${d_{s_2}}^* \in [0,1]$ thereby the total profit Π_{s_2} is concave in d. ${d_{s_2}}^*$ is decreasing in p and s, and the first derivative $\frac{\partial \Pi_{s_2}}{\partial d} = \frac{1-2p}{2(\beta-1)^2}$, thus $\frac{\partial \Pi_{s_2}}{\partial d} > 0$ when $0 < p < \frac{1}{2}$, and vice versa.Calculating the derivative of Π_{s_2} wrt λ and get $\frac{\partial {d_{s_2}}^*}{\partial \beta} = (p-c)(h+p-1)+(-\frac{d}{\beta}+d-p+1)((\beta-1)(-d+p-s)+\beta p)$, which is increasing in c, thereby when $\frac{\partial \Pi_{s_2}}{\partial \lambda} > 0$, $c_2 = p - \frac{(1+d-p-\frac{d}{\beta})((1-\beta)(d-p+s)+\beta p)}{1-h-p} < c < p$ is obtained, when $\frac{\partial \Pi_{s_2}}{\partial \lambda} < 0$, then $0 < c < c_2$. To examine the relationship between the total profit and the probability of product matching expectation β, there are two solutions are found but one is the maximum ${\beta_{s_2}}^* = \sqrt{\frac{d(d-p+s)}{(d-p+1)(d-2p+s)}}$ from solving the FOC $\frac{\partial \Pi_{s_2}}{\partial \beta} = 0$, yet ${\beta_{s_2}}^* > 1$ when

$0 < d - p + s < p$ which outside of $\in [0, 1]$, thereby Π_{s_2} is increasing in β if $0 < d - p + s < p$, otherwise decreasing if $d - p + s < 0$.

$\square$

Proof of Lemma 9. As in Scenario 4, alternative return option is offered for online customers. Thus, the total demand is $Q_{s_4} = d^2(-\lambda) + \frac{d\lambda(d-h-1)}{\beta} + h(d\lambda + \lambda - 1) + d\lambda - p + 1$, and its first derivative wrt d is $\frac{\partial Q_{s_4}}{\partial d} = -\frac{(\beta-1)\lambda(2d-h-1)}{\beta}$, thus $\frac{\partial Q_{s_4}}{\partial d} > 0$ when $0 < h < 2d-1$. The total profit is calculated $\Pi_{s_4} = \lambda(-\frac{(\beta-1)d(d-h-1)}{\beta} - p + 1)((\beta - 1)(d(-\alpha + c - 1) + d^2 + p - s) + \beta p) + (\lambda - 1)(p - c)(h + p - 1)$. To understand the effect of relevant factors on the total profit, calculating the first derivative wrt to c and get $\frac{\partial \Pi_{s_4}}{\partial c} = (\beta - 1)d\lambda(-\frac{(\beta-1)d(d-h-1)}{\beta} - p + 1) + (\lambda - 1)(-h - p + 1)$, because $1 - h - p > 0$ and $-\frac{(\beta-1)d(d-h-1)}{\beta} - p + 1 > 0$, then $\frac{\partial \Pi_{s_4}}{\partial c} > 0$ and the total profit is decreasing in c. Similarly, it is not easy to get $\frac{\partial \Pi_{s_4}}{\partial \alpha} > 0$ and $\frac{\partial \Pi_{s_4}}{\partial s} > 0$. The first derivative wrt h is $\frac{\partial \Pi_{s_4}}{\partial h} = \frac{(\beta-1)d\lambda((\beta-1)(d(-\alpha+c-1)+d^2+p-s)+\beta p)}{\beta} + (\lambda - 1)(p - c)$, and it is increasing in c, thus $c_3 = \frac{p(\beta-2\beta^2 d\lambda+\beta(3d-1)\lambda-d\lambda)-(\beta-1)^2 d\lambda(d^2-(\alpha+1)d-s)}{\beta^2 d^2\lambda-\beta(2d^2\lambda+\lambda-1)+d^2\lambda}$ is gained by solving $\frac{\partial \Pi_{s_4}}{\partial h} = 0$ wrt c. The first derivative wrt λ is $\frac{\partial \Pi_{s_4}}{\partial \lambda} = (-\frac{(\beta-1)d(d-h-1)}{\beta} - p + 1)((\beta - 1)(d(-\alpha + c - 1) + d^2 + p - s) + \beta p) + (p - c)(h + p - 1)$, which is increasing in s because $-\frac{(\beta-1)d(d-h-1)}{\beta} - p + 1 > 0$ and $1 - \beta > 0$. Hence, $s_1 = d^2 - d(1 + \alpha - c) + \frac{(1-2\beta)p}{1-\beta} + \frac{\beta(p-c)(-h-p+1)}{(1-\beta)^2 d(d-h-1)+\beta(1-\beta)(1-p)}$ by solving $\frac{\partial \Pi_{s_4}}{\partial \lambda} = 0$ wrt s, because $s < p$ and it would not be profitable if $s < c$, thus the total profit is increasing in λ if $s_1 < s \leq p$; otherwise, decreasing in λ if $c < s < s_1$;

Transforming Q_{s_4} from a quartic equation to a cubic equation, then using Cardano's method to get $d_1 s_4 = \phi + \sqrt[3]{\gamma - \sqrt{\gamma^2 + \varsigma^3}} + \sqrt[3]{\gamma + \sqrt{\gamma^2 + \varsigma^3}}$, $d_2 s_4 = \phi - \frac{1}{2}(\sqrt[3]{\gamma - \sqrt{\gamma^2 + \varsigma^3}} + \sqrt[3]{\gamma + \sqrt{\gamma^2 + \varsigma^3}}) + \frac{i\sqrt{3}}{2}(\sqrt[3]{\gamma - \sqrt{\gamma^2 + \varsigma^3}} - \sqrt[3]{\gamma + \sqrt{\gamma^2 + \varsigma^3}})$, and $d_3 s_4 = \phi - \frac{1}{2}(\sqrt[3]{\gamma - \sqrt{\gamma^2 + \varsigma^3}} + \sqrt[3]{\gamma + \sqrt{\gamma^2 + \varsigma^3}}) - \frac{i\sqrt{3}}{2}(\sqrt[3]{\gamma - \sqrt{\gamma^2 + \varsigma^3}} - \sqrt[3]{\gamma + \sqrt{\gamma^2 + \varsigma^3}})$, where $\varsigma = \frac{1}{6(1-\beta)}(1 + p - 3\beta p + (\beta - 1)(-\alpha + h(-\alpha + c - 1))) - \phi^2$, $\gamma = \frac{(h-\alpha+c)(4\beta+(\beta-1)((c-\alpha)(\alpha-c+2)+h(h+2)+4(p-s)))}{64(\beta-1)}$, and $\phi = \frac{1}{4}(2 + \alpha - c + h)$. Knowing $0 < d < 1$, then ${d_{s_4}}^* = \phi + \sqrt[3]{\gamma - \sqrt{\gamma^2 + \varsigma^3}} + \sqrt[3]{\gamma + \sqrt{\gamma^2 + \varsigma^3}}$, to examine the result is interior solution ${d_{s_4}}^* \in [0, 1]$. First, as $\alpha - c + h < 2$ thus $0 < \phi < 1$, and $\sqrt[3]{\gamma - \sqrt{\gamma^2 + \varsigma^3}} + \sqrt[3]{\gamma + \sqrt{\gamma^2 + \varsigma^3}} > 0$, thus get ${d_{s_4}}^* > 0$. Further examining solutions when $0 < {d_{s_4}}^* < 1$, then get a condition $\frac{1}{-4} < \varsigma < 0$ and $\phi < 1 - 2\sqrt{-\varsigma}$ and $\sqrt{-\varsigma^3} < \gamma < \frac{1}{2}(1 - \phi)(1 + 3\varsigma - 2\phi + \phi^2)$. $\square$

Proof of Proposition 7. To get the demand change between scenario 2 and 1, I subtract the demand in scenario 1 Q_{s_1} (5.7)from that in scenario 2 Q_{s_2} (5.12), then get Proposition 7 (i) $\Delta = \frac{(\beta-1)d}{\beta} + (\delta-1)(h+2p-2)$. By subtracting store demands in scenario 1 $\delta(1-\lambda)(1-h-p)$ from that in scenario 2 $(1-\lambda)(1-h-p)$, the variance in the store demand can be obtained $(1-\delta)(1-\lambda)(1-h-p) < 0$ ($\delta > 1$, $\lambda < 1$ and $1-h-p > 0$), thus the store demand decreases. Similarly, the online demand variance $(\frac{d(1-\beta)}{\beta} + (\delta-1)(1-p))\lambda < 0$ is obtained by subtracting $\delta\lambda(1-p)$ from $\lambda(1+d-p-\frac{d}{\beta})$, thereby the online demand decreases.

To get the profit change between scenario 2 and 1, I subtract the profit in scenario 1 Π_{s_1} (5.8) from that in scenario 2 Π_{s_2} (5.13), then get $\Delta = \frac{(\beta-1)d}{\beta} + (\delta-1)(h+2p-2)$

□

Proof of Proposition 8. To get the demand change between scenario 2 and 4, I subtract the demand in scenario 2 Q_{s_2} (5.11)from that in scenario 4 Q_{s_2} (5.16), then get Proposition 8 (i) $\Delta = Q_{s_4} - Q_{s_2} = \frac{d(d-h)(1-\beta)\lambda}{\beta}$. Thus, when $d > h$, $\Delta > 0$, and vice versa. By solving FOC wrt d and finding the second derivative is positive, Δ is known to be convex in d and Δ is minimum when $d = \frac{h}{2}$. Calculating FOC wrt h and find that Δ is decreasing in h; similarly, Δ is decreasing in β if $d > h$, or increasing in β if $d < h$; and Δ is increasing in λ if $d > h$, or decreasing in λ if $d < h$.

By subtracting the total profit in scenario 2 $\Pi_{s_2}(d)$ (5.13) from that in scenario 4 $\Pi_{s_4}(d)$ (5.18), $\Delta = \Pi_{s_4} - \Pi_{s_2} = -\frac{\lambda((\beta-1)d^2-(\beta-1)d(h+1)+\beta(p-1))((\beta-1)d(-\alpha+c-1)+(\beta-1)d^2+(2\beta-1)p-\beta s+s)}{\beta} - (-\frac{d}{\beta}+d-p+1)((\beta-1)\lambda(-d+p-s)+\beta\lambda p)$ is obtained as the variance in the total profit in Proposition 8 (ii). Its first derivative wrt s is $\frac{(\beta-1)^2 d\lambda(d-h)}{\beta}$, thereby Δ is increasing in the salvage value s if $d > h$, and vice versa. Its first derivative wrt α is $\frac{(\beta-1)d\lambda((\beta-1)d^2-(\beta-1)d(h+1)+\beta(p-1))}{\beta}$, because the constraints: the probability of online demand is $\frac{\beta-(\beta-1)d^2+(\beta-1)d(h+1)-\beta p}{\beta} > 0$, thereby Δ is increasing in α. Its first derivative wrt c is $-\frac{(\beta-1)d\lambda((\beta-1)d^2-(\beta-1)d(h+1)+\beta(p-1))}{\beta}$, therefore, Δ is decreasing in c.

Table 16: Numerical Results for the Optimal Total Profit Variance between Scenario 4 and 2 (when $h < d$)

Optimal result for $\Pi_{s_4}(d) - \Pi_{s_2}(d)$ when $1 < h < d$, α=0.1, λ=0.3												
p	**0.45**				**0.55**				**0.65**			
c	**0.135**				**0.165**				**0.195**			
s	**0.3375**				**0.4125**				**0.4875**			
β	**0.7**	**0.75**	**0.8**	**0.85**	**0.7**	**0.75**	**0.8**	**0.85**	**0.7**	**0.75**	**0.8**	**0.85**
$h =$ 0.1	2.00E-02	1.02E-02	3.68E-03	-2.26E-04	3.55E-02	2.32E-02	1.42E-02	7.72E-03	5.15E-02	3.25E-02	2.51E-02	1.59E-02
$h =$ 0.2	1.65E-02	7.23E-03	1.20E-03	-2.13E-03	3.13E-02	1.96E-02	1.12E-02	5.40E-03	4.66E-02	3.25E-02	2.15E-02	1.32E-02
$h =$ 0.3	1.31E-02	4.22E-03	-1.28E-03	-4.04E-03	2.71E-02	1.60E-02	8.19E-03	3.09E-03	4.17E-02	2.82E-02	1.80E-02	1.05E-02

Optimal result for $\Pi_{s_4}(d) - \Pi_{s_2}(d)$ when $1 < h < d$, α=0.2, λ=0.3												
p	**0.45**				**0.55**				**0.65**			
c	**0.135**				**0.165**				**0.195**			
s	**0.3375**				**0.4125**				**0.4875**			
β	**0.7**	**0.75**	**0.8**	**0.85**	**0.7**	**0.75**	**0.8**	**0.85**	**0.7**	**0.75**	**0.8**	**0.85**
$h =$ 0.1	2.46E-02	1.41E-02	6.83E-03	2.17E-03	3.91E-02	2.64E-02	1.67E-02	9.66E-03	4.37E-02	3.91E-02	2.70E-02	1.74E-02
$h =$ 0.2	2.07E-02	1.09E-02	4.20E-03	1.82E-04	3.46E-02	2.25E-02	1.36E-02	7.27E-03	4.90E-02	3.46E-02	2.33E-02	1.46E-02
$h =$ 0.3	1.68E-02	7.60E-03	1.57E-03	2.17E-03	3.00E-02	1.86E-02	1.04E-02	4.88E-03	5.42E-02	3.01E-02	1.97E-02	1.18E-02

Optimal result for $\Pi_{s_4}(d) - \Pi_{s_2}(d)$ when $1 < h < d$, α=0.3, λ=0.3												
p	**0.45**				**0.55**				**0.65**			
c	**0.135**				**0.165**				**0.195**			
s	**0.3375**				**0.4125**				**0.4875**			
β	**0.7**	**0.75**	**0.8**	**0.85**	**0.7**	**0.75**	**0.8**	**0.85**	**0.7**	**0.75**	**0.8**	**0.85**
$h =$ 0.1	2.91E-02	1.80E-02	9.98E-03	4.56E-03	4.28E-02	2.95E-02	1.93E-02	1.16E-02	5.70E-02	4.15E-02	2.90E-02	1.89E-02
$h =$ 0.2	2.49E-02	1.45E-02	7.20E-03	2.50E-03	3.79E-02	2.54E-02	1.60E-02	9.14E-03	5.14E-02	3.67E-02	2.51E-02	1.60E-02
$h =$ 0.3	2.06E-02	1.10E-02	4.42E-03	4.31E-04	3.29E-02	2.13E-02	1.27E-02	6.66E-03	4.57E-02	3.20E-02	2.13E-02	1.32E-02

Table 17: Numerical Results for the Optimal Total Profit Variance between Scenario 4 and 2 (when $d < h < 1 - p$)

Optimal result for $\Pi_{s_4}(d) - \Pi_{s_2}(d)$ when $d < h < 1 - p$, α=0.1, λ=0.3												
p	**0.45**				**0.55**				**0.65**			
c	**0.135**				**0.165**				**0.195**			
s	**0.3375**				**0.4125**				**0.4875**			
β	**0.7**	**0.75**	**0.8**	**0.85**	**0.7**	**0.75**	**0.8**	**0.85**	**0.7**	**0.75**	**0.8**	**0.85**
$h =$ 0.1	-9.71E-08	-9.86E-08	-1.19E-07	-1.33E-07	-9.44E-08	-9.35E-08	-9.46E-08	-9.75E-08	-9.01E-08	-9.04E-08	-9.29E-08	-9.14E-08
$h =$ 0.2	-9.18E-08	-9.25E-08	-9.34E-08	-9.45E-08	-9.22E-08	-9.30E-08	-9.25E-08	-9.34E-08	-9.13E-08	-9.14E-08	-9.15E-08	-9.14E-08
$h =$ 0.3	-1.08E-07	-1.18E-07	-1.33E-07	-9.27E-08	-9.16E-08	-9.17E-08	-9.15E-08	-9.18E-08	-9.10E-08	-9.11E-08	-9.11E-08	-9.12E-08

Optimal result for $\Pi_{s_4}(d) - \Pi_{s_2}(d)$ when $d < h < 1 - p$, α=0.2, λ=0.3												
p	**0.45**				**0.55**				**0.65**			
c	**0.135**				**0.165**				**0.195**			
s	**0.3375**				**0.4125**				**0.4875**			
β	**0.7**	**0.75**	**0.8**	**0.85**	**0.7**	**0.75**	**0.8**	**0.85**	**0.7**	**0.75**	**0.8**	**0.85**
$h =$ 0.1	-9.97E-08	-2.50E-07	-2.06E-07	-1.68E-07	-1.01E-07	-1.06E-07	-1.03E-07	-9.03E-08	-9.30E-08	-9.23E-08	-9.28E-08	-9.08E-08
$h =$ 0.2	-9.57E-08	-9.32E-08	-9.56E-08	-9.85E-08	-9.69E-08	-9.38E-08	-9.44E-08	-9.40E-08	-9.28E-04	-8.29E-04	-9.15E-08	-9.17E-08
$h =$ 0.3	-1.09E-07	-9.19E-08	-9.27E-08	-9.37E-08	-9.31E-08	-9.26E-08	-9.18E-08	-9.32E-08	-1.76E-03	-1.66E-03	-9.12E-08	-9.13E-08

Optimal result for $\Pi_{s_4}(d) - \Pi_{s_2}(d)$ when $d < h < 1 - p$, α=0.3, λ=0.3												
p	**0.45**				**0.55**				**0.65**			
c	**0.135**				**0.165**				**0.195**			
s	**0.3375**				**0.4125**				**0.4875**			
β	**0.7**	**0.75**	**0.8**	**0.85**	**0.7**	**0.75**	**0.8**	**0.85**	**0.7**	**0.75**	**0.8**	**0.85**
$h =$ 0.1	2.97E-04	2.52E-04	2.05E-04	1.56E-04	1.28E-04	1.09E-04	8.92E-05	6.80E-05	1.38E-05	1.18E-05	9.66E-06	7.39E-06
$h =$ 0.2	8.07E-06	4.95E-06	2.78E-06	1.35E-06	-4.26E-04	-1.09E-07	-1.13E-07	-1.07E-07	-4.52E-04	-4.04E-04	-3.42E-04	-2.69E-04
$h =$ 0.3	-9.20E-08	-9.42E-08	-9.30E-08	-9.62E-08	-1.04E-07	-9.41E-08	-9.52E-08	-9.64E-08	-1.17E-03	-1.10E-03	-9.65E-04	-7.82E-04

□

Proof of Lemma 10. The total profit $\hat{\Pi}_{s_1} = \delta(t+1)((\lambda-1)(p-c)(h+p-1)+\beta\lambda p-(\beta-1)\lambda(p-1)(p+s(t-1)))$, becuase $\frac{\partial\hat{\Pi}_{s_1}}{\partial c} = \delta(1-h-p)(1+t)(\lambda-1) < 0$ and $\frac{\partial\hat{\Pi}_{s_1}}{\partial h} = (p-c)(1+t)(\lambda-1) < 0$ thereby $\hat{\Pi}_{s_1}$ is decreasing in c and h, but $\frac{\partial\hat{\Pi}_{s_1}}{\partial s} = (1-p)(1-t^2)(1-\beta)\delta\lambda > 0$ and$\frac{\partial\hat{\Pi}_{s_1}}{\partial\beta} = \delta\lambda(t+1)(p-(p-1)(p+s(t-1))) > 0$ due to the constraints: $1-h-p > 0$ and $0 < s < p$, so increasing in s, δ and β. □

Proof of Lemma 11. The total profit $\hat{\Pi}_{s_2} = (t+1)((\lambda-1)(p-c)(h+p-1)+(-\frac{d}{\beta}+d-p+1)((\beta-1)\lambda(-d+p+st-s)+\beta\lambda p))$, becuase $\frac{\partial\hat{\Pi}_{s_2}}{\partial c} = (\lambda-1)(t+1)(-h-p+1) < 0$ and $\frac{\partial\hat{\Pi}_{s_1}}{\partial h} = (p-c)(1+t)(\lambda-1) < 0$ thereby $\hat{\Pi}_{s_2}$ is decreasing in c and h, but $\frac{\partial\hat{\Pi}_{s_1}}{\partial s} = \frac{(\beta-1)\lambda(t-1)(t+1)(\beta+(\beta-1)d-\beta p)}{\beta} > 0$ due to the constraints: $1-h-p > 0$ and $-\frac{d}{\beta}+d-p+1 > 0$, so increasing in s. The only solution is found $d_{s_2} = \frac{\beta-3\beta p+p+s(\beta-\beta t+t-1)}{2-2\beta}$ from solving the FOC $\frac{\partial\hat{\Pi}_{s_2}}{\partial d} = 0$. Then, the second derivative is found $\frac{\partial^2\hat{\Pi}_{s_2}}{\partial^2 d} = -\frac{2(\beta-1)^2\lambda(t+1)}{\beta} < 0$. A solution is found when examining the result is interior solution $d_{s_2} \in [0,1]$ and thereby $\hat{d}^*_{s_2} = \frac{\beta-3\beta p+p+s(\beta-\beta t+t-1)}{2-2\beta}$. □

Proof of Lemma 12. The total profit $\hat{\Pi}_{s_4} = ((t+1)((\lambda-1)(p-c)(h+p-1)-\frac{1}{\beta}(\lambda((\beta-1)d^2-(\beta-1)d(h+1)+\beta(p-1))((\beta-1)d(-\alpha+c-1)+(\beta-1)d^2+(2\beta-1)p+(\beta-1)s(t-1))))$, becuase $\frac{\partial\hat{\Pi}_{s_4}}{\partial c} = (t+1)((\lambda-1)(-h-p+1)-\frac{(\beta-1)d\lambda((\beta-1)d^2-(\beta-1)d(h+1)+\beta(p-1))}{\beta}) < 0$ due to the constraints: $1-h-p > 0$ and $\frac{\beta-(\beta-1)d^2+(\beta-1)d(h+1)-\beta p}{\beta} > 0$, thereby $\hat{\Pi}_{s_2}$ is decreasing in c, but $\frac{\partial\hat{\Pi}_{s_4}}{\partial s} = -\frac{(\beta-1)\lambda(t-1)(t+1)((\beta-1)d^2-(\beta-1)d(h+1)+\beta(p-1))}{\beta} > 0$ and $\frac{\partial\hat{\Pi}_{s_4}}{\partial\alpha} = \frac{(\beta-1)d\lambda(t+1)((\beta-1)d^2-(\beta-1)d(h+1)+\beta(p-1))}{\beta} > 0$due to the constraints, so $\hat{\Pi}_{s_4}$ is increasing in s and α. Regarding to the proof of ${d_{s_4}}^*$ in 12 (i), the similar calculation is in Proof of Lemma 9. □

Proof of Proposition 9. $\Delta_{\hat{s_1}-s1}$ is obtained by subtracting (5.8)from (5.21). Calculating the derivative of $\Delta_{\hat{s_1}-s1}$ wrt t and get $\frac{\partial\Delta_{\hat{s_1}-s1}}{\partial t} = \delta(-c(\lambda-1)t(h+p-1)+pt(h(\lambda-1)-(\beta-1)\lambda(st-2)+1)+p^2(-(-\beta\lambda+(\beta-2)\lambda t+t))+(\beta-1)\lambda st^2)$. The only solution is found $t^* = -\frac{(\lambda-1)(c-p)(h+p-1)+(\beta-1)\lambda(p-1)p-\beta\lambda p}{2(\beta-1)\lambda(p-1)s}$ from solving the FOC $\frac{\partial\Delta_{\hat{s_1}-s1}}{\partial t} = 0$. Then, the second derivative is found $\frac{\partial^2\Delta_{\hat{s_1}-s1}}{\partial^2 t} = -2s\delta\lambda(1-p)(1-\beta) < 0$. To examine the result is interior solution $t^* \in [0,1]$, firstly,knowing the constraints, there is solution for $t^* > 0$, to decide whether $t^* < 1$, then I compare the numerator and denominator and get is variance $\Delta = \delta(-c(\lambda-1)t(h+$

$p-1)+pt(h(\lambda-1)-(\beta-1)\lambda(st-2)+1)+p^2(-(-\beta\lambda+(\beta-2)\lambda t+t))+(\beta-1)\lambda st^2)$ is increasing in s and c, we thereby the condition is met when $\Delta > 0 : c_4 < c < p$ and $s_2 < s \leq p$. Therefore, the total profit $\Delta_{\hat{s_1}-s1}$ is concave in t.

☐

Proof of Proposition 10. $\Delta_{\hat{s_2}-s2}$ is obtained by subtracting (5.13)from (5.24). Calculating the derivative of $\Delta_{\hat{s_2}-s2}$ wrt t and get $\frac{\partial\Delta_{\hat{s_2}-s2}}{\partial t} = -\frac{1}{\beta}(\beta c(\lambda-1)(h+p-1)-p(\beta+d\lambda+\beta^2\lambda(3d-2st+2)+\beta\lambda(-4d+2st-2)+\beta h(\lambda-1))+(\beta-1)\lambda(\beta+(\beta-1)d)(d-2st)+\beta p^2(2(\beta-1)\lambda+1))$. The only solution is found $t^*{}_{s2} = \frac{1}{2(\beta-1)\lambda s(\beta+(\beta-1)d-\beta p)}(\beta c(\lambda-1)(h+p-1)+(\beta-1)d\lambda(\beta+(\beta-1)d)-p(\beta^2(3d+2)\lambda+\beta(-4d\lambda+h(\lambda-1)-2\lambda+1)+d\lambda)+\beta p^2(2(\beta-1)\lambda+1))$ from solving the FOC $\frac{\partial\Delta_{\hat{s_2}-s2}}{\partial t} = 0$. Then, the second derivative is found $\frac{\partial^2\Delta_{\hat{s_2}-s2}}{\partial^2 t} = \frac{2(\beta-1)\lambda s(\beta+(\beta-1)d-\beta p)}{\beta} < 0$. The two solutions to $\Delta_{\hat{s_2}-s2} = 0$ wrt t are $t = 0$ and $t = 2t^*{}_{s2}$, thus $\Delta_{\hat{s_2}-s2}$ may concave in t if $0 < 22t^*{}_{s2} < 1$, otherwise, it is increasing in t if if $22t^*{}_{s2} > 1$. The only solution is found $\hat{d}'{}_{s2} = \frac{\beta-3\beta p+p-\beta st+st}{2-2\beta}$ from solving the FOC $\frac{\partial\Delta_{\hat{s_2}-s2}}{\partial d} = 0$, and the second derivative is found $\frac{\partial^2\Delta_{\hat{s_2}-s2}}{\partial^2 d} = -\frac{2(\beta-1)^2\lambda t}{\beta} < 0$, there is solution when solving $0 < \hat{d}'{}_{s2} < 1$.

☐

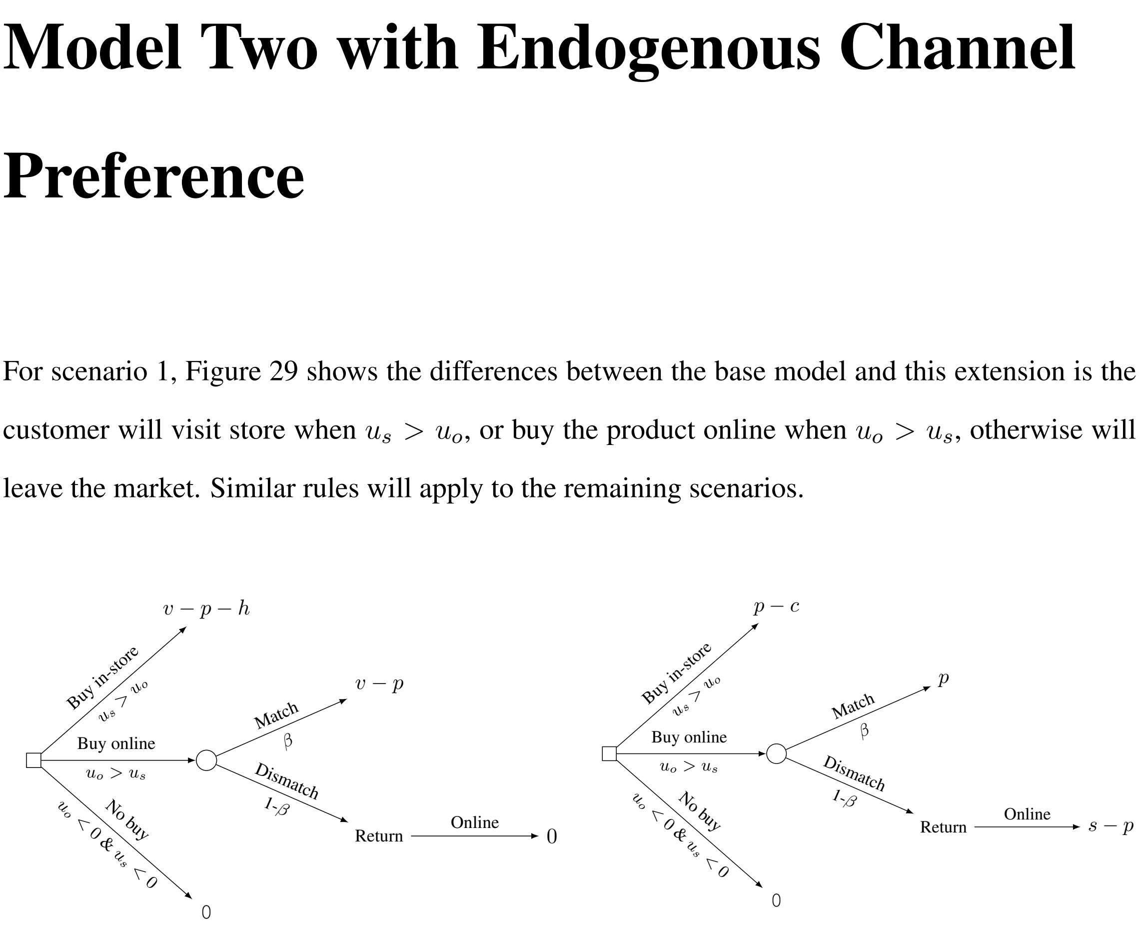
Proof of Proposition 11. $\Delta_{\hat{s_4}-s4}$ is obtained by subtracting (5.18)from (5.27). Calculating the derivative of $\Delta_{\hat{s_4}-s4}$ wrt t and get $-\frac{1}{\beta}(\lambda(-\beta+(\beta-1)d(d-h-1)+\beta p)((\beta-1)(d(-\alpha+c-1)+d^2+p+s(t-1))+\beta p)+\beta(\lambda-1)(c-p)(h+p-1)+(\beta-1)\lambda s(t+1)(-\beta+(\beta-1)d(d-h-1)+\beta p))$. The only solution is found $t^*{}_{s4} = -\frac{d(-\alpha+c-1)+\frac{\beta(\lambda-1)(c-p)(h+p-1)}{(\beta-1)\lambda(-\beta+(\beta-1)d(d-h-1)+\beta p)}+d^2+\frac{\beta p}{\beta-1}+p}{2s}$ from solving the FOC $\frac{\partial\Delta_{\hat{s_4}-s4}}{\partial t} = 0$. Then, the second derivative is found $\frac{\partial^2\Delta_{\hat{s_4}-s4}}{\partial^2 t} = -\frac{1}{\beta}(2(\beta-1)\lambda s(-\beta+(\beta-1)d(d-h-1)+\beta p)) < 0$. The two solutions to $\Delta_{\hat{s_4}-s4} = 0$ wrt t are $t = 0$ and $t = 2t^*{}_{s4}$, thus $\Delta_{\hat{s_4}-s4}$ may concave in t if $0 < 2t^*{}_{s4} < 1$, otherwise, it is increasing in t if if $2t^*{}_{s4} > 1$.

☐

Appendix C

Model Two with Endogenous Channel Preference

For scenario 1, Figure 29 shows the differences between the base model and this extension is the customer will visit store when $u_s > u_o$, or buy the product online when $u_o > u_s$, otherwise will leave the market. Similar rules will apply to the remaining scenarios.



(a) Customer's Utility

(b) Retailer's Profit

○ = Chance node □ = Decision node

Figure 29: The sequence of customer decisions and associated utilities and retailer profits in scenario 1 when customer channel choices are endogenous

Proof of demand change between scenario 1 and 2. The total demand change between scenario 2 and 1 become $\Delta_{s2-s1} = {Q'}_{s_2} - {Q'}_{s_1} = \frac{(\beta-1)d}{\beta} + (\delta - 1)(p-1)$, which is increasing in β but decreasing in d, p and δ. ☐

Proof of demand change between scenario 2 and 4. The total demand change between scenario 2 and 4 become $\Delta_{s4-s2} = {Q'}_{s_4} - {Q'}_{s_2} = -\frac{(\beta-1)d(d-h)}{\beta}$, which is decreasing in h, and increasing in β if $d < h$ or decreasing in β if $d > h$, and increasing in d if $d > \frac{h}{2}$ or decreasing in h if $d < \frac{h}{2}$. ☐

Proof of profit change between scenario 1 and 2. The total profit change between scenario 2 and 1 become ${\Delta'}_{s2-s1} = {\Pi'}_{s_2} - {\Pi'}_{s_1} = \frac{d(\beta(h-c)-\beta p+p+(\beta-1)s)}{\beta} + \frac{(\delta-1)\big(c(\beta+h-\beta p+p-1)+(\beta-1)\big((2h-1)p-hs+p^2\big)\big)}{\beta-1} + \frac{(\beta-1)d^2}{\beta}$, which is decreasing in s and concave in d, and $d^* = \frac{\beta(h-c)-\beta p+p+(\beta-1)s}{2-2\beta}$ after examining the result is interior solution $d^* \in [0,1]$. ☐

Proof of profit change between scenario 2 and 4. The total demand profit between scenario 2 and 4 become ${\Delta'}_{s4-s2} = {\Pi'}_{s_4} - {\Pi'}_{s_2} = - - \frac{d}{\beta}(cd(2\beta - \beta d + d + (\beta-1)h - 1) + (\beta-1)d^3 - (\beta - 1)d^2(\alpha + h + 2) + dh(\alpha(\beta-1) - 1) + (\beta-1)d(\alpha + p - s) + h(\alpha\beta - \beta p + p + (\beta-1)s))$, which is decreasing in s if $d > h$ or increasing in s if $d < h$, and non-monotonic in d. ☐

Glossary

COVID-19	Coronavirus is a disease with person-to-person transmission and high infection rate, which started since end of 2019 and caused a on-going global pandemic. 79
omnichannel	omnichannel is a business approach that fully integrates physical stores with online channels to deliver a seamless and consistent shopping experience. 2

Acronyms

3PL	Third Party Logistics 83
B&Q	Block and Quayle 147
BOPS	Buy Online and Pick-up In-store 3, 83
BORS	Buy Online and Return In-store 3
C&C	Click & Collect 3, 77
CFS	Contingent Free Shipping 23
DC	Distribution Centre 4
DID	Difference in Difference 20
EUT	Expected Utility Theory 62
FR	Full Refund 26
H&M	Hennes and Mauritz 147
IMRG	Interactive Media in Retail Group 141
LP	Linear Program 25
MAUT	Multi-attribute Utility Theory 39

MBG	Money Back Guarantees 30
MINLP	Mixed Integer Nonlinear Program 25
NLP	Nonlinear Program 24
NSD	Next Scheduled Deadline 21
O2O	Online to Offline 18
O2S	Online to Store 18
OFAT	One-factor-at-a-time 71
OOS	Out of Stock 5
POS	Point of Sale 2
RM	Revenue Management 39, 85
ROPS	Reserve Online Pay in Store 3
SFS	Ship from Store 4
SKU	Stock Keeping Unit 9
STS	Ship to Store 4, 83, 95
TFS	Threshold-based Free Shipping 22
VR	Virtual Reality 146

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